Annex 551

A. Pathak et al., “Impacts of climate change on the tourism sector of a Small Island Developing State: A case study for the Bahamas”, *Environmental Development,* 2021

Environmental Development 37 (2021) 100556

Contents lists available at ScienceDirect

Environmental Development

journal homepage: www.elsevier.com/locate/envdev

Impacts of climate change on the tourism sector of a Small Island Developing State: A case study for the Bahamas

Arsum Pathak[a,*], Philip E. van Beynen[a], Fenda A. Akiwumi[a], Kenyon C. Lindeman[b]

[a] *Geography, Environmental Science and Policy Program, School of Geosciences, University of South Florida, Tampa, FL, 33620, USA*
[b] *Program in Sustainability, Florida Institute of Technology, Melbourne, FL, 32901, USA*

ARTICLE INFO

Keywords:
Climate change impact
Hurricanes
Tourism
Sea level rise
Small Island Developing States (SIDS)

ABSTRACT

This study examines the direct and indirect impacts of climate change to the tourism sector on the islands of New Providence and adjacent Paradise Island in the Bahamas. The assessment was carried out by conducting a geospatial analysis of tourism establishments at risk using Geographic Information Systems (GIS). We combined the geospatial analysis with publicly available databases to assess the integrated climate-related impacts pertaining to a Small Island Developing State (SIDS) economy. Our study estimated that many tourism properties currently lie in a storm surge zone and the extent of properties at risk increases with a future scenario of a 1 m rise in sea level. While sea level rise (SLR) by itself only threatens a small number of properties, when combined with weak (Category 1), moderate (Category 3) and strong (Category 5) storms the resulting coastal flooding impacts 34%, 69%, and 83% of the tourism infrastructure (hotels and resorts), respectively. In addition to flooding, properties are also susceptible to coastal erosion with 28% of the total hotels and resorts on the two islands being situated within 0–50 m and 60% of the tourism infrastructure within 0–100 m of the coastline. Considering the economic importance of the sector, the potential impacts on the tourism infrastructure will cause significant losses in revenue and employment for the two islands. Furthermore, the majority of the tourism on these islands is beach-based and visitor expenditures will decline due to their vulnerability. These losses will have far-reaching social-economic consequences for the Bahamas. Our findings reveal a need for integrated coastal zone management that incorporates tourism management strategies with adaptation measures to deal with climate change.

1. Introduction

While many recent studies have identified the impacts of climate change on coastal tourism (Becken, 2013; Fang et al., 2018), there has been a lack of focus on integrated assessments that analyze the full range of potential climate-induced impacts on a specific destination (Nurse et al., 2014; Scott et al., 2016; Scott and Verkoeyen, 2017). In particular, there is a dearth of research on the cumulative effects of these complex impacts on the tourism sector of Small Island Developing States (SIDS), on which many are economically dependent (Scott et al., 2016; Scott and Verkoeyen, 2017). Our paper examines the multiple direct and indirect

* Corresponding author. Geography, Environmental Science and Policy Program, School of Geosciences, University of South Florida, 4202 E Fowler Ave, Tampa, FL, 33620, USA.

E-mail addresses: arsumpathak@usf.edu (A. Pathak), vanbeyne@usf.edu (P.E. van Beynen), fakiwumi@usf.edu (F.A. Akiwumi), lindeman@fit.edu (K.C. Lindeman).

https://doi.org/10.1016/j.envdev.2020.100556
Received 18 March 2020; Received in revised form 4 August 2020; Accepted 19 August 2020
Available online 28 August 2020

climate-induced impacts on one of the tourism-reliant SIDS – the Bahamas. We evaluate the implications of these impacts at the national level. Taking into consideration the multi-dimensionality of climate change impacts on the prospects of tourism for SIDS sets the foundation for both an integrated vulnerability assessment and potential adaptation measures (Scott and Verkoeyen, 2017).

Agenda 21 of the Earth Summit held in Rio De Janeiro, Brazil, June 1992 recognized SIDS as a group of countries with special environment and development challenges. At present, there are fifty-eight SIDS designated by the United Nations (UN), out of which 38 are UN members while 20 are non-UN members or associate members of regional commissions. These SIDS are spread over three regions – the Caribbean, the Pacific, and AIMS (Atlantic, Indian Ocean, Mediterranean, and the South China Sea) (UN-OHRLLS, 2020). The countries vary in terms of their physical size as well as economic, social, and environmental conditions. Most, however, share a common vulnerability to climate change-induced sea level rise (SLR), changes in sea surface temperature, precipitation, and extreme events (Church et al., 2013; Nurse et al., 2014; Oppenheimer et al., 2019). This vulnerability mostly stems from their low elevation and densely populated coastal areas.

Climate change manifests itself in many ways such as changes in sea levels, storm surges, and sea surface temperatures (Church et al., 2013). A growing number of studies focus on the combined impacts of SLR and storm surge in coastal areas (Frazier et al., 2010; Kleinosky et al., 2007; Neumann et al., 2015; Silver et al., 2019). In the Bahamas, Silver et al. (2019) found an increase in shoreline exposure and population to coastal hazards with an increase in SLR. However, concerning coastal tourism, relatively few studies have attempted to investigate such combined effects of SLR and storm surge for SIDS. To the best of our knowledge, the only quantitative analysis of the combined impacts of SLR and storm surge in the coastal tourism sector have been conducted in China (see Fang et al., 2016). Considering the recent catastrophic damages from the Atlantic Ocean hurricanes Irma and Dorian on several Caribbean SIDS, assessing the risk posed by storm surge coupled with the projected SLR to tourism infrastructure is essential for these developing nations.

During the Atlantic hurricane season in 2016, Hurricane Matthew hit the South coast of New Providence Island with a storm surge height of more than 2 m causing estimated damages of USD 600 million in the Bahamas (Stewart and Berg, 2017). Tourism-related infrastructure such as Nassau airport and surrounding roads were flooded or damaged (Stewart and Berg, 2017). Researchers predict an increase in the frequency of such severe Category (Cat) 4 and 5 storms like Matthew and more recent Dorian in the 21st century (Bender et al., 2010; Walsh et al., 2016). From the point of view of this study, hurricane Dorian is the most recent and prominent example of extreme events and their impacts on the wider social-economic and environmental conditions of the Bahamas (IDB, 2019). Pacific SIDS that rely on tourism have also been severely impacted during the South Pacific cyclone season. One recent example from 2018 is Cyclone Gita, a Cat 4 storm, that made landfall in Tonga causing widespread infrastructural damages. With an increase in the frequency of more severe storms worldwide over the coming years combined with SLR, potential damages could be exacerbated.

Many SIDS are dependent on single economic sectors such as tourism that provide the main source of employment and economic growth. In the Caribbean region, tourism created one in four new jobs and contributed to 20% of the total visitor exports in 2019 (WTTC, 2020). The tourism sector generated USD 3678 million accounting for 81.6% of the Bahamas visitor exports. In addition to foreign exchange, this sector, in particular hotels and restaurants, is a significant area of interest for foreign direct investments in the Caribbean SIDS. A well-managed tourism sector can also provide opportunities for the growth of other sectors such as fisheries (UNCTAD, 2014). While the tourism sector constitutes part of regional assessments, specific destination-focused research is essential to understand the multifaceted nature of climate change impacts on tourism. The Economic Commission for Latin America and the Caribbean (ECLAC) has produced some country-level assessments of climate change impacts on tourism for several Caribbean SIDS (ECLAC, 2011). However, the assessments lack consideration of multiple impacts. For example, the ECLAC report for the Bahamas "An Assessment of the Economic Impact of Climate Change on the Tourism Sector in the Bahamas" used a Tourism Climate Index (TCI) to model changes in tourist demand but lacked a clear focus of the direct changes on the source market due to climate change.

For this study, we examine the risks posed by climate change to the Bahamas tourism sector. We consider different direct and indirect impacts that may affect the tourism sector in particular and the Bahamas, in general. Specifically, we used integrated impact pathways adapted from the conceptual framework of Scott et al. (2008), Scott, Hall, and Stefan (2012a), and Scott and Verkoeyen (2017) that may affect the tourism sector in the SIDS. Our main research objectives are to 1) assess the inundation and coastal flooding related impacts on coastal tourism by a 1m SLR and storm surge, 2) assess the impacts on tourism due to flooding and erosion exacerbated by a future SLR scenario and, 3) quantitatively assess the major social-economic and environmental losses stemming from these projected impacts. The overall goal is to timely identify climate risks which can then support decision-making and adaptation planning for tourism stakeholders subjected to these changing climatic conditions.

Many SIDS have developed national strategies in the form of National Adaptation Programmes of Action (NAPAs) and National Communications (NCs) to plan for future climatic changes. While the tourism sector constitutes a part of these reports, most SIDS lack specific planning for climate change while ensuring the growth and management of their main economic sector, tourism. A few exceptions such as the Barbados and Belize have developed dedicated departments for coastal zone management and devised Integrated Coastal Zone Management (ICZM) plans and policies. However, the examples of such integrated responses are relatively limited in most SIDS.

Our selection of the Bahamas is based on the following: a) it faces similar vulnerabilities to climate change as other SIDS, b) it is a heavily tourism reliant economy that provides an avenue for understanding the spillover effects of climate change at the country level, and c) the recent encounters of high-intensity hurricane events in the country. The Bahamas is a large archipelago with a land area of 10,010 km^2 comprising of 700 islands of which 30 are inhabited (CIA, 2018). The islands are dominated by two carbonate platforms with less than 10 m depth (Buchan, 2000). In the SIDS, the Bahamas has the highest share of the population, 82.8%, living in the Low Elevation Coastal Zones (LECZ), the contiguous area along the coast that is less than 10 m above sea level (Mycoo and Donovan, 2017). One hundred percent of the population in the country lives within 25 km of coastline (Mycoo and Donovan, 2017). In 2019, tourism in the Bahamas contributed to 43.3% of the GDP (WTTC, 2020). A total of 52.2% of the jobs are supported by tourism and the sector generated 81.6% of the total visitor export-related revenue in 2019 (WTTC, 2020). The Bahamas have experienced five major hurricanes over the past five years. These include a Cat 5 hurricane in 2019, Dorian, after facing a Cat 4 hurricane Matthew in 2016. Other major hurricanes such as Maria and Irma caused damages to some smaller islands in the Bahamas. Nevertheless, all hurricane events, regardless of their magnitude, disrupt the national government, alter visitor's perception, and decrease tourism-related revenue. The Bahamas, therefore, is a good example of a SIDS to achieve our research objectives. The paper is structured as follows. In section 2, we describe the methodology of our study beginning with a thorough description of our study area. This is followed by the explanation of our findings in Section 3. We discuss our most important findings in section 4 and finally, section 5 concludes our study.

2. Materials and methods

2.1. Study area

Two islands of the Bahamas – New Providence (NP) and the adjacent Paradise Island (PI), hereafter NP and PI (Fig. 1) were chosen for this study because they have the highest room count of tourism accommodations (62.04%), and a large number of employees, visitors and related expenditures in the sector. The Bahamas' Ministry of Tourism (MOT) lists NP as generating more than 90% of the jobs in the accommodation and food service sector from 1999 to 2012 (MOT, 2019). Out of the 1.63 million visitors in the Bahamas in 2018, 67.2% (1.09 million) stayed on these two islands. The islands have consistently contributed the most to the visitor expenditure since 1989 (the earliest data available at the MOT). Based on the visitor expenditure data provided by the MOT, 67–68% of the visitor expenditures in 2015-16 came from NP and PI (MOT, 2016). Out of this total expenditure on the islands, stopover visitors (who stay at least one night) contributed as high as 86.8% to the total visitor expenditure while cruise visitors and day visitors who do not stay overnight contributed to 13.08% and 0.09% respectively. Many family islands in the Bahamas Archipelago such as Abaco and Eleuthera as well as Grand Bahama Island are growing as tourism destinations, but NP/PI combined dominate the sector (see Fig. 2 for comparative statistics).

NP and PI of the Bahamas Archipelago have the highest contribution to the tourism sector. These islands contributed 47.8% of the total revenue to the Bahamas GDP (USD 4.3 billion) in 2017 (WTTC, 2018). As much as 72.8% of the total exports in the Bahamas are generated as spending by international visitors (WTTC, 2018). The sector is also the largest contributor to employment in NP with 53.1% females and 46.9% males employed in the sector (MOF, 2018). Thus, tourism provides important job opportunities for the local

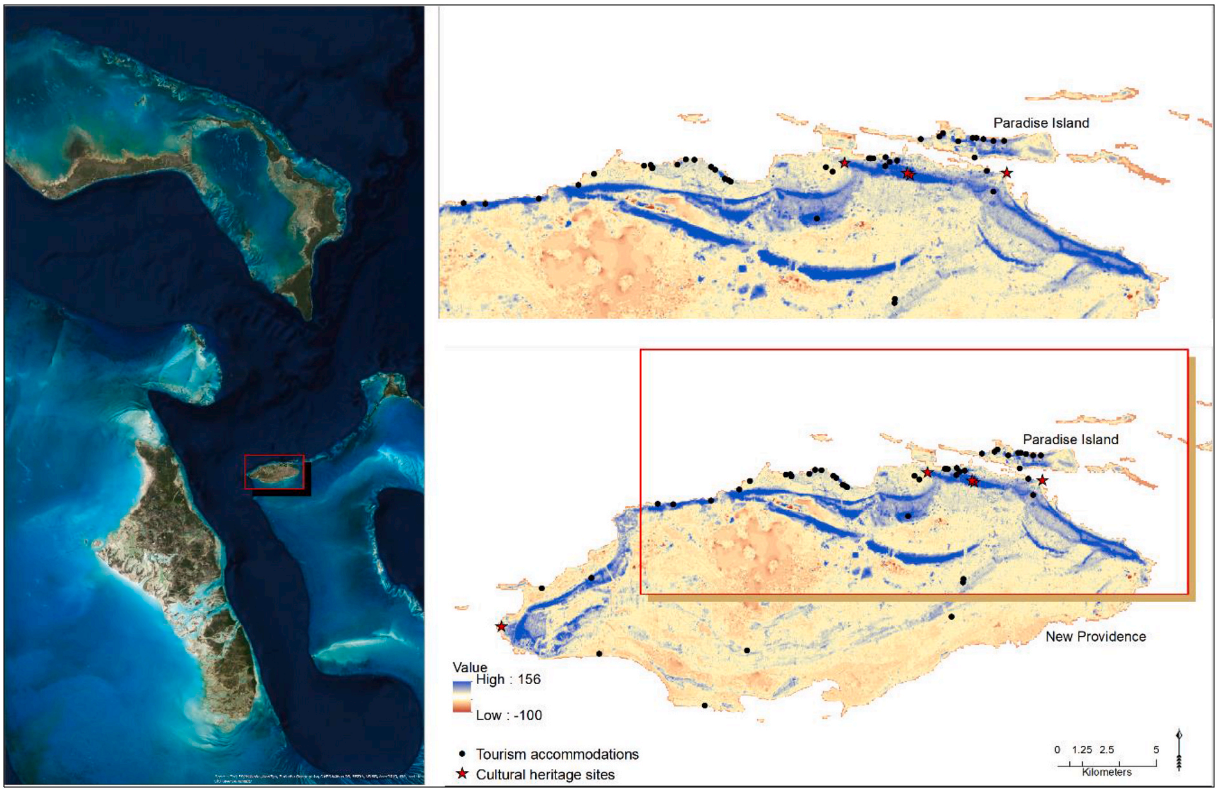


Fig. 1. Location of the study area (left); DEM of study area showing the location of tourism infrastructure (bottom right); close up view of the populated northern coast and the adjacent Paradise Island (top right).

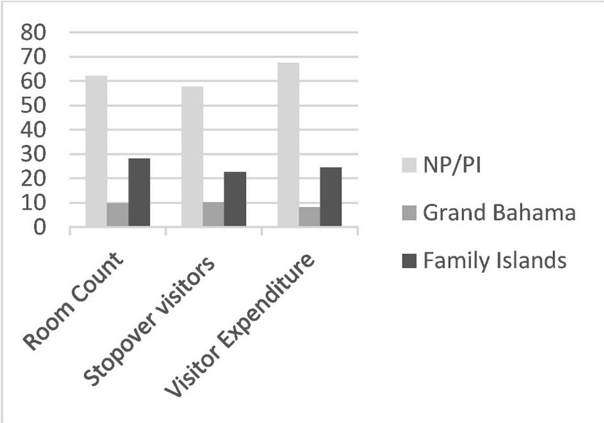


Fig. 2. Percentage of contribution to the selected tourism-related indicators from three main island groups in the Bahamas in 2018.

population. Considering the importance of the tourism industry in the Bahamas, any potential climate-induced losses to its two main tourism-generating islands will likely have far-reaching social-economic implications. Therefore, these islands together provide an avenue for understanding the potential impacts of climate change and its spillover effects on the entire country.

2.2. Methodology

The four impact pathways through which climate change may affect tourism are – a) direct impacts from changing climate, b) indirect environmental change and cultural heritage impacts, c) indirect impacts associated with societal change and, d) impacts induced by climate change mitigation and adaptation in other sectors (Scott et al., 2008, 2012a; Scott and Verkoeyen, 2017). We operationalized three of these impact pathways by developing specific indicators for the quantification of impacts and potential losses (Fig. 3).

The indicators for different types of impacts were selected based on suitability to the study area, literature review, and the

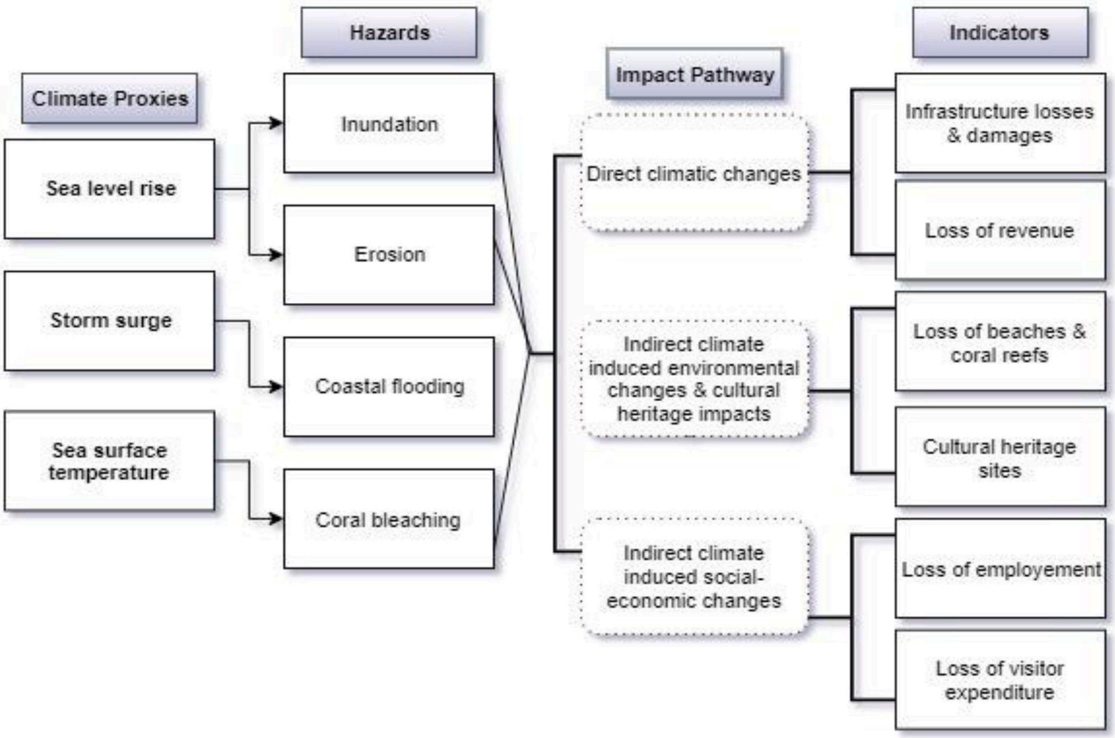


Fig. 3. Selected climate change impact pathways for tourism in SIDS.

availability of data. A detailed description of the chosen indicators is provided below (Table 1).

2.2.1. Sea level rise and storm surge

In a recent report published by the IPCC, Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), the rate of Global Mean Sea Level (GMSL) can reach 15 mm/year if the Antarctic contributions to GHGs are taken into account (IPCC, 2019). According to the report, SLR projections vary from a lower bound of 0.43 m (Slangen et al., 2014) to as high as 2.46 m (Le Bars, Drijfhout and de Vries, 2017) depending upon the baseline period and the choice of probabilistic or semi-empirical models (IPCC, 2019).

Local sea level data is not available for the study area. The nearest tide gauge data is available for the Settlement Point in the Bahamas maintained by the Permanent Service for Mean Sea Level (PSMSL, 2020). A time-series analysis of the tide gauge SLR data available from 1986 to 2000 and 2005–2016 shows an upward trend in sea level. However, the discontinuity and gaps in the available measurements make the available GMSL projections a more reliable choice of SLR. Considering the variability in global projections and gaps in the regional dataset, this study uses a conservative 1 m SLR scenario by 2100 that has been commonly used in similar studies that evaluated impacts of SLR on tourism infrastructure (e.g., Fang et al., 2016; Isaac, 2013; Scott et al., 2012b; Simpson et al., 2010). The Second National Communication document recognizes that the rate of SLR in the Bahamas is slower than vertical land movement. It also suggests that “sea level is rising at a rate of 0.2 mm/yr (the difference between vertical land movement and thermal expansion) (p.33)” and the future SLR will be in line with the global trends (The Commonwealth of the Bahamas, 2014).

We used the SLOSH (Sea, Lake and Overland Surges from Hurricanes) model to calculate potential surge for an area by using a series of historical or hypothetical hurricanes of various Saffir-Simpson categories, speed, landfall location, and direction (e.g., Frazier et al., 2010; Sealy and Strobl, 2017). Each model run reflects the maximum surge height for a particular grid cell. The outputs from each model run are combined to form a composite Maximum Envelope of Water (MEOWs) for each hurricane category, speed, and direction on the Saffir-Simpson Scale (National Hurricane Center, 2003). A further composite called Maximum of MEOWS (MOM) is generated for all simulated hurricanes for a given Saffir-Simpson scale category regardless of landfall direction and speed (Glahn et al., 2009). Here we use the MOM outputs generated from the SLOSH display in the Bahamas Basin that encompasses the entire study area. Gridded layers as shapefiles were downloaded for three hurricane categories: weak (Cat 1), moderate (Cat 3), and strong (Cat 5). The MOM outputs provide a conservative estimate of surge height as it does not account for wind-driven waves that increase the storm surge height (Frazier et al., 2010). Since storm surge is the most significant concern for the coastal Bahamas, the product is useful for making early decisions by planners and fits the purpose of our study.

2.2.2. Tourism infrastructure and cultural heritage sites

We used the tourism infrastructure on the islands of NP and PI for the above analysis. Only formal accommodation providers such as hotels and resorts are included in our analysis as they generate the highest revenue for the entire sector. An initial list of tourism hotels and resorts (n = 57) was obtained from the Directory of Hotels – June 2018 published by the Bahamas Ministry of Tourism (MOT, 2018). This document provides a comprehensive account of tourism type, location, address, and room count. These properties were identified in Google Earth to verify their geographic location. During this step, two properties were eliminated due to missing geographic information on Google Earth or lacking any online records for identification (such as an address, website, etc.). Two more properties were eliminated due to a practically insignificant room count of five or less. A geospatial dataset of the final tourism properties (hotels and resorts; n = 53) was prepared for the analysis. Out of these properties, 40 hotels/resorts were located on the

Table 1
Indicators used to examine three impact pathways. USD: US dollars.

Indicators	Metric	Data Source and Analysis	Rationale for Use
Infrastructure losses and damages	Property count (number of hotels and resorts)	Elevation data (ALOS GDEM) Major tourism properties point shapefile (hotels and resorts) Island boundaries shapefile (Humanitarian Data Exchange) SLOSH gridded shapefiles *Geospatial analysis*	Coastal resort properties in the Caribbean are vulnerable to 1m SLR (Isaac, 2013; Scott, Simpson and Sim, 2012b)
Loss of revenue	Loss in occupancy	Room count (MOT, 2018)	Tourism sector contributed to 47.8% of total GDP in the Bahamas (WTTC, 2018)
Loss of beaches and coral reefs	Properties susceptible to erosion Loss reef area	Beach width Distance from the coast, meters Coral reef cover, sq. km (Arkema et al., 2017; Simpson et al., 2012)	Beaches and coral reefs are important factors for tourism destinations (Uyarra et al., 2005)
Cultural heritage sites	Number of sites susceptible to SLR, storm surge	Heritage site point shapefiles *Geospatial analysis*	Heritage tourism is growing as a tourism market in the Caribbean (Jordan and Jolliffe, 2013)
Loss of employment	Ratio of bed capacity to staff	Occupational and wages data (MOF, 2018)	Tourism generated > 3 million jobs in SIDS and supported 55.7% of employment in the Bahamas in 2017 (WTTC, 2018)
Loss of visitor expenditure	Loss of tourists due to losses in recreational services provided by beaches and coral reefs	Average expenditure per number of tourists (MOT, 2017)	International visitors spent more than USD 2 billion (72.8% of total exports) in the Bahamas in 2017 (WTTC, 2018)

island on NP while 15 properties were located on PI. The properties were further categorized based on their location as designated in the Directory: beachfront (n = 27) and inland (n = 26); and type: budget (n = 24), economy (n = 13) and luxury (n = 16). The geospatial database also contained the following information: geographic coordinates of the property, elevation, and distance from the coast. A point shapefile containing the central point of each resort/hotel was created in ArcGIS version 10.4. A 100 m property buffer was applied to the point feature before conducting geospatial analysis to account for the total area of the properties.

In addition to tourism infrastructure, we also considered several cultural heritage sites on the two islands in our analysis. The official website of the Bahamas lists 17 cultural heritage sites in the Bahamas, nine of which are located on NP and PI. Of these, three cultural sites were historical villages and geographically dispersed over the islands. These villages do not have delineated boundaries and are spread out in a manner that made it difficult for mapping and conducting geospatial analysis, which excluded them from the study. Therefore, five cultural heritage sites were chosen for analysis: three forts, one national park, and one historic tourist attraction.

There are other critical infrastructures such as road networks and airports that are relevant to tourism management. A detailed impact analysis of key infrastructures for climate-induced SLR and storm surge in the Caribbean SIDS has already been conducted by Simpson et al. (2010) and therefore, we focused our analysis on the accommodation infrastructure most closely and directly related to generating tourism-related revenues.

2.2.3. Coastal flooding scenarios: current and future hazard assessment

The first step in this analysis was the delineation of the flood risk zones due to storm surge in the study area. A methodology similar to Frazier et al. (2010) was adopted. Current exposure of the tourism infrastructure to storm-surge flooding was estimated using SLOSH. The MOM outputs for each hurricane category were compared with a 30-m digital elevation model (DEM) of the study area. The DEM, also known as ALOS (Advanced Land Observing Satellite) DEM, was downloaded from the Japan Aerospace Exploration Agency (JAXA).

ALOS DEM is one of the most recent global DEM's available and has better vertical accuracy when compared with other comparable DEMs such as SRTM and ASTER GDEM (Grohmann, 2018; Santillan and Makinano-Santillan, 2016). An accuracy assessment is regarded as best practice for elevation centered geospatial analysis such as inundation and flooding (Gesch, 2018). We used the Trimble TSC3 handheld device based on Real-time Kinematic (RTK) surveying to collect ground truth GPS points. The values of elevation at the ground GPS points were compared with different global DEM elevations. We found that ALOS and SRTM GDEM had lower mean differences in the elevation than ASTER GDEM when compared to the GPS points. However, due to more missing values in the SRTM DEM, we chose to use ALOS DEM for our analysis.

ArcGIS was used for creating the flood risk maps and conducting the analysis. The first step was to convert the MOM shapefiles into raster grids using inverse distance weighted (IDW) interpolation. Raster calculator in the spatial analyst toolbox was then used to identify the areas where storm surge height exceeded the DEM elevation. This method generated a binary raster with the flooded and non-flooded cells. This raster was reclassified to create a final storm surge raster i.e. flood risk map containing only the flooded cells for each hurricane category. The cells that were surrounded by higher, non-flooded land and not hydrologically connected to the coastline were manually removed from the risk zones.

To compute future hazard zones enhanced by SLR, the DEM was modulated to represent a future scenario of 1 m SLR by lowering the elevation of the DEM by a meter through a raster calculator. The mapping process, described above, was used for newly created DEM to delineate enhanced areas with SLR and storm surge.

2.2.4. Calculating impact assessments

These flood risk maps were overlaid with the point shapefile of tourism infrastructure to assess properties at risk. To further quantify major social-economic and environmental losses associated with tourism, the following secondary datasets were used:

a) *Inundation related losses* - calculated by considering the total loss of revenue in terms of room count and average room rate in USD. The data on room count was obtained from the Bahamas MOT. While inundation may result in a total loss, a property affected by storm surge may not be completely destroyed. Consistent with other studies in the Caribbean (Moore et al., 2010) and more specifically in the Bahamas (ECLAC, 2011), this study uses a hurricane damage estimate of 10%, 35% and 75% for a Cat 1, 3 and 5 storm respectively. The total loss in room count was adjusted to account for these damage percentages. The most recent average daily rate (USD) of the rooms (ADR = Room Revenues/Rooms Sold), $303 for the Bahamas (STR, 2019), was used for calculating revenue losses. The revenue was calculated at a present-day ADR value i.e. it does not take into account future increases in the hotel prices and new constructions.
b) *Coastal erosion* - calculated using Bruun Rule, a two-dimensional conceptual model for predicting SLR induced erosion, which assumes that the coast retreats 50–100 times the vertical increase in sea level (Bruun, 1962). This rule has been criticized for being too simplistic and omitting important variables such as slope and lithology of the coast (Cooper and Pilkey, 2004). However, Atkinson et al. (2018) found shoreline recession relative to rising water levels falling within 25% of the prediction within the Bruun Rule. The rule has also been used recently in coastal destinations such as Thailand (Ritphring et al., 2018), Gambia (Amuzu et al., 2018) and many SIDS where data on the physical parameters of the coast are still lacking (Mueller and Meindl, 2017; Scott et al., 2012b). It was evident during field observations that the islands have a consistent beach profile with mostly sandy beaches and shallow slopes. Therefore, Bruun rule was used for an approximate estimation of the coastal properties at risk of erosion.

To determine erosion through the Bruun Rule, beach width in the two islands were initially evaluated from Google Earth images, however, it was evident that the width does not exceed 50 m for the two islands. Consequently, property distance from the coast was

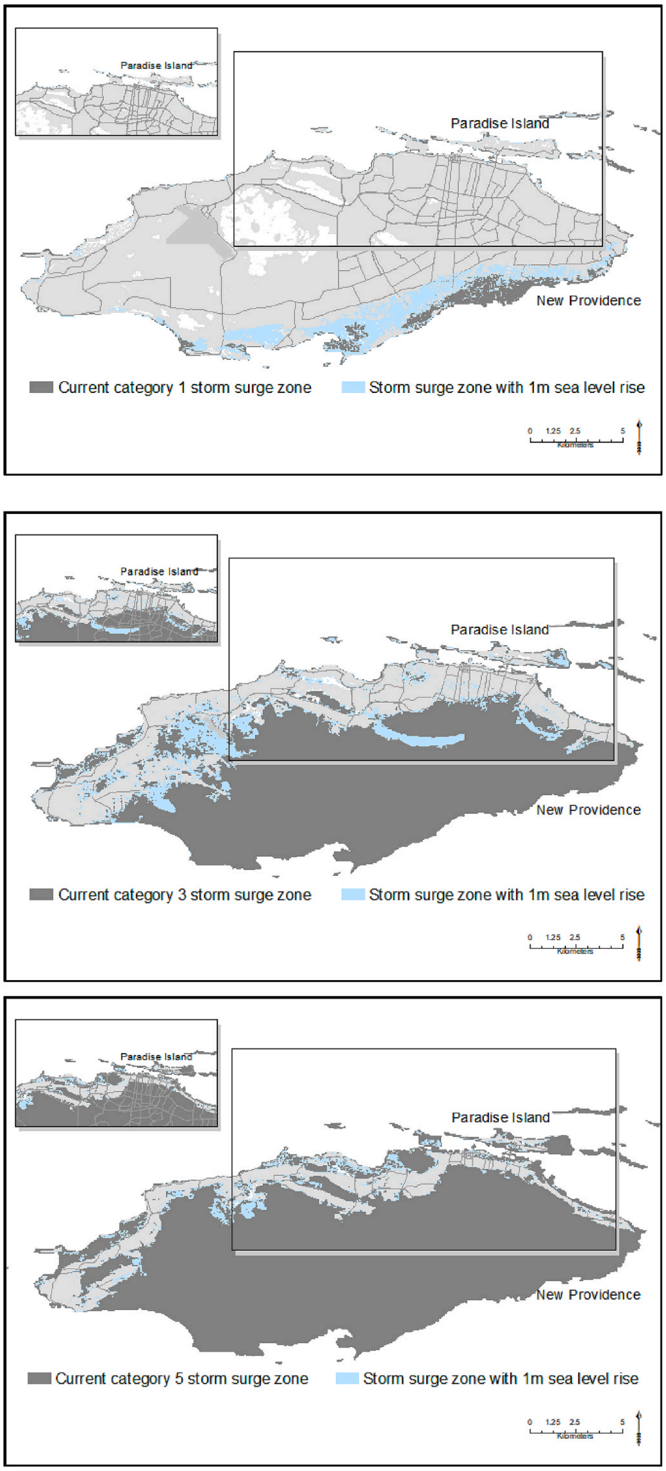


Fig. 4. Coastal flooding caused by storm surge and 1 m of sea level rise for a) weak storm (Cat 1) b) moderate storm (Cat 3), and c) strong storm (Cat 5).

used as an indicator of beach loss. If the properties were impacted by coastal erosion, this means that there is essentially no beach remaining after the storm, and the hotel is exposed to erosion related damages.

c) *Coral bleaching* - used as an indicator of loss of coral reefs. Global mean sea surface temperature can rise from 0.73 °C (RCP 2.6) up to 2.58 °C (RCP 8.5) by 2100 placing coral reefs from moderate to very high risks from climate change (Oppenheimer et al., 2019). IPCC's SR1.5 estimated a decline of 70–90% of coral reefs even with RCP2.6 and more than 99% coral reefs lost beyond a global temperature increase of 2 °C (Hoegh-Guldberg et al., 2018). Further, Burke et al. (2011) estimated 79% of the coral reefs in the Bahamas are threatened due to local and thermal stress. In the absence of more local studies that consider the site-specific risks to coral reefs based on their type, depth, etc., we used a conservative estimate of 70% decline in the coral reefs by the end of the century. Data on the total coral reef area for the Bahamas and reef area in NP is taken from the CARIBSAVE "Climate Change Risk Profile for The Bahamas" report (Simpson et al., 2012).
d) *Loss of employment* - computed by considering the average employee per room. Data on the average employee per room for the three different classes of accommodations as adjusted from the Caribbean Hotel and Tourism Association (CHTA): 2.8 for luxury hotels, 1.5 for moderate hotels, and 0.7 for a budget property. The most recent data on hotel employment (MOF, 2018) is only available for NP and shows 13,863 persons employed in the sector. The average employee to room ratio was extended to PI to estimate the total number of hotel employees on the two islands (n = 23,864).
e) *Loss of tourists and related expenditures* - quantified through the loss of natural resources (beaches and coral reefs) vital for tourism. The following data sources were used: an exit survey conducted by Research and Statistics Department of the Bahamas MOT (2017) that provides data on the visitor's preference for beaches and coral reef-related activities (snorkeling and scuba diving) in the Bahamas. The exit survey provided the percent of visitors who primarily visited the islands of NP and PI for their beaches. We then used the data from MOT on total stopover visitors to assess the number of beach visitors. These numbers were compared with the total visitors in the Bahamas to calculate the total visitor losses in the country due to lost beaches on the two islands. Similarly, the average expenditure per tourist (USD 1212.098) was calculated using MOT data on stopover visitors and visitor expenditure from 1990 to 2016 (MOT, 2016). Total visitor expenditure in the Bahamas was USD 2663.8 million (WTTC, 2018).

We limited our analysis to stopover visitors (who stay at least one night), deliberately excluded cruise and day visitors who do not stay overnight, and thus, do not contribute to the accommodation sector.

3. Results

Final flood risk maps for Cat 1, Cat 3, and Cat 5 storm at a present SLR scenario showed the changes in storm surge with a future increase of 1 m SLR (Fig. 4). The following section details various climate-related impacts relevant to the study area.

3.1. Direct climatic changes

Tourism properties at risk of SLR induced inundation: Results indicate that six properties (11%) are at risk of permanent inundation i.e. complete loss of occupancy due to a 1 m rise in sea level. These include one budget, one luxury, and four economy hotels and resorts. As expected, all of these are coastal beachfront properties. A total room capacity of 756 rooms will be impacted under this scenario.

Tourism properties at risk due to coastal flooding: Sea level rise considerably increases the extent of storm surge caused by various categories of storms (Fig. 4). Considerably more properties are impacted by storm-surge hazards as compared to permanent inundation. At present, coastal flooding caused by a weak (Cat 1), moderate (Cat 3) and strong (Cat 5) storm can potentially affect 34% (n = 18), 69% (n = 37), 83% (n = 44) of the tourism infrastructure (hotels and resorts), respectively. The percentage of infrastructure at risk increases considerably with the addition of a SLR scenario. For example, the number of properties increases from 18 to 27 when a Cat 1 storm is amplified by a 1 m SLR, resulting in a more than 18% increase of risk. Similarly, a Cat 3 and Cat 5 storm poses risk from

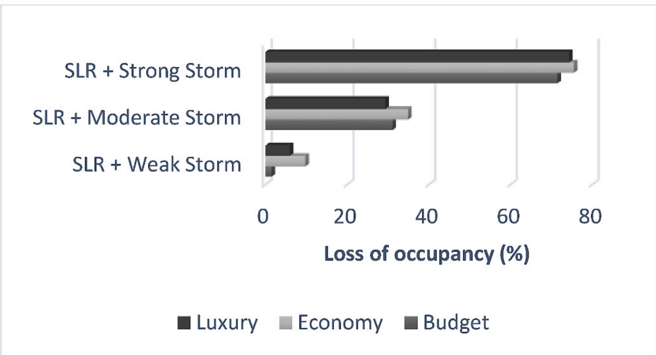


Fig. 5. Loss of occupancy in the tourism sector based on the property type due to sea level rise and storm surge.

75% (n = 40) to as much as 90% (n = 48) of the tourism properties when enhanced by a meter rise in SLR by 2100.

Tourism properties at risk due to sea level rise induced coastal erosion: 96% of the beachfront tourism properties (n = 27) are located within 100 m of the coast. Of these 27 properties, 12 are within 0–50 m of the coastline. For the inland properties (n = 26), six properties lie within 100 m of the coastline and three are within 50 m of the coastline. In summary, 28% of the total properties on the two islands are within 0–50 m while 60% of the tourism infrastructure resides within 0–100 m of the coastline.

Loss of occupancy and revenue: Assuming total losses by a 1 m SLR, 7% (756 rooms) of the total room count will be uninhabitable for accommodating visitors on the two islands. In addition, storm surge will also cause potential damage to the tourism infrastructure. A Cat 1 storm coupled with SLR will pose losses of occupancy to around 579 rooms (10% of a total 5795 rooms) whereas a Cat 5 storm surge will damage more than 7777 rooms on the two islands.

Fig. 5 presents the relative losses in room count based on the property type. More economy properties are impacted in the future 1 m SLR and all associated storm surge scenarios as compared to budget and luxury accommodations. Only 3% of luxury properties are at risk of potential SLR induced inundation. For these properties, the occupancy related losses increase from 5.9% to 29.2% when the storm category changes from Cat 1 to Cat 3. Comparatively, 14.4% and 19.8% of the budget and economic properties are at risk from the SLR and these risks increase to 31%–34.9% for Cat 1 and Cat 3 storm categories respectively. In the event of a strong storm, most properties will face a similar level of risks: 71.4% for budget, 75.4% for the economy, and 74.3% for luxury properties.

The decrease in revenues (Fig. 6) was estimated as follows: 7% for SLR, 5.5% for a weak storm (Cat 1), 30% for a moderate storm (Cat 3), and 74% for a strong storm (Cat 5) by 2100. Amongst other business interruptions due to flooding and inundation, the potential losses in occupancy will decrease revenues significantly.

3.2. *Indirect climate-induced environmental changes and cultural heritage impacts*

Loss of beaches: At present, the beach width for all the beaches on the two islands do not exceed 50 m putting them at risk of potential erosion caused by rising sea level. The erosion of coastal properties indicates that the beaches will be lost much earlier than the properties themselves. Potentially 60% of the coastal properties are susceptible to damages from erosion in the study area. In terms of occupancy, this damage translates into a room count of more than 92% (9727 rooms) in the two islands.

Loss of coral reefs: The Bahamas could possibly lose as much as 1390 sq. km of its coral reefs due to rising ocean temperature. NP consists of 30 sq. km (approx. 1.5%) of the total reef region in the Bahamas. Assuming a 70% decline in coral reef cover, NP could lose 21 sq. km of its coral reef cover. These losses will be exacerbated if the local threats such as overfishing, pollution, and coastal development are also taken into account (Burke et al., 2011). The coral reefs in NP are at high risk of coastal development and dredging while human activities such as pressure from fishing and invasive lionfish add to this risk (Arkema et al., 2017). The losses in the fringing coral reefs, mostly present on the northern side of the island, will alter many ecosystem services such as storm protection, local finfish fisheries, habitat for spiny lobster (main export of the Bahamas), and visitor expenditure (Arkema et al., 2017). It is worth noting that there is some evidence that suggests several reef species demonstrate higher resilience through adaptation and acclimatization to changing climate than others (Palumbi et al., 2014). However, for this study, we assume a total loss of coral reefs because such a fine level analysis is beyond the scope of our study.

Cultural heritage sites: Only one of the five cultural heritage sites face risks of inundation due to a meter SLR. This site, Fort Montagu, is also susceptible to all three storm surges and lies within less than 50 m of the coastline. In addition, the Clifton Heritage National Park on NP Island is at risk of flooding by a moderate (Cat 3) and strong (Cat 5) storm at the present SLR levels which obviously increases with the 1 m rise in sea level. The other three sites, due to their high elevation, are not at current or future risks of storm surge and SLR.

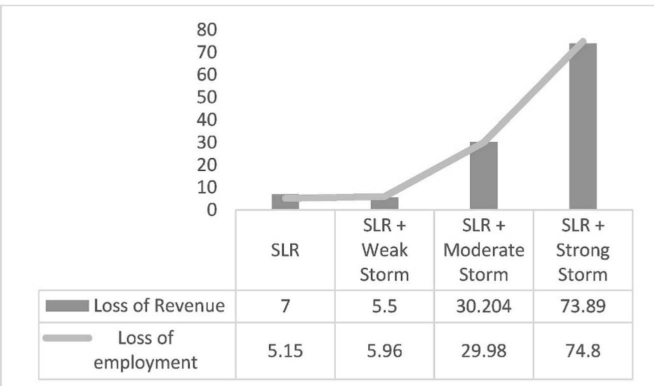


Fig. 6. Losses from SLR and SLR plus differing storm categories as a percent of total revenue and employment opportunities generated by the tourism sector in NP and PI.

3.3. Indirect climate-induced social-economic changes

Loss of employment: Sea level rise will directly affect only a small percentage (5.14%) of the total employment in the travel and tourism sector (Fig. 6). However, the number of employees will be significantly impacted due to storm surge with more than 74% of the total employment at risk due to a strong Cat 5 storm by 2100. These values are conservative estimates, as they do not account for future employment growth in the tourism sector.

Loss of tourist expenditures: The highest loss of tourism expenditure will result from the loss of beaches. The beaches of NP and PI are listed by 86% of tourists as the main reason why they come to the islands (Exit Survey, Bahamas MOT, 2017). Considering a total loss of beaches by 2100, this will result in a 56.17% decline of the total visitors in the Bahamas and a decrease in visitor expenditure by USD 981.75 million (36.8% of total visitor expenditure).

The 2017 exit survey conducted by the MOT found that coral reef-related activities such as snorkeling, and scuba diving are less preferred by visitors to NP and PI (39% and 7% respectively). The loss of coral reefs described above may induce losses up to 30.04% and 19.71% (USD 525.13 million) in terms of visitors and expenditure lost to the national Bahamas economy.

4. Discussion

Our findings show that the tourism sector on the islands of NP and PI is threatened by SLR and storm surge. Six properties (11%) are located within 1 m SLR and face the risk of inundation. Thirty-four percent (34%) of the coastal tourism businesses on the islands of NP and PI are currently located in a Cat 1 storm surge zone and more than 83% are located in a Cat 5 storm surge zone. With the future projected increase in SLR, the exposure from these storms can significantly increase to as much as 90% of the properties vulnerable if a Cat 5 storm makes landfall on these two islands. Even in a conservative scenario of Cat 1 storm surge, up to 51% of the properties will be vulnerable with a 1 m SLR scenario. It is worth noting that many recent studies have even considered an increase in sea level to as much as 2 m and beyond (Compact, 2015; Le Bars et al., 2017). This will be highly consequential to the tourism sector as well as the Bahamas as a whole. Any adaptation planning needs to consider these higher-end scenarios.

While SLR may pose direct inundation threats to only a small number of properties, the findings from storm surge exposure are pertinent to the Bahamas taking into consideration past hurricane devastation in the country. The Bahamas lost 10% of its GDP (estimated up to USD 551 million) due to hurricanes Frances and Jeanne in 2014 (The Commonwealth of the Bahamas, 2014). Hurricane Matthew in 2016 caused USD 129 million in damages to the tourism sector in the Bahamas (ECLAC, 2019). Even though it caused mild damage to the tourism infrastructure in NP, the island accounted for more than 40 percent of the total losses in the tourism sector of the Bahamas (ECLAC, 2019). The recent catastrophe from Hurricane Dorian, a Cat 5 storm, demonstrated the country's vulnerability to extreme weather events. Dorian's impacts were not on NP and PI but the Abaco and Grand Bahama Island to the north which differ in their geology from NP/PI. However, the tourism in NP/PI still suffered due to the consequences of Dorian due to potential tourists assuming that these two southern islands were also physically impacted by the storm. Notwithstanding potential changes in hurricane frequency and intensity of future Atlantic hurricanes (Bender et al., 2010; Walsh et al., 2016), this is a major threat as storm surge risks will be much greater for each hurricane category with rising sea levels. The Bahamas building code (2003) was mandated to provide standards on building design. These findings emphasize the need for further strengthening and updating the building codes to match the intensity of future events. This is a further step towards addressing Sustainable Development Goal (SDG) 13, particularly Target 13.1, which calls for strengthening resilience to climate disasters.

Inter-American Development Bank (IDB) estimated total costs of the impacts of the hurricane Dorian at USD 3.4 billion, accounting for a quarter of the country's GDP with the tourism sector bearing the highest losses (IDB, 2019). These losses are forecasted to be USD 325 million due to decreases in visitor arrivals and changes in tourist preference due to damaged structures (IDB, 2019). The sector faced damages up to USD 530 million (IDB, 2019). These impacts will be exacerbated by post disasters issues such as disaster debris, contaminated freshwater lenses, and declines in fishery production (EDM, 2019) that further magnify the losses to the tourism industry on the affected islands, as well as the broader social-economic situation in the country.

With regard to property type and increased storm surge, low budget and economy class properties are at greater risk compared to large luxury accommodations. Such properties with limited capital will have greater difficulty recovering from storm damage. Less than half of the small hotels interviewed on the islands of NP and PI could afford hurricane insurance coverage due to low occupancy, high operating costs, and high insurance premiums (Thomas, 2012). An Australian study presented similar findings where small-scale businesses lacked coverage compared to larger tourism enterprises (Cioccio and Michael, 2007). In the Bahamas, insurance premiums are likely to increase further following hurricane Dorian, thus, adding to the vulnerability of smaller tourism businesses.

Natural resources such as beaches and coral reefs are vital to the tourism sector. The vulnerability of beaches is most pertinent to NP and PI as these coastal features buffer hotels and resorts on the southern side of the islands from the full extent of damage that can be wrought by the hurricanes. They also attract the highest number of tourists and therefore revenue. While coral reef-based activities such as snorkeling and diving are comparatively less preferred by tourists, the reefs remain a substantial draw and provide many ecosystem services such as storm protection and fisheries' habitat. Silver et al. (2019) modeled the coastal protection benefits of ecosystems in the Bahamas and found that these ecosystems were vital in reducing shoreline exposure to coastal hazards for all Bahamian islands. This was also evident in our study where the northern side of the NP Island, where the majority of the tourism infrastructure located, benefits from wave attenuation and storm protection provided by the nearby Cays and the fringing reef. In contrast, the southern side of the island is more exposed due to its lack of physical barriers and the shallow waters of this region of the Great Bahama Bank.

The reefs are also an important habitat for spiny lobster, which is one the main export fisheries of the Bahamas and contributes to more than 90% of the exports from the country (FAO, Bahamas, 2018). In addition to overexploitation and coastal zone development, lobster and finfish fisheries are sensitive to damages to coral reefs (FAO, Bahamas, 2018). Caribbean Challenge Initiative (CCI) and the Bahamas Protected are involved in the effective management of Marine Protected Areas (MPAs) in the country. In the NP, two MPAs – Southwest NP Marine Managed Area (SWMMA) and Bonefish Pond National Park generate ecosystem services in terms of recreation, tourism, fisheries habitat, and storm protection values (Arkema et al., 2017). However, these areas are threatened by human activities such as dredging, oil leaks, extensive fishing, and tourist pressure (Arkema et al., 2017).

In the Bahamas, coastal ecosystems are tied to the economic development that requires an integrated management approach (Arkema and Ruckelshaus, 2017). Such planning goes towards meeting SDG 14.2 for sustainable management of marine and coastal ecosystems, as well as SDG 14.7 for increasing the economic benefits of tourism to SIDS. In 2002, a preliminary document for the national ICZM planning process for the Bahamas was introduced with the cooperation of the Inter-American Development Bank (IDB). This document assessed the current coastal zone management issues in the country and proposed guidelines such as zoning ordinances and marine protected areas to safeguard the coastal ecosystems and promote sustainable use of resources. More recently, IDB has provided a USD 35 million loan to the Bahamas for Climate-resilient Coastal Management and Infrastructure Program, out of which USD 23.5 million are dedicated towards shoreline stabilization and coastal flood control measures on NP Island (IDB, 2017). The program also calls for natural infrastructure based coastal protection strategies and building national capacity for ICZM. Similarly, Vision 2040, National Development Plan of the Bahamas, highlights researching and implementing climate change adaptation and mitigation measures and integrating disaster risk reduction into development policies as important goals. While ICZM has been in the Bahamas planning process for more than a decade now, there is still no national framework or dedicated unit for ICZM in the country.

In our paper, we evaluated the effects of climate change on two main tourism islands in the Bahamas. It is evident from the findings that a multitude of the impacts that the sector may face will have spillover effects on the whole country. Nonetheless, tourism's contribution to the social-economic conditions of the Bahamas cannot be neglected. Therefore, integrated management is required to manage sector sustainably while dealing with climate change. Many recent plans and programs in the country have focused on such integrated planning. With a few exceptions such as Barbados and Belize, the scope of ICZM remains a challenge for most SIDS and requires further research. Our findings present the first step to understand the different climate-induced risks and the ways that climate change can affect a specific tourism-based economy. Taking into account the magnitude of these impacts and the increasing storm frequencies in the Bahamas by each passing year, we further emphasize the urgent need for integrated planning. This comes at a time when travel-based revenues for SIDS will be further reduced for at least 1–2 years with other scenarios depending on how the still-developing COVID-19 pandemic disrupts travel and other tourism sectors, which will vary geographically. Currently, the Bahamas is coping with the aftermath of Hurricane Dorian (a Cat 5 storm), and combined with the pandemic, the impacts are particularly unprecedented and challenging. The pandemic provides a snapshot of the fragility of the tourism sector due to its dependence on international markets in SIDS. At the same time, it also focuses attention on the need for integrated planning that pro-actively accounts for external shocks and disruptions.

Even in the face of shocks and challenges discussed in this study and beyond, the tourism industry is no less resilient with the ability to bounce back and continuing to grow. Just from 2017 to 2018, there was a 10.5% increase in tourist arrivals in the Bahamas (Caribbean Tourism Organization, 2019) and WTTC (2018) predicted an increase of more than 3% per annum in tourism's contribution to the Bahamas' GDP and employment sector over the next decade, although this was before Hurricane Dorian and COVID-19. Currently, the tourism industry is concentrated on the islands of NP/PI with heavy dependence on direct foreign investments. The country is aiming to develop tourism on family islands and new destinations through strengthening their intra-island airlift and transportation linkages to increase visitation beyond the NP/PI islands (National Development Plan, 2017). Some islands such as San Salvador, Great and Little Inagua, Mayaguana and the Ragged Island Chains have less exposed shorelines due to their higher elevations, rocky shorelines and lower exposure to storm surge as compared to the more vulnerable Abaco, Andros and NP/PI islands (Silver et al., 2019). The potential of extending tourism to these islands needs to be explored to effectively manage the growing industry. In order to do so, the sector needs to improve its value chain by building domestic capacity and improving linkages between foreign and domestic firms. However, the ideal strategies would be those that support climate change adaptation. This will require an integration of public and private stakeholders involved in the tourism sector of the country. Hess and Kelman (2017) suggested mechanisms such as public-private partnerships, building standards and regulations, adaptation taxes and funds, and risk transfer mechanisms for the tourism industry to support adaptation for climate change in SIDS. Specific case studies on the adaptation potential of the SIDS′ tourism sector and their perception towards such measures will also help advance the sustainability of the sector as well as the whole country.

5. Conclusion

In the Bahamas, similar to many other SIDS, there is a clear need for diversification from a single economic base such as tourism that is very climate sensitive. However, the current importance of tourism to these countries with otherwise limited resources cannot be ignored. Our study examines specific risks to tourism from climate change to support efforts for integrated climate risk management in the Bahamas. We find that the multiple and complex issues of many tourism-related impacts in the country warrant an ICZM planning process and associated updates of the Bahamas building codes to better prepare for future extreme weather events. However, it should be noted that other interacting factors may also shape the future of tourism in the Bahamas. These include changes in mitigation and adaptation planning of other sectors such as global aviation policies or the local construction sector, changes in the US economy (the largest visitor expenditure in the Bahamas), and other non-climate stressors. Limiting our study to stopover visitors also excludes other types of tourism such as cruise visitors and day tourists. We also acknowledge that there are factors such as rising groundwater levels and precipitation changes that can induce inland flooding in the country and impact the tourism infrastructure.

However, including all these factors and their implications to the tourism sector is beyond the scope of our research.

To improve our understanding of the multitude of the climate-related impacts faced by many SIDS, more country and island-specific studies are needed to draw out comparisons among SIDS. Thus, continuing such analysis on a case-by-case basis in the future will provide opportunities for better coastal management while supporting the growth of tourism for many other SIDS that are economically and socially dependent on the tourism sector.

Author statement

Arsum Pathak: Conceptualization, Methodology, Formal analysis, Data curation, Writing – Original Draft, Visualization. Philip E. van Beynen: Conceptualization, Writing – Review & Editing, Supervision, Project Administration. Fenda A. Akiwumi: Writing – Review & Editing, Supervision, Project Administration. Kenyon C. Lindeman: Conceptualization, Resources, Writing – Review & Editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank the Tharp Research Endowed Scholarship, School of Geosciences, University of South Florida, Tampa, FL USA, for funding the fieldwork. We thank the Bahamas Ministry of Tourism, in particular, Geneva Cooper and Bonnie Rolle, for facilitating the fieldwork. We thank Dr. Kathleen Sullivan Sealey, University of Miami, for providing helpful initial expertise on the study area. Many thanks to Ela Bialkowska-Jelinksa for her GIS guidance. We also thank the reviewers for their comments that considerably improved the quality of this paper.

References

Amuzu, J., Jallow, B.P., Kabo-Bah, A.T., Yaffa, S., 2018. The Socio-Economic Impact of Climate Change on the Coastal Zone of the Gambia.

Arkema, K.K., Ruckelshaus, M., 2017. Transdisciplinary research for conservation and sustainable development planning in the Caribbean. In: Conservation for the Anthropocene Ocean. Academic Press, pp. 333–357.

Arkema, K., Fisher, D., Wyatt, K., 2017. Economic Valuation of Ecosystem Services in Bahamian Marine Protected Areas. Prepared for BREEF by the Natural Capital Project. Stanford University.

Atkinson, A.L., Baldock, T.E., Birrien, F., Callaghan, D.P., Nielsen, P., Beuzen, T., et al., 2018. Laboratory investigation of the Bruun Rule and beach response to sea level rise. Coast. Eng. 136, 183–202.

Becken, S., 2013. A review of tourism and climate change as an evolving knowledge domain. Tourism Management Perspectives 6, 53–62.

Bender, M.A., Knutson, T.R., Tuleya, R.E., Sirutis, J.J., Vecchi, G.A., Garner, S.T., Held, I.M., 2010. Modeled impact of anthropogenic warming on the frequency of intense Atlantic hurricanes. Science 327 (5964), 454–458.

Bruun, P., 1962. Sea level rise as a cause of shore erosion. J. Waterw. Harb. Div. 88 (1), 117–132.

Buchan, K.C., 2000. The Bahamas. Mar. Pollut. Bull. 41 (1–6), 94–111.

Burke, L., Reytar, K., Spalding, M., Perry, A., 2011. Reefs at Risk Revisited. World Resources Institute.

Caribbean Tourism Organization, 2019. Caribbean tourism performance 2019 preliminary arrivals data. Retrieved. http://www.caribbeanhotelandtourism.com/wp-content/uploads/2019/04/Caribbean-Tourism-Performance-2018-Preliminary-Arrivals-Data-CTO.pdf. (Accessed 5 December 2019).

Central Intelligence Agency (CIA), 2018. The world factbook: Bahamas, the. Retrieved May 21, 2020, from. https://www.cia.gov/library/publications/the-world-factbook/geos/bf.html.

Church, J.A., Clark, P.U., Cazenave, A., Gregory, J.M., Jevrejeva, S., Levermann, A., et al., 2013. Sea Level Change. PM Cambridge University Press.

Cioccio, L., Michael, E.J., 2007. Hazard or disaster: tourism management for the inevitable in northeast victoria. Tourism Manag. 28 (1), 1–11.

Cooper, J.A.G., Pilkey, O.H., 2004. Sea level rise and shoreline retreat: time to abandon the Bruun Rule. Global Planet. Change 43 (3–4), 157–171.

Economic Commission for Latin America and the Caribbean (ECLAC), 2011. An assessment of the economic impact of climate change on the tourism sector in the Bahamas. Retrieved. https://repositorio.cepal.org/bitstream/handle/11362/38601/LCCARL315_en.pdf?sequence=1&isAllowed=y. (Accessed 25 October 2019).

Economic Commission for Latin America and the Caribbean (ECLAC), 2019. Assessment of the effects and impacts of hurricane Matthew - the Bahamas. Retrieved 5 Jan 2020 from. https://www.cepal.org/sites/default/files/static/files/matthew_bahamas_.pdf.

Environment and Disaster Management. (EDM), 2019. Hurricane dorian: environmental issues in the Bahamas. http://envirodm.org/post/hurricane-dorian-environmental-issues-in-the-bahamas. (Accessed 12 December 2019).

Fang, Y., Yin, J., Wu, B., 2016. Flooding risk assessment of coastal tourist attractions affected by sea level rise and storm surge: a case study in Zhejiang Province, China. Nat. Hazards 84 (1), 611–624.

Fang, Y., Yin, J., Wu, B., 2018. Climate change and tourism: a scientometric analysis using CiteSpace. J. Sustain. Tourism 26 (1), 108–126.

Fishery and Aquaculture Country Profiles. (FAO). Bahamas, 2018. Country profile fact sheets. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 05 07 2018. http://www.fao.org/fishery/.

Frazier, T.G., Wood, N., Yarnal, B., Bauer, D.H., 2010. Influence of potential sea level rise on societal vulnerability to hurricane storm-surge hazards, Sarasota County, Florida. Appl. Geogr. 30 (4), 490–505.

Gesch, D.B., 2018. Best practices for elevation-based assessments of sea level rise and coastal flooding exposure. Front. Earth Sci. 6, 230.

Glahn, B., Taylor, A., Kurkowski, N., Shaffer, W.A., 2009. The role of the SLOSH model in National Weather Service storm surge forecasting. Natl. Weather Digest 33 (1), 3–14.

Grohmann, C.H., 2018. Evaluation of TanDEM-X DEMs on selected Brazilian sites: comparison with SRTM, ASTER GDEM and ALOS AW3D30. Remote Sens. Environ. 212, 121–133.

Hess, J., Kelman, I., 2017. Tourism industry financing of climate change adaptation: exploring the potential in small island developing states. Climate, Disaster and Development Journal 2 (2), 33–45.

Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I., Guiot, J., 2018. Global warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. *Impacts of 1.5° C global warming on natural and human systems*.

Inter-American Development Bank (IDB), 2017. Climate-resilient coastal management and infrastructure program. Retrieved 5 Jan 2020 from. https://www.iadb.org/en/project/BH-L1043.
Inter-American Development Bank (IDB), 2019. Assessment of the effects and impacts of hurricane dorian in the Bahamas. Retrieved 5 Jan 2020 from. https://www.iadb.org/en/damages-and-other-impacts-bahamas-hurricane-dorian-estimated-34-billion-report.
IPCC, 2019. Summary for policymakers. In: Pörtner, H.-O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Nicolai, M., Okem, A., Petzold, J., Rama, B., Weyer, N. (Eds.), IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (in press).
Isaac, M., 2013. *The Implications of Sea level Rise for Tourism in St. Lucia* (Master's Thesis. University of Waterloo.
Jordan, L.A., Jolliffe, L., 2013. Heritage Tourism in the Caribbean: Current Themes and Challenges.
Kleinosky, L.R., Yarnal, B., Fisher, A., 2007. Vulnerability of Hampton Roads, Virginia to storm-surge flooding and sea level rise. Nat. Hazards 40 (1), 43–70.
Le Bars, D., Drijfhout, S., de Vries, H., 2017. A high-end sea level rise probabilistic projection including rapid Antarctic ice sheet mass loss. Environ. Res. Lett. 12 (4), 044013.
Ministry of Finance. (MOF), 2018. Occupations & Wages in the Hospitality Sector New Providence. Department of Statistics. https://www.bahamas.gov.bs/wps/wcm/connect/bdf18cdd-82c1-49a5-895b-a53100437766/HOTEL 2018 - Final.pdf?MOD=AJPERES.
Ministry of Tourism. (MOT), 2016. Yearly expenditure comparisons by Qtr & visitor type. Yearly expenditure comparisons by Qtr & visitor type. Research and statistics department. Retrieved 21 Oct 2019 from. http://www.tourismtoday.com/services/statistics/expenditure.
Ministry of Tourism. (MOT), 2017. Tour operator & media survey. Research and statistics department. http://www.tourismtoday.com/sites/default/files/tour_operator_and_media_brochure_summary_2017.pdf. (Accessed 21 October 2019).
Ministry of Tourism. (MOT), 2018. Directory of Hotels – June 2018. Hotel Licensing Department, Ministry of Tourism. http://www.tourismtoday.com/sites/default/files/hotel_directory_2018_-_final_version.pdf. (Accessed 25 October 2019).
Ministry of Tourism. (MOT), 2019. Statistics. http://www.tourismtoday.com/services/statistics.
Moore, W.R., Harewood, L., Grosvenor, T., 2010. The Supply Side Effects of Climate Change on Tourism.
Mueller, N.J., Meindl, C.F., 2017. Vulnerability of caribbean island cemeteries to sea level rise and storm surge. Coast. Manag. 45 (4), 277–292.
Mycoo, M., Donovan, M.G., 2017. A Blue Urban Agenda: Adapting to Climate Change in the Coastal Cities of Caribbean and Pacific Small Island Developing States.
National Development Plan, 2017. National development plan of the Bahamas - 2nd working draft (the Bahamas). http://www.vision2040bahamas.org/media/uploads/2nd_Working_Draft_of_the_NDP_website_30.11.17c.pdf.
National Hurricane Center (NHC), 2003. SLOSH Model. https://www.nhc.noaa.gov/surge/slosh.php. (Accessed 25 October 2019).
Neumann, J.E., Emanuel, K., Ravela, S., Ludwig, L., Kirshen, P., Bosma, K., Martinich, J., 2015. Joint effects of storm surge and sea level rise on US Coasts: new economic estimates of impacts, adaptation, and benefits of mitigation policy. Climatic Change 129 (1–2), 337–349.
Nurse, L.A., McLean, R.F., Agard, J., Briguglio, L.P., Duvat-Magnan, V., Pelesikoti, N., Tompkins, E., Webb, A., 2014. Small islands. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1613–1654.
Oppenheimer, M., Glavovic, B.C., Hinkel, J., van de Wal, R., Magnan, A.K., Abd-Elgawad, A., Cai, R., Cifuentes-Jara, M., DeConto, R.M., Ghosh, T., Hay, J., Isla, F., Marzeion, B., Meyssignac, B., Sebesvari, Z., 2019. sea level rise and implications for low-lying islands, coasts and communities. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (in press).
Palumbi, S.R., Barshis, D.J., Traylor-Knowles, N., Bay, R.A., 2014. Mechanisms of reef coral resistance to future climate change. Science 344 (6186), 895–898.
Permanent Service for Mean Sea Level. (PSMSL), 2020. In: Tide Gauge Data. Retrieved 25 Nov 2019 from http://www.psmsl.org/data/obtaining/.
Ritphring, S., Somphong, C., Udo, K., Kazama, S., 2018. Projections of future beach loss due to sea level rise for sandy beaches along Thailand's coastlines. J. Coast Res. 85 (sp1), 541–545.
Santillan, J.R., Makinano-Santillan, M., 2016. Vertical accuracy assessment OF 30-M resolution ALOS, ASTER, and SRTM global DEMS over northeastern MINDANAO, Philippines. *International Archives of the photogrammetry*. Remote Sensing & Spatial Information Sciences 41.
Scott, D., Verkoeyen, S., 2017. In: Jones, A., Phillips, M. (Eds.), Assessing the Climate Change Risk of a Coastal-Island Destination. *Global climate Change and Coastal Tourism: Recognizing Problems, Managing Solutions and Future Expectations*, Centre for Agriculture and Biosciences International (CABI), pp. 62–73. Wallingford, UK.
Scott, D., Amelung, B., Becken, S., Ceron, J.P., Dubois, G., Gössling, S., et al., 2008. Climate Change and Tourism: Responding to Global Challenges, vol. 230. World Tourism Organization, Madrid, pp. 1–38.
Scott, D., Hall, C.M., Stefan, G., 2012a. Tourism and Climate Change: Impacts, Adaptation and Mitigation. Routledge.
Scott, D., Simpson, M.C., Sim, R., 2012b. The vulnerability of Caribbean coastal tourism to scenarios of climate change related sea level rise. J. Sustain. Tourism 20 (6), 883–898.
Scott, D., Hall, C.M., Gössling, S., 2016. A review of the IPCC Fifth Assessment and implications for tourism sector climate resilience and decarbonization. J. Sustain. Tourism 24 (1), 8–30.
Sealy, K.S., Strobl, E., 2017. A hurricane loss risk assessment of coastal properties in the Caribbean: evidence from the Bahamas. Ocean Coast Manag. 149, 42–51.
Silver, J.M., Arkema, K.K., Griffin, R.M., Lashley, B., Lemay, M., Maldonado, S., et al., 2019. Advancing coastal risk reduction science and implementation by accounting for climate, ecosystems, and people. Frontiers in Marine Science 6, 556.
Simpson, M.C., Scott, D., Harrison, M., Silver, N., O'Keeffe, E., Harrison, S., Taylor, M., Sim, R., Lizcano, G., Wilson, M., Rutty, M., Stager, H., Oldham, J., New, M., Clarke, J., Day, O.J., Fields, N., Georges, J., Waithe, R., McSharry, P., 2010. Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean. United Nations Development Programme (UNDP), Barbados, West Indies.
Simpson, M.C., Clarke, J.F., Scott, D.J., New, M., Karmalkar, A., Day, O.J., Taylor, M., Gossling, S., Wilson, M., Chadee, D., Stager, H., Waithe, R., Stewart, A., Georges, J., Hutchinson, N., Fields, N., Sim, R., Rutty, M., Matthews, L., Charles, S., 2012. CARIBSAVE Climate Change Risk Atlas (CCCRA) - the Bahamas. *DFID, AusAID and the CARIBSAVE Partnership*.
Slangen, A.B.A., Carson, M., Katsman, C.A., Van de Wal, R.S.W., Köhl, A., Vermeersen, L.L.A., Stammer, D., 2014. Projecting twenty-first century regional sea level changes. Climatic Change 124 (1–2), 317–332.
Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group (Compact), 2015. Unified Sea Level Rise Projection for Southeast Florida. A Document Prepared for the Southeast Florida Regional Climate Change Compact Steering Committee, p. 35.
Stewart, S.R., Berg, R., 2017. National hurricane center tropical cyclone report.
STR, 2019. Hotel Performance in the Caribbean Region. Caribbean Hotel & Tourism Association. http://www.caribbeanhotelandtourism.com/wp-content/uploads/2019/07/STR-Caribbean-Hotel-Performance-Report-June-2019.pdf.
The Commonwealth of the Bahamas, 2014. Second national communication of the Commonwealth of the Bahamas under the united nations framework convention on climate change. https://unfccc.int/sites/default/files/resource/bhsnc2.pdf. (Accessed 25 October 2019).
Thomas, A.D., 2012. *An integrated View: Multiple Stressors and Small Tourism Enterprises in the Bahamas* (Doctoral Dissertation. Rutgers University-Graduate School-New Brunswick).
UN-OHRLLS, 2020. About SIDS - UN-OHRLLS. Retrieved 9 Jan 2020 from. http://unohrlls.org/about-sids/.
UNCTAD, 2014. FDI in small island developing states: its limitations and potential. https://unctad.org/en/PublicationsLibrary/webdiaeia2014d6_en.pdf.
Uyarra, M.C., Cote, I.M., Gill, J.A., Tinch, R.R., Viner, D., Watkinson, A.R., 2005. Island-specific preferences of tourists for environmental features: implications of climate change for tourism-dependent states. Environ. Conserv. 32 (1), 11–19.
Walsh, K.J., McBride, J.L., Klotzbach, P.J., Balachandran, S., Camargo, S.J., Holland, G., et al., 2016. Tropical cyclones and climate change. Wiley Interdisciplinary Reviews: Climate Change 7 (1), 65–89.
WTTC, W., 2018. Travel and Tourism: Economic Impact 2017 Bahamas. WTTC, London. (Accessed 15 November 2019).
WTTC, W., 2020. 2020 Annual Research: Key Highlights Bahamas. WTTC, London. (Accessed 15 May 2020).

Annex 552

S. N. Willner et al., “Investment incentive reduced by climate damages can be restored by optimal policy”, *Nature Communications,* 2021

nature COMMUNICATIONS

ARTICLE

https://doi.org/10.1038/s41467-021-23547-5 OPEN

Investment incentive reduced by climate damages can be restored by optimal policy

Sven N. Willner[1,4✉], Nicole Glanemann[1,4] & Anders Levermann[1,2,3✉]

Increasing greenhouse gas emissions are likely to impact not only natural systems but economies worldwide. If these impacts alter future economic development, the financial losses will be significantly higher than the mere direct damages. So far, potentially aggravating investment responses were considered negligible. Here we consistently incorporate an empirically derived temperature-growth relation into the simple integrated assessment model DICE. In this framework we show that, if in the next eight decades varying temperatures impact economic growth as has been observed in the past three decades, income is reduced by ~ 20% compared to an economy unaffected by climate change. Hereof ~ 40% are losses due to growth effects of which ~ 50% result from reduced incentive to invest. This additional income loss arises from a reduced incentive for future investment in anticipation of a reduced return and not from an explicit climate protection policy. Under economically optimal climate-change mitigation, however, optimal investment would only be reduced marginally as mitigation efforts keep returns high.

[1]Potsdam Institute for Climate Impact Research, Potsdam, Germany. [2]Columbia University, New York, NY, USA. [3]Institute of Physics, Potsdam University, Potsdam, Germany. [4]These authors contributed equally: Sven N. Willner, Nicole Glanemann. ✉email: sven.willner@pik-potsdam.de; anders.levermann@pik-potsdam.de

With future emissions of greenhouse gases climate change is likely to impact not only natural systems[1–3] but economies worldwide[4–7]. If these impacts alter future economic development, the financial losses will be significantly higher than the possible direct damages. Recent econometric analyses suggest that theses impacts may not just cause direct damage costs but decelerate economic growth and thus lead to persistent income losses in the future[8–11]. Such growth effects may significantly increase the total economic damage caused by climate change[12–17].

A global analysis[9] of the last three decades shows a maximum in the change of economic growth per capita at an annual average temperature of 13 °C. Increasing temperatures lead to a shift along this growth curve and overall yield a reduction in economic growth under future warming[9], thus reducing production and income. A decline in productivity, i.e. the efficiency in transforming production input into goods and services, caused by temperature stress[9,18,19] will evoke a response in investment behaviour. In general, it is to be expected that damages will reduce the incentive to invest and thereby lower the investment rate which will further reduce economic growth (Fig. 1). So far, this effect was suggested to be negligible[13]. However, other studies suggest a lasting effect of rising temperature on productivity as well as on asset valuations[20].

Here we investigate the response of future economic investment as a central part of the growth effect under unmitigated climate change as well as under optimal climate policy. To this end we employ a standard economic growth model (DICE-2013R[21]), which is designed to compute the economically optimal investment strategy in a changing environment. These growth models frame the investment decision as an inter-temporal trade-off between present-day consumption and investment for production to enable more consumption in the future. It computes the investment path that is considered to be welfare-optimal by maximising the temporally aggregated societal value or utility of consumption. It is important to note that we do not claim that the results of our computation represent a projection of the actual future economic path. Instead we compute the optimal economic path under different assumptions. This path is optimal in the sense that it optimises the global utility of consumption. While we cannot claim that this is how the economy evolves, we can compare the resulting paths with and without climate damages and make a relative statement about the investment in both cases. This represents an estimate of the effect of climate change damages on future investment even in the absence of policy measures such as carbon taxes or a carbon trading scheme.

Here we show that, if in the next eight decades varying temperatures impact economic growth in the same way as has been observed in the past three decades, the economically optimal investment response almost doubles the income loss from climate-induced growth reduction. This additional income loss arises from a reduced incentive for future investment in anticipation of a reduced return not from an explicit climate protection policy. In computing the economic path that optimises this century's global consumption under unmitigated climate change, we find a 22% income reduction compared to an economy unaffected by climate change. Hereof 40% are losses due to growth effects of which 48% result from a reduced incentive to invest under climate damages. On the other hand, economically optimal climate-change mitigation yields less than half the costs of unmitigated climate change. In this case, not only direct damages are reduced significantly, but also the effect of climate change on growth. As anticipated returns keep high, investment is only reduced marginally under climate abatement.

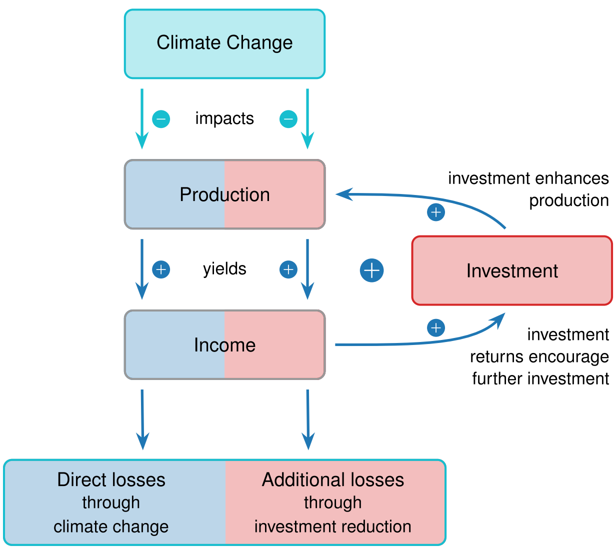


Fig. 1 Illustration of the investment effect. Climate change reduces productivity, which translates into direct income losses (blue boxes). The prospect of reduced investment returns in the future renders investment less attractive. Accordingly, economically optimal investment is reduced and less production enhancing capital is accumulated. As a result, economic growth slows down and yields a future of persistently lowered income. This effect arising through reduced investment incentives is here referred to as the additional investment effect (depicted by red boxes).

Results

Approach. In light of recent empirical studies[8–11] suggesting more considerable losses, we reconsider the role of the additional investment effect in exacerbating future income losses with and without climate-change mitigation. To this end, we modify the integrated assessment model DICE-2013R[21] such that it accounts for the estimated global growth impacts[9]. DICE is based on a neoclassical growth model[22–24], which computes economic growth effects caused by changes in investment. To preserve this feature, we develop an iterative process in DICE-2013R to find a productivity loss function that, taken together with the endogenously derived optimal investment response, reproduces the projected growth impacts in the absence of climate policy (Fig. 2; see Methods for more detailed information). This empirical productivity function yields direct damage costs of almost 10% of income for a warming of 3 °C compared to at most 5% in most previous studies[13,21,25,26].

With the iterative damage implementation in DICE-2013R, we compute the investment paths under different premises. $I_{\mathrm{opt}}^{\mathrm{nocc}}$ denotes the optimal investment in the absence of climate change; $I_{\mathrm{unadj}}^{\mathrm{cc}}$ denotes the investment in the presence of climate change but with unadjusted (i.e. same) investment rates compared to the case without climate change; and $I_{\mathrm{opt}}^{\mathrm{cc}}$ denotes the optimal investment under climate change in the sense as to maximise welfare. The optimal adjustment of investment to perceived climate damages already reduces the investment rate compared to a scenario with the absence of climate change significantly (Fig. 3).

Investment response. The optimal investment path under unmitigated climate change, $I_{\mathrm{opt}}^{\mathrm{cc}}$, yields a decrease in cumulative investment of 22% by 2100 compared to an economy without climate change, $I_{\mathrm{opt}}^{\mathrm{nocc}}$ (Fig. 4a). This leads to income losses over time (Fig. 4b) totalling to 104trn USD. The reasons for the income losses are (a) recurring direct damages caused by the

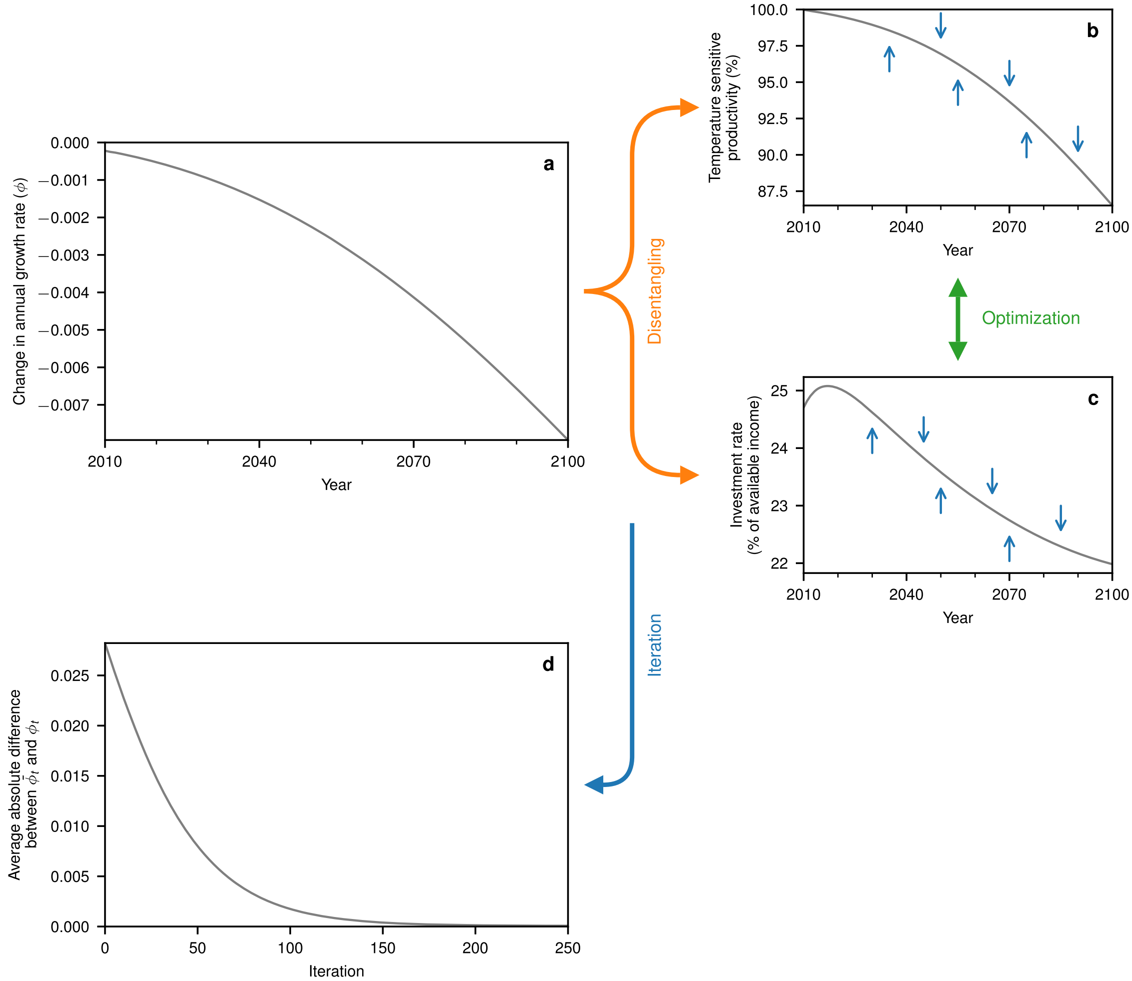


Fig. 2 Schematic representation of the iterative procedure. The estimated change in the annual growth rate due to temperature increase[9] (**a**) is disentangled into (**b**) the respective temperature-sensitive productivity function and into (**c**) its associated optimal investment response in the business-as-usual scenario, which is characterised by inaction of climate policy. **d** The iterated growth rate converges towards the estimated growth rate after ~200 iterations. Source data are provided as a Source Data file.

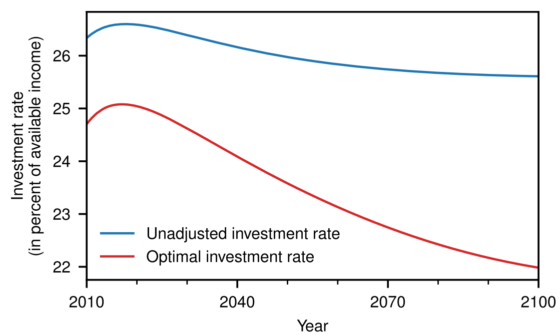


Fig. 3 Comparison of the unadjusted and optimal investment rate. The optimal investment rate is significantly lower than the unadjusted version. Note that the unadjusted investment rate is the same for a scenario with climate change and one without. Source data are provided as a Source Data file.

warming that reduce the income available each year (63trn USD or 60%), (b) thereby slowed economic growth due to the reduced availability of investable income (22trn USD or 21%), and (c) the amplification of the decelerated economic growth through a reduced incentive to invest because of the anticipation of smaller future return of this investment (20trn USD or 19%); as illustrated in Fig. 1 by light blue, dark blue, and red shading, respectively. The influence of the investment reduction on the income loss is quantified by the comparison of cases with optimal investment rates (with and without climate change) with the case with unadjusted investment (I^{cc}_{unadj}, red shaded area in each panel of Fig. 4).

The total income losses due to climate change without climate policy amount to 22% of the total income in 2100 (Fig. 5a). Hereof 40% are losses due to growth effects (9% of the total income, Fig. 5b). Of these growth effects 48% are due to the reduced investment (4% of the total income, Fig. 5c).

The role of social preferences. As commonly applied in economic growth models[24], the social preferences of consumption changes are represented by two parameters; the 'initial rate of social time preference' which expresses how strongly current consumption is favoured over future consumption and the 'elasticity of marginal utility of consumption' which captures the nonlinearity in the value of consumption for society (confer Methods for more details). We adhere to the original calibration of these parameters in DICE-2013R, which are chosen to resemble observed market interest rates to reflect plausible

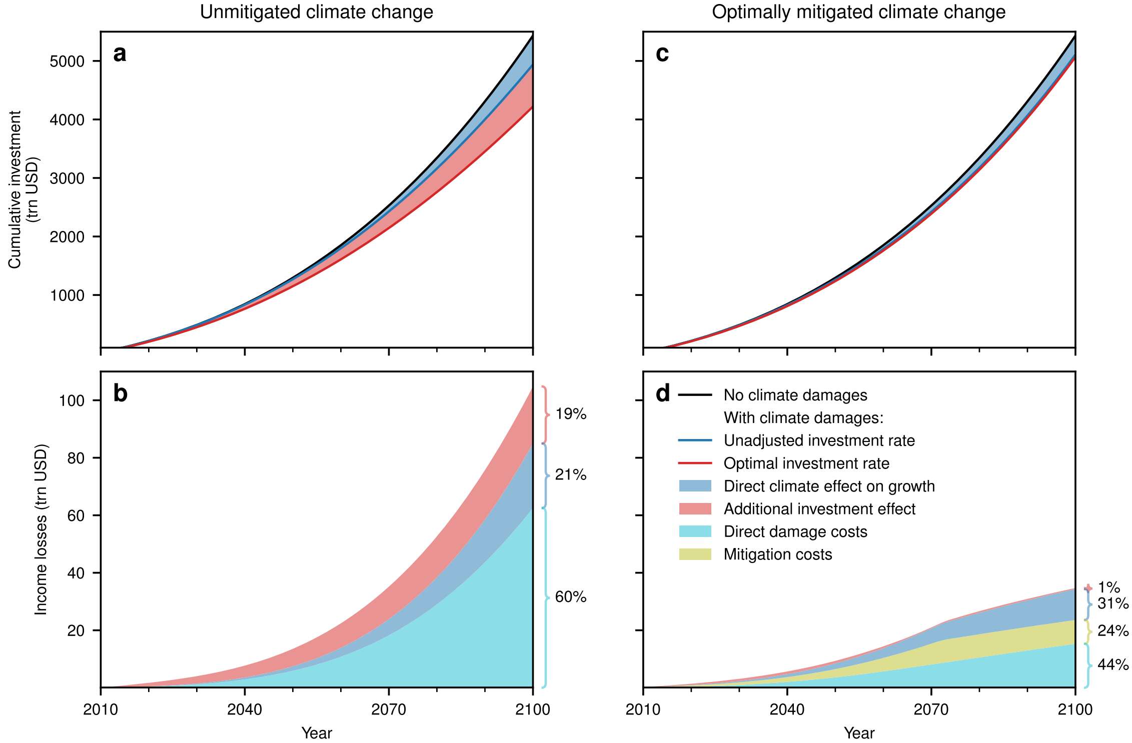


Fig. 4 The growth effects in the absence of climate policy (a, b) and under economically optimal mitigation of emissions (c, d). a Unadjusted investment behaviour and particularly optimal investment lead to cumulative investment gaps through the climate effect on growth and the additional investment effect, respectively. **b** The income losses that occur for unadjusted investment behaviour (direct damage costs and the hereby induced growth effects) and for optimal investment (additional investment effect). **c, d** Economically optimal climate policy diminishes the climate effect on growth and renders the additional investment effect to be insignificant for (**c**) cumulative investment and for (**d**) income losses. Source data are provided as a Source Data file.

investment behaviour[26,27] and provide a broad sensitivity analysis with respect to these normative parameters.

Although the results are qualitatively the same for different values of these parameters, the magnitude of the investment effect varies significantly (Fig. 6, unhatched areas indicated values used in the economic literature[28]). For comparison we define the relative investment gap $\frac{\left(I_{\rm opt}^{\rm nocc}-I_{\rm opt}^{\rm cc}\right)}{\left(I_{\rm opt}^{\rm nocc}-I_{\rm unadj}^{\rm cc}\right)}$ (Fig. 6a). Positive values in 2100 suggest the existence of negative growth effects for a wide range of social preferences. For all considered preference combinations, we observe that the economically optimal decision is to reduce the investment rate (Fig. 6b). Furthermore, the optimal investment rate tends to decline over time for a large range of values (Fig. 6c). For very low values of the rate of social time preference (see Methods), the investment rate increases over time to counteract deficient consumption possibilities in the future.

The role of mitigation. These computations compare different investment strategies without considering any policy to reduce carbon emissions. For comparison with the costs and benefits of climate-change mitigation, DICE-2013R allows to include the reduction of greenhouse gases as an additional means to maximise welfare. In that, mitigation reduces future emission intensity of production at the cost of present production. In computations that use this additional freedom of choice, no restriction on the global mean temperature is imposed, but the climate-induced damages yield an economically optimal warming around 2 °C compared to pre-industrial levels (Fig. 7b). We refer to these computations as climate-policy cases compared to the cases with unmitigated climate change.

To avoid future damages, in the optimal optimal climate-policy scenario emissions are cut back until they are completely phased out by 2070 leading to the strong limit in temperature increase (2 °C by 2100; Fig. 7a, b). As a consequence of this climate policy, temperature-sensitive productivity decreases only to ~97% of its value without climate change by 2100 (Fig. 7c), thus avoiding climate damages.

Whereas the reduction in investment in the unmitigated climate change scenario has only a small effect on temperature evolution—and thus only partially avoids damages—(Fig. 7b), reducing long-term emission intensity of production has a much larger effect. Accordingly, in the presence of an (optimal) climate-policy, the investment effect almost vanishes. Of the 35trn USD total income losses in 2100 only 1% (0.4trn USD) are due to investment reduction (Fig. 4d). Also, direct damages only total 15trn USD (44%) leading to growth effects of 11trn USD (31%). With the standard DICE mitigation cost function, mitigation costs sum up to 8trn USD or 24% of total income losses. Cumulative investment is thus reduced by only 6% through the direct climate effect on growth and 1% through the additional investment effect (Fig. 4c). As the optimal investment rate has only to be slightly adjusted in the climate-policy scenario, it also only has a negligible effect onto the optimal emission reduction (Fig. 7a). Thus, whereas the investment reduction under unmitigated climate change fails to properly avoid damages, proper mitigation does so quite well—keeping overall investment rates almost untouched.

The results of this paper can be summarised along the line of different economic response options to climate change. In the

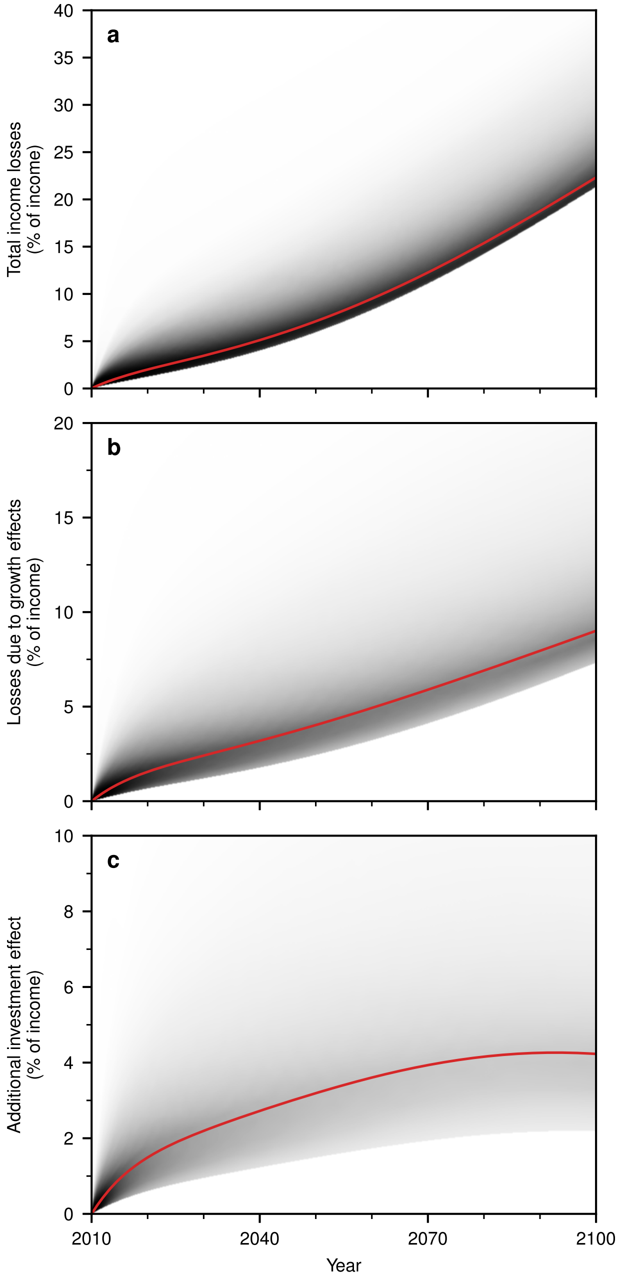


Fig. 5 The influence of social preferences on the growth effects and income losses. Depicted are (relative to the income without climate change) the shares of (**a**) the total income losses; **b** the income losses caused through the growth effects; and (**c**) the income losses induced by the additional investment effect. Their magnitude depends on the social preferences. Solutions for alternative social preferences are illustrated by the grey area around the baseline solutions (red curves). The parameters are chosen uniformly within the unhatched area in Fig. 6. The shade of grey indicates the frequency with which the solution occurs. Source data are provided as a Source Data file.

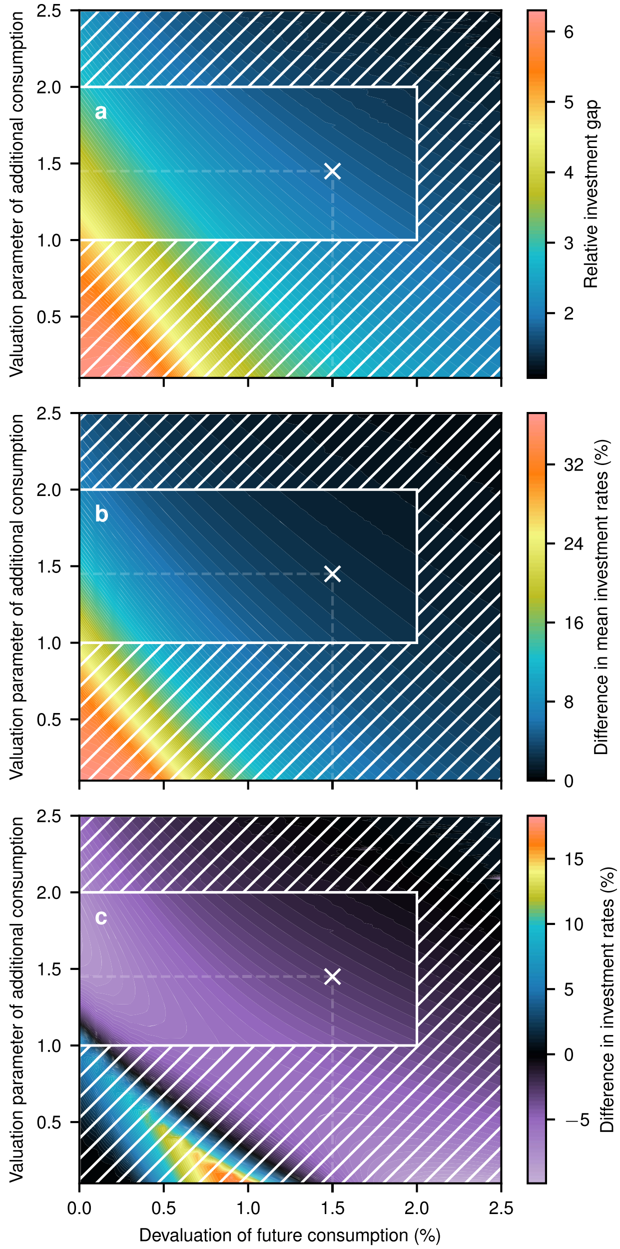


Fig. 6 The effect of alternative social preferences. a The ratio of the investment gaps $\frac{(I^{nocc}_{opt}-I^{cc}_{opt})}{(I^{nocc}_{opt}-I^{cc}_{unadj})}$ in 2100. **b** Difference between the temporally averaged unadjusted and optimal investment rates of the years 2010–2100. **c** Difference in the optimal investment rate between 2100 and 2010. The unhatched area depicts the range as commonly used in the economic literature and the white marker indicates the baseline calibration. Source data are provided as a Source Data file.

absence of climate change the investment growth would be strongest (black curve, Fig. 4a). Climate damages, however, reduce this investment by reducing the available capital (blue curve, Fig. 4a). The natural response of economic actors to the associated reduction in investment returns is to reduce the investment further (red curve, Fig. 4a). The additional investment reduction in response to the smaller anticipated returns is one and a half times the investment reduction due to the reduced capital from climate damages alone. This evolution corresponds to an adaptation-only perspective in which the economic actors simply respond to the climate damages without the perceived or real ability to mitigate climate change. It thereby depicts a guardrail for a possible future evolution. If, on the other hand, the ability to mitigate climate change is provided, on the economically optimal path the investment incentives stay almost as high as in the no-climate-change scenario and investment rates are only marginally reduced (red line, Fig. 4c).

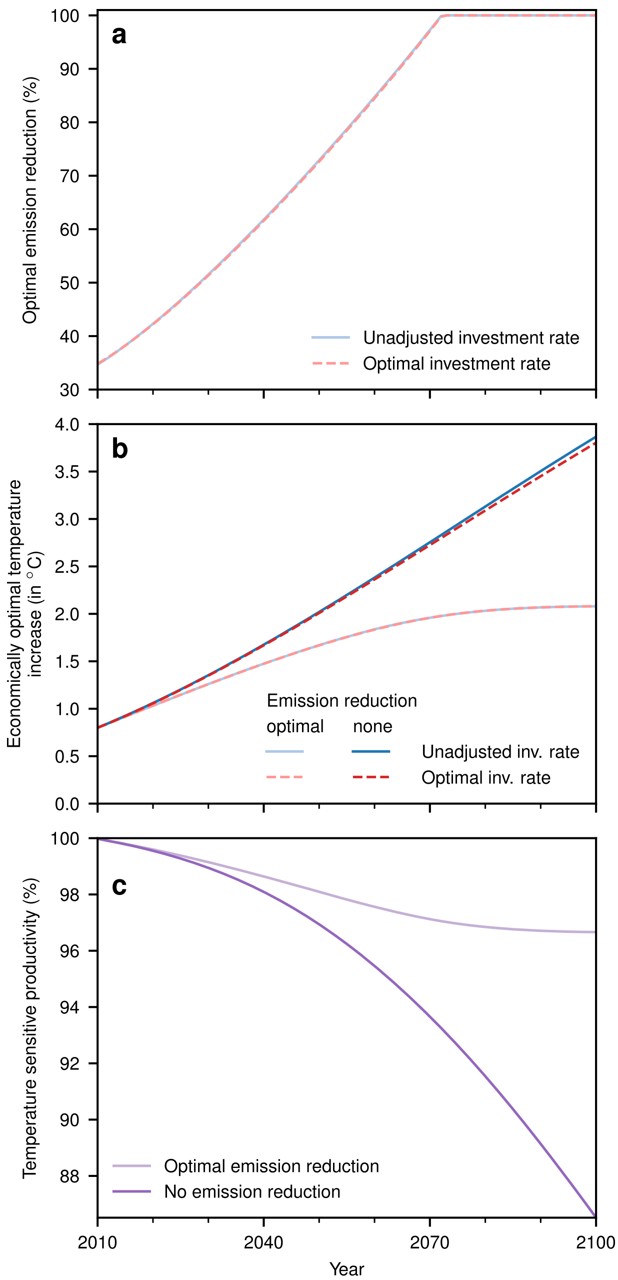


Fig. 7 Optimal mitigation and its effects. a Optimal emission reduction rates are almost identical for the two assumptions of investment behaviour. **b** Economically optimal mitigation limits warming to almost 2 °C by 2100. **c** With unmitigated climate change, temperature-sensitive productivity decreases to ~86% by 2100, while economically optimal mitigation protects the economy from major productivity losses. Source data are provided as a Source Data file.

Discussion

Obviously the representation of the economic and the climate dynamics in the economic model applied here is very simple. It is however sufficient to provide an estimate of the optimal investment paths under a number of different assumptions. In particular it is assumed that the relationship between temperature and economic growth as found in the data for the years 1960–2010 remains a good approximation for the future[9].

The incorporated investment decision rationale does not reflect any intention to reduce climate impacts for the purpose of the protection of society[29]. Instead it only aims at optimising utility of consumption. Thus, any reduced carbon emissions that might result from this optimisation are a reflection of the economic utility of such action. The decision rationale thus reflects a natural internalisation of the climatic externality without the use of globally coordinated policy instruments such as carbon pricing. That is because the climate-related growth reduction as applied here is derived from an observed relation between regional temperature and economic growth that does not result from a policy-driven internalisation of climatic damages, neither directly through compensation or indirectly through a carbon price. The only decision rationale that is reflected in our computations is that the investor has to decide how much to consume now and how much to invest for the future in order to maximise the utility of consumption. Under climate change economic productivity is reduced which means that more of the income is consumed and not invested because investment yields less return than in a world without climate change. As this is in a utility maximising context, keeping investments at the level in absence of climate change would actually be counterproductive and reduce utility—the returns of the additional investment are too low to balance the values that could not have been consumed earlier. Overall, the investment effect in our study is significantly higher than in previous computations because the observed climate impact on economic growth[9] is larger than prior estimates.

Also, one must consider that DICE as a normative rather than descriptive model only yields paths optimal under its full constraints, in this case climate damages and mitigation. However, especially with difference in time scales between real-world investment and changes in climate impacts real-world investors might not follow this path. Though leading to smaller reduction in investment, this would mean larger damages and smaller returns on this investment.

We focus here on the direct damage costs, based on econometric analysis, and the associated investment response. Other effects that might become relevant in the future are thus not captured in this study. For instance, the investment effect could turn out to be less severe, if adaptation turns out to be more effective in protecting labour and capital productivity from warming than it was observed to be in the past. After all, the investment effect itself already is a form of adaptation, but alas not a productive one. The positive effect of adaptation can be, however, lessened or even reversed, if its financing requires withdrawing qlarge-scale amounts of resources from otherwise investable income. Lacking resources for research, product development, and education—whether caused by the growth effects discussed or by reallocation effects—can be another potential barrier to economic growth. Further growth effects, which are not captured by the growth projection used in this analysis, can stem from destruction of productive capital or from changes in the capital depreciation rate by climate-induced extreme weather events. Though these would be a potential target of additional investment its returns cannot be higher than when done in the absence of climate change. In the context of this study, replacement only occurs for missed production, not capital, and even that is limited by the anticipation of future damages, hence the investment effect.

Overall, our results stress that climate-change mitigation is in the strong interest of investors as the investment effect almost vanishes under optimal conditions. By contrast, continuing the business-as-usual path means either reducing investment in light of reduced marginal returns or risking additional missallocations with low returns that also reduce overall societal welfare.

We assume here that the observed climate impact on economic growth[9] can be extrapolated into the future. This, however, neglects futher potential impacts such as high-order effects in the economic system[30–33] or climate tipping points[34,35]. All these channels require in-depth research to gain a complete picture of economic climate impacts. In shedding light on the investment response, we aim to contribute here to the qualitative understanding of one piece of the puzzle.

Methods

General framework. In order to investigate the investment effect, we choose to transfer the recent climate-impact estimates by Burke et al.[9] to the integrated assessment model DICE-2013R[21].

Burke et al.[9] estimate the relationship between temperature and changes in the development of economic growth based on observed data from 1960 to 2010. They present the results for individual countries (e.g. Extended Data Fig. 4 in Burke et al.[9]) and for the global sample (Extended Data Table 1 in Burke et al.[9]). They also compare data from 1960–1989 to 1990–2010 and find that this relationship has not changed significantly. Extrapolating this relationship into the future, they derive a future economic growth path under climate change.

In this growth path, direct productivity losses and the associated investment response are undistinguishable. The implementation of this growth path in DICE-2013R would thus turn it into an exogenous growth model, which has a possibly non-optimal investment path imposed upon externally. To maintain endogeneity of growth, we seek a productivity loss function in DICE-2013R that is consistent with the estimated growth impacts. For this, we take into account that the estimated relationship has not changed over the past decades and that it only applies where the fundamental dynamics resembles the one during the estimation period. These two aspects imply that, in order to disentangle productivity losses from growth effects, we have to impose assumptions about potential drivers of growth effects in the past. First, as resources spent on mitigation and adaptation have been rather small, growth effects that might be induced by reallocating investment resources for mitigation or adaptation purposes can be ignored; second, as the estimated relationship has not changed over time, notable adaptation was not induced and can thus be abstracted from; and third, the investment decision is sensitive to the emergence of future productivity losses, but the implications of the chosen investment path for future emissions and their accompanied climate-related impacts are not fed back into the decision making process. We believe that these climate considerations have not played a role for investment in the past. This is supported by the observation that the estimated relationship remained the same for several decades despite increased availability of information about the climate problem.

In order to analyse the additional investment effect, we include the resulting productivity loss function as the damage cost function in the original DICE-2013R version. We here follow Fankhauser and Tol[13] and compare the income pathways for optimal investment and unadjusted investment behaviour that reflects ignorance of future productivity losses.

Note that, in contrast to our derivation of the direct productivity losses, which is based on a descriptive approach, we do not impose any additional assumptions on the investment decision. Whereas in the former case the investment decision is constraint by assumptions about past investment behaviour, in the latter case it accounts for all information and thus produces the economically optimal growth path.

Climate impact projections. The temperature impact projections by Burke et al.[9] describe future changes in observed levels of global income Y per capita L relative to a world with temperatures fixed at their 1980–2010 average. In particular, the evolution of income per capita is given as

$$\frac{Y_{t+1}}{L_{t+1}} = \frac{Y_t}{L_t}\left(1+\eta_t+\phi_t\right) \tag{1}$$

for all years t. Here η_t is the growth rate in the absence of climate change and ϕ_t the additional effect of warming on growth in that year. The growth rate ϕ_t is expressed in terms of a historical response function h as

$$\phi_t = h\left(T_t^{\mathrm{ATM}}\right) - h\left(\overline{T}^{\mathrm{ATM}}\right), \tag{2}$$

with T_t^{ATM} being the temperature in a given year t after 2010 and $\overline{T}^{\mathrm{ATM}}$ being the average 1980–2010 temperature. The historical response function h is estimated as

$$h\left(T_t^{\mathrm{ATM}}\right) = \beta_1 T_t^{\mathrm{ATM}} + \beta_2\left(T_t^{\mathrm{ATM}}\right)^2, \tag{3}$$

with $\beta_1 = 0.0135$ and $\beta_2 = -0.0005$. This calibration represents the main specification excluding data of countries with fewer than 20 years of growth data (Extended Data Table 1 in Burke et al.[9]).

It is important to remark that climate impacts on the economy are given here in terms of a growth rate. These growth effects need to be distinguished from damage functions that reduce the level of GDP. Typically, these level effect functions are relative productivity functions, which summarise the productivity reduction of labour and capital due to warming. As also explained by Burke et al.[9], the standard Cobb–Douglas production function can be extended to account for temperature-sensitive labour productivity A^L and temperature-sensitive capital productivity A^K as

$$Y_t = A_t\left(A^K\left(T_t^{\mathrm{ATM}}\right)K_t\right)^{\gamma}\left(A^L\left(T_t^{\mathrm{ATM}}\right)L_t\right)^{1-\gamma} \tag{4}$$

$$= \underbrace{A^K\left(T_t^{\mathrm{ATM}}\right)^{\gamma} A^L\left(T_t^{\mathrm{ATM}}\right)^{1-\gamma}}_{=f\left(T_t^{\mathrm{ATM}}\right)} A_t K_t^{\gamma} L_t^{1-\gamma} \tag{5}$$

$$= f\left(T_t^{\mathrm{ATM}}\right) Y_t^{\mathrm{gross}} \tag{6}$$

with gross GDP at the beginning of the period Y_t^{gross}, temperature insensitive total factor productivity A_t, productive capital K_t, labour L_t, output elasticity of capital γ and temperature-sensitive productivity $f\left(T_t^{\mathrm{ATM}}\right)$, $0 \le f\left(T_t^{\mathrm{ATM}}\right) \le 1$. GDP net of level damage costs, Y_t, can be considered to be the same as the observed income levels in Equation (1). One could similarly assume different temperature sensitivities as, for instance, temperature shocks can have a sizable impact on total factor and labor productivity[20]. Here, we only assume that, in its net effect, temperature acts onto gross GDP as $Y_t = f\left(T_t^{\mathrm{ATM}}\right) Y_t^{\mathrm{gross}}$.

Transferring the growth estimates to DICE. We transfer the global growth impacts estimated by Burke et al.[9] (Extended Data Table 1 in Burke et al.[9]) to the global model DICE-2013R[21] with a simulation period corresponding to the projection period in Equation (2). For consistency with the estimated impacts, we also recalibrate this model to an annual time step version with 600 years by closely following the approach described by Cai et al.[36]. Furthermore, it is important to note that the warming effect in Equation (3) is expressed in terms of absolute annual temperature T_t^{ATM}, whereas in DICE-2013R temperature increase $\Delta T_t^{\mathrm{ATM}}$ (in °C from 1900) is considered. We thus convert temperature increase $\Delta T_t^{\mathrm{ATM}}$ into absolute temperature according to

$$T_t^{\mathrm{ATM}} = \Delta T_t^{\mathrm{ATM}} - \Delta T_{2010}^{\mathrm{ATM}} + T_{2010}^{\mathrm{ATM}} \tag{7}$$

with $\Delta T_{2010}^{\mathrm{ATM}}$ being the temperature increase in the initial simulation period, 2010. As the initial period might be unusually cold or warm due to variations in weather, we use the average temperature over 2005–2010 to calibrate the initial absolute temperature T_{2010}^{ATM}. The data for calibration is compiled from a NASA dataset[37,38]. The global average temperature increase in 2010, $\Delta T_{2010}^{\mathrm{ATM}}$, stems from the original DICE-2013 version.

To implement the growth impacts, we disentangle the productivity loss function as described by Equation (4) from the investment response, which jointly cause the growth impact ϕ_t. For this, we have developed an algorithm, in which we adjust the productivity loss function in DICE-2013R iteratively and solve for the optimal investment response. To be consistent with the assumption that growth effects induced by reallocating investment resources for mitigation or adaptation purposes can be ignored, we exclude the option to reduce emissions optimally. As stated above, we also assume that the investment decision process optimises the response to future productivity losses without account for its direct impact on emissions and consequent climate-induced damages. Essentially, this assumption is tantamount to postulating that the investment decision is made under ignorance of the temperature-productivity nexus. Accordingly, we seek a time-series f_t, rather than a temperature dependent function, that fulfills

$$f_{t+1}\frac{Y_{t+1}^{\mathrm{gross}}}{L_{t+1}} = \frac{Y_t}{L_t}\left(1+\eta_t+\phi_t\right). \tag{8}$$

For f in the initial period we approximate $f_1 \approx \left(1+\phi_0\right) \approx 0.99981$ with ϕ_0 resulting from of Equation (2) with the temperature average of the preceding 5 years (2004–2009).

The iteration then proceeds as follows. We initialise the productivity with $f_t^{(1)} = 1$ for all $t, 1 \le t \le 600$. For each iteration step n DICE-2013R finds an optimally chosen investment response to a given $f_t^{(n)}$. This yields the time series of income $Y_t^{gross,(n)}$ and $Y_t^{(n)}$. Further, investing according to the investment rate s_t^{nocc} optimal in absence of climate change, $I_t^{\mathrm{nocc}} = s_t^{\mathrm{nocc}} Y_t^{gross,(n)}$ yields the corresponding growth rate, $\eta_t^{(n)}$. Using the temperature time series $\Delta T_t^{ATM,(n)}$ we can, from Equation (2), derive the temperature-growth effect $\phi_t^{(n)}$ that follows the estimation of Equation (3). Equation (8) then provides a time series $\widetilde{f}_t$, which we use to update the productivity for the next iteration step,

$$f_t^{(n+1)} = f_t^{(n)} + \frac{\widetilde{f}_t - f_t^{(n)}}{2}. \tag{9}$$

The actual temperature-growth effect $\overline{\phi}_t^{(n)}$ in iteration step n as given by Equation (8) is sought to converge to that given by the estimation in Equation (2). Thus, the iteration algorithm is stopped once the time-average absolute deviation between $\phi_t^{(n)}$ and $\overline{\phi}_t^{(n)}$ has become sufficiently small ($<6 \cdot 10^{-5}$). At the same time, the optimal investment rate and the productivity function converge.

Eventually, the time series $f_t^{(n_{\mathrm{last}})}$ and the temperature increase $\Delta T_t^{ATM,(n_{\mathrm{last}})}$ of the last iteration define the temperature-sensitive productivity function

$$f\left(\Delta T_t^{\mathrm{ATM}}\right) := f_t^{(n_{\mathrm{last}})}, \tag{10}$$

in which we interpolate $f_t^{(n_{\text{last}})}$ linearly for the 600 sampling points of $\Delta T_t^{ATM,(n_{\text{last}})}$. This function then replaces the damage cost function in the annual-period DICE-2013R model version.

Background information on the social preferences. The preferences as displayed in Figs. 5 and 6 are represented by the initial rate of social time preference and the elasticity of the marginal utility of consumption. The initial rate of social time preference ρ is used to assign different weight to the utility U of per capita consumption $c_t = \frac{C_t}{L_t}$ at different time points $t \in [1, T]$ in the overall welfare function. In DICE, this social welfare function W is given by

$$W = \sum_{t=1}^{T} \left(\frac{1}{1+\rho}\right)^{t-1} L_t U(c_t). \tag{11}$$

In other words, ρ relates to impatience in consumption: a higher initial rate of social time preference gives more emphasis to present rather than to future utility. In such a case, society is inclined to consume more today and to invest less for future consumption possibilities.

The elasticity of the marginal utility of consumption θ, $\theta \geq 0$, determines the gain in utility due to additional consumption, irrespective of the timing of its appearance. It enters the utility function as

$$U(c_t) = \begin{cases} \frac{c_t^{1-\theta}}{1-\theta} & \text{for } \theta \neq 1 \\ \ln c_t & \text{for } \theta = 1 \end{cases} \tag{12}$$

The calibration of these parameters is controversially discussed in climate economics as they reflect either how decisions shall be formed on account of ethical concerns or how decisions are actually made. Ethical considerations are, for instance, reflected by an almost zero initial rate of social time preference, as it assigns future generations the same relevance as the current generation[39,40]. In contrast, the choice of a higher rate reflects that people usually prefer consuming today rather than postponing it. Likewise, the consumption elasticity parameter can be determined either based on empirical studies[28] or by answering the normative question of how much importance additional consumption shall have for the society's wellbeing[27].

Together, these two parameters affect the trade-off in the allocation of available income between consumption and investment, and thus influence the additional investment effect.

Data availability

The source data underlying the figures are provided as a Source Data file. Source data are provided with this paper.

Code availability

The code used in this study is available from the authors upon request.

Received: 27 January 2020; Accepted: 29 April 2021;
Published online: 31 May 2021

References

1. Field, C. et al. *IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2014).
2. Frieler, K. et al. Limiting global warming to 2° c is unlikely to save most coral reefs. *Nat. Clim. Change* **2**, 1–6 (2012).
3. Schellnhuber, S., Rahmstorf, H. J. & Winkelmann, R. Why the right climate target was agreed in paris. *Nat. Clim. Change* **6**, 649–653 (2016).
4. Burke, M. & Emerick, K. Adaptation to climate change: evidence from us agriculture. *Am. Econ. J: Econ. Policy* **8**, 106–140 (2016).
5. Carleton, T. A. & Hsiang, S. M. Social and economic impacts of climate. *Science* **353**, 1112 (2016).
6. Hinkel, J. et al. Coastal flood damage and adaptation costs under 21st century sea-level rise. *PNAS* **111**, 3292–3297 (2014).
7. Hsiang, S. M., Burke, M. & Miguel, E. Quantifying the influence of climate on human conflict. *Science* **341**, 1235367 (2013).
8. Bansal, R. & Ochoa, M. Welfare Costs of Long-Run Temperature Shifts. *NBER Working Papers* **17574** (2011).
9. Burke, M., Hsiang, S. M. & Miguel, E. Global non-linear effect of temperature on economic production. *Nature* **527**, 235–239 (2015).
10. Dell, B. M. et al. Temperature and income: reconciling new cross-sectional and panel estimates. *Am. Econ. Rev.* **99**, 198–204 (2009).
11. Dell, M., Jones, B. F. & Olken., B. A. Temperature shocks and economic growth: evidence from the last half century. *Am. Econ. J: Macroecon* **4**, 66–95 (2012).
12. Dietz, S. & Stern, N. Endogenous growth, convexity of damage and climate risk: how nordhaus' framework supports deep cuts in carbon emissions. *Econ. J.* **125**, 574–620 (2015).
13. Fankhauser, S. & Tol, R. S. J. On climate change and economic growth. *Res. Energy Econ.* **27**, 1–17 (2005).
14. Moore, F. C. & Diaz, D. B. Temperature impacts on economic growth warrant stringent mitigation policy. *Nat. Clim. Change* **5**, 127–132 (2015).
15. Pindyck, R. S. Uncertain outcomes and climate change policy. *J. Environ. Econ. Manag.* **63**, 289–303 (2012).
16. Pindyck, R. S. Climate change policy: what do the models tell us? *NBER Working Paper Series* **51**, 1–23 (2013).
17. Revesz, R. L. et al. Global warming: improve economic models of climate change. *Nature* **5**, 1–9 (2014).
18. Heal, G. & Park, J. Temperature stress and the direct impact of climate change: a review of an emerging literature. *Rev. Environ. Econ. Policy* **10**, 347–362 (2016).
19. Mendelsohn, R., Morrison, W., Schlesinger, M. E. & Andronova, N. G. Country-specific market impacts of climate change. *Clim. Change* **45**, 553–569 (2000).
20. Donadelli, M., Jüppner, M., Riedel, M. & Schlag, C. Temperature shocks and welfare costs. *J. Econ. Dyn. Control* **82**, 331–355 (2017).
21. Nordhaus, W.*The Climate Casino* (Yale University Press, 2013).
22. Cass, D. Optimum growth in an aggregative model of capital accumulation. *Rev. Econ. Stud.* **32**, 233–240 (1965).
23. Koopmans, T. C. On the concept of optimal economic growth. *Academiae Scientiarum Scripta Varia* **28**, 1–75 (1965).
24. Ramsey, F. P. A mathematical theory of saving. *Econ. J.* **38**, 543–559 (1928).
25. Lessmann, K. et al. The stability and effectiveness of climate coalitions a comparative analysis of multiple integrated assessment models. *Environ. Resourc. Econ.* **62**, 811–836 (2015).
26. Nordhaus, W. D.*A Question of Balance* (Yale University Press, 2008).
27. Goulder, L. H. & Roberton, C. W. The choice of discrount rate for climate change policy evaluation. *Clim. Change Econ.* **3**, 1250024 (2012).
28. Evans, D. J. The elasticity of marginal utility of consumption: estimates for 20 oecd countries. *Fiscal Stud.* **26**, 197–224 (2005).
29. Rezai, A. The opportunity cost of climate policy: a question of reference. *Scandinav. J. Econ.* **113**, 885–903 (2011).
30. Hallegatte, S. An Adaptive Regional Input-Output Model and its Application to the Assessment of the Economic Cost of Katrina. *Risk Analys.* **28**, 779–799 (2008).
31. Levermann, A. Make supply chains climate-smart. *Nature* **506**, 27–29 (2014).
32. Wenz, L. & Levermann, A. Enhanced economic connectivity to foster heat stress-related losses. *Sci. Adv.* **2**, e1501026 (2016).
33. Willner, S. N., Otto, C. & Levermann, A. Global economic response to river floods. *Nat. Clim. Change* **8**, 594–598 (2018).
34. Lenton, T. M. et al. Tipping elements in the Earth's climate system. *Proceed. Natl Acad. Sci.* **105**, 1786–1793 (2008).
35. Lenton, T. M. & Ciscar, J.-C. Integrating tipping points into climate impact assessments. *Clim. Change* **117**, 585–597 (2013).
36. Cai, Y., Judd., K. L. & Lontzek, T.S. Continuous-Time Methods for Integrated Assessment Models. *NBER Working Papers* **18365** (2012).
37. GISTEMP Team. GISS Surface Temperature Analysis (GISTEMP), version 4. NASA Goddard Institute for Space Studies (2011). URL https://data.giss.nasa.gov/gistemp/.
38. Lenssen, N. J. L. et al. Improvements in the GISTEMP Uncertainty Model. *J. Geophys. Res.: Atmos.* **124**, 6307–6326 (2019).
39. Broome, J. The ethics of climate change. *Sci. Am.* **298**, 96–102 (2008).
40. Stern, N. *The Economics of Climate Change: The Stern Review*. (Cambridge University Press, 2006).

Acknowledgements

This research has received funding from the Horizon 2020 Framework Programme of the European Union (grant agreement no. 820712) and the German Federal Ministry of Education and Research (BMBF) under the research project CLIC (FKZ: 01LA1817C).

Author contributions

S.W., A.L., and N.G. designed the analysis. S.W. and N.G. developed the methods and conducted the analysis. S.W., A.L., and N.G. discussed the results and wrote the paper.

Funding

Open Access funding enabled and organized by Projekt DEAL.

Competing interests
The authors declare no competing interests.

Additional information
Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41467-021-23547-5.

Correspondence and requests for materials should be addressed to S.N.W. or A.L.

Peer review information *Nature Communications* thanks the anonymous reviewer(s) for their contribution to the peer review of this work.

Annex 553

F. Shear et al., “Sensing the heat: Climate change vulnerability and foreign direct investment inflows”, *Research in International Business and Finance,* 2023

Research in International Business and Finance
Volume 66, October 2023, 102005

Sensing the heat: Climate change vulnerability and foreign direct investment inflows

Falik Shear [a], Badar Nadeem Ashraf [b], Shazaib Butt [c]

Show more

Add to Mendeley Share Cite

https://doi.org/10.1016/j.ribaf.2023.102005

Get rights and content

open access

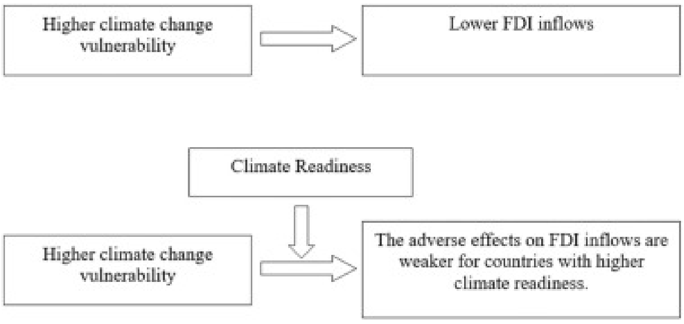
Highlights

- FDI inflows are lower in countries that are more vulnerable to climate change.
- Effect is not significant for underdeveloped countries where market size drives FDI inflows.
- Climate change readiness weakens the adverse effects of climate change on FDI inflows.

Abstract

We investigate whether climate change vulnerability determines foreign direct investment (FDI) inflows. We reason that multinational firms foresee a higher climate change vulnerability of host-country a locational disadvantage while making FDI allocation decisions. Utilizing annual data from 152 countries spanning the period 1996–2019 and employing the panel pooled ordinary least square regressions, we evidence that FDI inflows are lower in countries more vulnerable to climate change. We also observe that FDI inflows are only sensitive to climate-related risks in high- and middle-income countries, but not in low-income countries where the market size is a primary driver of FDI inflows. Moreover, we also find that host countries may weaken the adverse effects of climate change vulnerability on FDI inflows by strengthening the economic, institutional, and social environment.

Graphical Abstract



Climate change vulnerability and FDI inflows

Research in International Business and Finance 66 (2023) 102005

Contents lists available at ScienceDirect

Research in International Business and Finance

journal homepage: www.elsevier.com/locate/ribaf

Sensing the heat: Climate change vulnerability and foreign direct investment inflows

Falik Shear [a], Badar Nadeem Ashraf [b,*], Shazaib Butt [c]

[a] Faisalabad Business School, National Textile University, Faisalabad, Pakistan
[b] LSBU Business School, London South Bank University, London SE1 0AA, United Kingdom
[c] Royal Docks School of Business and Law, University of East London, London E16 2RD, United Kingdom

ARTICLE INFO

Keywords:
Climate change
Vulnerability
Readiness
FDI inflows

ABSTRACT

We investigate whether climate change vulnerability determines foreign direct investment (FDI) inflows. We reason that multinational firms foresee a higher climate change vulnerability of host-country a locational disadvantage while making FDI allocation decisions. Utilizing annual data from 152 countries spanning the period 1996–2019 and employing the panel pooled ordinary least square regressions, we evidence that FDI inflows are lower in countries more vulnerable to climate change. We also observe that FDI inflows are only sensitive to climate-related risks in high- and middle-income countries, but not in low-income countries where the market size is a primary driver of FDI inflows. Moreover, we also find that host countries may weaken the adverse effects of climate change vulnerability on FDI inflows by strengthening the economic, institutional, and social environment.

1. Introduction

The impact of climate on economic outcomes has long been acknowledged and evidenced (Dell et al., 2014). Generally, the extant studies show that natural disasters and gradual global warming significantly affect long-run economic growth (Klomp and Valckx, 2014; Kahn et al., 2021). The less clear are the channels through which climate change affects economic outcomes. In this regard, some recent studies have documented that countries with vulnerable climates pay higher costs on sovereign borrowing (Kling et al., 2018), and firms in countries with vulnerable climate face higher financial constraints, pay higher costs of capital, and prefer long-term funding (Huang et al., 2018; Kling et al., 2021). Extending this debate, we have two objectives in this study. First, we explore whether foreign direct investment (FDI from hereafter) inflows are sensitive to a country's vulnerability to climate risks. Second, we investigate whether a country's readiness to cater to climate risks helps alleviate the adverse consequences of climate vulnerability on FDI inflows.

International risk theory (Buckley et al., 2016; Buckley et al., 2020; Okafor et al., 2022) and the eclectic framework also referred to as the OLI (i.e., Ownership, Location, and Internalization) paradigm of Dunning (1977) are widely used to explain FDI inflows to different countries. The former theory suggests that multinational enterprises (MNEs from hereafter) consider host country risks while making FDI decisions. As such, FDI inflows would be lower to countries with higher political, economic and financial risks. According to this theory, MNEs tend to invest in developing, often high risk, countries based on the belief that they can mitigate the risks. The latter, OLI paradigm, suggests that FDI inflows depend on the locational advantages linked with a foreign country. As such, FDI inflows

* Corresponding author.
E-mail address: ashrafb4@lsbu.ac.uk (B.N. Ashraf).

https://doi.org/10.1016/j.ribaf.2023.102005
Received 31 October 2022; Received in revised form 9 April 2023; Accepted 29 May 2023
Available online 1 June 2023

are sensitive to host countries' macroeconomic and institutional environment, including the market size, the extent of market openness, infrastructure availability, labor market conditions, institutional environment and economic policy uncertainty (Cheng and Kwan, 2000; Leahy and Montagna, 2001; Bjorvatn and Eckel, 2006; Alfaro et al., 2008; Julio and Yook, 2016). Building on these theories, we argue host country's climate vulnerability is an important risk factor and locational disadvantage that influences multinational firms' FDI decisions.

Climate-related physical and regulatory risks can cause a decrease in FDI inflows to a country. Physical risks, such as extreme weather events, rising sea levels, and natural disasters, can damage infrastructure, disrupt supply chains, and reduce business productivity, thus making countries and regions less attractive for FDI. Additionally, regulatory risks may arise from governments' efforts to combat climate change through policies and regulations such as carbon taxes, emissions trading schemes, and renewable energy targets. These measures can increase the cost of doing business and reduce profitability, which can ultimately discourage FDI. Our main hypothesis is that FDI inflows would be lower in countries with higher vulnerability to climate risks.

We use the climate vulnerability index developed by the Notre-Dame Global Adaptation Initiative (ND-GAIN) to proxy a country's vulnerability to climate change. Higher values of climate vulnerability index represent that a country is more exposed and sensitive to the negative impact of climate change in terms of potential changes in cereal yields, annual ground water recharge, deaths from diseases, heatwave hazard, flood hazard, urban concentration, quality of transport and trade infrastructure, hydropower generation capacity, sea level rise impacts, electricity access, and disaster preparedness.

To conduct our empirical analysis, we collected annual data from 152 countries spanning the period between 1996 and 2019. Utilizing the panel pooled ordinary least square regressions, we find that countries with higher vulnerability to the adverse effects of climate change tend to attract lower FDI inflows. We observe that these findings stand for several robustness tests including alternative measures of climate vulnerability, alternative estimation method of two-step system GMM panel regressions, and endogeneity tests.

We also investigate whether a country's readiness to cater climate risks helps in alleviating the adverse consequences of climate change on FDI inflows. Using ND-GAIN climate readiness index, which captures a country's economic, governance and social readiness, we observe a higher readiness weakens the adverse effects of climate vulnerability on FDI inflows.

We make multiple contributions to the literature. First, we complement the studies which have explored that climate change vulnerability is having grave economic consequences in terms of financing, asset pricing, investment, and economic output and productivity (Volz et al., 2020; Beirne et al., 2021a; b; Kling et al., 2021; Acharya et al., 2022; Boitan and Marchewka-Bartkowiak, 2022; Cevik and Jalles, 2022; Zhang, 2022). Adding to it, we find that a country's higher vulnerability to climate change adversely affects FDI inflows.

Second, we add to the literature which examines the country-level determinants of FDI inflows (Cheng and Kwan, 2000; Leahy and Montagna, 2001; Bjorvatn and Eckel, 2006; Alfaro et al., 2008; Julio and Yook, 2016; Okafor et al., 2022). This literature largely explores institutional, resources, and policy related country-level factors. We find that climate change vulnerability is another potential risk that drives FDI location decisions.

Third, we add to the literature that examines whether and how FDI decisions are influenced by environmental risks (Escaleras and Register, 2011; Li and Zhang, 2019; Li and Gallagher, 2022). These studies largely explore the effects of physical climate risks, such as natural disasters including floods and hurricanes, on the extent of FDI inflows, including whether foreign owned facilities, as compared to local ones, are more exposed to such risks. Extending this debate, we explore whether FDI destination decisions are driven by host country climate vulnerability.

The rest of the paper is organized as follows. The next section discusses the theoretical framework in the context of existing literature. Section 3 outlines data collection procedures. Fourth section introduces empirical methodology. Fifth section reports empirical results. The final section concludes the study.

2. Theoretical framework and literature review

Our study builds on the two streams of recent literature. First stream are the studies that have investigated the effect of climate change on economies. Second stream explores the country-specific determinants of FDI inflows.

Regarding the first stream, there is an active research agenda on the relevance of climate change risks. Climatic factors can directly affect economic outcomes such as output, investment and productivity (Batten, 2018). Effects of climate change are getting more visible. The recent empirical evidence is supporting that sophisticated debt, equities and real estate markets are pricing the climate change risks. For instance, using data from different geographic regions, some studies show that climate change proxies have a significant positive association with sovereign debt yields (Kling et al., 2018; Volz et al., 2020; Beirne et al., 2021a; b; Boitan and Marchewka-Bartkowiak, 2022; Cevik and Jalles, 2022). Considering the spreads on bank loans, Correa et al. (2022) explore that following a disaster corporate loan spreads spike even for those borrowers who were unaffected during the disaster. Loan spreads increase the highest for weaker borrowers with the most extreme exposure to the disasters.

For stocks, Zhang (2022) and Acharya et al. (2022) find that overall stock markets negatively respond to increased climate risks. Bernstein et al. (2019) and Giglio et al. (2021) show that homes that are exposed to the risks of sea level rise or floods sell for lower prices as compared to the similar properties but without exposure to such risks.

Effects are not linear. For instance, Acharya et al. (2022) show that although higher local exposure of GDP to heat stress is associated with higher spreads on municipal bonds arising mainly from the expected increase in energy expenditures and decrease in labor productivity, however the effect is larger for lower-rated, revenue-only and longer-term bonds. For S&P 500 companies, they observe that, with higher exposure to heat stress, expected returns increase on all stocks whereas yields only increase for sub-investment grade corporate bonds but not for investment grade bonds. The effects are only significant after 2013–2015 and for heat stress exposure but not for other physical risks. Zhang (2022) suggests that economic variables in less developed countries are less responsive to climate risks than those in developed countries, due to a combination of lower awareness of climate risks and the absence of clear climate-related policies.

Some studies such as Cevik and Jalles (2022) and Beirne et al. (2021a) also show that countries' greater resilience offsets some of these adverse effects of climate change. Abdelzaher et al. (2020) explore that countries that are more innovative, internationally open and have better regulatory quality are less vulnerable to the adverse effects of climate change. Countries' better performance in environment, social and governance indicators is also negatively associated with sovereign default risk and bond spreads (Crifo et al., 2017; Capelle-Blancard et al., 2019).

Regarding the second stream, multinational corporations (MNCs) act cautiously while devising overseas investments strategies because of the additional risks involved in international business dealings. In general, MNCs tend to invest in locations with lower risks and higher returns. According to the OLI framework, FDI inflows would be lower in locations with higher risks (Dunning, 1977). For instance, recent studies have shown country-level institutional or policy risks are negatively associated with FDI inflows (Cheng and Kwan, 2000; Leahy and Montagna, 2001; Bjorvatn and Eckel, 2006; Alfaro et al., 2008; Julio and Yook, 2016; Okafor et al., 2022). Recently, the country-specific risks are getting even more important for international business activity due to trade disputes, conflicts, wars, terrorism, fraught political regimes and corruption (Cavusgil et al., 2020). Overseas risks remain relevant even for experienced and professionally owned MNCs (Buckley et al., 2020). According to the UNCTAD,[1] global FDI inflows in 2018 were 13% lower than in the year 2017.

Building on this framework, a scarce recent literature has starting shedding light on how environmental risks affect FDI inflows. For instance, using data from 94 countries over the period 1984–2004, Escaleras and Register (2011) explore that the number of natural disasters striking a country is negatively associated with the FDI inflows. Li and Zhang (2019) show that FDI inflows are relatively higher in South, as compare to the North, of Qinling Mountains–Huai River line of China due to better air quality which leads to lower health risks and insurance costs. Li and Gallagher (2022) show that across countries the foreign-owned facilities are less exposed to physical climate risks, such as floods, heat and water stress, sea level rise and hurricanes, as compared to local-owned facilities. Likewise, FDI from China, which is a major emerging source of outbound FDI, is more exposed to climate related risks such as floods, water stress, and hurricanes across countries, compared with other foreign facilities. Extending this literature, we examine whether MNCs consider a country's vulnerability to climate change as a risk while making investment decisions.

The concept of vulnerability to climate change has grasped attention since the study of Füssel (2007). A higher vulnerability to climate change may affect overall business environment including occupational health and safety, capital investment, and the extent of business activity including in agriculture and tourism sectors of the economy (Dogru et al., 2019; Lu et al., 2019; Ansah et al., 2021). For instance, the literature survey by Ansah et al. (2021) concludes that climate change is associated with injuries, fatigue, exhaustion, psychological stress, cardiovascular and respiratory issues, chronic illnesses including cancer and kidney diseases and in extreme cases, death to workers. Lu et al. (2019) build a production function including rainfall and temperature with standard variables of labor force and technology and observe that increased rainfall and larger variations in temperature negatively affects economic development. Climate change driven increase in temperatures boost the likelihood of droughts that hurts the agri-businesses. Hong et al. (2019) show that returns of stocks of food companies are lower in countries with higher vulnerability to droughts. Dogru et al. (2019) find that tourism sector is more vulnerable, as compared to the whole economy, to adverse consequences of climate change. Wilbanks and Fernandez (2014) frame how human developed roads and urban infrastructure get exposed to climate change. Framework of Linnenluecke et al. (2011) suggests that climate change may disrupt firm operations through floods, droughts or sea level rises, or disruption to firm's resource base, suppliers or customers. Firms may respond by reallocating their operations from vulnerable locations to more safe locations.

Notwithstanding the above discussion, the adoptability to climate change creates enormous new investment opportunities (Kobayashi-Soloman, 2019). For instance, Chen and Chu (2022) argue that although infrastructure deteriorates due to climate change however the adverse effects can be mitigated by expanding investments in infrastructure projects and low-carbon sectors. The model of Lu et al. (2019) also demonstrates that climate change leads to higher capital investments. Chang et al. (2019) frame the economic effects of climate change with Leontief input-output method and show that industrial output decreases with higher global warming and long-term changes in rainfall. And to prevent these negative effects, the capital investments in industrial sector needs to be increased. Abdelzaher et al. (2020) use a sample of 73 countries over the period 1998–2013 and find that a higher R&D expenditures to GDP ratio, openness to trade, and better regulatory quality reduce a country's vulnerability to climate change. Xu et al. (2022) employ firm level data from 43 countries over the period 2001–2020 and show that both short- and long-run climate risks promote value-enhancing corporate risk-taking behavior.

Based on above discussion, we expect climate change vulnerability is likely to influence FDI inflows. Further, whether the effect is positive, or negative is uncertain. We also explore whether countries' greater preparedness minimizes the adverse effects of climate change on FDI inflows.

3. Data collection

We collected data of FDI inflows and other macroeconomic variables from World Development Indicators database. The data of

[1] For reference please visit:https://unctad.org/data-visualization/global-foreign-direct-investment-flows-over-last-30-years

Table 1
Summary statistics. This table reports summary statistics of main variables.

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Log(FDI inflows)	3099	20.747	2.511	10.361	27.322
Climate vulnerability	3099	0.430	0.096	0.241	0.705
Climate preparedness	3099	0.418	0.137	0.118	0.816
GDP growth	3099	3.838	4.119	-36.658	53.382
Inflation	3099	7.178	27.594	-18.109	1058.374
Trade-openness	3099	84.055	49.319	1.219	437.327
Labor force	3099	68.130	10.182	40.630	90.340
Market size	3099	16.082	1.740	11.475	21.065

Table 2
Impact of climate vulnerability on FDI inflows. This table presents the regression results regarding the effect of climate vulnerability on FDI inflows and the moderating role of climate preparedness on this relationship. Dependent variable equals natural log of annual FDI inflows in all models. Climate vulnerability, Climate preparedness and their interaction term, Climate vulnerability × Climate preparedness, are the main variables of interest. All models are estimated with Pooled panel OLS regressions with standard errors clustered at country-level. Standard errors are reported in parentheses. * ** , * * and * indicate significance levels at 1%, 5% and 10% levels, respectively.

Variables	Log (FDI inflows)		
	(1)	(2)	(3)
Climate vulnerability	-11.746 * **	-12.236 * **	-19.791 * **
	(4.476)	(4.321)	(5.311)
Climate preparedness			-10.132 * **
			(3.832)
Climate vulnerability × Climate preparedness			23.339 * **
			(8.371)
GDP growth		0.026 * *	0.025 * *
		(0.011)	(0.011)
Inflation		-0.001 *	-0.001
		(0.001)	(0.001)
Trade-openness		-0.026 *	-0.018
		(0.014)	(0.014)
Labor force		0.004 *	0.004 *
		(0.002)	(0.002)
Market size		1.280 * **	1.081 * *
		(0.482)	(0.480)
Constant	24.099 * **	6.691	12.269
	(2.045)	(7.463)	(7.755)
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	3099	3099	3099
Countries	152	152	152

climate vulnerability and readiness indexes was collected from ND-GAIN. All variables are measured at country-level with annual frequency. After dropping observations with missing values, our final unbalanced panel dataset consists of 3099 annual observations for 152 countries over the period 1996–2019. Table A1 in Appendix A lists the countries included in our sample.

4. Empirical methodology

We specify following panel ordinary least squares regression model to examine the impact of climate vulnerability on FDI inflows.

$$Log(FDI \quad inflows)_{c,t} = \alpha_c + \beta_1(Climate \quad vulnerability_{c,t}) + \sum_{k=1}^{k}\beta_k X_{c,t}^k + \sum_{c=1}^{C-1}\epsilon_t C_t + \varepsilon_{c,t-} \tag{1}$$

Here, Log (FDI inflows) represents annual FDI inflows for country c at year t. Log (FDI inflows) equals the natural log of annual foreign direct investment inflows of a country.

Climate vulnerability is proxied with the Climate vulnerability index of ND-GAIN. The Climate Vulnerability index measures the propensity or predisposition of human societies to be negatively impacted by climate hazards. It provides a comprehensive measure of climate vulnerability, taking into account a country’s exposure, sensitivity and adaptive capacity to climate hazards in six key life-supporting sectors: food, water, health, ecosystem services, human habitat, and infrastructure. The index comprises 36 factors, with 12 factors allocated to each of the three components - exposure, sensitivity, and adaptive capacity - consisting of two factors for each of the six sectors.

Exposure factors include the climate-induced potential changes in cereal yields, population, annual water runoff, groundwater recharge, mortality rate associated with climate-induced diseases, the length of transmission season of vector-borne diseases,

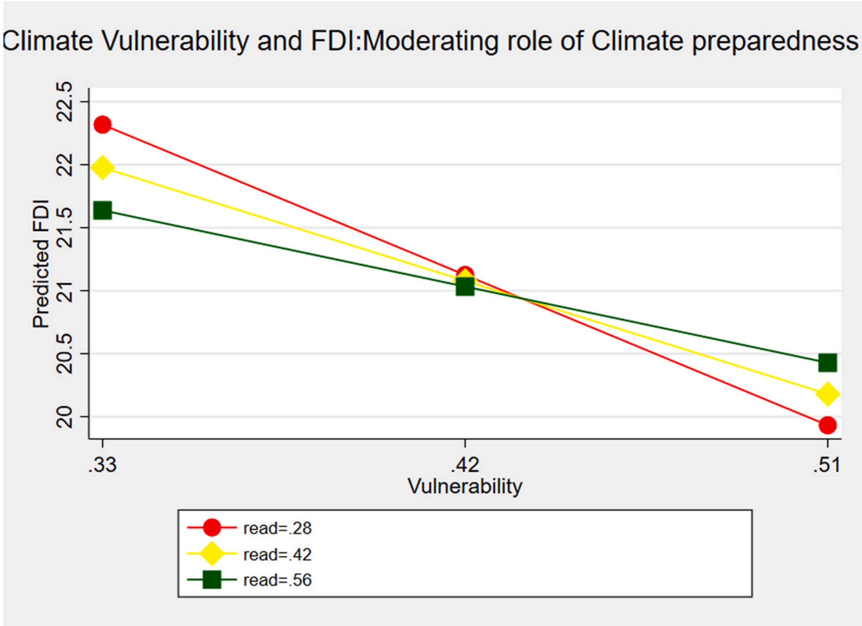


Fig. 1. : Moderating effect of climate readiness on the relationship between climate vulnerability and FDI inflows.

Table 3

Impact of climate vulnerability on FDI inflows- country income levels. This table presents the regression results regarding the effect of climate vulnerability on FDI inflows for various income groups of countries. Dependent variable equals natural log of annual FDI inflows in all models. Climate vulnerability is the main variable of interest. All models are estimated with Pooled panel OLS regressions with standard errors clustered at country-level. Standard errors are reported in parentheses. * ** , * * and * indicate significance levels at 1%, 5% and 10% levels, respectively.

Variables		Log (FDI inflows)	
	(1)	(2)	(3)
	High Income	Middle Income	Lower Income
Climate vulnerability	-26.018 * **	-28.489 * **	-22.854
	(7.001)	(4.888)	(17.085)
GDP growth	0.023	0.022	0.021
	(0.017)	(0.015)	(0.016)
Inflation	0.003	-0.002 * *	-0.002
	(0.020)	(0.001)	(0.002)
Trade-openness	0.010 * **	0.010 * **	0.021 * **
	(0.004)	(0.003)	(0.008)
Labor force	0.051	-0.018	-0.003
	(0.032)	(0.021)	(0.057)
Market size	0.991	3.326 * **	3.915 * **
	(0.685)	(0.494)	(0.702)
Constant	0.000	-16.972 *	-35.299 *
	(0.000)	(9.075)	(19.504)
Country FE	Yes	Yes	Yes
Observations	995	1729	370
Countries	46	85	20

distribution of biomes, marine biodiversity, warm periods, flood hazards, hydropower generation capacity, and sea level rise impacts.

Sensitivity factors include food import dependency, rural population, fresh water withdrawal rate, water dependency ratio, slum population, dependence on external resource for health services, dependency on natural capital, ecological footprint, urban concentration, age dependency ratio, dependency on imported energy, and the population living under 5 m above sea level.

Adaptive capacity factors include agriculture capacity, child malnutrition, access to reliable drinking water, dam capacity, medical staff, access to improved sanitation facilities, protected biomes, engagement in international environment conventions, quality of trade and transport related infrastructure, paved roads, electricity access, and disaster preparedness.

The data of these factors is drawn from a variety of sources, including the World Bank, the United Nations, and national statistical agencies. The vulnerability index ranks countries according to their exposure, sensitivity and capacity to adapt to the negative effects of climate change, the most vulnerable countries receiving a higher score and vice versa. Recent literature has employed climate

Table 4

Impact of previous climate vulnerability on current FDI inflows. This table presents the regression results regarding the effect of climate vulnerability on FDI inflows after including climate vulnerability at various lags. Dependent variable equals natural log of annual FDI inflows in all models. Climate vulnerability is the main variable of interest. All models are estimated with Pooled panel OLS regressions with standard errors clustered at country-level. Standard errors are reported in parentheses. * ** , * * and * indicate significance levels at 1%, 5% and 10% levels, respectively.

Variables	Log (FDI inflows)		
	(1)	(2)	(3)
Climate vulnerability (Lag 1)	-26.941 * **		
	(4.002)		
Climate vulnerability (Lag 2)		-26.635 * **	
		(4.007)	
Climate vulnerability (Lag 3)			-25.313 * **
			(3.857)
GDP growth	0.026 * *	0.029 * **	0.038 * **
	(0.011)	(0.011)	(0.009)
Inflation	-0.001 * *	-0.002 * *	-0.002 * *
	(0.001)	(0.001)	(0.001)
Trade-openness	0.011 * **	0.010 * **	0.010 * **
	(0.002)	(0.002)	(0.003)
Labor force	-0.021	-0.023	-0.020
	(0.016)	(0.017)	(0.018)
Market size	2.900 * **	2.788 * **	2.691 * **
	(0.488)	(0.494)	(0.500)
Constant	-11.148	-9.330	-8.504
	(8.908)	(9.002)	(9.154)
Country FE	Yes	Yes	Yes
Observations	2945	2801	2659
Countries	151	151	151

Table 5

Impact of climate vulnerability on FDI inflows- V20 group of most vulnerable countries. This table presents the regression results regarding the effect of climate vulnerability on FDI inflows using new proxy for climate vulnerability. Dependent variable equals natural log of annual FDI inflows in all models. V20 group of most vulnerable countries is the main variable of interest and equals 1 for sample countries that are the members of V20 group of most climate vulnerable countries, and 0 otherwise. All models are estimated with Pooled panel OLS regressions with standard errors clustered at country-level. Standard errors are reported in parentheses. * ** , * * and * indicate significance levels at 1%, 5% and 10% levels, respectively.

Variables	Log (FDI inflows)
	(1)
V20 group of most vulnerable countries	-4.350 * **
	(0.794)
GDP growth	0.021 * *
	(0.010)
Inflation	-0.003 * *
	(0.001)
Trade Openness	0.014 * **
	(0.002)
Labor Force	-0.007
	(0.019)
Market Size	4.067 * **
	(0.492)
Constant	-41.388 * **
	(7.816)
Country FE	Yes
Observations	3099
Countries	152

vulnerability index to examine the effect of climate vulnerability on economic growth (Adom and Amoani, 2021), inflation (Iliyasu et al., 2023), currency valuation (Cheema-Fox et al., 2022), and corporate sustainable practices (Jia and Li, 2020).

$X^k_{c,t}$ represents the country-level control variables including year-on-year GDP growth, inflation, market size (i.e., the natural log of

Table 6

Impact of climate vulnerability on FDI inflows- additional control variables. This table presents the regression results regarding the effect of climate vulnerability on FDI inflows for various after controlling for various governance indicators. Dependent variable equals natural log of annual FDI inflows in all models. Climate vulnerability is the main variable of interest. All models are estimated with Pooled panel OLS regressions with standard errors clustered at country-level. Standard errors are reported in parentheses. * ** , * * and * indicate significance levels at 1%, 5% and 10% levels, respectively.

Variables	Log (FDI inflows)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Climate vulnerability	-27.36 * **	-27.76 * **	-27.19 * **	-26.49 * **	-26.61 * **	-27.36 * **	-22.489 * *
	(4.774)	(4.613)	(4.893)	(4.883)	(4.930)	(4.770)	(10.608)
GDP growth	0.0232 * *	0.0230 * *	0.0236 * *	0.0246 * *	0.0246 * *	0.0232 * *	0.029
	(0.0108)	(0.0107)	(0.0107)	(0.0102)	(0.0107)	(0.0107)	(0.020)
Inflation	-0.00801 *	-0.00741 *	-0.00771 *	-0.00657	-0.00764 *	-0.00788 *	-0.047
	(0.00423)	(0.00427)	(0.00425)	(0.00408)	(0.00420)	(0.00420)	(0.033)
Trade-openness	-0.0266	-0.0242	-0.0258	-0.0264	-0.0276	-0.0255	0.006
	(0.0171)	(0.0173)	(0.0173)	(0.0170)	(0.0170)	(0.0173)	(0.007)
Labor force	0.0108 * **	0.0112 * **	0.0108 * **	0.0109 * **	0.0107 * **	0.0107 * **	0.014
	(0.00242)	(0.00243)	(0.00243)	(0.00237)	(0.00241)	(0.00244)	(0.046)
Market size	2.798 * **	2.828 * **	2.810 * **	2.890 * **	2.815 * **	2.806 * **	2.982 * *
	(0.523)	(0.533)	(0.555)	(0.572)	(0.547)	(0.541)	(1.497)
Voice and Accountability	0.0871						
	(0.180)						
Political stability and absence of Violence/Terrorism		0.170 *					
		(0.0993)					
Government Effectiveness			0.211				
			(0.198)				
Regulatory Quality				0.658 * **			
				(0.193)			
Rule of Law					0.419 * *		
					(0.197)		
Control of corruption						0.186	
						(0.201)	
Economic Policy Uncertainty index							-0.001
							(0.001)
Constant	-8.952	-9.391	-9.193	-10.74	-9.219	-9.007	-20.307
	(9.631)	(9.806)	(10.27)	(10.57)	(10.11)	(9.973)	(26.404)
Observations	2543	2540	2540	2540	2543	2542	366
Countries	140	140	140	140	140	140	20
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

the total population), trade openness (i.e., imports+exports/GDP), and labor force. Similar control variables have been added by Nguyen and Lee (2021) and others. Table A2 in Appendix A reports variables definitions, while Table A3 the expected relationships between FDI inflows and control variables. C_t is a set of country-level fixed-effects dummy variables to control for time-invariant country characteristics such as regulations or cultures. $\varepsilon_{c,t}$ is an error term. We use heteroskedastic-robust standard errors to estimate *p*-values in regressions.

To examine whether a country's preparedness to cater climate change affects its ability to eliminate or minimize the adverse effects of climate change on FDI inflows, we introduce the following interaction term in the model.

$$Log(FDI \quad inflows)_{c,t} = \alpha_c + \beta_1(Climate \quad vulnerability_{c,t}) + \beta_2(Climate \quad preparedness_{c,t}) + \beta_3(Climate \quad vulnerability_{c,t} \times \text{Climate preparedness}_{c,t}) + \sum_{k=1}^{k} \beta_k X_{c,t}^k + \sum_{c=1}^{C-1} \epsilon_t C_t + \varepsilon_{c,t-} \quad (2)$$

Climate preparedness is proxied with the climate readiness index of ND-GAIN. Climate readiness index measures a country's ability to leverage investments and convert them to adaptation actions. It considers the economic, governance and social readiness of countries. Economic readiness is represented by the ease of doing business index. Governance readiness captures political stability, control of corruption, rule of law and regulatory quality. Social readiness incorporates social inequality, ICT infrastructure, education, and innovation. The readiest countries have a higher score and vice versa. The interaction term, $\text{Climate vulnerability}_{c,t} \times \text{Climate preparedness}_{c,t}$, is the main variable of interest and captures the joint effect of climate vulnerability and preparedness. We expect that the adverse effect of climate vulnerability on FDI inflows would be weaker for countries with higher levels of preparedness.

5. Empirical analysis

Table 1 reports summary statistics. Mean value of Log (FDI inflows) is 20.47 with a minimum value of 10.3 and a maximum of 27.3 showing considerable variation in FDI inflows. Climate vulnerability index spans from 0.24 to 0.7 with a mean value of 0.43. There is also considerable variation in countries' preparedness to manage the effects of climate change as shown by the minimum, 0.11, and

Table 7

Impact of climate vulnerability on FDI inflows- dynamic panel two-step system GMM model. This table presents the two-step system GMM regression results regarding the effect of climate vulnerability on FDI inflows. Dependent variable equals natural log of annual FDI inflows in all models. Climate vulnerability is the main independent variable of interest. Model (1) is estimated with Pooled panel OLS regression model. Model (2) is estimated with two-step dynamic system GMM regression results. Model (3) is estimated with panel fixed-effects regression model. P-values are reported in parentheses. * ** , * * and * indicate significance levels at 1%, 5% and 10% levels, respectively.

Variables	Log (FDI inflows)		
	Pooled OLS	Two-step System GMM	Panel Fixed-Effects
	(1)	(2)	(3)
Log (FDI inflows)$_{t-1}$	0.557 * **	0.430 * **	0.345 * **
	(0.000)	(0.000)	(0.000)
Log (FDI inflows)$_{t-2}$	0.259 * **	0.134 * **	0.103 * **
	(0.000)	(0.000)	(0.000)
Climate vulnerability	-2.557 * **	-5.818 * **	-6.825 * **
	(0.000)	(0.000)	(0.001)
GDP growth	0.026 * **	0.020 * **	0.036 * **
	(0.000)	(0.000)	(0.000)
Inflation	-0.000	-0.003 *	0.000
	(0.912)	(0.066)	(0.962)
Trade-openness	0.002 * **	0.003 * **	-0.000
	(0.000)	(0.000)	(0.930)
Labor force	0.004 * *	0.009 * **	-0.014 * *
	(0.012)	(0.000)	(0.041)
Market size	0.150 * **	0.369 * **	0.456 * *
	(0.000)	(0.000)	(0.019)
Time FE	Yes	Yes	Yes
Constant	2.081 * **	5.143 * **	7.604 * *
	(0.000)	(0.000)	(0.019)
Diagnostic tests			
AR(1)		-6.82 * **	
		(0.000)	
AR(2)		-0.35	
		(0.729)	
Hansen test		69.22	
		(0.878)	
F-test		57515.95 * **	
		(0.000)	
No. of instruments		70	
Observations	2628	2628	2628
R-squared	0.896		0.486
Countries	151	151	151

maximum, 0.816, values of climate preparedness index.

Table 2 reports main regression results. Consistent with our expectation, climate vulnerability index enters negative, significant suggesting FDI inflows are lower in countries that are more vulnerable to climate change. Results of control variables, such as higher FDI inflows in countries with higher GDP growth rates, more open to international trade, and with larger market size, are consistent with previous literature. Our findings are in line with previous studies of Li and Zhang (2019) who find negative impact of climate related factors on FDI. These results are also consistent with Escaleras and Register (2011) who conclude that climate risks, such as natural disasters, extreme weather events, and sea-level rise, can significantly reduce FDI inflows to affected countries.

The positive, significant interaction term, Climate vulnerability × Climate preparedness, in Model 3 shows the adverse effect of climate vulnerability on FDI inflows is lower in countries that are more prepared to cater climate change. We also keep the Climate preparedness index in Model 3, where we estimate the joint effect of climate vulnerability and prepareness on FDI inflows. Recent literature (Asongu et al., 2017; Asongu et al., 2018; Asongu and Nwachukwu, 2018a; b) have used the similar regressions to estimate the joint effects with interaction terms.

To demonstrate how climate readiness moderates the relationship between FDI inflows and climate vulnerability, we have plotted Fig. (1) based on the findings from Model 3 of Table 2. The graph depicts the negative association between FDI inflows and climate vulnerability, as evidenced by the downward sloping lines. However, the lines have different slopes at mean and ± one standard deviation of the mean value of the climate readiness index, indicating that the strength of the negative association varies across different levels of climate readiness. In particular, the steeper line, which is marked with circles at both ends, shows that the decline in FDI inflows in response to a one-unit increase in climate vulnerability is more pronounced at lower levels of climate readiness. On the other hand, the flat line, which is marked with squares at both ends, shows that the decline in FDI inflows is less pronounced at higher levels of climate readiness.

Table 8
Impact of climate vulnerability on net FDI inflows. This table presents the regression results regarding the effect of climate vulnerability on net FDI inflows and the moderating role of climate preparedness on this relationship. Dependent variable equals net annual FDI inflows in all models. Climate vulnerability, and the interaction term, Climate vulnerability × Climate preparedness, are the main variables of interest. All models are estimated with Pooled panel OLS regressions with standard errors cluster at country-level. Standard errors are reported in parentheses. * ** , * * and * indicate significance levels at 1%, 5% and 10% levels, respectively.

Variables	Net FDI inflows		
	(1)	(2)	(3)
Climate vulnerability	-43.808 * **	-8.196 *	-8.623
	(4.310)	(4.569)	(5.453)
Climate preparedness			-0.573
			(3.830)
Climate vulnerability × Climate preparedness			1.276
			(8.528)
GDP growth		0.034 * **	0.034 * **
		(0.008)	(0.008)
Inflation		-0.000	-0.000
		(0.000)	(0.001)
Trade-openness		0.003	0.003
		(0.003)	(0.003)
Labor force		-0.028	-0.028
		(0.018)	(0.018)
Market size		1.674 * **	1.660 * **
		(0.505)	(0.523)
Constant	38.751 * **	-0.649	-0.283
	(1.867)	(7.731)	(8.371)
Country FE	Yes	Yes	Yes
Time FE	No	Yes	Yes
Observations	2169	2169	2169
R-squared	0.190	0.387	0.387
Countries	133	133	133

5.1. Country income levels and the effect of climate change on FDI inflows

Zhang (2022) observes economic variables in less developed countries, as compared to developed ones, are less sensitive to climate risks because of the lack of awareness to climate risks and clear climate related policies. To explore whether the effect of climate change vulnerability on FDI inflows differs with income levels of countries, we use IMF categorization and divide sample countries into three subgroups: high-income, middle-income and low-income countries. We re-estimate Eq. (1) one-by-one for all three sub-samples. As shown in the Table 3, the coefficients of climate change vulnerability variable are significant only for high-income and middle-income countries, but not for low-income countries. On the contrary, market size is positively significant for low-income countries. These results suggest that FDI inflows for low-income countries are not driven by climate related risks but by their market size. One potential explanation is that MNCs are more tolerant to risks in underdeveloped countries. MNCs may be more accustomed to dealing with political and economic instability, and therefore may be more willing to take on additional risks associated with climate change.

5.2. Previous climate related risks of a country and FDI inflows

MNEs' managers are likely to consider a country's previous vulnerability to climate related risks while making FDI location decisions. To check this possibility, we examine whether current years' FDI inflows are associated with previous years' values of vulnerability index. For doing so, we lag climate vulnerability index by one-period, two-periods, and three-periods. As shown in Table 4, lagged values of climate vulnerability index enter negative and significant with FDI inflows. These results imply that MNCs consider a country's previous history of climate vulnerability while making FDI decisions.

5.3. Robustness checks

In additional robustness tests, we use alternative definition of climate change vulnerability and add additional control variables in the model.

As an alternative measure of countries' climate change vulnerability, we create a dummy variable equal to one for 43 sample countries that are the members of Vulnerable Twenty (V20) Group and zero otherwise. V20 Group is a dedicated cooperation initiative of 55 nations that are systemically vulnerable to climate change. As shown in Table (5), the dummy variable representing V20 Group members enters negative and significant implying that these countries received lower FDI inflows as compared to their counterparts.

MNEs managers consider country risks related to institutional environment and government economic policies while making FDI destination decisions (Cheng and Kwan, 2000; Leahy and Montagna, 2001; Bjorvatn and Eckel, 2006; Alfaro et al., 2008; Julio and Yook, 2016). We add governance and policy uncertainty indicators as additional variables to control these effects. For doing so, first we re-estimate Eq. (1) by including six World Governance Indicators including voice and accountability, political stability, government

Table A1
List of countries. This table lists the countries included in the sample.

Albania	Dominican Republic	Lithuania	Serbia
Algeria	Ecuador	Luxembourg	Sierra Leone
Angola	El Salvador	Madagascar	Singapore
Armenia	Equatorial Guinea	Malaysia	Slovenia
Australia	Estonia	Maldives	Solomon Islands
Austria	Ethiopia	Mali	South Africa
Azerbaijan	Fiji	Malta	Spain
Bahamas	Finland	Mauritania	Sri Lanka
Bahrain	France	Mauritius	Sudan
Bangladesh	Gabon	Mexico	Sweden
Barbados	Gambia	Moldova, Republic	Switzerland
Belarus	Georgia	Mongolia	Syrian Arab Republic
Belgium	Germany	Montenegro	Tajikistan
Benin	Ghana	Morocco	Tanzania
Bhutan	Greece	Mozambique	Thailand
Bosnia and Herzegovina	Guatemala	Myanmar	Timor-Leste
Botswana	Guinea	Namibia	Togo
Brazil	Guinea-Bissau	Nepal	Tonga
Brunei Darussalam	Guyana	Netherlands	Tunisia
Bulgaria	Haiti	New Zealand	Turkey
Burkina Faso	Honduras	Nicaragua	Uganda
Burundi	Hungary	Niger	Ukraine
Cambodia	Iceland	Nigeria	United Arab Emirates
Cameroon	India	Norway	United Kingdom
Canada	Indonesia	Oman	United States
Central African	Iran	Pakistan	Uruguay
Chad	Iraq	Panama	Vanuatu
Chile	Ireland	Papua New Guinea	Venezuela
China	Israel	Paraguay	Viet Nam
Colombia	Italy	Peru	Yemen
Comoros	Jamaica	Philippines	Zambia
Congo	Japan	Poland	Zimbabwe
Democratic republic of Congo	Jordan	Portugal	
Costa Rica	Kazakhstan	Qatar	
Cote d'Ivoire	Kenya	Romania	
Croatia	Kuwait	Russian Federation	
Cyprus	Kyrgyzstan	Rwanda	
Czech Republic	Latvia	Samoa	
Denmark	Lebanon	Saudi Arabia	
Djibouti	Lesotho	Senegal	

effectiveness, regulatory quality, rule of law and control of corruption, from World Bank one-by-one. Second, we include Economic Policy Uncertainty (EPU) index of Baker et al. (2016) which is available for 20 countries as an additional control variable.

As shown in Table (6), climate vulnerability index enters negative and significant even after controlling for governance and EPU indexes. Consistent with intuition, political stability, regulatory quality and rule of law variables are positively associated with FDI inflows. Together, these results confirm that our results are not driven by omitted variable bias.

As another robustness test, we estimate a dynamic panel system generalized method of moments (GMM) regression model (Arellano and Bover, 1995; Blundell and Bond, 1998). System GMM estimator helps to control for the bias due to persistence in dependent variable, unobserved fixed effects, and endogeneity between dependent and independent variables. We may suspect bias due to these factors in our model. For instance, FDI inflows persist because of long-term international business relationships where firms keep expanding, reinvesting, or reorganizing (Eichengreen et al., 2018; Ng et al., 2022). Likewise, country-level fixed characteristics, such as culture or stable formal institutions, have not been observed in our model. Finally, the climate change vulnerability might be endogenous; on the one hand, higher vulnerability reduces FDI inflows, while, on the other hand, higher FDI inflows may contribute to CO_2 emissions thereby increasing the climate vulnerability. Likewise, GDP growth is also endogenous; higher economic growth attracts FDI inflows while higher FDI inflows would further increase the GDP growth.

Results of system GMM regressions together with diagnostics tests are reported in Table 7. We use two period lags of dependent variable as explanatory variables as the p-value of AR(2) was not insignificant with one period lag. We assume climate vulnerability and GDP growth as endogenous variables and use their one period lag together with lagged values of Log (FDI inflows) as instruments.

As shown in the Model (2), Table 7, system GMM diagnostics tests also validate the use of system GMM estimator. For instance, the estimated values of coefficients of lagged FDI inflows variables with GMM estimator lie between their estimated values with panel fixed effects and pooled OLS estimators. Likewise, AR(1) is significant while AR(2) is insignificant. Finally, consistent with the advice of Roodman (2009), the models include year fixed-effects dummies and the number of instruments is lower than the number of countries. Climate vulnerability index still enters negative and significant in the system GMM regressions further validating the main results.

Table A2
Variable definitions. This table presents the definitions of main variables.

Variable	Measurement	Data source
Dependent variable		
Log(FDI inflows)	Log(FDI inflows) is equal to the natural log of annual foreign direct investment inflows of a country.	World Development Indicators, World Bank
Main explanatory variables		
Climate Vulnerability	Climate Vulnerability Index from Notre-Dame Global Adaptation Initiative (ND-GAIN). This index captures a country's vulnerability to climate change based on a range of factors, including a country's exposure to climate hazards (such as floods, droughts, and extreme temperatures), its sensitivity to the effects of climate change (such as changes in precipitation patterns and sea level rise), and its capacity to adapt to these changes. Higher values of the index represent higher climate vulnerability and vice versa.	Notre-Dame Global Adaptation Initiative (ND-GAIN)
Climate preparedness	Climate Preparedness Index from Notre-Dame Global Adaptation Initiative (ND-GAIN). This index captures a country's climate preparedness across economic, governance and social dimensions. More prepared countries have ease of doing business, better institutional framework, higher education level and a culture of innovation.	
Control variables		
GDP growth	Equals the year-on-year growth in nominal gross domestic product (GDP) of a country.	
Inflation	Equals annual percentage change in consumer goods prices in a country.	
Trade openness	Trade openness= (imports+exports)/GDP. Imports, exports and GDP (i.e, gross domestic product) are measured at annual frequency for each country.	
Labor Force	The labor force participation rate, referred as the proportion of individuals aged 15–64 who are currently engaged in the labor force.	World Development Indicators, World Bank
Market size	Equals the natural log of total population, measured annually for each country.	
Economic Policy Uncertainty	EPU index created by Baker, Bloom, and Davis (2016). The index measures the level of uncertainty in economic policy that is based on news articles. The index is computed using a text-based approach that analyzes the frequency of specific terms related to economic policy, uncertainty, and the future in major newspapers of a country. The higher the EPU index, the greater the degree of uncertainty and vice versa.	Baker, Bloom, and Davis (2016)
Voice and Accountability	The extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.	World Governance Indicators, World Bank
Political Stability and Absence of Violence/Terrorism	The likelihood of political instability and/or politically motivated violence, including terrorism.	
Government Effectiveness	The quality of public services, the degree of bureaucracy, and the competence of civil servants in formulating and implementing policies.	
Regulatory Quality	The degree to which regulations are transparent, effective, and fairly enforced, as well as the government's commitment to enforcing regulations.	
Rule of Law	The extent to which agents have confidence in and abide by the rules of society, and the quality of contract enforcement, property rights, the police, and the courts.	
Control of Corruption	The degree to which public power is exercised for private gain, including petty and grand corruption, and the effectiveness of anti-corruption efforts.	

Table A3
Summary of the literature regarding determinants of FDI. This table summarizes the literature on the determinants of FDI inflows.

Variable	Paper	Relationship with FDI inflows
GDP growth	Asamoah et al. (2016) and (Nguyen and Lee, 2021)	(+) Growing economies attract higher FDI inflows
Inflation	Asamoah et al. (2016) and (Nguyen and Lee, 2021)	(-) Higher inflation results in lower FDI inflows
Trade openness	Asiedu (2002) andAsongu et al. (2018)	(+) Higher trade is associated with more FDI inflows
Labor force	Nguyen and Lee (2021) and (Nguyen and Lee, 2021)	(+) Labor availability increase FDI inflows
Market size	Resmini (2000)	(+) Larger markets attract higher FDI inflows
Economic Policy Uncertainty	Nguyen and Lee (2021)	(-) Higher policy uncertainty reduces FDI inflows
Governance Indicator	Gani (2007) andQuang et al. (2022)	(+) Better governance increases FDI inflows

In the above analysis, we utilized the logarithm of FDI inflows as the dependent variable. However, a significant drawback of this measure is that it fails to capture the FDI retained by a country. For instance, if a country has a high influx of FDI, but also experiences significant outflows of FDI, the net FDI inflows may be considerably lower. This indicates that the country is not retaining as much foreign investment as it is receiving. To overcome this limitation, we employed the net FDI inflows as an alternative dependent variable. As shown in Table 8, the climate vulnerability index has a significant negative association with net FDI inflows, suggesting that net FDI retained by countries decreases with higher vulnerability to climate change. These results are in line with the main findings and again confirm our hypothesis. Interestingly, the interaction term, though positive, is not significant with net FDI inflows. These findings, combined with the above main results, indicate that while climate preparedness may be a factor in attracting foreign investments, it may not be as effective in retaining them over time.

6. Conclusion

This study aims to gauge the impact of climate vulnerability on FDI inflows. Employing data from 152 countries over the period 1996–2019, we find a strong negative association between climate change vulnerability and FDI inflows. However, the climate preparedness moderates this negative relationship; that is, the negative association weakens for countries that are more prepared in terms of economic, governance and social environment to cater the adverse effects of climate change. We also observe climate vulnerability is not a significant factor for low-income countries, where market size is the main driver of FDI inflows.

Our empirical findings have important implications for countries and MNEs. First, they help to understand another channel, foreign capital, through which climate change adversely affects the economy. As foreign capital plays an important role in economic development, countries should try to manage climate risk so that adverse consequences in terms of receipts of foreign capital can be avoided. Enhancing the economic, institutional, and social environment can help countries mitigate climate risks and maintain a favorable environment for foreign capital investment. Second, MNEs must consider climate risk as a crucial factor when pursuing internationalization, and implementing a comprehensive risk management strategy that addresses climate risks can increase their chances of success in global markets. Failing to account for climate risks could result in significant financial and reputational losses, making it imperative for MNEs to prioritize climate risk management in their international operations.

Future research can explore the connection between MNEs' experience with climate-vulnerable countries and their investment patterns in regions that are susceptible to the adverse effects of climate change.

CRediT authorship contribution statement

All authors contributed equally to the manuscript.

Data Availability

Data will be made available on request.

Appendix A

See Table A1–A3.

References

Abdelzaher, D.M., Martynov, A., Abdel Zaher, A.M., 2020. Vulnerability to climate change: are innovative countries in a better position? Res. Int. Bus. Financ. 51, 101098.
Acharya, V., Johnson, T., Sundaresan, S.M., Tomunen, T., 2022. Is Physical Climate Risk Priced? Evidence from Regional Variation in Exposure to Heat Stress.
Adom, P.K., Amoani, S., 2021. The role of climate adaptation readiness in economic growth and climate change relationship: an analysis of the output/income and productivity/institution channels. J. Environ. Manag. 293, 112923.
Alfaro, L., Kalemli-Ozcan, S., Volosovych, V., 2008. Why doesn't capital flow from rich to poor countries? An empirical investigation. Rev. Econ. Stat. 90, 347–368.
Ansah, E.W., Ankomah-Appiah, E., Amoadu, M., Sarfo, J.O., 2021. Climate change, health and safety of workers in developing economies: a scoping review. J. Clim. Change Health 3, 100034.
Arellano, M., Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. J. Econ. 68, 29–51.
Asamoah, M.E., Adjasi, C.K.D., Alhassan, A.L., 2016. Macroeconomic uncertainty, foreign direct investment and institutional quality: evidence from Sub-Saharan Africa. Econ. Syst. 40, 612–621.
Asiedu, E., 2002. On the determinants of foreign direct investment to developing countries: is Africa different? World Dev. 30, 107–119.
Asongu, S., Akpan, U.S., Isihak, S.R., 2018. Determinants of foreign direct investment in fast-growing economies: evidence from the BRICS and MINT countries. Financ. Innov. 4.
Asongu, S.A., Nwachukwu, J.C., 2018a. Educational quality thresholds in the diffusion of knowledge with mobile phones for inclusive human development in sub-Saharan Africa. Technol. Forecast. Soc. Change 129, 164–172.
Asongu, S.A., Nwachukwu, J.C., 2018b. Openness, ICT and entrepreneurship in sub-Saharan Africa. Inf. Technol. People 31, 278–303.
Asongu, S.A., Le Roux, S., Biekpe, N., 2017. Environmental degradation, ICT and inclusive development in Sub-Saharan Africa. Energy Policy 111, 353–361.
Batten, S., 2018. Climate change and the macro-economy: a critical review.
Beirne, J., Renzhi, N., Volz, U., 2021a. Bracing for the Typhoon: climate change and sovereign risk in Southeast Asia. Sustain. Dev. 29, 537–551.
Beirne, J., Renzhi, N., Volz, U., 2021b. Feeling the heat: climate risks and the cost of sovereign borrowing. Int. Rev. Econ. Financ. 76, 920–936.
Bernstein, A., Gustafson, M.T., Lewis, R., 2019. Disaster on the horizon: the price effect of sea level rise. J. Financ. Econ. 134, 253–272.
Bjorvatn, K., Eckel, C., 2006. Policy competition for foreign direct investment between asymmetric countries. Eur. Econ. Rev. 50, 1891–1907.
Blundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. J. Econ. 87, 115–143.
Boitan, I.A., Marchewka-Bartkowiak, K., 2022. Climate change and the pricing of sovereign debt: insights from European markets. Res. Int. Bus. Financ. 62, 101685.
Buckley, P.J., Chen, L., Clegg, L.J., Voss, H., 2016. Experience and FDI risk-taking: a microfoundational reconceptualization. J. Int. Manag. 22, 131–146.
Buckley, P.J., Chen, L., Clegg, L.J., Voss, H., 2020. The role of endogenous and exogenous risk in FDI entry choices. J. World Bus. 55, 101040.
Capelle-Blancard, G., Crifo, P., Diaye, M.-A., Oueghlissi, R., Scholtens, B., 2019. Sovereign bond yield spreads and sustainability: an empirical analysis of OECD countries. J. Bank. Financ. 98, 156–169.
Cavusgil, S.T., Deligonul, S., Ghauri, P.N., Bamiatzi, V., Park, B.I., Mellahi, K., 2020. Risk in international business and its mitigation. J. World Bus. 55, 101078.
Cevik, S., Jalles, J.T., 2022. This changes everything: climate shocks and sovereign bonds*. Energy Econ. 107, 105856.
Chang, J., Guo, A., Wang, Y., Ha, Y., Zhang, R., Xue, L., Tu, Z., 2019. Reservoir operations to mitigate drought effects with a hedging policy triggered by the drought prevention limiting water level. Water Resour. Res. 55, 904–922.
Cheema-Fox, A., Serafeim, G., Wang, H., 2022. Climate change vulnerability and currency returns. Financ. Anal. J. 78, 37–58.
Chen, B., Chu, L., 2022. Decoupling the double jeopardy of climate risk and fiscal risk: a perspective of infrastructure investment. Clim. Risk Manag. 37, 100448.

Cheng, L.K., Kwan, Y.K., 2000. What are the determinants of the location of foreign direct investment? The Chinese experience. J. Int. Econ. 51, 379–400.
Correa, R., He, A., Herpfer, C., Lel, U., 2022. The rising tide lifts some interest rates: climate change, natural disasters, and loan pricing. Int. Financ. Discuss. Pap.
Crifo, P., Diaye, M.-A., Oueghlissi, R., 2017. The effect of countries' ESG ratings on their sovereign borrowing costs. Q. Rev. Econ. Financ. 66, 13–20.
Dell, M., Jones, B.F., Olken, B.A., 2014. What do we learn from the weather? The new climate-economy literature. J. Econ. Lit. 52, 740–798.
Dogru, T., Marchio, E.A., Bulut, U., Suess, C., 2019. Climate change: vulnerability and resilience of tourism and the entire economy. Tour. Manag. 72, 292–305.
Dunning, J.H., 1977. Trade, location of economic activity and the MNE: a search for an eclectic approach. The International Allocation of Economic Activity. Springer, pp. 395–418.
Eichengreen, B., Gupta, P., Masetti, O., 2018. Are capital flows fickle? Increasingly? And does the answer still depend on type? Asian Econ. Pap. 17, 22–41.
Escaleras, M., Register, C.A., 2011. Natural disasters and foreign direct investment. Land Econ. 87, 346–363.
Füssel, H.-M., 2007. Vulnerability: a generally applicable conceptual framework for climate change research. Glob. Environ. Change 17, 155–167.
Gani, A., 2007. Governance and foreign direct investment links: evidence from panel data estimations. Appl. Econ. Lett. 14, 753–756.
Giglio, S., Maggiori, M., Rao, K., Stroebel, J., Weber, A., 2021. Climate change and long-run discount rates: evidence from real estate. Rev. Financ. Stud. 34, 3527–3571.
Hong, H., Li, F.W., Xu, J., 2019. Climate risks and market efficiency. J. Econ. 208, 265–281.
Huang, H.H., Kerstein, J., Wang, C., 2018. The impact of climate risk on firm performance and financing choices: an international comparison. J. Int. Bus. Stud. 49, 633–656.
Iliyasu, J., Mamman, S.O., Ahmed, U.A., 2023. Impact of climate change on output and inflation in. Africa's Larg. Econ. Clim. Dev. 1–12.
Jia, J., Li, Z., 2020. Does external uncertainty matter in corporate sustainability performance? J. Corp. Financ. 65.
Julio, B., Yook, Y., 2016. Policy uncertainty, irreversibility, and cross-border flows of capital. J. Int. Econ. 103, 13–26.
Kahn, M.E., Mohaddes, K., Ng, R.N.C., Pesaran, M.H., Raissi, M., Yang, J.-C., 2021. Long-term macroeconomic effects of climate change: a cross-country analysis. Energy Econ. 104, 105624.
Kling, G., Lo, Y.C., Murinde, V., Volz, U., 2018. Climate vulnerability and the cost of debt. Available at SSRN 3198093.
Kling, G., Volz, U., Murinde, V., Ayas, S., 2021. The impact of climate vulnerability on firms' cost of capital and access to finance. World Dev. 137, 105131.
Klomp, J., Valckx, K., 2014. Natural disasters and economic growth: a meta-analysis. Glob. Environ. Change 26, 183–195.
Kobayashi-Soloman, E., 2019. Climate change: the greatest opportunity of all time. Forbes.
Leahy, D., Montagna, C., 2001. Unionisation and foreign direct investment: challenging conventional wisdom? Econ. J. 110, C80–C92.
Li, W., Zhang, K., 2019. Does air pollution crowd out foreign direct investment inflows? Evidence from a quasi-natural experiment in China. Environ. Resour. Econ. 73, 1387–1414.
Li, X., Gallagher, K.P., 2022. Assessing the climate change exposure of foreign direct investment. Nat. Commun. 13, 1–9.
Linnenluecke, M.K., Stathakis, A., Griffiths, A., 2011. Firm relocation as adaptive response to climate change and weather extremes. Glob. Environ. Change 21, 123–133.
Lu, S., Bai, X., Zhang, X., Li, W., Tang, Y., 2019. The impact of climate change on the sustainable development of regional economy. J. Clean. Prod. 233, 1387–1395.
Ng, J.C.Y., Chan, T.C.H., Tsang, K.P., Leung, C.K.Y., 2022. Greenfield foreign direct investment: Social learning drives persistence. J. Int. Money Financ. 126, 102641.
Nguyen, C.P., Lee, G.S., 2021. Uncertainty, financial development, and FDI inflows: global evidence. Econ. Model. 99.
Okafor, L.E., Hassan, M.K., Rashid, M., Prabu, D., Sabit, A., 2022. Risk dimensions, risk clusters, and foreign direct investments in developing countries. Int. Rev. Econ. Financ. 82, 636–649.
Quang, P.T., Rasoulinezhad, E., Linh, N.N., Thao, D.P., 2022. Investigating the determining factors of sustainable FDI in Vietnam. China Financ. Rev. Int.
Resmini, L., 2000. The determinants of foreign direct investment in the CEECs: new evidence from sectoral patterns. Econ. Transit. 8, 665–689.
Roodman, D., 2009. How to do xtabond2: an introduction to difference and system GMM in Stata. Stata J. 9, 86.
Volz, U., Beirne, J., Ambrosio Preudhomme, N., Fenton, A., Mazzacurati, E., Renzhi, N., Stampe, J., 2020. Climate change and sovereign risk.
Wilbanks, T.J., Fernandez, S., 2014. Framing climate change implications for infrastructures and urban systems. In: Wilbanks, T.J., Fernandez, S. (Eds.), Climate Change and Infrastructure, Urban Systems, and Vulnerabilities. Island Press/Center for Resource Economics, Washington, DC, pp. 17–40.
Xu, W., Gao, X., Xu, H., Li, D., 2022. Does global climate risk encourage companies to take more risks? Res. Int. Bus. Financ. 61, 101658.
Zhang, S.Y., 2022. Are investors sensitive to climate-related transition and physical risks? Evidence from global stock markets. Res. Int. Bus. Financ. 62, 101710.

Annex 554

J. A. Soussane et al., “Does Climate Change Constitute a Financial Risk to Foreign Direct Investment? An Empirical Analysis on 200 Countries from 1970 to 2000”, *Weather, Climate, and Society*, 2023, pp. 31-43

Does Climate Change Constitute a Financial Risk to Foreign Direct Investment? An Empirical Analysis on 200 Countries from 1970 to 2020

JIHAD AIT SOUSSANE,[a] DALAL MANSOURI,[a] MOHAMED YASSINE FAKHOURI,[a] AND ZAHRA MANSOURI[a]

[a] *Faculty of Economics and Management, Laboratory of Economics and Management of Organizations, Ibn Tofail University, Kenitra, Morocco*

(Manuscript received 17 February 2022, in final form 28 July 2022)

ABSTRACT: In this paper, we study the role of climate change as a financial risk for foreign investors. Multinational enterprises seek to internationalize where financial risk is at the minimum level, including the climate change risk on profitability and productivity. Thereby, we conducted an empirical analysis of the effect of climate change on inward foreign direct investment (FDI) net inflows using data from 200 countries and times series from 1970 to 2020 and employing two categories of climate change indicators: Climatology and climate-related natural hazards. Using the estimation methods of fully modified ordinary least squares and robust weighted least squares, we concluded that the rise of climatology indicators (mean annual temperature and precipitations) negatively impacts inward FDI. Second, we conclude that most climate-related natural hazards (coastal/rural/urban floods, landslides, and cyclones) deter FDI while extreme heat and wildfires show no significant effect. In addition, the results show that the negative impact of climate change is more severe when the host economy depends on agricultural activities and there is no significant investment in research and development as compared with countries that depend on service and manufacturing activities and are more innovative and invest in technology infrastructure. Furthermore, we conclude that poorer host countries experience more severe effects of climate change on FDI than rich countries in terms of GDP per capita.

SIGNIFICANCE STATEMENT: The purpose of the paper is to investigate the effect of climate change on inflows of cross-border capital in 200 countries. In other words, we see if rising temperature and natural hazards related to climate change affect the decision of firms to invest in a given country. The results show that global warming and unstable meteorological indicators deter firms from investing abroad. Equally, natural hazards linked to climate change (coastal/rural/urban floods, landslides, and cyclones) constitute an investment risk. The finding suggests that the deterring effects of climate change are less severe when a given country depends less on agriculture and more on industrial sectors and when that country is more developed and technologically advanced.

KEYWORDS: Social science; Climate change; Regression analysis; Economic value

1. Introduction

The international economy is confronted frequently with multiple sources of technological, social, and environmental risks. These are either classic such as uncertainty in economic policy, geopolitical risks, commodity shocks, or many observed new risks observed recently, such as risks linked to climate change. Indeed, climate change refers to all the climatic variations that result in a warming or cooling of a given place, leading to extreme climatic damage, namely, sea level rise, droughts, floods, melting ice, cyclones, forest destabilization and fires, reduction of biodiversity (World Bank Group 2021; https://climateknowledgeportal.worldbank.org).

The United Nations Intergovernmental Panel on Climate Change (IPCC) published in August 2021 its new report containing new climate forecasts around the world. They forecasted an increase in the global average temperature by 1.5°C over the next 20 years, as well as the melting ice and rising sea levels by about 20 cm since 1900. On the other hand, scientists estimate that this increase could reach up to 1 m by 2100 and nearly 2 m by 2300 (IPCC 2021).

Today it not only represents one of the most significant threats to the environment and biodiversity, but climate change also has serious social, economic, and financial consequences. In addition, the effects of climate change on economies depend on their level of economic development, technological level, and sectoral structure related to the dominant activity such as industry, agriculture, or trade. Generally, the economic impact of climate change manifests itself in economic growth, wealth creation, productivity, and international trade. Equally, climate change harms territorial competitiveness and the performance of their attractiveness in terms of foreign direct investments (FDI; Wade and Jennings 2016; Auffhammer 2019; Kahn et al. 2019; Tol 2020).

Indeed, understanding the economic consequences of climate change becomes necessary not only for climate economists but also for professionals as investors involved in the modeling and forecasting of macroeconomic variables so they can reduce financial risks when investing in foreign markets.

Although climate change is one of the main factors affecting investor behavior, empirical studies focused on the impact on other economic variables while omitting the attractiveness of investments and FDI decision-making. According to our research, the only study analyzing the effect of changing climatology on FDI is the study of Barua et al. (2020) with panel data from 80 countries. They concluded that rising

Corresponding author: Jihad Ait Soussane, jihad.aitsoussane@gmail.com

DOI: 10.1175/WCAS-D-22-0027.1

temperature and falling precipitation have a long-term negative impact on FDI. However, their results are heterogeneous because the temperature rise has a different effect on FDI inflows in the countries depending on their level of development. For natural disasters, many studies analyzed their impact on FDI location decisions (Noy and Vu 2010; Escaleras and Register 2011; Boustan et al. 2012; Doytch and Klein 2018; Doytch 2019; Oh et al. 2020; Neise et al. 2022). However, these studies have not distinguished natural disasters related to climate and meteorology from the geophysical ones, like earthquakes and volcanos. Despite that the work of Doytch (2019) has separated the natural disasters into different categories, including those that are related to climate change, the study has not focused on the effect of climate change on FDI and ignored the other indicators of climate change as climatology parameters (precipitations and temperature). In addition, the author used the frequency of natural disasters per year as an explanatory variable. Our study uses a more sophisticated indicator, which is the score of natural disaster hazards constructed by the Think Hazard organization, and its data are available on the Climate Change Knowledge Portal (CCKP). The author also used subpanels to compare the different effects of natural disasters on FDI between different geographies. Our paper uses moderating variables (GDP per capita, research and development, and the contribution of sectors to the GDP) to investigate the heterogeneity of the effect without the need to produce subpanels.

Therefore, our paper constitutes a novelty in the literature on FDI location factors by extensively analyzing the effect of climate change on inward FDI. In particular, our study differs from other studies by analyzing climate change in both aspects, the climatology indicators (temperature and precipitations) and natural disasters related to climate, in which previous papers worked only on one angle. Second, the data used in the empirical study are widely larger than other studies by working on 200 countries from 1970 to 2020. Third, previous papers have not used moderating variables to study the heterogeneity effect of climate change on FDI. In other words, climate change affects the inward FDI of host countries depending on their development level, sector's contribution to their GDP, and technological level. The previous studies only differentiated the effect by geographical location, which is less sophisticated than using moderating variables.

Thus, this paper aims to answer the following hypothesis: climate change constitutes a financial risk to foreign international investment. To investigate this hypothesis, we use an econometric model to analyze data of 200 countries over 51 years from 1970 to 2020. We divide the analysis into two axes, where each axis represents a substudy in itself, for two reasons: The first reason is strategic because there is no previous study on the effect of climate change using different measures and indicators. Therefore, we regrouped all the variables into two groups to facilitate the interpretation and the empirical analysis. The second reason is technical due to the incoherence of data: while climatology indicators are panel datasets, the data on natural disasters exist for one year as a cross-sectional dataset. Therefore, to avoid estimation errors, it is better to separate each group/axis in a different model for different estimations. These two groups of climate change variables are as follows:

1) The first axis will analyze the impact of two meteorological indicators, the average annual precipitation and temperature, using panel data from 200 countries over 51 years.
2) The second axis will analyze the impact of seven natural hazard indicators related to climate change (coastal floods, cyclones, extreme heat, landslides, river floods, urban floods, and wildfires) using cross-sectional data for 194 countries for 2010.

This paper is organized as follows: section 2 will present the literature review of the impact of climate change on FDI location choice. Section 3 will explain the research design to answer the research hypotheses. Section 4 will discuss the empirical results in detail.

2. Literature review of the effect of climate change on foreign direct investment

a. *General overview*

The literature recognized the impact of climate change on the economy depending on the sector and industry under study (Auffhammer 2019; Tol 2020). The different analyzes of this impact cover the field of economic growth, wealth creation, productivity, and business activities (Smith and Hitz 2003; Hallegatte et al. 2011; Groth and Brunsmeier 2016; Arnell et al. 2019). However, studies addressing the effect of climate change on domestic and foreign investment remain omitted despite being one of the factors affecting investment location decisions. In addition, it is plausible that the impact of climate change on FDI is more significant than on domestic investment because the foreign investor regularly faces a higher level of financial risks as stipulated by the hypothesis of liability of foreignness that can lead to loss of capital and investment in the host economy. In other words, the FDI faces many risks, including climate change and resulting natural disasters. The occurrence of risks related to climate change can cause damage to production sites and burden the host country's economy due to the destruction of infrastructure, logistics, and assets. Therefore, climate change tends to increase the occurrence and magnitude of natural disasters, rising temperatures, and drought (IPCC 2018). It constitutes a higher financial risk to foreign investors where natural disasters related to climate change put economies at risk, leading the multinational enterprises (MNEs) to consider the occurrence of natural disasters when making investment decisions and locating their FDI (Mani et al. 2003).

It turns out that the issue of climate change is increasingly relevant for the location of FDI because many sectors are more exposed to climate change, and the reorganization of the movement of FDI is linked to the climate in host countries. Therefore, one could say that the nature of the impact of climate change on investment depends on the sensitivity of each real sector and economic activity. However, climate change has not yet become a determinant/deterrent of FDI location decision literature (Neise et al. 2022).

For this, Moreno et al. (1996), in the second assessment report of the IPCC, classify sectors sensitive to climate change into three main categories:

1) economic activities directly sensitive to climate change, including infrastructure, real estate, construction, transport operation, and tourism,
2) economic activities with markets sensitive to climate change, including air conditioning equipment, adaptive building design, and construction, as well as transport infrastructure and services, and
3) economic activities based on inputs sensitive to climate change are industries that depend on the primary sector (agriculture and forestry), domestic and industrial biomass, and fossil/renewable energy.

b. *Hypotheses development*

1) The effect of climatology indicators changes on FDI

Climate change can negatively impact investment levels and discourage FDI such as drought and declining rainfall by deteriorating the productivity of several sectors like agriculture, agroindustry, and energy. Hence, production shocks resulting from climate change can reduce investments in agroindustry. In addition, the decrease in the level of precipitation and the availability of water can impact investments in hydropower. Indirectly, global warming and drought can negatively affect domestic and foreign investment through transmission channels such as the reduction of labor productivity and the volume of trade (Jones and Olken 2010; Niemelä et al. 2002). Also, Mercer (2015) argues that climate change may negatively impact return on investment (ROI) over the next 35 years for industries of fossil fuel, utilities, industrials, and consumer staples. And since FDI is determined primarily by ROI, climate change negatively impacts FDI through the return on investment channel. However, climate change can positively impact ROI in renewable energy, nuclear, and information and communication technology (ICT) activities, which deters FDI.

Ernst & Young (2016) proposed six reasons why climate change constitutes a financial investment risk and therefore deters FDI: 1) physical risks are the damage to infrastructure, land, buildings, and stocks or infrastructure; 2) secondary risks are the spillover effects of physical risk such as lower crop yields and resource shortages; 3) political risks: financial losses resulting from climate policies, such as carbon taxes, emission ceilings, or the withdrawal of subsidies; 4) liability risks are the financial liabilities, including insurance claims and legal damages, resulting from tort or negligence; 5) transitional risks are the financial losses resulting from disorderly or volatile adjustments in the value of assets; and 6) reputational risk: loss of trust and reputation due to actions incompatible with climate objectives.

However, the rising temperature can encourage investment in new activities and make particular regions favorable for the production of some goods as agriculture in relatively colder territories and prospecting for energy and mines in ice zones (Arctic). Furthermore, the rise in temperature changes the energy demand and could encourage investment in the energy sector.

The empirical studies have examined the impact of climate change on overall investment without distinguishing between domestic and foreign ones. For example, Dell et al. (2012) concluded that the decrease in rainfall impacts the overall investment negatively for rich countries, while the effect of the increase in temperature is insignificant. They argue that climate change may indirectly affect aggregate investment through the productivity of real sectors.

2) The effect of climate-related natural disasters on FDI

FDI is affected by the frequency of natural disasters. The negative impact of natural disasters manifested in the destruction of infrastructure, displacement of the local population, and decline in human capital resources. In addition, natural disasters cause bank liquidity shocks that discourage capital investment (Kato and Okubo 2018). However, in the long run, the impact becomes positive because natural disasters represent opportunities to be seized, such as the replacement and reconstruction of infrastructure and the updating of intangible capital (Noy and Vu 2010; Escaleras and Register 2011; Boustan et al. 2012; Doytch and Klein 2018; Doytch 2019; Oh et al. 2020; Neise et al. 2022).

Moreover, the theoretical basis of the economic analysis of natural disasters lies in the theory of growth by analyzing the short and long-term impact of these disasters on GDP. As already mentioned, natural disasters negatively impact FDI in the short term, but in the long term, GDP would rebound to a level exceeding the precatastrophic level. This hypothesis has its origin in the theory of endogenous growth under the hypothesis of "creative destruction." In this context, reference is made to the "upgrading destruction" hypothesis where natural disasters destroy old assets with outdated technology and rebuild with new advanced practices and technology (Noy and Vu 2010; Doytch and Klein 2018). However, some characterize this hypothesis by arguing that growth converges to the precatastrophic level because the rise in marginal productivity is explained by a lack of capital available for the same amount of labor (Boustan et al. 2020). However, the impact of natural disasters depends on the country's level of development.

Yang (2008) has studied the effect of hurricanes; as the most common and destructive types of natural disasters; on international financial flows including FDI. The author used meteorological data on storm paths and constructed a time-varying storm index from 1970 to 2002 of 87 countries. The empirical results show that FDI as a private flow is negatively affected by hurricane exposure and this effect appears greater in the richer half of the sample countries. The author explains the result by arguing that natural disasters may reflect the fall of rates of return on investment and increased risk perceptions on the part of international investors. Escaleras and Register (2011) worked on the effect of total events of natural disasters (earthquakes, floods, volcanos, landslides, windstorms) in a panel of 94 countries from 1984 to 2004 using the fixed effects model. They concluded that total damages in the prior 5–25 years affect negatively inward FDI. Kukułka (2014) studied the effect of natural disasters on inward FDI in southeastern Asian countries (Indonesia, Malaysia, Philippines, Thailand, and Vietnam) using times series from 1950 to 2013 and the ordinary least squares (OLS) estimation method. The results show a negative impact of the occurrence of natural disasters on inward FDI in Thailand and Malaysia and an insignificant impact on the remaining countries.

Anuchitworawong and Thampanishvong (2015) analyzed inward FDI in Thailand from 1971 to 2012 using a system of simultaneous equations. They found that the degree of severity of natural disasters negatively affects inward FDI in Thailand. Doytch (2019) analyzed the effect of different natural disasters on FDI in manufacturing and service sectors using panel data of 69 countries from 1980 to 2011. The author finds that manufacturing FDI is negatively affected in the short run and positively in the long run for all types of natural disasters. However, the author stated that the effect in the service sector is unclear by finding that meteorological disasters do not affect FDI and climate, hydrological disasters have long-lasting negative effects and geophysical disasters have a positive impact on FDI in the long run.

3. Research design and method

a. Sample description and data sources

The empirical analysis is based on panel data of 200 countries[1] during the period 1970–2020. The selection of the sample is due to the significance of inward foreign direct investment according to the United Nations Conference on Trade and Development (UNCTAD) database. Therefore, those absent from the panel are because the data on inward FDI is nonsignificant to consider or not provided by the local authorities. In addition, the absence of data on the independent variables is a sufficient reason to exclude a country from the panel.

Data on inward foreign direct investment as the dependent variable are provided by UNCTAD (https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=96740), which collects statistics on international capital for the balance of payments. On the other hand, the data on climate change indicators, as explanatory variables, are taken for the database of the World Bank. Particularly, the data on climatology indicators (mean annual temperature and mean annual precipitation) are collected from the database provided by CCKP (https://climateknowledgeportal.worldbank.org/download-data), a division of the World Bank that provides data on historical and projected climate, its vulnerabilities, and impacts. Data on climate-related natural hazard indicators are collected from the Think Hazard organization and are available on the CCKP database. For the moderating variables, the data on all variables related to gross domestic product and research and development are taken from the database of the World Bank (https://data.worldbank.org/indicator/).

b. Research hypotheses

Inspired by the literature review and aims to investigate the role of climate change as a financial risk to foreign investors, which affects the behavior of foreign investors when it comes to the location decision of their FDI, we formulate the central research hypothesis as follows: to what extent does climate change affect inward FDI?

To investigate this research hypothesis, we aim to confirm subhypotheses that are drawn from the literature review and formulated by the equations and research hypotheses described above:

- H1: More changes in climatology indicators, the more the climate change constitutes a financial risk to foreign investors. In other words, the changes in climatology indicators negatively impact inward FDI. In particular, a higher mean annual temperature and precipitation deters inward FDI.
- H2: More climate-related natural hazard indicators are higher, and more climate change constitutes a financial risk to foreign investors. In other words, a lower score of climate-related natural hazards (coastal flood, cyclone, extreme heat, landslide, river flood, urban flood, wildfire) impacts negatively inward FDI.

To investigate the two research hypotheses, we conduct an empirical analysis using an econometric model as presented below.

c. Variables description

1) The endogenous variable: FDI

According to the research hypothesis, we aim to identify the effect of climate change on the location decision of foreign capital. Therefore, FDI is the practical proxy variable usually employed by empirical researchers when answering this kind

[1] Afghanistan, Albania, Algeria, Angola, Anguilla, Antigua and Barbuda, Argentina, Armenia, Aruba, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bermuda, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, the British Virgin Islands, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Cambodia, Cameroon, Canada, Cayman Islands, the Central African Republic, Chad, Chile, China, China (Macao Special Administrative Region), Colombia, Comoros, Republic of the Congo, Democratic Republic of the Congo, Cook Islands, Costa Rica, Côte d'Ivoire, Croatia, Cyprus, Czechia, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Eswatini, Ethiopia, Fiji, Finland, France, French Polynesia, Gabon, The Gambia, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kiribati, South Korea, North Korea, Kuwait, Kyrgyzstan, Laos, Latvia, Lebanon, Lesotho, Liberia, Libya, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Marshall Islands, Mauritania, Mauritius, Mexico, Micronesia, Moldova, Mongolia, Montenegro, Montserrat, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Caledonia, New Zealand, Nicaragua, Niger, Nigeria, North Macedonia, Norway, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russia, Rwanda, Saint Helena, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Samoa Sao Tome and Principe, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, Solomon Islands, Somalia, South Africa, South Sudan, Spain, Sri Lanka, State of Palestine, Sudan, Suriname, Sweden, Switzerland, Syria, Tajikistan, Tanzania, Thailand, Timor-Leste, Togo, Tonga Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Turks and Caicos Islands, Tuvalu, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States of America, Uruguay, Uzbekistan, Vanuatu, Venezuela, Vietnam, Yemen, Zambia, and Zimbabwe.

of research hypothesis related to internationalization and capital movement. Generally, the FDI is defined, according to the International Monetary Fund, as the portion held in the capital of a company that must be greater than 10% to distinguish it from the portfolio investment. In addition to direct equity investments, direct investments also include advances in associates' current accounts and private loans contracted by foreign plants with their parent companies, as well as reinvested profits. In particular, the variable used for the empirical analysis is the net flow of inward foreign direct investment.

2) THE EXPLANATORY VARIABLES: CLIMATE CHANGE

(i) Climatology indicators

The mean annual temperature is the average temperature of the maxima and minima for the warmest and coldest months. The glossary of CCKP defines the temperature as the expected temperature in degrees, valid for the indicated hour. Global temperature is an average of air temperature recordings from weather stations on land and sea and some satellite measurements. Extreme temperature events (maxima and minima) may have short-term durations of a few days with temperature increases of over 5°C above the normal temperatures.

The mean annual precipitation is calculated by summing the rainfall for a given year. The snowfall is considered an assumed water equivalent of the rainfall by using a specific gravity of 0.1 for freshly fallen snow. This means 25.4 cm of freshly fallen snow is assumed to be equal to 2.54 cm of rain. The glossary of CCKP defines precipitation as "water released from clouds in the form of rain, freezing rain, sleet, snow, or hail. It is the primary connection in the water cycle that provides for the delivery of atmospheric water to the Earth" (World Bank Group 2021, p. 7).

(ii) The climate-related natural hazard indicator

Climate-related natural hazard indicators provide a general view of the natural disasters for a given country that should be considered when investing abroad. The score ranges from 1 to 4: 1 for high hazard, 2 for medium hazard, 3 for low hazard, and 4 for very low hazard. The glossary of CCKP defines some of the natural hazards as follows: floods, including coastal, river, and urban ones, are the "overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged (World Bank Group 2021, p. 6)." The cyclone is defined as a "rapid-onset event that takes place in days or weeks (in contrast to slow-onset climate changes that occur over long periods) (World Bank Group 2021, p. 8)." Extreme heat is three or more days of above-average temperatures, generally defined as passing a certain threshold (e.g., above the 85th percentile for average daily temperature in a year).

3) THE MODERATING VARIABLES

The first type of moderating variable is GDP per capita, which is used to moderate the effect of climate change on capital mobility in the sense that is usually employed by empirical analysis as a proxy for the level of development and market strength and economic resilience to exogenous shocks. Furthermore, GDP per capita is a gross domestic product, measured by current U.S. dollars, divided by midyear population. The World Bank defines GDP as "the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources" (Glossary of the World Bank; https://databank.worldbank.org/metadataglossary/africa-development-indicators/series/NY.GDP.MKTP.PP.KD#:~:text=GDP%20is%20the%20sum%20of,the%20value%20of%20the%20products).

The second type of moderating variable is the contribution by a specific sector to the value-added (percent of GDP). The present analysis uses three main sectors: industry, agriculture, and commerce. The underlying hypothesis is that the effect of climate change on FDI attractiveness depends on which sector is more dominant in the economy. For this matter, we use the part of the industry sector in GDP that includes subsectors of mining, manufacturing, construction, electricity, water, and gas; the part of the agriculture sector in GDP that includes subsectors of forestry, hunting, and fishing, as well as cultivation of crops and livestock production; and the part of the commerce sector in GDP that is the sum of merchandise exports and imports.

The third type of moderating variable is the R&D expenditure part in GDP. Research and development (R&D) could play a role in moderating the effect of climate change on FDI because R&D indicates the level of innovation and scientific progress of a given country. R&D expenditure includes both capital and current expenditures in the four main sectors: business enterprise, government, higher education, and private nonprofit. R&D covers basic research, applied research, and experimental development.

4) CONTROL VARIABLES

Our data on inward FDI are mixed and do not distinguish between vertical from horizontal foreign direct investment, which leads us to use the knowledge-capital model (KCM) introduced by Carr et al. (2001). That conceptual model aims to identify the type of FDI by computing other location factors of FDI: market size, trade tariffs, and factor endowment. In other words, location factors explain the type of FDI and its motivation, whether horizontal or vertical. According to the knowledge-capital model, horizontal FDI is affected positively by large market size and high tariffs. The vertical FDI is affected negatively by high tariffs and positively impacted by input endowment.

Inspired by the theoretical model of KCM, we include the variables as follows: Market size measured by current GDP is a proxy for market size. For factor endowment, we use the revealed comparative advantage (RCA), which is based on the Ricardian trade model to indicate the competitiveness of a country that has on other countries. The revealed comparative advantage is the exports share of a product *j* with the total exports of a given country divided by the exports share of the product in the total exports of a zone reference. And finally, we use the weighted average tariffs effectively applied (TAR). In addition, we add the rule of law index as a proxy for institutional quality that reflects "perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence." This index is ranged between −2.5 for weak rule of law and 2.5 for strong rule of law.

d. *Empirical model*

To identify the effect of climate change on foreign investors behavior, we formulate the general hypothesis as a linear model to measure the marginal impact of climate change indicators on inward FDI as below:

$$\mathrm{FDI} = \alpha + \beta\mathrm{Climate\_Change} + \sum\beta_k(X) + \varepsilon.$$

The dependent variable is the foreign direct investment regressed by the main explanatory variables related to climate change. In addition, we use moderating variables to control the effect of climate change on foreign investment behavior. Last, we add other control variables inspired by the knowledge-capital model. The following equations capture the particular hypotheses depending on subresearch hypothesis.

1) THE IMPACT OF CLIMATOLOGY CHANGE ON FOREIGN INVESTMENT

The following two models, Eqs. (3.1) and (3.2), respectively, are the formulation of the first research hypothesis (H1) by representing the effect of changing of climatology on inward FDI along with the presence of the five moderating variables and four control variables:

$$\begin{aligned}\mathrm{FDI}_{it} = {} & \alpha_i + \beta_1\mathrm{MAT}_{it} + \beta_2(\mathrm{MAT}\times\mathrm{GDPA})_{it} + \beta_3(\mathrm{MAT}\times\mathrm{GDPI})_{it} + \beta_4(\mathrm{MAT}\times\mathrm{GDPC})_{it} + \beta_5(\mathrm{MAT}\times\mathrm{GDP})_{it}\\ & + \beta_6(\mathrm{MAT}\times\mathrm{RD})_{it} + \beta_7\mathrm{Market}_{it} + \beta_8\mathrm{RCA}_{it} + \beta_9\mathrm{TAR}_{it} + \beta_{10}\mathrm{IQ}_{it} + \varepsilon_{it} \quad \text{and}\end{aligned} \tag{3.1}$$

$$\begin{aligned}\mathrm{FDI}_{it} = {} & \alpha_i + \beta_1\mathrm{MAP}_{it} + \beta_2(\mathrm{MAP}\times\mathrm{GDPA})_{it} + \beta_3(\mathrm{MAP}\times\mathrm{GDPI})_{it} + \beta_4(\mathrm{MAP}\times\mathrm{GDPC})_{it} + \beta_5(\mathrm{MAP}\times\mathrm{GDP})_{it}\\ & + \beta_6(\mathrm{MAP}\times\mathrm{RD})_{it} + \beta_7\mathrm{Market}_{it} + \beta_8\mathrm{RCA}_{it} + \beta_9\mathrm{TAR}_{it} + \beta_{10}\mathrm{IQ}_{it} + \varepsilon_{it}.\end{aligned} \tag{3.2}$$

FDI denotes the net flow of inward FDI in millions of current USD in the country *i* in year *t*, MAT denotes the mean annual temperature measured by the Celsius metric in the country *i* in year *t*, MAP denotes the mean annual precipitation measured by the millimeter metric in the country in year *t*, GDPA is the part of agriculture in the GDP of country *i* in year *t*, GDPI is the part of the industry in the GDP of country *i* in year *t*, GDPC is the part of commerce and trade in the GDP of country *i* in year *t*, GDP denotes the GDP per capita in current USD of country *i* in year *t*, RD indicates the part of the expenditure of research and development in GDP of country *i* in year *t*, RCA_i indicates the revealed comparative advantage of country *i* in year *t*, Market_i denotes the gross domestic product in current USD by millions in host country *i* in year *y*, Tar_i indicates the weighted average tariffs effectively applied on imports of country *i* in year *t*, IQ_{it} denotes the rule of law index of country *i* in year *t*, α denotes the specific fixed effect of each country to control for the omitted factors relatively stable over time, and ε is the normally distributed error term.

2) THE IMPACT OF CLIMATE-RELATED NATURAL HAZARDS ON FOREIGN INVESTMENT

The following seven models—Eqs. (3.3), (3.4), (3.5), (3.6), (3.7), (3.8), and (3.9)—are the formulation of the second research hypothesis (H2) by representing the effect of a climate-related natural hazard on inward FDI along with the presence of the five moderating variables and four control variables:

$$\begin{aligned}\mathrm{FDI}_i = {} & \alpha_i + \beta_1\mathrm{CF}_i + \beta_2(\mathrm{CF}\times\mathrm{GDPA})_i + \beta_3(\mathrm{CF}\times\mathrm{GDPI})_i\\ & + \beta_4(\mathrm{CF}\times\mathrm{GDPC})_i + \beta_5(\mathrm{CF}\times\mathrm{GDP})_i\\ & + \beta_6(\mathrm{CF}\times\mathrm{RD})_i + \beta_7\mathrm{Market}_i + \beta_8\mathrm{RCA}_i\\ & + \beta_9\mathrm{TAR}_i + \beta_{10}\mathrm{IQ}_i + \varepsilon_i,\end{aligned} \tag{3.3}$$

$$\begin{aligned}\mathrm{FDI}_i = {} & \alpha_i + \beta_1\mathrm{CY}_i + \beta_2(\mathrm{CY}\times\mathrm{GDPA})_i\\ & + \beta_3(\mathrm{CY}\times\mathrm{GDPI})_{it} + \beta_4(\mathrm{CY}\times\mathrm{GDPC})_i\\ & + \beta_5(\mathrm{CY}\times\mathrm{GDPC})_i + \beta_6(\mathrm{CY}\times\mathrm{RD})_i\\ & + \beta_7\mathrm{Market}_i + \beta_8\mathrm{RCA}_i + \beta_9\mathrm{TAR}_i + \beta_{10}\mathrm{IQ}_i + \varepsilon_i,\end{aligned} \tag{3.4}$$

$$\begin{aligned}\mathrm{FDI}_i = {} & \alpha_i + \beta_1\mathrm{EH}_i + \beta_2(\mathrm{EH}\times\mathrm{GDPA})_i\\ & + \beta_3(\mathrm{EH}\times\mathrm{GDPI})_i + \beta_4(\mathrm{EH}\times\mathrm{GDPC})_i\\ & + \beta_5(\mathrm{EH}\times\mathrm{GDP})_i + \beta_6(\mathrm{EH}\times\mathrm{RD})_i\\ & + \beta_7\mathrm{Market}_i + \beta_8\mathrm{RCA}_i + \beta_9\mathrm{TAR}_i + \beta_{10}\mathrm{IQ}_i + \varepsilon_i,\end{aligned} \tag{3.5}$$

$$\begin{aligned}\mathrm{FDI}_i = {} & \alpha_i + \beta_1\mathrm{LS}_i + \beta_2(\mathrm{LS}\times\mathrm{GDPA})_i + \beta_3(\mathrm{LS}\times\mathrm{GDPI})_i\\ & + \beta_4(\mathrm{LS}\times\mathrm{GDPC})_i + \beta 5(\mathrm{LS}\times\mathrm{GDP})_i\\ & + \beta_6(\mathrm{LS}\times\mathrm{RD})_i + \beta_7\mathrm{Market}_i + \beta_8\mathrm{RCA}_i\\ & + \beta_9\mathrm{TAR}_i + \beta_{10}\mathrm{IQ}_i + \varepsilon_i,\end{aligned} \tag{3.6}$$

$$\mathrm{FDI}_i = \alpha_i + \beta_1 \mathrm{RF}_i + \beta_2(\mathrm{RF} \times \mathrm{GDPA})_i + \beta_3(\mathrm{RF} \times \mathrm{GDPI})_i + \beta_4(\mathrm{RF} \times \mathrm{GDPC})_i + \beta_5(\mathrm{RF} \times \mathrm{GDP})_i + \beta_6(\mathrm{RF} \times \mathrm{RD})_i + \beta_7 \mathrm{Market}_i + \beta_8 \mathrm{RCA}_i + \beta_9 \mathrm{TAR}_i + \beta_{10} \mathrm{IQ}_i + \varepsilon_i, \quad (3.7)$$

$$\mathrm{FDI}_i = \alpha_i + \beta_1 \mathrm{UF}_i + \beta_2(\mathrm{UF} \times \mathrm{GDPA})_i + \beta_3(\mathrm{UF} \times \mathrm{GDPI})_i + \beta_4(\mathrm{UF} \times \mathrm{GDPC})_i + \beta_5(\mathrm{UF} \times \mathrm{GDP})_i + \beta_6(\mathrm{UF} \times \mathrm{RD})_i + \beta_7 \mathrm{Market}_i + \beta_8 \mathrm{RCA}_i + \beta_9 \mathrm{TAR}_i + \beta_{10} \mathrm{IQ}_i + \varepsilon_i, \quad \text{and} \quad (3.8)$$

$$\mathrm{FDI}_i = \alpha_i + \beta_1 \mathrm{WF}_i + \beta_2(\mathrm{WF} \times \mathrm{GDPA})_i + \beta_3(\mathrm{WF} \times \mathrm{GDPI})_i + \beta_4(\mathrm{WF} \times \mathrm{GDPC})_i + \beta_5(\mathrm{WF} \times \mathrm{GDP})_i + \beta_6(\mathrm{WF} \times \mathrm{RD})_i + \beta_7 \mathrm{Market}_i + \beta_8 \mathrm{RCA}_i + \beta_9 \mathrm{TAR}_i + \beta_{10} \mathrm{IQ}_i + \varepsilon_i. \quad (3.9)$$

FDI denotes the net flow of inward FDI in millions of current USD in country i, CF denotes the score of hazardous costal flood in country i, CY denotes the score of hazardous cyclone in country i, EH denotes the score of hazardous extreme heat in country i, LS denotes the score of hazardous landslide in country i, RF denotes the score of hazardous river flood in country i, UF denotes the score of hazardous urban flood in country i, WF denotes the score of hazardous wildfire in country i, GDPA is the part of agriculture in the GDP of country i, GDPI is the part of industry in the GDP of country i, GDPC is the part of commerce and trade in the GDP of country i, GDP denotes the GDP per capita in current USD of country i, RD indicates the part of expenditure of research and development in GDP in country I, RCA_i indicates the revealed comparative advantage of country i in year t, Market_i denotes the gross domestic product in current USD by millions in host country i in year y, Tar_i indicates the weighted average tariffs effectively applied on imports of country I in year t, IQ_{it} denotes the rule of law index of country i in year t, α denotes the specific fixed effect of each country to control for the omitted factors relatively stable over time, and ε is the normally distributed error term.

e. *Estimation method*

This paper works on panel data where $N = 200$ country and $T = 51$ (from 1970 to 2020). Hence, we choose the estimation method of fully modified ordinary least squares (FMOLS) proposed by Pedroni (2001). These estimators have the advantage of producing unbiased estimators even with endogenous regressors and of allowing the coefficients to differ between countries. The chosen panel method is the: the "grouped mean" estimation. According to Pedroni (2001), an advantage of the grouped-mean estimator over the "pooled" estimator is that the t statistic for this estimator allows for a more flexible alternative hypothesis. Indeed, grouped-mean estimators are based on panel interdimensions, whereas pooled estimators are based on panel intradimensions.

However, for the second group of equations, the data are cross sectional because of the presence of data for 2010 only. In addition, because of the lack of data, the number of countries is reduced to 194 countries. We chose the robust least squares (RLS) estimation method for the second group of models because OLS estimators are much less robust under the existence of observations outside the norm for our regression model. Thus, the outliers would not accurately reflect the underlying statistical relationship between the dependent and explanatory variables. In other words, outliers tend to pull the least squares fit too far in their direction by receiving much more weight than they deserve, which causes heteroscedasticity and normality problems. Thus, the estimators of robust least squares reduce the influence of these outliers to provide better data by downweighting the outliers, which makes their residuals larger and easier to identify. In particular, we use the M estimation technique elaborated by Huber (1973) that addresses dependent variables, that is, FDI's outliers, where there are large residuals because its values differ noticeably from the regression model norm. Consequently, robust weighted least squares (RWLS) provide an alternative to other least squares estimation methods by requiring less restrictive assumptions about normality and homoscedasticity using the Welsch function as the best of other weight functions (Yulita et al. 2018).

4. Results and discussion

The present section is presenting the empirical estimation of the models discussed in the previous section. The presentations of the empirical results follow the same structure explained previously where we conduct two separate analyses of the effect of climate change on inward FDI. Section 4a analyzes the effect of climatology variables on inward FDI by the difference between the mean annual temperature and the mean annual precipitations. Section 4b answers the research hypothesis on the effect of different natural disasters related to climate changes on FDI as cyclones, floods, and extreme heat.

a. *The effect of climatology indicators changes on FDI*

Table 1 represents the estimate of Eq. (3.1) with an included period number of 51 and included cross-sectional number of 183, which gives an unbalanced total panel number of 5529. For the moderating variable, we include the ones related to the sector's contribution to GDP.[2] Table 2 represents the estimate of Eq. (3.1) with an included period number of 24 and included cross-sectional number of 138, which gives an unbalanced total panel number of 1834. For the moderating variable, we include the ones related to GPD per capita and R&D.

[2] The model has been split into two equations because of data incompatibility considering that the data on RD begins from 1996 whereas the other control variables begin from 1970, which would produce a significant imbalance in panel.

TABLE 1. Effect of mean annual temperature on FDI with moderating role of sector's contribution in GDP. On e, two, and three asterisks indicate significance levels at 10%, 5%, and 1%, respectively. The estimation method is FMOLS with no trend specification. The panel method is grouped. The selection of lag order is based on the vector autoregressive (VAR) specification method where the criterion likelihood ratio (LR), final prediction error (FPE), Akaike information criterion (AIC), Schwarz criterion (SC), and Hannan Quinn (HQ) indicate the optimum lag order at 8, 9, and 10.

Variables	Coef	Std error	t statistic
MAT	-204.7291^{**}	83.7144	-2.4455
MAT × GDPA	-3.3114^{***}	2.3224	1.4258
MAT × GDPI	-1.2745^{*}	0.7075	1.8018
MAT × GDPC	1.7465	3.6587	0.4773
Market	$1.37 \times 10^{-8***}$	2.51×10^{-10}	54.5997
RCA	-2426.1690^{**}	1130.3260	-2.1464
TAR	150.1565^{*}	108.8787	1.3791
IQ	2760.8050^{***}	687.3469	4.0166
MAT(−8)	-102.7679^{**}	49.0808	-2.0938
MAT(−9)	195.4096^{***}	51.8867	3.7660
MAT(−10)	123.0607^{**}	50.3845	2.4424
Adjusted R^2		0.6687	

According to all estimates, the MAT affects negatively inward FDI at a significance level of 5%. This result is compatible with the literature in the sense that global warming deteriorates productivity and hinders economic growth (Wade and Jennings 2016; Hallegatte et al. 2017; Auffhammer 2019; Arnell et al. 2019; Tol 2020), hence the attractiveness of FDI. The present results confirm hypothesis H1.

Particularly, the data show that this negative impact is only valid for economies that tend to rely on agriculture and the industrial sector at a significance level between 1% and 5%, while those who depend on the service sector as commerce and trade are not affected that much. In other words, more important is the part of the agricultural and industrial sector in the value-added formation (GDP) of a country, more likely it suffers from the negative impact of rising mean annual temperature on its economy and therefore its attractiveness of FDI. The contribution of the service sector (commerce) in the GDP has no impact on FDI attractiveness. On the other hand, it shows that GDP per capita does not moderate the relationship between MAT and FDI that indicates that the level of development and wealth creation is not a factor in the equation. However, R&D plays a positive moderator that means that countries who invest more in research and innovation face fewer consequences of climate change.

In general, the rise of mean annual temperature constitutes a financial risk to foreign investors. The empirical results show that the MAT impacts negatively inward FDI, which means the rise of global temperature restrains productivity and troubles foreign investors' investment estimates. For moderating variables, we conclude that the contribution of the agricultural and industrial sector in the GDP is a negative moderator of the impact on FDI, which means that the more the economy depends on agriculture and industry the more the negative impact on FDI is severe (the agriculture is tenser than the industry). In addition, R&D is a positive moderator, which means the more the country invests in innovative technologies, the less is exposed to the negative impact of rising temperature on FDI. On the other hand, the contribution of commerce to GDP, as well as GDP per capita, has no moderating role.

TABLE 2. As in Table 1, but for the effect of mean annual temperature on FDI with moderating role of GDP per capita and R&D.

Variables	Coef	Std error	t statistic
MAT	-265.6808^{**}	167.6444	-1.5847
MAT × GDP	0.0057	0.0051	1.1149
MAT × RD	121.7778^{*}	143.9914	0.8457
Market	$1.43 \times 10^{-8***}$	4.12×10^{-10}	34.654
RCA	-3274.7030	3127.839	-1.0469
TAR	334.7311^{*}	289.6256	1.1557
IQ	1702.1780^{**}	1822.1690	0.9341
MAT(−8)	49.4556	147.3400	0.3356
MAT(−9)	369.1858^{***}	134.8802	2.7371
MAT(−10)	-68.9074	129.9212	-0.5303
Adjusted R^2		0.7820	

Table 3 represents the estimate of Eq. (3.2) with an included period number of 51 and included cross-sectional number of 183, which gives an unbalanced total panel number of 5529. For the moderating variable, we include the ones related to the sector's contribution to GDP. Table 4 represents the estimate of Eq. (3.2) with an included period number of 24 and included cross-sectional number of 138, which gives an unbalanced total panel number of 1834. For the moderating variable, we include the ones related to GPD per capita and R&D.

In general, the estimation results show that the MAP affects negatively inward FDI at a significance level of 5%. This result is compatible with the literature in the sense that the rising of mean precipitation in a country would not be adequate to its infrastructure and productive system, which also deteriorates its productivity and hence the mobility of FDI (Doytch 2019). The present results confirm hypothesis H1.

TABLE 3. As in Table 1, but for the effect of mean annual precipitation on FDI with moderating role of sector's contribution in GDP.

Variables	Coef	Std error	t statistic
MAP	-1.8546^{*}	1.0653	-1.7408
MAP × GDPA	-0.0616^{*}	0.0389	1.5850
MAP × GDPI	0.0095	0.0516	0.1850
MAP × GDPC	0.0086	0.0100	0.8585
Market	$1.38 \times 10^{-8***}$	2.53×10^{-10}	54.485
RCA	-837.6715	1112.871	-0.7527
TAR	268.3752^{**}	109.8945	2.4421
IQ	2615.0810^{***}	661.2594	3.9546
MAP(−8)	-0.5508	0.4472	-1.2316
MAP(−9)	0.3694	0.4770	0.7744
MAP(−10)	1.5267^{***}	0.5102	2.9920
Adjusted R^2		0.6957	

TABLE 4. As in Table 1, but for the effect of mean annual precipitation on FDI with moderating role of GDP per capita and R&D.

Variables	Coef	Std error	t statistic
MAP	-2.7620^{**}	2.417 913	-1.1423
MAP × GDP	0.0001^{**}	6.79×10^{-5}	2.1784
MAP × RD	1.6079^{*}	1.643 262	0.9785
Market	$1.43 \times 10^{-8****}$	3.96×10^{-10}	36.1950
RCA	-992.2190	2863.988	-0.3464
TAR	451.9769^{*}	302.2649	1.4953
IQ	512.6796^{*}	1997.9090	0.2566
MAP(−8)	-0.5637	1.4367	-0.3923
MAP(−9)	2.9077^{*}	1.5014	1.9366
MAP(−10)	-0.5873	1.4758	-0.3979
Adjusted R^2		0.7798	

TABLE 5. Similar to Table 1, but for the effect of coastal flood hazard score on FDI. The estimation method is RWLS with M estimation. The covariance type for the estimation is Huber type with Welsch function for the weight. The scale estimate used is Huber.

Variable	Coef	Std error	Z statistic
C	3657.2840^{***}	510.3339	7.1664
CF	8578.4590^{***}	545.6483	15.721
CF × GDPA	56.4380^{***}	18.830	2.9971
CF × GDPI	-228.8181^{***}	21.293 62	-10.745
CF × GDPC	-99.4154^{***}	4.739 208	-20.977
CF × GDP	470.7925^{***}	43.291 11	10.875
CF × RD	865.0310^{***}	193.9740	4.4595
Adjusted Rw^2		0.1416	
Rn^2 statistic		683.3651^{***}	

The result above is confirmed with moderating variable: the data show that this negative impact is only valid for economies that tend to rely on the agriculture sector at a significance level of 1%, while those who depend on the industrial and service sector (commerce and trade) are not significant. In other words, more important is the part of the agricultural sector in the value-added formation (GDP) of a country, more likely it suffers from the negative impact of rising mean annual precipitation on its economy and therefore its attractiveness of FDI. While the contribution of the industrial and service sector (commerce) to the GDP has no impact on FDI attractiveness. Equally, it shows that GDP per capita does not moderate the relationship between MAP and FDI, which indicates that the level of development and wealth creation is not a factor in the equation. However, R&D plays a positive moderator, which means that countries who invest more in research and innovation face fewer consequences of changing in precipitations.

In general, the change of mean annual precipitation constitutes a financial risk to foreign investors. The empirical results show that the MAP impacts negatively inward FDI, which means the change of global level of precipitations restrains productivity and troubles foreign investors' investment estimates. For moderating variables, we conclude that the contribution of the agricultural sector in the GDP is a negative moderator of the impact on FDI, which means that the more the economy depends on agriculture the more negative impact on FDI is severe In addition, the R&D is a positive moderator, which means more the country invests in innovative technologies, the less is exposed to the negative impact of changing in precipitation level on FDI. On the other hand, the contribution of industry and commerce to GDP, as well as GDP per capita, have no moderating role.

In addition, the estimations of control variables show a positive effect of market size on inward FDI, which indicates the horizontal nature of the investments. According to the KCM, the horizontal FDI are seeking large market size and economic growth to increase the commercial profit of MNE. In addition, high tariffs affect inward FDI, which confirms the horizontal type under the premise that these types of investment are called "tariff-jumping FDI" where high tariffs encourage the MNE to bypass the border and create local subsidiaries. However, the RCA as proxy for factor endowment has inconclusive results, which is reasonable due to the fact that horizontal FDI do not consider factor endowment as vertical FDI. Last, institutional quality positively affects inward FDI, which is not surprising due to the large amount of literature supporting good governance as a strong determinant of FDI location choice.

We can now reach our first conclusion: The first hypothesis claims that changes in climatology indicators impact inward FDI negatively, which confirms the finding of Barua et al. (2020). In particular, climate change–related precipitations and temperature constitute a financial risk to foreign investors especially when the economy depends on agricultural activities, and there is no significant investment in research and development. Furthermore, we conclude that economic development (GDP per capita and the contribution of industry and service in the added value) has no role in moderating the negative effect of climate change on the economy and international investment.

b. *The effect of climate-related natural hazard indicators on FDI*

Table 5 represents the estimate of Eq. (3.3) with an included observation of 56 after adjustment. According to the estimates, the CF score impacts positively inward FDI at a significance level of 1%. This result is compatible with the literature in the sense that natural disasters related to climate change deteriorate productivity and hinder economic growth; hence, the attractiveness of FDI. In other words, a higher score of coastal flood means less risk of getting it. The present results confirm hypothesis H2, which means that coastal flood represents a financial risk of foreign investment. Particularly, the data show that this positive impact is enhanced for economies that tend to rely on the agriculture sector at a significance level of 1%. Equally, the higher the country's GDP per capita and R&D expenditure, the more the score of coastal flood attracts FDI.

On the other hand, the higher the contribution of the service and industrial sector in GPD, the less FDI the country receives. In other words, the more important is the part of the

TABLE 6. As in Table 5, but for the effect of cyclone hazard score on FDI.

Variable	Coef	Std error	Z statistic
C	10 033.3800***	386.5981	25.9529
CY	1121.5580***	367.5041	3.0518
CY × GDPA	−42.9735***	6.9567	−6.1772
CY × GDPI	−39.7976***	11.9389	−3.3334
CY × GDPC	−22.1693***	3.2659	−6.7880
CY × GDP	−105.2067***	22.9533	−4.5835
CY × RD	−995.0481***	150.3078	−6.6200
Adjusted Rw^2		0.1026	
Rn^2 statistic		281.0429***	

TABLE 8. As in Table 5, but for the effect of landslide hazard score on FDI.

Variable	Coef	Std error	Z statistic
C	3790.4060***	288.1814	13.1528
LS	4318.7710***	271.3952	15.9132
LS × GDPA	−82.9969***	8.4393	−9.8345
LS × GDPI	−41.9602***	11.3046	−3.7117
LS × GDPC	−32.0864***	2.3740	−13.5152
LS × GDP	249.7675***	19.9138	12.542 40
LS × RD	−311.8106***	103.1896	−3.0217
Adjusted Rw^2		0.0491	
Rn^2 statistic		444.6610***	

industrial and commercial sector in the value-added formation (GDP) of a country, the less likely that it suffers from the negative impact of the coastal flood on its economy and therefore its attractiveness of FDI.

Table 6 represents the estimate of Eq. (3.4) with an included observation of 36 after adjustment. According to the estimates, the CY score impacts positively inward FDI at a significance level of 1%. Even so, a cyclone is a rapid onset event, and it causes devastating damage to infrastructure, which deters foreign investment. In other words, a higher score of cyclone means less risk of getting it. The present results confirm hypothesis H2, which means that cyclone represents a financial risk for foreign investors. Particularly, the data show that all the moderating variables have negative signs at a significance level of 1%, which means this positive impact matters for economies that tend to be less rich and invest less in R&D.

Table 7 represents the estimate of Eq. (3.5) with an included observation of 77 after adjustment. According to the estimates, the EH score does not affect inward FDI. This result is explained by the fact that extreme heat is a rapid onset event that takes place only for a few days. Unlike cyclones, extreme heat is a well-managed risk, therefore, the score of extreme heat would not impact the location decision of foreign investors. The results infirm hypothesis H2 and conclude that extreme heat is not a financial risk for foreign investors. On the other hand, the data show that the score impacts positively when the country has higher GDP per capita and a technologically innovative structure.

Table 8 represents the estimate of Eq. (3.6) with an included observation of 78 after adjustment. According to the estimates, the LS score has a positive effect on the inward FDI significance level of 1%. The result is explained by the fact that landslides have a devastating effect on countries' infrastructure, therefore, the score of landslides would attract location foreign investors. The results confirm hypothesis H2 that the landslides represent a financial risk for foreign investors. Furthermore, the data show that GDP per capita enhances the positive effect, which means that a high level of development mitigates the risk of landslides.

Table 9 represents the estimate of Eq. (3.7) with an included observation of 76 after adjustment. According to the estimates, the RF score has a positive effect on the inward FDI significance level of 1%. The result is explained by the fact that rural floods have a devastating effect on countries' infrastructure, therefore, the score of rural would attract location foreign investors. The results confirm hypothesis H2 that rural represents a financial risk for foreign investors. Furthermore, the data show that GDP per capita and R&D expenditure enhance the positive effect, which means that a high level of development and technological capacities mitigate the risk of rural floods.

Table 10 represents the estimate of Eq. (3.8) with an included observation of 76 after adjustment. According to the estimates, the UF score has a positive effect on the inward FDI significance level of 1%. The result is explained by the fact that rural floods have a devastating effect on countries' infrastructure, therefore, the score of urban would attract location foreign investors. The results confirm hypothesis H2 that urban represents a financial risk for foreign investors. Furthermore, the data show that GDP per capita and R&D expenditure enhance the positive effect, which means that a

TABLE 7. As in Table 5, but for the effect of extreme heat hazard score on FDI.

Variable	Coef	Std error	Z statistic
C	7899.2840***	432.4177	18.2677
EH	−335.7792	326.4139	−1.0286
EH × GDPA	−23.5966**	9.6275	−2.4509
EH × GDPI	−95.6841***	11.3716	−8.4142
EH × GDPC	−5.3496**	2.3866	−2.2414
EH × GDP	189.8575***	27.2283	6.9727
EH × RD	435.7014***	84.3463	5.1656
Adjusted Rw^2		0.0330	
Rn^2 statistic		202.9118***	

TABLE 9. As in Table 5, but for the effect of rural flood hazard score on FDI.

Variable	Coef	Std error	Z statistic
C	9543.6280***	476.4885	20.0290
RF	1073.9710**	490.8048	2.1881
RF × GDPA	−68.8654***	15.1781	−4.5371
RF × GDPI	−193.1247***	24.4598	−7.8955
RF × GDPC	−25.7669***	4.5294	−5.6888
RF × GDP	62.4833	50.7455	1.2313
RF × RD	155.5424	169.3416	0.9185
Adjusted Rw^2		0.0340	
Rn^2 statistic		204.9114***	

TABLE 10. As in Table 5, but for the effect of urban flood score on FDI.

Variable	Coef	Std error	Z statistic
C	8728.8270***	435.2870	20.0530
UF	2730.6670***	456.8638	5.9769
UF × GDPA	−121.5418***	13.1798	−9.2217
UF × GDPI	−167.2122***	20.8061	−8.0366
UF × GDPC	−37.3386***	4.0686	−9.1771
UF × GDP	129.9834***	40.2592	3.2286
UF × RD	239.0364**	118.3437	2.0198
Adjusted Rw^2		0.0446	
Rn^2 statistic		265.6986***	

TABLE 11. As in Table 5, but for the effect of wildfire score on FDI.

Variable	Coef	Std error	Z statistic
C	9448.8770***	390.5104	24.19622
WF	−764.5433**	338.8088	−2.2565
WF × GDPA	−107.3944***	15.4682	−6.9428
WF × GDPI	−64.5302***	18.3421	−3.5181
WF × GDPC	−7.8703**	3.7326	−2.1084
WF × GDP	−52.2538*	30.4394	−1.7166
WF × RD	−20.8305	129.5137	−0.1608
Adjusted Rw^2		0.0202	
Rn^2 statistic		146.0541***	

high level of development and technological capacities mitigate the risk of urban flood.

Table 11 represents the estimate of Eq. (3.9) with an included observation of 78 after adjustment. According to the estimates, the WF score affects negatively the inward FDI significance level of 1%, which informs hypothesis H2 that wildfire represents a financial risk for foreign investors.

We can now reach our second conclusion: the second hypothesis claims that scores of climate-related natural hazards affect inward FDI positively. In other words, a higher risk of climate-related natural hazards impacts FDI location decisions negatively, which confirms the work of Noy and Vu (2010), Escaleras and Register (2011), Boustan et al. (2012), Doytch and Klein (2018), Doytch (2019), Oh et al. (2020), and Neise et al. (2022). Thus, climate change–related natural hazard constitutes a financial risk to foreign investors. These findings are significant for floods (rural, urban, and coastal) and landslides. However, the data show no significant effect of extreme heat and wildfires on FDI location decisions. Furthermore, we conclude that economic development (GDP per capita and R&D expenditure) plays a positive moderator. It means a rich and more innovative country could handle natural hazards with less severe damage than could a poor and less innovative country.

5. Conclusions

Investing abroad is a decision that considers numerous variables in the perspective of making sure as much as it takes that this decision shall be profitable for the investor. Among others, climate change occupies an important place in decision-making when it comes to starting a business abroad or investing in an existing foreign structure, as the shifts in weather patterns, changes in temperature, and risks of desertification are likely to drive the investor to reconsider investing in a certain region.

Hence, for a multinational corporation whose strategy is to establish a lasting interest in a foreign company—in the framework of foreign direct investment—the climate change effects on the decision of investing overseas vary depending on the sectors and their sensitivity to climate change, which the existing literature has classified into two main categories.

For economic activities that are directly exposed to climate change, the effects on investment are whether positive—such as a region with high temperatures promoting FDI in the energy sector—or negative—such as the desertification phenomenon that discourages FDI. Also, in the cases of economic activities with markets sensitive to climate change as well as activities based on inputs sensitive to the latter, effects are apprehended indirectly through transmission channels. Climate change can be considered as a financial investment risk for an MNE, in terms of physical and secondary risks, political risks, liability risks, etc., exposing the investing company to eventual high losses.

On the empirical level, our study tries to investigate the role of climate change as a financial risk to foreign investors and how does it affect foreign investors' behavior, which the literature has not treated and remained focused on overall investment. Thus, to conduct our empirical analysis, we used data of 200 countries during the period 1970–2020, as the endogenous variable is inward foreign direct investment; the explanatory variables are climatology indicators (mean annual temperature and precipitation) and climate-related natural hazard indicators; and other moderating variables.

Hence, following the main research hypothesis, the general hypothesis, and the subsequent hypotheses, we concluded first that climate change–related to precipitations and temperature constitute a financial risk to foreign investors especially when the economy is more agricultural and there is no significant investment in R&D, then we found that a higher risk of climate-related natural hazard impact negatively the location decision of international investment.

Climate change as a financial risk for the foreign investor would be helpful for public officials in charge of public policies related to the territorial attractiveness of FDI. By considering this factor as a determinant of the location choice of MNE, the host country has to implement measures to reduce the risk of climate change and its implication on the local economy, productivity, and stability. Furthermore, public officials need to consider more investment in research and development so the country can achieve a sufficient level of technological capacities and innovation to absorb negative chocs from climate change.

However, some limits restrained our work. For instance, the lack of well-constructed data on climate change is a major research hypothesis for empirical analysis to deduct more detailed results. In addition, sectoral data on inward FDI are not available on a large scale, which deprives the empirical work of heavy analysis. Furthermore, the literature review did not give us some form of "knowledge-capital model" to identify the type of FDI, whether it is horizontal or vertical, and its motivation, whether it is market seeking, resource seeking, efficiency seeking, or cost seeking. Hence, the development of the present study will be at a case-study level so we can consider the sectoral differences, the type of FDI, and its motivation.

Data availability statement. Datasets analyzed during the current study are available at the UNCTAD (https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=96740), Climate Knowledge Portal (https://climateknowledgeportal.worldbank.org/download-data), and World Bank (https://data.worldbank.org/indicator/).

REFERENCES

Anuchitworawong, C., and K. Thampanishvong, 2015: Determinants of foreign direct investment in Thailand: Does natural disaster matter? *Int. J. Disaster Risk Reduct.*, **14**, 312–321, https://doi.org/10.1016/j.ijdrr.2014.09.001.

Arnell, N. W., J. A. Lowe, A. J. Challinor, and T. J. Osborn, 2019: Global and regional impacts of climate change at different levels of global temperature increase. *Climatic Change*, **155**, 377–391, https://doi.org/10.1007/s10584-019-02464-z.

Auffhammer, M., 2019: The (economic) impacts of climate change: Some implications for Asian economies. ADBI Working Paper 1051, 31 pp., https://www.adb.org/sites/default/files/publication/543321/adbi-wp1051.pdf.

Barua, S., S. Colombage, and E. Valenzuela, 2020: Climate change impact on foreign direct investment inflows: A dynamic assessment at the global, regional and economic level. SSRN Rep., 40 pp., https://ssrn.com/abstract=3674777.

Boustan, L. P., M. E. Kahn, and W. R. Paul, 2012: Moving to higher ground: Migration response to natural disasters in the early twentieth century. *Amer. Econ. Rev.*, **102**, 238–244, https://doi.org/10.1257/aer.102.3.238.

——, ——, P. W. Rhode, and M. L. Yanguas, 2020: The effect of natural disasters on economic activity in US counties: A century of data. *J. Urban Econ.*, **118**, 103257, https://doi.org/10.1016/j.jue.2020.103257.

Carr, D. L., J. R. Markusen, and K. E. Maskus, 2001: Estimating the knowledge-capital model of the multinational enterprise. *Amer. Econ. Rev.*, **91**, 693–708, https://doi.org/10.1257/aer.91.3.693.

Dell, M., B. F. Jones, and B. A. Olken, 2012: Temperature shocks and economic growth: Evidence from the last half century. *Amer. Econ. J.*, **4**, 66–95, https://doi.org/10.1257/mac.4.3.66.

Doytch, N., 2019: Upgrading destruction? How do climate-related and geophysical natural disasters impact sectoral FDI. *Int. J. Climate Change Strategies Manage.*, **12**, 182–200, https://doi.org/10.1108/IJCCSM-07-2019-0044.

——, and Y. L. Klein, 2018: The impact of natural disasters on energy consumption: An analysis of renewable and non-renewable energy demand in residential and industrial sectors. *Environ. Prog. Sustainable Energy*, **37**, 37–45, https://doi.org/10.1002/ep.12C640.

Ernst & Young, 2016: Climate change: The investment perspective. Ernst & Young Doc., 20 pp., https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/banking-and-capital-markets/ey-climate-change-and-investment.pdf.

Escaleras, M., and C. A. Register, 2011: Natural disasters and foreign direct investment. *Land Econ.*, **87**, 346–363, https://doi.org/10.3368/le.87.2.346.

Groth, M., and A. Brunsmeier, 2016: A cross-sectoral analysis of climate change risk drivers based on companies' responses to the CDP's climate change information request. Leuphana Universität Lüneburg Institute of Economics Working Paper Series in Economics 364, 22 pp., https://www.econstor.eu/bitstream/10419/155672/1/861808584.pdf.

Hallegatte, S., F. Henriet, and J. Corfee-Morlot, 2011: The economics of climate change impacts and policy benefits at city scale: A conceptual framework. *Climatic Change*, **104**, 51–87, https://doi.org/10.1007/s10584-010-9976-5.

——, A. Vogt-Schilb, M. Bangalore, and J. Rozenberg, 2017: *Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters*. Climate Change and Development Series, World Bank, 201 pp., https://openknowledge.worldbank.org/handle/10986/25335.

Huber, P. J., 1973: Robust regression: Asymptotics, conjectures and Monte Carlo. *Ann. Stat.*, **1**, 799–821, https://doi.org/10.1214/aos/1176342503.

IPCC, 2018: *Global Warming of 1.5°C*. V. Masson-Delmotte et al., Eds., Cambridge University Press, 630 pp., https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_Low_Res.pdf.

——, 2021: *Climate Change 2021: The Physical Science Basis*. V. Masson-Delmotte et al., Eds., Cambridge University Press, 2391 pp., https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf.

Jones, B. F., and B. A. Olken, 2010: Climate shocks and exports. *Amer. Econ. Rev.*, **100**, 454–459, https://doi.org/10.1257/aer.100.2.454.

Kahn, M. E., K. Mohaddes, R. N. C. Ng, M. H. Pesaran, M. Raissi, and J.-C. Yang, 2019: Long-term macroeconomic effects of climate change: A cross-country analysis. IMF Working Paper 2019/215, 59 pp., https://www.imf.org/-/media/Files/Publications/WP/2019/wpiea2019215-print-pdf.ashx.

Kato, H., and T. Okubo, 2018: The impact of a natural disaster on foreign direct investment and vertical linkages. SSRN Rep., 38 pp., https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2983835.

Kukułka, A. 2014: Natural disasters and FDI inflow in the developing countries of South Eastern Asia. Wrocławiu University of Economics Research Paper 370, 208–216, https://www.dbc.wroc.pl/Content/29254/Kukulka_Natural_Disasters_And_FDI_Inflow_2014.pdf.

Mani, M. M., M. M. Keen, and M. P. K. Freeman, 2003: Dealing with increased risk of natural disasters: Challenges and options. International Monetary Fund Doc., 38 pp., https://www.imf.org/-/media/Websites/IMF/imported-full-text-pdf/external/pubs/ft/wp/2003/_wp03197.ashx.

Mercer, 2015: Investing in a time of climate change. Mercer Rep., 108 pp., https://www.ifc.org/wps/wcm/connect/e9bfa328-e091-465b-9da6-8fe312261b98/Investing+in+a+time+of+climate+change.pdf?MOD=AJPERES&CVID=kTFEATf.

Moreno, R. A., J. Skea, A. Gacuchi, D. L. Greene, W. Moomaw, T. Okita, A. Riedacker, V. L. Tran, 1996: Industry, energy, and transportation: Impacts and adaptation. *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change*, J. J. Houghton et al., Eds., Cambridge University Press, 365–398.

Neise, T., F. Sohns, M. Breul, and J. Revilla Diez, 2022: The effect of natural disasters on FDI attraction: A sector-based analysis over time and space. *Nat. Hazards*, **110**, 999–1023, https://doi.org/10.1007/s11069-021-04976-3.

Niemelä, R., M. Hannula, S. Rautio, K. Reijula, and J. Railio, 2002: The effect of air temperature on labor productivity in call centers—A case study. *Energy Build.*, **34**, 759–764, https://doi.org/10.1016/S0378-7788(02)00094-4.

Noy, I., and T. B. Vu, 2010: The economics of natural disasters in a developing country: The case of Vietnam. *J. Asian Econ.*, **21**, 345–354, https://doi.org/10.1016/j.asieco.2010.03.002.

Oh, C. H., J. Oetzel, J. Rivera, and D. Lien, 2020: Natural disasters and MNC sub-national investments in China. *Multinatl. Bus. Rev.*, **28**, 245–274, https://doi.org/10.1108/MBR-02-2020-0044.

Pedroni, P., 2001: Fully modified OLS for heterogeneous cointegrated panels. *Nonstationary Panels, Panel Cointegration, and Dynamic Panels*, B. H. Baltagi, T. B. Fomby, and R. Carter Hill, Eds., Advances in Econometrics, Vol. 15, Emerald Group Publishing Limited, 93–130.

Smith, J., and S. Hitz, 2003: Background paper: Estimating global impacts from climate change. Vol. 12, OECD Workshop on the Benefits of Climate Policy: Improving Information for Policy Makers Doc. ENV/EPOC/GSP (2002), 101 pp., https://www.oecd.org/env/cc/2482270.pdf.

Tol, R. S. J., 2020: The economic impacts of climate change. *Rev. Environ. Econ. Policy*, **8**, 4–25, https://doi.org/10.1093/reep/rex027

Wade, K., and M. Jennings, 2016: The impact of climate change on the global economy. Schroders Talking Point Doc., 11 pp., https://prod.schroders.com/globalassets/digital/insights/pdfs/the-impact-of-climate-change-on-the-global-economy.pdf.

World Bank Group, 2021: Glossary of terms and definitions. Climate Change Knowledge Portal Doc., 11 pp., https://climateknowledgeportal.worldbank.org/media/document/CCKP_glossary.pdf.

Yang, D., 2008: Coping with disaster: The impact of hurricanes on international financial flows, 1970–2002. *B.E. J. Econ. Anal. Policy*, **8**, https://doi.org/10.2202/1935-1682.1903.

Yulita, T., K. A. Notodiputro, and K. Sadik, 2018: M-estimation use bisquare, Hampel, Huber, and Welsch weight functions in robust regression. *Int. J. Sci. Res. Sci. Eng. Technol.*, **4** (9), 425–430, https://ijsrset.com/IJSRSET184964.

Annex 555

K. P. Gallagher et al., "Reforming Bretton Woods institutions to achieve climate change and development goals", *One Earth,* 2023*,* pp. 1291-1303

One Earth

CellPress
OPEN ACCESS

Perspective

Reforming Bretton Woods institutions to achieve climate change and development goals

Kevin P. Gallagher,[1] Rishikesh Ram Bhandary,[1,*] Rebecca Ray,[1] and Luma Ramos[1]
[1]Boston University Global Development Policy Center, Boston, MA, USA
*Correspondence: rrbhanda@bu.edu
https://doi.org/10.1016/j.oneear.2023.09.009

SUMMARY

Nation-states will need to mobilize a stepwise increase in domestic resources and put in place a broad array of new policies in order to meet the targets set out under the Paris Agreement on climate change and the Sustainable Development Goals. To avoid the catastrophic social, economic, and ecological damages associated with climate change, nation-states across the world need to alter the structure of their economies to deliver economic growth and prosperity in a manner that is socially inclusive, low carbon, and resilient to climate and other external shocks. The Bretton Woods Institutions (BWIs)—the International Monetary Fund and the World Bank and other multilateral development banks—will need to play an important supporting and coordinating role in these efforts. This perspective outlines the scale of the financing challenge for developing countries and offers a series of policy reform proposals at the BWIs that can help align developing economy growth trajectories with climate and development goals.

INTRODUCTION

In order to meet Paris Agreement targets to limit global warming to 1.5°C, greenhouse gas emissions must peak before 2025 and decline by 43% by 2030.[1] Given the slow pace of progress to this end, the United Nations Emissions Gap Report states that "The task facing the world is immense: not just to set more ambitious targets, but also to deliver on all commitments made. This will require not just incremental sector-by- sector change, but wide-ranging, large-scale, rapid and systemic transformation."[2] Indeed, at the release of the 2023 Intergovernmental Panel on Climate Change (IPCC) report, Working Group III Co-Chair Jim Skea said, "It's now or never, if we want to limit global warming to 1.5°C."[3]

A deep literature and policy debate has emerged on the policy options for combatting climate encompassing pricing tools such as carbon taxes and emissions trading schemes, hard regulations on carbon intensive behavior, green industrial policy, the reduction of harmful subsidies, the introduction of green subsidies, investing in climate-resilient agriculture and infrastructure, and beyond.[4,5] While economists continue to emphasize carbon pricing as a first-best policy tool, the slow progress, political difficulty, and efficacy of carbon pricing have shifted emphases to a broader policy mix.[6]

The Independent High-Level Expert Group on Climate Finance, at the request of the Egyptian Presidency of COP27, the UK Presidency of COP26, and the UN Climate Change High Level Champions for COP26 and COP27, estimates that the resource mobilization needs to meet these goals in emerging market and developing countries (beyond China) are $2.4 trillion per year by 2030, $1 trillion of which will need to come from external sources such as global private capital markets, bilateral aid, and multilateral institutions. While the estimates of the High-Level Expert Group are the most accepted, there are a handful of other such estimates by organizations such as the New Climate Economy, the OECD, and the World Bank each with different assumptions and targets but all in agreement that a stepwise increase in financing is needed, especially for developing countries.[7–9]

Achieving these goals in the developing world will take enormous efforts between now and 2030. Developing countries are set back by decades of loss and damage, multiple shocks since the onset of the COVID-19 crisis, and a resulting "new normal" where the cost of financing is increasingly becoming out of reach. Mobilizing resources at this level will therefore require significant policy change among domestic actors and international financial institutions and arrangements. This perspective will focus on the international aspects of such resource mobilization, with principal attention to the role of the Bretton Woods Institutions (BWIs): multilateral development banks (MDBs) and the International Monetary Fund (IMF).

Following this brief introduction, the rest of this perspective is in two further parts. The next section will more fully outline the challenges faced by developing countries in mobilizing resources for climate action. The final section will present the reforms necessary across the international financial institutions that are necessary.

The challenge: Financing for a rapid transformation

Stepwise investments are needed to generate structural change in emerging market and developing economies such that the new engines of growth are underpinned by low-carbon and climate-resilient forms of economic activity. There is no "one size fits all" approach to the different structural changes that developing countries will need to pursue. Furthermore, this rapid resource mobilization will need to be calibrated in a fiscally sound and a financially stable manner. The economic

Box 1. Five structural transformation pathways for developing countries

(1)First movers, countries that need to mobilize capital in order to invest in a new capital stock where little capital exists in the first place. For instance, in much of sub-Saharan Africa, there is a lack of manufacturing capabilities and appropriate grid connectivity to harness the abundance of clean energy sources and consumer demand of a rapidly growing continent;
(2)New winners, where states that are blessed with the vital "transition materials" and industries that form the basis of a new economy can work to harness those resources, increase value addition, and strengthen economy-wide linkages in a manner that ensures macroeconomic stability, shared prosperity, and environmental sustainability not only globally but where these materials are generated;
(3)Large emitters and future large emitters, which need to make massive investments to replace the existing capital stock through structural change away from fossil fuel production and consumption patterns toward clean energy, energy efficiency, and beyond;
(4)Fossil fuel extractors, who are not high carbon emitters themselves but whose economies are dependent on exporting fossil fuels and need to diversify their economic base and change the structure of their economies toward new sources of foreign exchange and exports while buttressing themselves from "transition spillovers" that arise from the global shift away from fossil fuels;
(5)Climate-vulnerable economies, who need to mobilize capital in order to reinforce their existing capital stock to adapt to climate change, build a new climate-resilient capital stock, and become more resilient to loss and damage from climate shocks.
Source: Gallagher and Bhandary (2023).

environment that developing countries face poses significant challenges between now and 2030, and international economic organizations are being called on to step up their role to assist developing countries on this journey.

To maintain economic growth and development during this rapid transformation, significant changes will be required in the composition and technique of economic activity, as well as in fiscal and financial policy. In a landmark article, Grossman and Krueger (1995) outlined the pathway for economic growth and structural change while reducing overall levels of environmental degradation.[10] To these authors, pollution is a function of the "scale," "composition," and "technique/technology" effects of the economic process. If overall pollution (or in this case carbon dioxide emissions or the level of vulnerability) per unit of output are left unchanged, the scale effect of economic activity expansion will increase carbon emissions commensurate with the amount of economic growth. However, the scale effect can be counteracted through the composition and technique/technology effects. By definition, structural change alters the "composition" and "technique/technology" of economic activity—shifting from high- to low-carbon-intensive economic activities and the methods used to pursue them and from lower to higher levels of climate-resilient economic activity. Thus structural change can bring high levels of economic growth while also reducing carbon emissions and making economies more resilient to climate change through changes in the composition of economic activity. These forces can be further accelerated by policy changes and technological innovation that changes the overall level of carbon intensity of economic activity across different forms of economic activity. There is no uniform approach in terms of how the interactions between scale, composition, and technology effects manifest within different countries. In earlier work, the authors identified at least five categories of structural transformations across developing countries. This categorization is depicted in Box 1.

Of course, many countries do not simply fall into one of these five categories, and sometimes they can have characteristics of all five. South Africa, for example, still lacks sufficient grid connectivity, and the vast majority of its rural population still lacks energy access, leaving opportunities for "first mover" resource mobilization. South Africa also is blessed with many "transition materials" such as lithium, zinc, and manganese that are critical for the transition, giving that country "new winner" opportunities. Yet, South Africa is also a relatively "larger emitter" of greenhouse gases given its reliance on coal, as well as a "fossil fuel extractor" through its coal exports. Finally, South Africa has been subject to significant droughts and flooding, leaving it very "climate vulnerable."[11] South Africa is not unique in this regard; countries will need to chart structural change trajectories along each of these fronts in order to meet Paris targets and develop their economies.

Structural change of this magnitude entails a massive level of financial resource mobilization. While there is an abundance of capital in the world economy—the Financial Stability Board estimates that total assets and liabilities in the financial system are close to \$500 trillion—capital does not flow to productive development activity.[12] Indeed, the size of the global financial system has grown by orders of magnitude since 1980, yet total investment as a percent of GDP has stayed at 20% during the entire period. Worse, financial flows from advanced to developing economies are negative—meaning developing countries export more capital to the developed world than vice versa. This is largely a function of developing countries buffering themselves from boom and bust cycles through the purchasing of "safe" assets in advanced economies such as US Treasury Bonds. This "self-insurance" is also in part a function of the inadequacy of the balance of payments support system that is dominated by the IMF. Because the IMF puts harsh contractionary conditions on its lending to developing countries, they prefer to accumulate reserves to self-insure. This entails a massive transfer of wealth from developing to developed countries through the purchasing of reserves.[13] Finally, the climate crisis presents an exacerbation of a classic investment dilemma: necessary investments offer social rather than private returns, resulting in savings levels that are too high to support necessary aggregate demand (a "savings glut") but too low in the real investments areas

CellPress
OPEN ACCESS

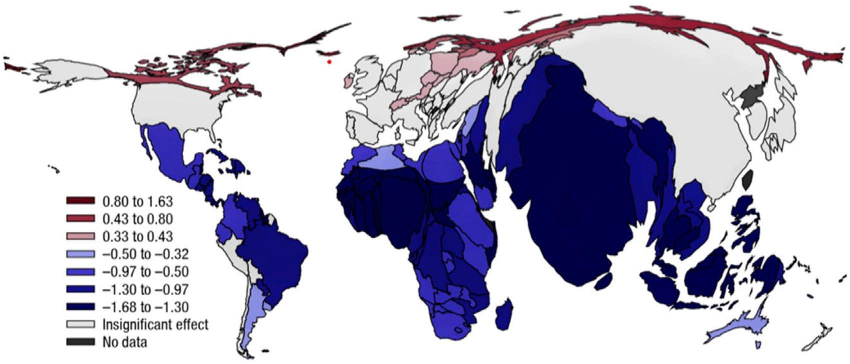


Figure 1. Climate change disproportionately impacts developing countries
Global map depicts how a 1°C increase impacts per capita economic output, relative to current per capita output, with country sizes rescaled by population. Source: IMF.[18] Reproduced with permission.

needed for green structural transformation.[14,15] The central task of a reformed international financial architecture is to steer capital flows to climate-aligned structural change for development.

In order to achieve the United Nations Sustainable Development Goals (SDGs) and the Paris Agreement, a global effort of massive resource mobilization and structural change is necessary and will need to be calibrated in a manner that is fiscally sound or financially stable, while also having immediate resilience to respond to climate shocks as these transformations occur or economies suffer significant economic costs that can wreak havoc on financial stability as well. Baarsch et al. show that climate change has already cost the most climate-vulnerable economies upward of 10% of GDP on average since 2000, much larger than the impact in advanced economies.[16] As shown in Figure 1, the IMF estimates that the impacts of a 1°C increase in global temperatures will have an outsized effect on per-capita incomes across the developing world moving forward.[17]

Climate change and climate change policy not only impact levels of economic growth and income but can also pose macroeconomic stability risks as well (Figure 2). These "macro-critical" risks are referred to as "physical risk," "transition risk," and "spillover transition risk." Physical risks are related to the actual physical impacts of climate change, through channels such as temperature increases, precipitation, extreme weather events, and so forth. When these risks occur, they can have both direct and indirect impacts on economies and financial systems. In the case of a hurricane in a small island developing state for instance, the hurricane can wipe out a significant amount of the capital stock in a country, triggering costs and liabilities across the economy and the associated financial sector.

Indeed, physical climate risk is associated with a vicious cycle of climate vulnerability and debt distress in developing countries. When physical risk occurs in the form of a climate shock (such as a hurricane in a small island developing state or a large flood such as in Pakistan) that can destroy the capital stock such as hotels, roads, and ports—and thus the loans, contracts, employment, and associated economic activity surrounding that capital stock—a country falls victim to capital flight, falling exchange rates, and rising cost of capital for rescue and rehabilitation at exactly the time when resources need to be mobilized and external debt needs to be serviced.[20] This vicious cycle is depicted in Figure 3. By definition, developing countries suffer from underinvestment, which leaves them more vulnerable to climate shocks. Kling et al. (2018) and Cevik et al. (2022) find that climate risks lead to a significant increase in borrowing costs for developing countries.[21,22] Beirne et al. (2021) find that climate risks impact the borrowing costs more significantly than for advanced economies.[23] Thus, when climate shocks do occur, the economic damages are higher and are thus associated with having a high debt burden because those countries need to borrow more to recovery from the shocks. However, because of the climate shock, external investors see the country as more risky, and therefore the country has to face a higher cost of capital, which is often too high, so the country has to continue to underinvest in a recovery and thus is lain evermore vulnerable for the next shock.

Returning to Figure 2, two other forms of macro-critical risk from climate change and climate change policy compound the debt-climate vicious cycle. "Transition risk" can occur as a country shifts from higher to lower carbon and more climate-resilient economy activity. By definition, such a shift creates new winners (new clean energy sectors) and losers (those fossil-fuel-intensive sectors that are being phased out) and can result in losses in income and employment, can result in stranded assets for banks and financial actors, and can result in significant financial sector instability. Even for relatively well-diversified economies like India, the fiscal impacts of a net-zero transition are substantia. Bhandari and Dwivedi (2022) find that public revenue from fossil fuels drops in a net-zero scenario, precisely as India needs to scale up resource mobilization. Revenue generated through a carbon tax does not offset the revenue losses from reduced fossil fuel use under a net-zero scenario either.[24]

Not only do domestic climate policies have the potential to trigger macroeconomic risks, but transition risk can also travel across borders. The third type of risk, "spillover transition risk," can occur when climate policy in one country has macro-critical impacts on another country. If a country bans coal use as an energy input and another country relies on those coal exports as a source of foreign exchange, such a shock to the coal exporter can have significant impacts on balance of payments and debt sustainability. Work by the United Nations Economic Commission for Latin America and the Caribbean modeled the impact of net-zero carbon policies in advanced economies on six large hydrocarbon producers in South America and found that the loss of oil export markets in those countries would have severe impacts on fiscal budgets and debt sustainability.[25] Moreover, the study found that only in two of those countries would a carbon tax recoup those revenues. Similarly, Gourdel et al. (2021) modeled the macro-critical impacts of China's net-zero policy on Indonesia, which exports a significant amount of

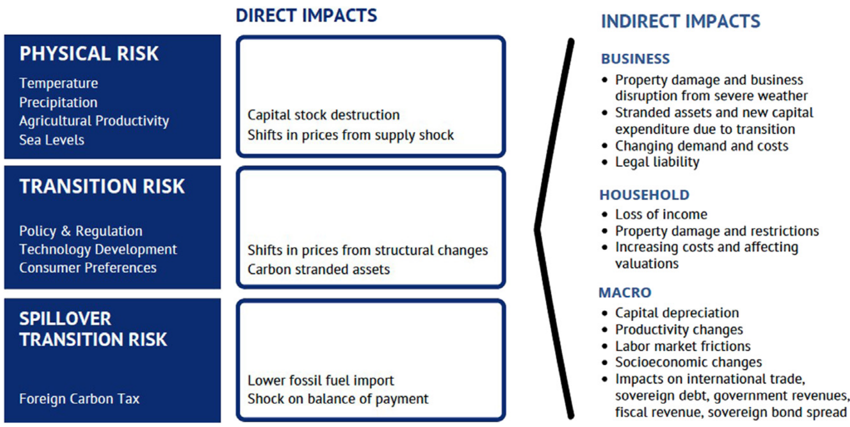


Figure 2. The macro-criticality of climate change
The figure depicts the direct and indirect impacts of climate risks. Reproduced fromTask Force et al.[19]

coal to China on an annual basis.[26] According to that work, Indonesia would suffer a major balance of payment shock that would ripple into the real economy in terms of lost jobs and businesses, as well as impacting the banking sector and a nations fiscal stability.

In addition to these risks, the international economic environment has worsened due to the multiple and compounding crises that have plagued developing countries over the past 5 years, making it imperative that the international community act with urgent ambition. The COVID-19 shock and its impacts on global value chains, the invasion of Ukraine, and climate change shocks themselves in South Africa, Pakistan, Nigeria, the Caribbean, and across the developing world have stressed fiscal budgets and the ability to mobilize domestic capital to their limit. This has been accentuated by the raising of interest rates in advanced economies in response to the globalization of inflation. External debt levels in developing countries have more than doubled since the 2008 global financial crisis. What is more, for those developing countries that do have borrowing space, the cost of capital is at new highs.[27] Chamon et al. (2022) find that an increasing number of developing countries lack the borrowing space to access capital markets.[28] Indeed, the authors find that only seven low-income countries had the necessary fiscal and borrowing space to make the climate investments needed. Rising debt levels and the higher cost of capital have been referred to as the "climate investment trap" for developing countries and are perhaps the biggest impediment to financing climate change-induced structural change between now and 2030.[11,29]

In an exercise for this paper, we identify 76 developing economies who face debt burdens that impede necessary climate investments. Countries are identified through two indices: the Debt and Climate Change Mitigation Index (DMI), which measures the extent to which near-term debt service payments interfere with climate change mitigation investment, and the Debt and Climate Change Adaptation Index (DAI), which measures the extent to which debt stock interferes with longer-term climate change adaptation investment. Of the 76 countries with high index scores for at least one of these indices, nearly half—36—have high scores on both. These 36 countries face high levels of both adaptation and mitigation needs and costs but are hampered in addressing them because of high debt burdens. Table 1 explores the distribution of these countries across the two indices.

DMI and DAI calculations are defined in detail in the experimental procedures. Briefly, the DMI takes into account each countries' near-term debt service obligations and climate change mitigation goals, as specified in their nationally determined contributions. Even with ambitious near-term climate change mitigation investments, however, climate change adaptation investments will be needed for many years to come. The DAI addresses these longer-term needs by taking into account debt stock levels and climate change vulnerability, as reflected in the Notre Dame GAIN Index.

Figure 4 exhibits the geographic distribution of these results, including several small island states, who face unique challenges from climate change. Countries' index scores are considered "high" if they are at or above the median levels for each. From this picture, it is clear that many developing countries will not be able to make necessary climate investments. The countries in light orange will struggle to make climate mitigation investments, and those in darker orange struggle to make adaptation investments. The maroon countries will suffer in both cases. Those countries in blue may not be locked out of the ability to make investments, but they now face a high cost of capital. The average private cost of capital for developing countries that can borrow ranges between 6% for developing countries in Asia and Oceania, 7.7% in Latin America and the Caribbean, and 12% for Africa.[30] Using a common guideline, a country's interest payments on external debt should not exceed the growth rate of the economy, or it will perpetually be in a debt overhang that will stunt long-run growth and resource mobilization.[31] The IMF projects that developing countries are likely to grow between 4% and 5% over the foreseeable future.[32] The international economic architecture is being called on to deliver low-cost financing for structural transformation and investment, to provide debt relief to some countries, and to coordinate actions across the world, or there will be no chance to meet our climate goals by 2030.

Reforming the Bretton Woods Institutions

Developing countries themselves will need to take the lead in aligning their development strategies to a climate-constrained world. Carbon pricing, regulation of inward capital flows and national financial actors toward productive and sustainable investments, and major public and private investment pushes for structural change should be the cornerstone of such effort. However, without parallel ambitious action and reform by the (BWIs), developing countries will not be able to mobilize the levels of finance necessary to transform their economies in a manner that will allow them to meet climate targets by 2030 in a stable manner. The costs of this inaction will be materially catastrophic and erode the legitimacy of the system itself.

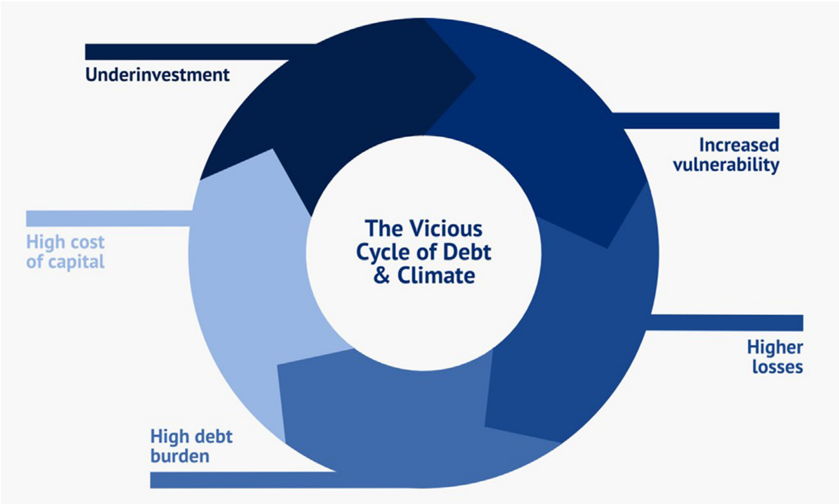


Figure 3. The vicious cycle of climate vulnerability and indebtedness
The channels working through the cyclical relationship between indebtedness and climate vulnerability.

To this end, the central mission of the BWIs will need to be to steer global capital flows toward emerging market and developing economy growth trajectories that are low carbon, socially inclusive, and climate resilient in a manner that is fiscally sound and financially stable. This will require a stepwise increase in the amount of development finance and major efforts to decrease the cost of capital through the major development banks—alongside careful surveillance and financial support by the IMF to ensure that such a massive level of resource mobilization maintains financial stability. Special attention is necessary for those countries at or near debt distress, such as those in Figure 4. For those in distress, the international system is not providing low-cost and better designed emergency financing and significant debt relief. Finally, there will need to be global coordination of national policies to ensure that the climate action (or inaction) of one country does not harm the actions of another.

Multilateral development banks can catalyze capital flows

MDBs have not kept up with the size of the world economy nor the climate and development needs of their members. Figure 5 exhibits how World Bank financing, as a share of GDP, has steadily declined over the last four decades. The figure shows total International Bank for Reconstruction and Development and International Development Association commitments (board approvals) weighted against GDP.

MDBs need to more explicitly align their work with the Paris Agreement and the SDGs. In order to meet the SDGs and Paris commitments, a stepwise increase in the level of capital MDBs have to work with is necessary, alongside reforming the policy mix within the MDBs to be more centered on investing in national development strategies that are equitable, low carbon, and resilient and that reduce poverty and provide global public goods, as well as to increase the voice and representation of the world's poorer countries and their citizens. Reform of the MDBs has already begun, but it needs to accelerate with more ambition in order to meet shared and agreed upon climate and development goals. The World Bank has been the first to start reforms. The World Bank's ''Evolution Roadmap'' seeks to expand the size of the World Bank and shift the bank's policies.[33] This effort is of vital importance as it will set a precedent for major reforms of the other major MDBs that will follow. Other major MDBs are the Asian Infrastructure Investment Bank, New Development Bank, Islamic Development Bank, Development Bank of Latin America, Asian Development Bank, African Development Bank, and the Inter-American Development Bank.

Increasing the scale of the MDBs can take place in three important ways. The first is by optimizing the level of capital that MDBs already hold. Through balance sheet optimization measures such as lowering the equity-to-loans ratio, MDBs can increase their financing without new injections of capital being required. The second and most important is increasing the capital base itself. MDBs run on a basic business model whereby member states ''pay in'' capital to the bank in the form of equity. MDBs then use the equity as collateral to raise funds through bond issuances in international capital markets. Finally, MDBs ''on-lend'' (relend) the proceeds of the bond issuance to member states. The level of paid-in capital is determined in large part by the relative size of member state economies, and voting power within the MDBs is commensurate to the amount of paid-in capital. Because MDBs are among the first creditors to be paid, and because they are backed by advanced economies with strong credit ratings, MDBs are able to raise funds at a much lower cost than developing country members. Moreover, most MDBs also offer concessional financing and grants through additional donations that make the cost of MDB financing even more affordable for membership.[34] The third way for MDBs to scale up their activities is to crowd-in private sector capital mobilization.

In recognition of the lack of scale across MDBs, the G20 organized the G20 Independent Panel for Review of Multilateral Development Banks Capital Adequacy Frameworks that examined the extent to which MDBs should optimize the balance sheets that MDBs currently have.[35] The G20 panel confirmed research that has shown that MDBs can increase their lending by $600 billion to $1.2 trillion without jeopardizing their credit ratings, and the G20 has called on MDBs to prudently stretch their balance sheets accordingly, and the World Bank has begun doing so by reducing its equity-to-loan ratio in a manner that will yield $5 billion annually in new lending.[36,37] Of the $1 trillion in external financing needs estimated by the Songwe-Stern report, a subsequent G20 report—the G20 Independent Expert Group (IEG) report on strengthening MDBs—estimates that $500 billion could be mobilized in the form of official development financing, which breaks down into $180 billion in additional concessional finance and $320 in additional non-concessional lending. The G20 IEG report expects MDBs to cover roughly half of the official development financing with the remainder coming from bilaterals and other multilaterals.

Table 1. Distribution of developing and emerging economies across debt and climate change indices

		Debt and Mitigation Index	
		low	high
Debt and Adaptation Index	high	20	36
	low	37	20

Hybrid forms of capital are another option discussed by the G20 panel. The African Development Bank (AfDB) is proposing that advanced economies and other countries with surplus levels of special drawing rights (SDRs—an international reserve asset created by the IMF based on a weighting of five major global currencies) on-lend SDRs to the AfDB for a set period of time that would allow them to be classified as equity and thus as collateral for more lending.[38] Another proposal is for central banks to purchase bonds from MDBs and convert them into perpetuity and thus allow MDBs to convert them to equity in order to increase lending.[39]

Crowding-in private capital mobilization (PCM) is also essential for achieving shared development and climate goals. To date, MDBs have not been very successful to this end. The IMF's Global Financial Stability Report has shown that MDBs have only mobilized 1.2 times the amount of private sector finance relative to MDB lending disbursements, with the World Bank mobilizing less than a dollar.[40] Part of the poor performance is the sheer fact that infrastructure and energy is a smaller proportion of some MDB portfolios relative to education and health for instance. It also is the case that MDBs operate in riskier countries that no amount of "sweetener" will secure certain investors. As the goal of the MDBs has been to "de-risk" projects to encourage private sector investment, the result has been that much of the risk has been transferred to developing countries. Public-private partnerships where investors and contractors seek upward of a 20% return in foreign currencies have accentuated debt distress and fiscal instability in many developing countries.[41–43] Private capital is now very expensive for developing countries.

PCM should be complemented with commensurate efforts of domestic resource mobilization, with special attention to catalyzing the more than $15 trillion in assets across the over 500 national, regional, and sub-regional development finance institutions.[44] Programs by the Inter-American Development Bank and the New Development Bank show that such institutions have missions and incentives that are more aligned with MDBs, demand lower rates of return than the private sector, and are better equipped to work with local firms and entrepreneurs, governments, and through domestic capital markets in local currencies.[45]

The most efficient way to conduct a capital increase is for member states to increase the level of paid-in capital. Experts have recommended tripling the lending volume by the World Bank's non-concessional arm (IBRD) to $100 billion a year to achieve total annual lending of $1 trillion by 2030. This implies an increase of $100 billion equity over the current level of $50 billion.[46] Not only will such an act increase the amount of lending that the MDBs will be able to provide, but it would expand the voice and representation of some member developing countries.

The political economy of a capital increase had been tenuous until recently. Many of the major shareholders face domestic political barriers to advancing a capital increase, and a number of developing countries in debt distress lack adequate levels of foreign exchange to pay in at this moment.[47] Moreover, there

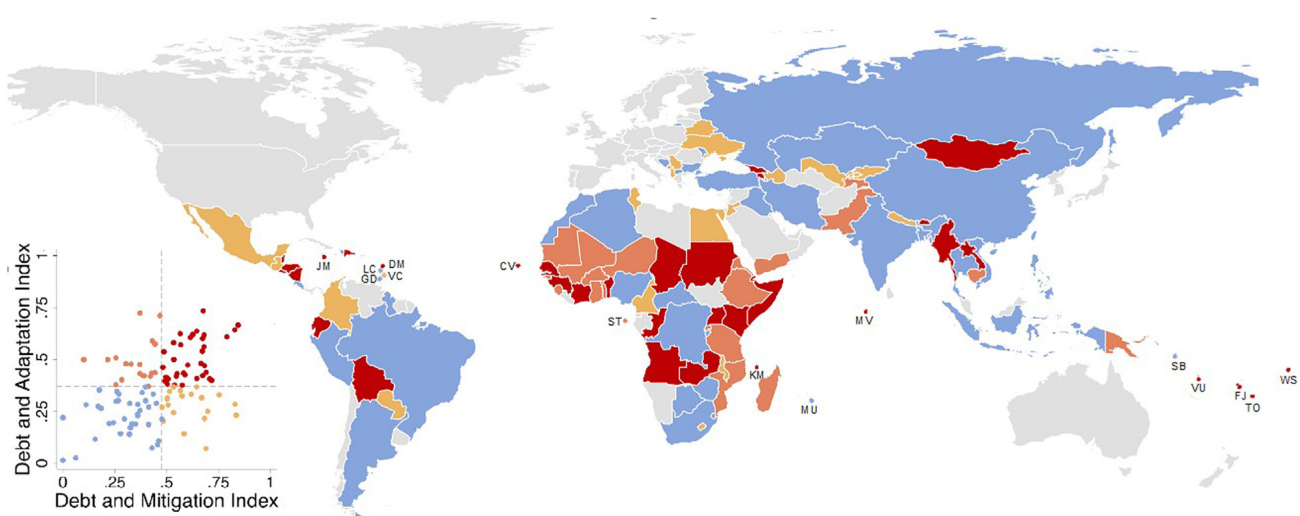


Figure 4. Debt and climate change burdens across the developing world

Developing countries are grouped according to where they score on two indices, Dept and Adaptation (DAI) and Debt and Mitigation (DMI), seen in the lower left inset. Details for these calculations are provided in the experimental procedures. Maroon countries have high burdens in both adaptation and mitigation, dark orange countries have high burdens in adaptation, and light orange countries have high burdens in mitigation. These countries will struggle to make investments in these respective areas. While the countries in blue may not be locked out of the ability to make investments, they still now face a high cost of capital. Small island developing states are shown as colored dots and labeled with ISO name abbreviations.

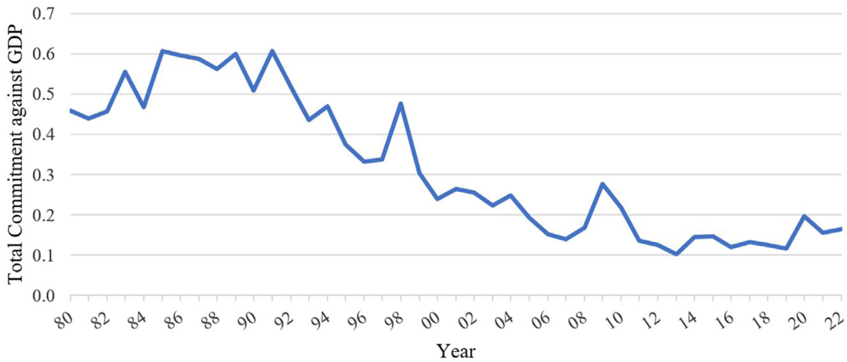


Figure 5. World Bank financing over time
Total World Bank lending (International Bank for Reconstruction and Development and International Development Association) against gross domestic product has fallen over time. Authors' calculations based on World Bank and IMF data: lending by the International Bank for Reconstruction and Development and International Development Association, divided by gross domestic product.

is significant debate about what a capital increase should be used for—with major shareholders wanting to earmark financing toward climate change mitigation and developing countries wanting to ensure that financing is truly additional and not at the expense of health and education finance, and it has a greater attention to adaptation and low-carbon growth trajectories.[48] Nevertheless, under the Indian presidency of the G20, there appeared to be a breakthrough with major shareholders and the G20's developing country members toward a capital increase.[49]

New capital can be channeled through new policy frameworks at the MDBs. MDB financing needs to support member countries to develop and implement new development strategies built around a variety of structural change trajectories necessary to achieve low-carbon, resilient, and socially inclusive economies. Referring back to Table 1, such strategies will come in very different forms depending upon the kind of structural change that a member state will face. It may be financing the creation of new clean energy industries, climate-smart agriculture, or phasing out coal-fired power plants. Such frameworks can be coupled with efforts to streamline environmental and social risk management systems in order to significantly speed up project design and approval while ensuring that big push investments enhance and protect natural capital and safeguard local voices and communities. As quantitative and case study evidence has thoroughly demonstrated, significant work is needed in this area as current MDB safeguard systems have become costly and time-consuming barriers for potential borrowers, while approaches that forgo these processes are associated with costly risks to projects, communities, and ecosystems (see, for example, Buntaine, Humphrey and Michaelowa, Gallagher and Kilby, and Ray et al.[50–53]).

Reforming the International Monetary Fund

The IMF has a role to play at the center of climate finance mobilization. The IMF has three core functions, surveillance, capacity building, and balance of payments financing. As the only global rules-based institution charged with maintaining the soundness of the global financial system, the IMF needs to ensure that countries can mobilize the massive amounts of financing needed in a manner that maintains fiscal and financial stability—while also helping countries prevent and mitigate the macro-critical risks that arise from climate change and climate change policy outlined in Figure 2.

The IMF has recently established an institution-wide climate strategy that is an important step forward, but the IMF needs further reform.[54,55] After having no established policy on climate change for decades, in a rapid period of time, the IMF has come to officially determine that climate change and climate change policy are macro-critical in the manner outlined in Figure 2, thus warranting full mainstreaming across Fund activities. To that end, the IMF has approved a Climate Change Strategy, has begun incorporating climate change into bilateral and multilateral surveillance, and has established a new lending facility partly dedicated to climate change called the Resilience and Sustainability Facility (RSF). Figure 6, through a heatmap, illustrates how the IMF has increasingly incorporated climate change into its surveillance reports. The scorecard rates Article IV reports on a scale of 0–6. A higher number on this scorecard suggests that climate change has been covered more extensively. While applauding this early movement by the IMF, the independent Task Force on Climate, Development, and the International Monetary Fund recently conducted a preliminary assessment of the Fund's activity on climate change and concluded that the IMF's multilateral surveillance activities are overly focused on carbon pricing as a "one size fits all" approach for climate action, that bilateral surveillance activities underestimate the macroeconomic implications of financing climate transitions in a financially stable manner, and that IMF balance of payments financing facilities lack the appropriate scale and are misaligned with the Paris Agreement.

The IMF will need to broaden multilateral surveillance activities beyond carbon pricing as both an instrument and a source of revenue for climate finance.[56] As noted earlier, carbon pricing schemes can often be the most economically optimal policy choice and a source of revenue, but they are very difficult to establish politically and have not always lived up to their promise.[6] A strategic focus and leadership on the global need for an investment-led approach to a resilient and just transition should also be at the center of the IMF's multilateral surveillance and leadership. Secondly, the IMF has a mandate to lead on the macroeconomic spillovers from climate change and climate change policy such as the physical risks from climate shocks triggered by the lack of climate action in large emitting countries as well as transition spillover risks triggered by climate action in one country that may adversely affect another country.[55]

The IMF will need to strengthen bilateral surveillance and capacity building as well. The IMF should be at the center of helping countries identify ways to mobilize finance in a fiscally sound and financially stable manner. Carbon pricing, investment-led approaches, and capital flow management measures that steer short-term capital flows toward structural change will all be important. But even more important is ensuring that in the aggregate that the myriad efforts at mobilizing climate

	2015	2016	2017	2018	2019	2020	2021	2022
Argentina		0	0		2			5
Australia	0	0	0	0	4		4	4
Brazil		1	1	0	1	1	1	
Canada		0	1	0	0		2	4
China	1	1	1	2	1	3	4	5
India	0	1	1	0	0		4	5
Indonesia	0	0	4	0	2	4		4
Iran	0	0	0	0				
Japan	0	0	0	3	4			4
Korea	0	1	0		0		2	2
Mexico	1	0	0	0	1	0	2	5
Russia	0	0	0	0	0	0		
Saudi Arabia	0	0	0	1	1		2	3
South Africa	0	0	0	0	1		3	
Thailand	0	0	0	0	2		4	4
Turkey		1	1	3	0		2	
U.K.	0	0	0	0		3	4	
Ukraine	0	2						
U.S.	1	0	0	0	0	2	4	4

Figure 6. Surveillance heatmap
The frequency of climate change coverage in IMF reports has increased over time. Article IV reports are rated on a scale from 0 to 6, where a higher number indicates climate change has been covered more extensively. Blank cells indicate years for which no Article IV reports are public. From "Task Force on Climate, Development and the IMF."[55]

finance are done in a stable manner. The IMF's Debt Sustainability Analysis (DSA) is a key tool in this regard. By incorporating the probability of climate shocks and climate financing needs in DSAs, IMF analysts and host countries will be able to make more informed decisions about financing strategies.[57] Other analytical tools need to be aligned with the Paris Agreement as well, such as the Financial Sector Assessment Program (FSAP) that examines the resilience of a country's financial system. Incorporating transition and transition spillover risk, physical risk, and massive resource mobilization needs into the FSAP tool will also allow the IMF to conduct better surveillance and capacity building to ensure that resource mobilization for climate change does not accentuate fiscal and financial instability.[55] The IMF has made initial strides on incorporating climate risks into FSAPs such as the 2022 Philippines FSAP that includes typhoon risks. However, FSAPs are yet to fully capture the impact of successive shocks, how physical climate risks interact with transition risks, and chronic risks.[55]

Finally, the IMF will need to play much more of a leadership role on the front lines of the climate crisis on the intersection between climate shocks, debt, and financial stability as outlined in Figure 3. The IMF has now officially extended its mandate to deal with the macro-critical aspects of climate change, approving an official climate strategy in 2021 (IMF, 2021). As discussed earlier, the more climate vulnerable a country becomes, the more they experience macroeconomic shocks and then seek IMF programs and debt relief. Correcting for this entails significant reform of the IMF lending toolkit and the role the IMF plays in debt distress. The IMF lending lacks the scale and proper design to be aligned with the Paris Agreement. IMF resources need to be boosted by an increase in IMF quotas (financial contributions to the IMF that are linked to voting power as in the MDBs), by further issuances and re-channeling of SDRs, and by financial contributions from major shareholders.

In addition to scale, IMF programs need to be in the form of green stimuli rather than fiscal consolidation. The RSF and more so the IMFs Rapid Credit Facility and Rapid Finance Facility are built to help countries recover from climate-related natural disasters. IMF lending programs such as these, however, tend to condition that countries engage in contractionary monetary and fiscal policies (raising interest rates and slashing public investment), which results in worsening economic growth prospects and debt sustainability, accentuating social and environmental outcomes.[58–61]

A more successful approach to reacting to the macro-critical aspects of climate change for the IMF is through a combination of climate-smart fiscal policy, significant public investment in green industry, adaptation, infrastructure, and social support for a just transition. Some of the IMF's own work supports this view. Recent IMF work finds that if nations phased out fossil fuel subsidies, ramped up renewable energy subsidies, and invested in sustainable infrastructure and social adjustment for those workers and entrepreneurs in incumbent fossil industries, the global economy would grow by close to an additional 1% and create an upward of 12 million new jobs through 2027.[62] Batini et al. (2022) find that green stimulus measures such as renewable energy and sustainable infrastructure have two to seven times the "multiplier effect" of brown stimulus measures, spurring much more growth from every dollar of public investment.[63] Furthermore, recent modeling work by the Brookings Institution shows that when recovery packages have a "big push" where the government implements the kinds of investments suggested in Songwe et al. (2022), they lead to higher growth, income, and creditworthiness.[7,64]

Finally, the IMF needs to play a much stronger role linking solutions to debt distress with climate action. The IMF does have a "Catastrophe Containment and Relief Trust (CCRT)" that makes loan payments to the IMF during times of stress (such as climate shocks) for the poorest countries. The CCRT should be scaled and expanded to a broader set of climate-vulnerable countries. Figure 7 shows how a substantial number of climate-vulnerable economies are not eligible to access the CCRT given that eligibility is based on national income.

What would be less resource intensive for the IMF would be to incorporate disaster clauses (clauses where countries can

CellPress
OPEN ACCESS

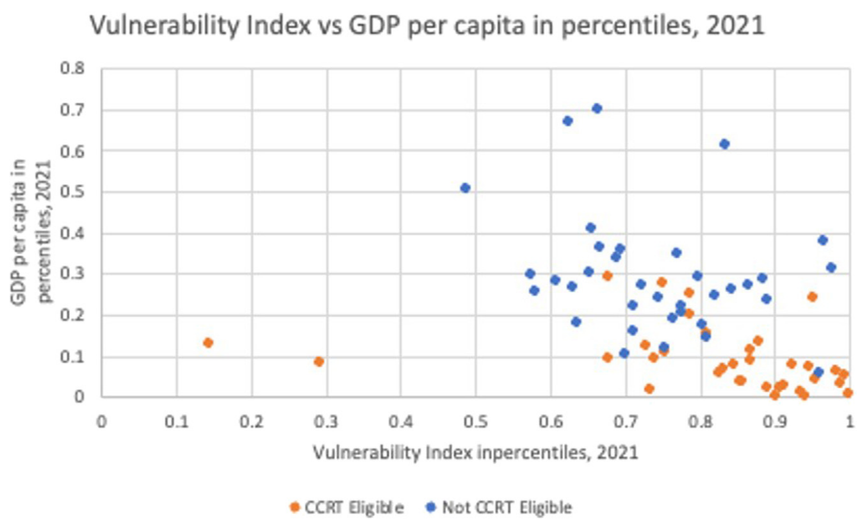


Figure 7. Climate vulnerability and catastrophe containment and relief trust eligibility

Countries ranking high on the climate vulnerability index are not necessarily eligible to access the International Monetary Fund's Catastrophe Containment and Relief Trust (CCRT). From "Task Force on Climate, Development and the IMF."[55]

suspend debt payments during climate shocks, which the World Bank has just enacted for "most vulnerable" countries) into all IMF lending instruments to climate-vulnerable countries. Lastly, climate-reformed DSAs should underpin situations where countries need debt relief. This would give the IMF and member states a better sense of the amount of debt relief needed in a country and increase the likelihood that a country will have the fiscal and borrowing space to recover from a debt crisis in a manner that is aligned with climate and development goals. The IMF will also need to play a more leading role in design policies that compel all creditors to comply with the level of treatment that a climate-aligned DSA suggests (see Volz et al.[65]).

Acting as a system for climate and development

Finally, it is important for the international financial institutions (IFIs) to act as a broader system and increase the voice and representation of the emerging market and developing countries that depend on these institutions most. In addition to the structural conditions described earlier whereby developing countries transfer capital to advanced economies rather than the reverse, there is a structural lack of voice and representation by the most climate-vulnerable emerging market and developing countries. Moreover, there is a lack of coordination among international economic institutions on global climate finance.

Institutions such as the World Bank and the IMF leave little voice and representation for the most climate-vulnerable countries. The lion's share of the voting power is held by the United States (who holds veto power) and other advanced economies. What is more, there is a gentlemen's agreement that the President of the World Bank will always be a US citizen and the Managing Director of the IMF will be a European citizen.[34] Merling shows that at the IMF, advanced economies have over 59% of the voting power yet have only drawn on IMF financing seven times since 2002.[66] Conversely, the most climate-vulnerable nations only have 5.3% of the vote despite having over 104 programs from the IMF since 2002.

Developing countries have engaged in a number of strategies both inside and outside the international financial institutions to boost their voice and representation in the system. Inside, a number of coalitions have arisen such as the Intergovernmental Group of 24 developing countries that work to act as a bloc within the IMF and World Bank to advance development-friendly proposals in those arenas. More recently, the V20 (now 68) group of Finance Ministers from the most climate-vulnerable developing countries have also formed a coalition and seek formal recognition within the World Bank, IMF, and the G20.

On the outside, developing countries have begun to construct their own set of institutions to provide the same services more conducive to their terms and to give themselves more leverage in the legacy institutions dominated by advanced economies. On development finance, developing countries have created a network of development finance institutions with assets totaling to $18.7 trillion dollars (four times that of the MDBs).[67] Institutions such as the Asian Infrastructure Investment Bank, the New Development Bank, the Development Bank of Latin America, the Development Bank of Southern Africa, the China Development Bank, and others are all among these lenders. Recently, these institutions have begun to meet and coordinate policy on climate change and other development issues under the auspices of an annual "Finance in Common" summit process.

In terms of liquidity finance, developing countries operate a network of regional financial arrangements such as the Arab Monetary Fund, the Latin American Reserve Fund, and the Chang Mai Initiative Multilateralization that collectively have upward of $1 trillion at their disposal—similar to the level of financing available through the IMF. These groups too have begun to coordinate as a system.[68] Other interesting developments are developing such as the "Bridgetown Initiative."[69] Spearheaded by Barbados' Prime Minister Mia Mottley, the initiative is focused on leveraging trillions of adaptation financing across the world. In 2023, they were successful in convincing France to host a summit on climate finance that pledged to increase efforts at climate financing within and outside of the international financial institutions moving forward. The Bridgetown Initiative evolved into a broader agenda as its champions sought to gain the support of a broader range of developing countries and other governments.

While all the activity within and outside the system is encouraging, it risks fragmentation, duplication, and inconsistency without coordination. The most globally representative body, the United Nations, has been relegated to the sidelines. The emergence in this century of the G20 has been more inclusive—at least to the largest developing countries—but it has mainly been deadlocked on climate and development and especially debt relief. While countries are in high-level agreement on

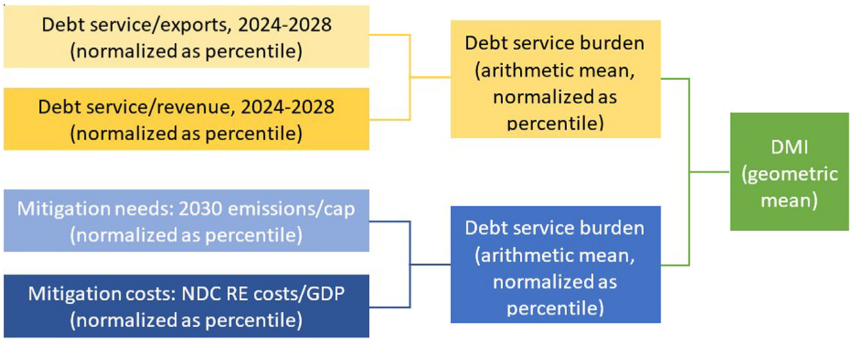


Figure 8. Debt and Climate Change Mitigation Index calculation
The Debt and Climate Change Mitigation Index (DMI) is defined as a geometric mean of a country's debt service burden and climate change mitigation needs and costs. Countries' debt service burdens are represented as the normalized value of the arithmetic mean of projected 2024–2028 debt service as a share of projected exports and as a share of projected government revenue. Climate change mitigation needs and costs are represented as the normalized value of the arithmetic mean of climate change mitigation needs (defined as the projected 2030 carbon emissions per capita under a business-as-usual scenario) and costs (defined as the renewable energy investment commitments in each country's Nationally Determined Contributions to the Paris Agreement as a share of their gross domestic product). Each element of the DMI is normalized as a percentile before incorporation.

the need for IFI reform to deliver on development and climate change goals, they do not fully converge on sequence, prioritization, and types of reforms needed. We are left with what Grabel refers to as "productive incoherence," whereby there are a multitude of blossoming initiatives within and outside of the system that are encouraging but that won't reach their full potential without concerted coordination. It is now or never.[70]

EXPERIMENTAL PROCEDURES

Resource availability

Lead contact

The lead contact is Kevin P. Gallagher, kpg@bu.edu.

Materials availability

This study did not generate new materials.

Data and code availability

This study did not generate new data or code.

Calculating debt indices

Climate change mitigation and adaptation investments are both essential and urgent. However, to be effective, climate change mitigation investments must be pursued within the next few years, while adaptation investments will be necessary for many years to come. For this reason, the Debt and Climate Change Mitigation Index (DMI) considers short-term debt repayment needs (over the next 5 years) as an impediment to near-term climate mitigation investment. In contrast, the Debt and Climate Change Adaptation Index (DAI) considers debt stock (which by definition has a longer-term impact than debt service) as an impediment to long-range climate change adaptation investments. Each of these two indices is described in detail below.

Debt and Climate Change Mitigation Index

Countries who score high on this index have high debt service levels over the next 5 years (as a share of government revenue and/or as a share of exports) and also face high levels of climate change mitigation needs and costs. Mitigation needs are measured as projected carbon emissions (CO_2 equivalent) per capita in 2030 in a business-as-usual projection. Mitigation costs are measured as countries' renewable energy ambitions reflected in their nationally determined contributions (NDCs) under the Paris Agreement on climate change, as a share of their GDP. These variables are combined in the DMI as follows, where "Serv." = external public sector debt service in nominal USD, 2024–2028; "Exp." = projected exports of goods and services in nominal USD, 2024–2028; "Rev." = projected government revenue in nominal USD, 2024–2028; "Emissions/pop" = projected emissions in 2030 under a BAU scenario; and "NDC RE goals" = renewable energy projects identified in Paris Agreement NDC (see Figure 8 for a schematic):

$$DMI = \sqrt{\left(\frac{Serv./_{Exp.} + Serv./_{Rev.}}{2}\right) \cdot \left(\frac{Emissions/_{pop.} + NDC\ RE\ costs/_{GDP}}{2}\right)} \quad \text{(Equation 1)}$$

Debt service burdens are measured in two ways (as a share of projected government exports and as a share of projected exports) to account for projection coverage gaps. Several countries with high mitigation needs and/or costs—including Bolivia and Mongolia—have either export or government revenue projections available but not both. For countries with both values, they are highly correlated (coefficient: 70.87), so this method does not bring any significant sacrifices in robustness.

For the sake of normalization, all values are measured as percentiles before being incorporated into averages. This allows for the fact that some elements are more heavily weighted upward or downward on average. For example, projected 2030 per capita emissions average 4.2 tons of CO_2 equivalent, while NDC renewable energy costs average 10.5% of GDP. Measuring each as percentiles allows for these variations without privileging the importance of one or the other in the final calculations.

The final DMI is calculated as a geometric, rather than arithmetic, mean to ensure that values of (or near) zero on either component will result in end values of (or near) zero. Thus, medium-to-high final DMI values necessarily indicate medium-to-high values of both components. The components are calculated as arithmetic means, so that countries facing high needs and/or high costs have high resulting component values.

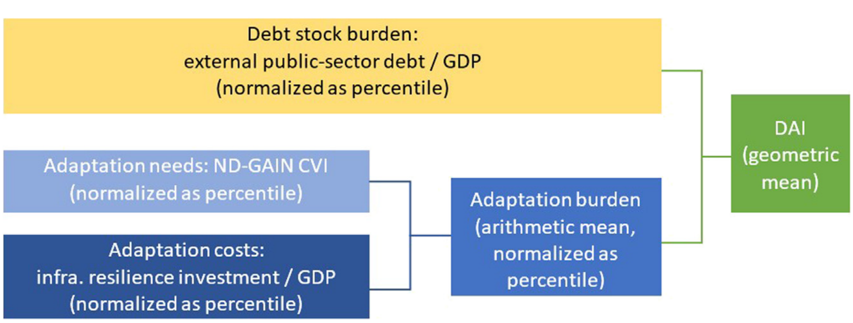


Figure 9. Debt and Climate Change Adaptation Index calculation method
The Debt and Climate Change Adaptation Index (DAI) is defined as a geometric mean of a country's debt stock burden and climate change adaptation burden. The debt stock burden is defined as external public sector debt as a share of gross domestic product. The climate change adaptation burden is defined as the arithmetic mean of adaptation needs (defined as the Notre Dame Global Adaptation Initiative Climate Vulnerability Index) and adaptation costs (defined as infrastructure resilience investment needs as a share of gross domestic product). Each element of the DMI is normalized as a percentile before incorporation.

Table 2. DMI and DAI elements: definitions, units, and sources

Variable	Definition and units	Source
Debt service, 2024–2028	external public sector debt service projections, measured in nominal USD	World Bank IDS database, 2022[71]
Exports, 2024–2028	exports of goods and services (calculated as projected growth applied to most recent actual values), measured in nominal USD	IMF IFS,[72] WEO databases,[73] April 2023; author calculations
Revenue, 2024–2028	government revenue (calculated as projected share of GDP applied to projected GDP), measured in nominal USD	IMF FM,[74] WEO databases,[73] April 2023; author calculations
Emissions per capita, 2030	projected per capita carbon emissions under a business-as-usual scenario in 2030, measured in tons of CO_2 equivalent per person.	Climate Resource 2022[75]
NDC costs/GDP	costs of renewable energy project identified in Nationally Determined Contributions to the Paris Club, measured as a share of GDP	Muñoz et al. 2018[76]
CVI	Climate Vulnerability Index, encompassing climate change exposure, sensitivity, and social resources for adaptive capacity	Chen et al. 2015[77]; ND-GAIN 2023[78]
Infrastructure/GDP	cost to strengthen existing and future infrastructure projects and enact coastal reinforcement	Bellon and Massetti 2022[79]; Nicholls et al. 2019[80]

Debt and Climate Change Adaptation Index

Even assuming vigorous near-term climate change mitigation investment, longer-term adaptation investment will still be necessary. Thus, this index relies on debt stock rather than next-5-year debt service. Countries who score high on the DAI have high debt stocks and high climate change adaptation needs and costs. Adaptation needs are measured in the Notre Dame ND-GAIN Climate Vulnerability Index. Adaptation costs are measured in the cost of infrastructure resilience investments as a share of GDP. These variables are combined in the Adaptation Index as follows, where "Debt stock/GDP" = external public sector debt in nominal USD as a share of GDP, 2021; "CVI" = Notre Dame ND-GAIN Climate Vulnerability Index; and "Infra/GDP" = cost of necessary infrastructure resilience investment as a share of GDP, 2019 (see Figure 9 for a schematic):

$$DAI = \sqrt{\left(\frac{Debt\ stock}{GDP}\right) \cdot \left(\frac{CVI + Infra./GDP}{2}\right)} \qquad \text{(Equation 2)}$$

As above, all index elements are normalized as percentiles before their incorporation into the final index, in order to ensure equal consideration. The final index is measured as a geometric mean in order to ensure that high resulting values indicate high levels of both major index components. The components are calculated as arithmetic means, so that countries facing high needs and/or high costs have high resulting component values.

Table 2 provides additional information about the indicators that inform each of these indices.

ACKNOWLEDGMENTS

The authors confirm contribution to the paper as follows: study conception and design: all authors; data collection: Rebecca Ray and Luma Ramos; analysis and interpretation of results: all authors; draft manuscript preparation: Kevin P. Gallagher, Rishikesh Ram Bhandary, Rebecca Ray. All authors reviewed the results and approved the final version of the manuscript.

DECLARATION OF INTERESTS

The authors declare no competing interests.

REFERENCES

1. (2022). IPCC. Summary for Policymakers.
2. Emissions, U.N.E.P. (2022). Gap Report 2022 [Internet] (UNEP). Available from: https://www.unep.org/emissions-gap-report-2022
3. IPCC (2022). The Evidence Is Clear: The Time for Action Is Now. We Can Halve Emissions by 2030. [Internet]. https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/.
4. Narassimhan, E., Gallagher, K.S., Koester, S., and Alejo, J.R. (2018). Carbon pricing in practice: a review of existing emissions trading systems. Clim. Pol. *18*, 967–991.
5. Haites, E. (2018). Carbon taxes and greenhouse gas emissions trading systems: what have we learned? Clim. Pol. *18*, 955–966.
6. Cullenward, D., and Victor, D.G. (2020). Making Climate Policy Work (Cambridge, UK ; Medford, MA: Polity Press), p. 241.
7. Songwe, V., Stern, N., and Bhattacharya, A. (2022). Finance for cliimate action: scaling up investment for climate and development [Internet]. Available from: https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2022/11/IHLEG-Finance-for-Climate-Action-1.pdf
8. Bhattacharya, A., Gallagher, K.P., Muñoz Cabré, M., Jeong, M., and Ma, X. (2019). Aligning G20 Infrastructure Investment with Climate Goals & the 2030. Agenda [Internet]. https://www.foundations-20.org/wp-content/uploads/2019/06/F20-report-to-the-G20-2019_Infrastrucutre-Investment.pdf.
9. World Bank (2023). What You Need to Know about How CCDRs Estimate Climate Finance Needs (World Bank). [Internet]. https://www.worldbank.org/en/news/feature/2023/03/13/what-you-need-to-know-about-how-ccdrs-estimate-climate-finance-needs.
10. Grossman, G.M., and Krueger, A.B. (1995). Economic Growth and the Environment. Q. J. Econ. *110*, 353–377.
11. Cassim, A., Radmore, J.V., Dinham, N., McCallum, S., Falconer, A., and Meattle, C. (2021). South African Climate Finance Landscape 2020. [Internet]. Climate Policy Initiative. https://www.climatepolicyinitiative.org/publication/south-african-climate-finance-landscape-2020/.
12. Global, F.S.B. (2022). Monitoring Report on Non-bank Financial Intermediation 2022 (Financial Stability Board). [Internet]. https://www.fsb.org/wp-content/uploads/P201222.pdf.
13. Ocampo, J.A. (2017). Resetting the International Monetary (Non)system: A Study Prepared by the United Nations University World Institute for Development Economics Research (UNU-WIDER), First edition (Oxford University Press), p. 269.
14. Stern, N., and Stiglitz, J.E. (2023). Climate change and growth. Ind. Corp. Change *32*, 277–303.

15. Stiglitz, J.E. (2022). Is it a turning point in the US economy? J. Pol. Model. *44*, 748–757.
16. Baarsch, F., Awal, I., and Schaeffer, M. (2022). Climate Vulnerable Economies: Loss Report. Economic Losses Attributable to Climate Change in V20 Economies over the Last Two Decades(2000-2019). . [Internet]. V20. https://www.v-20.org/wp-content/uploads/2022/06/Climate-Vulnerable-Economies-Loss-Report_June-14_compressed-1.pdf.
17. IMF (2017). Chapter 3: The Effects of Weather Shocks on Economic Activity: How Can Low-Income Countries Cope? [Internet] (International Monetary Fund). (World Economic Outlook). Available from: https://www.imf.org/en/Publications/WEO/Issues/2017/09/19/world-economic-outlook-october-2017
18. The, I.M.F. (2017). Effects of Weather Shocks on Economic Activity: How Can Low-Income Countries Cope? In World Economic Outlook October 2017 [Internet]. IMF. Available from: https://www.imf.org/en/Publications/WEO/Issues/2017/09/19/world-economic-outlook-october-2017
19. Ramos, L., Gallagher, K.P., Stephenson, C., and Monasterolo, I. (2021 Dec 31). Climate risk and IMF surveillance policy: a baseline analysis. Clim. Pol. *22*, 371–388.
20. UNCTAD. Staying afloat (2022). A Policy Agenda for Climate and Debt Challenges (UNCTAD). [Internet]. https://unctad.org/system/files/non-official-document/UNCTAD_Debt_and_Climate_Background_Note_COP27.pdf.
21. Kling, G., Volz, U., Murinde, V., and Ayas, S. (2021). The impact of climate vulnerability on firms' cost of capital and access to finance. World Dev. *137*, 105131.
22. Cevik, S., and Jalles, J.T. (2022). This changes everything: Climate shocks and sovereign bonds. Energy Econ. *107*, 105856.
23. Beirne, J., Renzhi, N., and Volz, U. (2021). Feeling the heat: Climate risks and the cost of sovereign borrowing. Int. Rev. Econ. Finance *76*, 920–936.
24. Bhandari, L., and Dwivedi, A. (2022) (Development and the IMF), India's Energy and Fiscal Transition [Internet]. Task Force on Climate. https://www.bu.edu/gdp/files/2022/03/TF-WP-03-FIN.pdf.
25. Titelman, D., Perez Benitez, N., Hanni, M., Perez Verdia Canales, C., and Saade Hazin, M. (2022). Fiscal Impact Estimates of a Net-Zero Emissions Transition for Major Hydrocarbon Producers in Latin America and the Caribbean (Development and the IMF). [Internet]. Task Force on Climate. https://www.bu.edu/gdp/files/2022/04/TF-WP-004-FIN.pdf.
26. Gourdel, R., Monasterolo, I., and Gallagher, K.P. (2022). Climate transition spillovers and sovereign risk: evidence from Indonesia. Task Force on Climate (Development and the IMF).
27. Ramos, L., Ray, R., Bhandary, R.R., Gallagher, K.P., and Kring, W. (2023). Debt Relief for a Green and Inclusive Recovery: Guaranteeing Sustainable Development (Boston University Global Development Policy Center; Centre for Sustainable Finance, SOAS, University of London; Heinrich-Böll-Stiftung). [Internet]. https://www.bu.edu/gdp/files/2023/05/DRGR_Report_May_2023_FIN.pdf.
28. Chamon, M d, Klok, E., Thakoor, V.V., and Zettelmeyer, J. (2022). Debt-for-climate Swaps: Analysis, Design, and implementation [Internet] (International Monetary Fund). Report No.: 2022/162. Available from: https://www.imf.org/en/Publications/WP/Issues/2022/08/11/Debt-for-Climate-Swaps-Analysis-Design-and-Implementation-522184
29. IRENA (2023). The Cost of Financing for Renewable Power. [Internet]. Abu Dhabi: IRENA. https://www.irena.org/Publications/2023/May/The-cost-of-financing-for-renewable-power.
30. United Nations. (2023). A World of Debt: A Growing Burden to Global Prosperity (United Nations). [Internet]. https://unctad.org/system/files/official-document/osgmisc_2023d4_en.pdf.
31. Panizza, U., Sturzenegger, F., and Zettelmeyer, J. (2009 Sep 1). The Economics and Law of Sovereign Debt and Default. J. Econ. Lit. *47*, 651–698.
32. IMF. World (2023). Economic Outlook July Update 2023 [Internet]. Available from: https://www.imf.org/en/Publications/WEO/Issues/2023/07/10/world-economic-outlook-update-july-2023
33. World Bank (2022). Evolving the World Bank Group's Mission, Operations, and Resources: A Roadmap (World Bank). [Internet]. https://documents1.worldbank.org/curated/en/099845101112322078/pdf/SECBOS0f51975e0e809b7605d7b690ebd20.pdf.
34. Humphrey, C. (2022). Financing the Future: Multilateral Development Banks in the Changing World Order of the 21st Century, 1st ed. (Oxford University Press).
35. G20 Expert Panel (2022). Boosting MDBs' Investing Capacity: An Independent Review of Multilateral Development Banks' Capital Adequacy Frameworks. [Internet]. https://www.dt.mef.gov.it/export/sites/sitodt/modules/documenti_it/rapporti_finanziari_internazionali/rapporti_finanziari_internazionali/CAF-Review-Report.pdf.
36. Munir, W., and Gallagher, K.P. (2020). Scaling Up for Sustainable Development: Benefits and Costs of Expanding and Optimizing Balance Sheet in the Multilateral Development Banks. J. Int. Dev. *32*, 222–243.
37. G20, I.E.G. (2023). Strengthening Multilateral Development Banks: The Triple Agenda. [Internet]. https://www.cgdev.org/publication/strengthening-multilateral-development-banks-triple-agenda.
38. Plant M. Funding hybrid capital at the AfDB is the best deal for SDR donors [Internet]. Center for Global Development; Available from: https://www.cgdev.org/blog/funding-hybrid-capital-afdb-best-deal-sdr-donors
39. Zucker-Marques, M., and Gallagher, K.P. (2023). Sustainable Future Bonds: Boosting MDB Lending and Improving the Global Reserve System, p. 24. GEGI Policy Brief [Internet]. https://www.bu.edu/gdp/files/2023/06/GEGI_PB_024_FIN.pdf.
40. IMF (2022). Scaling Up Private Climate Finance in Emerging Market and Developing Economies: Challenges and Opportunities. In Global Financial Stability Report: Navigating the High-Inflation Environment (IMF). [Internet]. https://www.imf.org/-/media/Files/Publications/GFSR/2022/October/English/ch2.ashx.
41. IEG. World Bank (2015). Group Support to Public-Private Partnerships: Lessons from Experience in Client Countries, FY02-12 [Internet] (World Bank Group). Available from: https://openknowledge.worldbank.org/handle/10986/22908
42. Kenny, C. (2022). The Simple Math of Development Finance [Internet]. CGD Notes. https://www.cgdev.org/publication/simple-math-development-finance.
43. Gabor, D. (2021). The Wall Street Consensus. Dev. Change *52*, 429–459.
44. Xu, J., Marodon, R., Ru, X., Ren, X., and Wu, X. (2021). What are public development banks and development financing institutions ?——qualification criteria, stylized facts and development trends. China Econ Q Int *1*, 271–294.
45. Smallridge, D., Buchner, B., Trabacchi, C., Netto, M., Loernzo, J.J.G., and Serra, L. (2012 Nov). The Role of National Development Banks in Intermediating International Climate Finance Set up Private Sector Investments [Internet] (Inter-American Development Bank). Report No.: IDB-DP-249. Available from: https://webimages.iadb.org/publications/english/document/The-Role-of-National-Development-Banks-in-Intermediating-International-Climate-Finance-to-Scale-Up-Private-Sector-Investments.pdf
46. Kharas, H., and Bhattacharya, H. (2023). The Trillion-Dollar Bank: Making IBRD Fit for Purpose in the 21st Century (Brookings Institution). [Internet]. https://www.brookings.edu/articles/the-trillion-dollar-bank-making-ibrd-fit-for-purpose-in-the-21st-century/.
47. Lawder, D., Singh, K., and Shalal, A. (2023). Yellen Rejects World Bank Capital Increase; No Challengers to U.S. Nominee to Lead Lender (Reuters). [Internet]. https://www.usnews.com/news/top-news/articles/2023-03-29/us-expects-bidens-nominee-ajay-banga-to-be-elected-as-world-bank-chief.
48. Where, D. (2023). Things Stand with World Bank Reform. Available from. https://www.devex.com/news/where-things-stand-with-world-bank-reform-105421.
49. Fox, H., and Reed, J. (2023). G20 Backs Bigger Role for Reformed World Bank. Financial Times [Internet]. https://www.ft.com/content/13a8bf37-29ba-4894-a0eb-401e4b42c725.
50. Buntaine, M. (2016). Giving Aid Effectively: The Politics of Environmental Performance and Selectivity at Multilateral Development Banks (Oxford University Press), p. 304.
51. Humphrey, C., and Michaelowa, K. (2013). Shopping for Development: Multilateral Lending, Shareholder Composition and Borrower Preferences. World Dev. *44*, 142–155.
52. Gallagher, K.P., and Kilby, C. (2018). The Political Economy of World Bank Lending: An Empirical Analysis of Environmental and Social Safeguards at the World Bank [Internet] (Boston University Global Development Center). Available from: https://www.bu.edu/gdp/files/2018/10/Kilby-Gallagher-WP-1.pdf
53. R. Ray, K.P. Gallagher, and C.A. Sanborn, eds. (2020). Development Banks and Sustainable Development in the Andean Amazon (Routledge).
54. IMF (2021). IMF Strategy to Help Members Address Climate Change Related Policy Challenges - Priorities, Modes of Delivery (Washington: International Monetary Fund). and Budget Implications [Internet]. https://www.imf.org/en/Publications/Policy-Papers/Issues/2021/07/30/IMF-Strategy-to-Help-Members-Address-Climate-Change-Related-Policy-Challenges-Priorities-463093.
55. (2023). Task Force on Climate, Development and the IMF (Task Force). In The International Monetary Fund, Climate Change and Development, R.R. Bhandary and M. Uy, eds..

56. He, X., and Uy, M. (2023). Task Force on Climate. In Cooperating to Address Climate Change with Pricing and Non-Pricing Measures (Development and the IMF).
57. Maldonado, F., and Gallagher, K.P. (2022). Climate Change and IMF Debt Sustainability Analysis (Development and the IMF). [Internet]. Task Force on Climate. https://www.bu.edu/gdp/files/2022/02/TF_WP_005_FIN.pdf.
58. Kentikelenis, A., and Stubbs, T. (2023). A Thousand Cuts: Social Protection in the Age of Austerity (Oxford University Press), p. 1.
59. Przeworski, A., and Vreeland, J.R. (2000). The effect of IMF programs on economic growth. J. Dev. Econ. *62*, 385–421.
60. Dreher, A. (2006). IMF and economic growth: The effects of programs, loans, and compliance with conditionality. World Dev. *34*, 769–788.
61. IMF (2018–2019). Review of Program Design and Conditionality (IMF). Report No.: Policy Paper No. 2019/012. Available from: https://www.imf.org/en/Publications/Policy-Papers/Issues/2019/05/20/2018-Review-of-Program-Design-and-Conditionality-46910
62. the Recovery [Internet]. IMF Greening, I.M.F. (2020), (Special Series on Fiscal Policies to Respond to COVID-19). Available from:. https://www.imf.org/en/Publications/SPROLLs/covid19-special-notes.
63. Batini, N., di Serio, M., Fragetta, M., Melina, G., and Waldron, A. (2021). Building Back Better: How Big Are Green Spending Multipliers? IMFO *47*.
64. Kharas, H., and Rivard, C. (2022). Debt, Creditworthiness, and Climate: A New Development Dilemma [Internet] (Brookings Institution). Report No.: 180. Available from: https://www.brookings.edu/wp-content/uploads/2022/12/Debt-creditworthiness-and-climate-1.pdf
65. Volz, U., Akhtar, S., Gallagher, K., Griffith-Jones, S., Haas, J., and Kraemer, M. (2021). Debt Relief for a Green and Inclusive Recovery: Securing Private-Sector Participation and Creating Policy Space for Sustainable Development. [Internet]. https://drgr.org/files/2021/06/DRGR-Report-2021-Securing-Private-Sector-Participation.pdf.
66. Merling, L. (2023). No Voice for the Vulnerable: Climate Change and the Need for Quota Reform at the IMF (GEGI Work Pap).
67. Xu, J., Marodon, R., and Ru, X. (2020). Identifying and Classifying Public Development Banks and Development Finance Institutions (AFD). [Internet]. https://financeincommon.org/identifying-and-classifying-public-development-banks-pdbs-and-development-finance-institutions-dfis.
68. Stubbs, T., Kring, W., Laskaridis, C., Kentikelenis, A., and Gallagher, K. (2021 Jan 1). Whatever it takes? The global financial safety net, Covid-19, and developing countries. World Dev. *137*. 105171–171.
69. Persaud, A. (2021). Debt, Natural Disasters, and Special Drawing Rights: A Modest Proposal. VoxEU.org [Internet]. https://voxeu.org/article/debt-natural-disasters-and-special-drawing-rights.
70. Grabel, I. (2019). When Things Don't Fall Apart: global financial governance and developmental finance in an age ... Of Productive Incoherence (MIT Press).
71. World Bank (2022). International Debt Statistics." Online database. https://databank.worldbank.org/source/international-debt-statistics. (Accessed 1 April 2023). accessed.
72. IMF (2023). International Finance Statistics." Online database. https://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b. (Accessed 1 May 2023). accessed.
73. IMF (2023). World Economic Outlook Database: April 2023 Edition (Online database). https://www.imf.org/en/Publications/WEO/weo-database/2023/April. (Accessed 1 May 2023). accessed.
74. IMF (2023). Fiscal Monitor." Online database. https://data.imf.org/?sk=4be0c9cb-272a-4667-8892-34b582b21ba6. (Accessed 1 May 2023). accessed.
75. Resource, C. (2022). NDCs." Online database. https://www.climate-resource.com/tools/ndcs/countries?sortBy=share_emissions_2030. (Accessed 1 May 2023). accessed.
76. Cabré, M.M., Gallagher, K.P., and Li, Z. (2018). Renewable Energy: The Trillion Dollar Opportunity for Chinese Overseas Investment. China and. World Economy *26*, 27–49. https://doi.org/10.1111/cwe.12260.
77. Chen, C., Noble, I., Hellmann, J., Coffee, J., Murillo, M., and Chawla, N. (2015). University of Notre Dame Global Adaptation Index: Country Index Technical Report. Notre Dame. https://gain.nd.edu/assets/254377/nd_gain_technical_document_2015.pdf.
78. Notre Dame Global Adaptation Initiative (ND-GAIN) (2023). Climate Vulnerability Index." Online database. https://gain.nd.edu/our-work/country-index/rankings/. (Accessed 1 May 2023). accessed.
79. Bellon, M., and Massetti, E. (2022). Economic Principles for Integrating Adaptation to Climate Change into Fiscal Policy (International Monetary Fund). https://www.imf.org/-/media/Files/Publications/Staff-Climate-Notes/2022/English/CLNEA2022001.ashx.
80. Nicholls, R.J., Jochen, Hinkel, Daniel, Lincke, and Thomas, van der Pol (2019). Global Investment Costs for Coastal Defense through the 21st Century (World Bank). https://documents1.worldbank.org/curated/en/433981550240622188/pdf/WPS8745.pdf.

Annex 556

S. Millard, “Macroeconomics and Climate Change”, *National Institute Economic Review*, 2023, pp. 1-7

National Institute Economic Review (2023), 264: 1, 1–7
doi:10.1017/nie.2023.18

COMMENTARY

MACROECONOMICS AND CLIMATE CHANGE

Stephen Millard[1,2]

[1]The National Institute of Economic and Social Research, London, UK
[2]Centre for Macroeconomics, Durham University Business School and University of Portsmouth
Email: s.millard@niesr.ac.uk

Climate change and its consequences are the most important issues affecting the UK economy over the coming century and will present a critical challenge for the UK government moving forward. In particular, the challenge of getting to net zero by 2050 is going to have major ramifications for the macroeconomy. In this commentary, I lay out some of the work that has been done on the implications of climate change and the transition to net zero for the macroeconomy. Economic activity as currently structured involves using fossil fuels as part of the production process. But this releases carbon dioxide into the atmosphere and leads to higher temperatures. I take this as given, simply noting that if this rise in temperature and the change in weather patterns associated with it are going to be stopped, if not reversed, at some point in the future, then we have to move to a 'net zero' (or even 'net negative') economy in which output is produced using only those inputs which do not produce greenhouse gases.

This commentary is structured as follows. Given that climate change is already visible through higher temperatures and different weather patterns, I start by considering the direct effects of climate change on the macroeconomy, that is, 'physical risks'. Climate change can affect the macroeconomy through higher temperatures, more frequent storms, floods and other extreme weather events, and so forth. More generally, an increase in extreme weather events, and so forth, is likely to result in increased volatility in the macroeconomy and I consider what that may mean for macroeconomic policy. Having discussed physical risks, I then consider work looking at 'transition risks', that is, the macroeconomic effects of the transition to net zero. As I said earlier, for climate change to be stopped, the economy must move to net zero.[1] This will mean both explicit government policies aimed at steering the economy towards net zero and private-sector action, in particular investing in green technologies to make the transition happen. I first examine the macroeconomic effects of three government policies: direct regulation, a carbon tax and a 'cap-and-trade' policy.[2] I then examine the effects of the transition on the natural rate of interest, r^*.[3] The final section offers some overall conclusions.

1. Physical risks

The physical effects of climate change are likely to become ever more noticeable and intense. Leaving aside the temperature increase itself, global warming has been shown to result in an increase in the frequency and impact of extreme weather events (see, e.g. Stott, 2016; Stott *et al.*, 2016). Bindoff *et al.* (2013) showed that climate change has already led to an increase in the frequency of daily temperature

[1]Even once the world economy is at net zero, temperatures will still continue to rise for a while as the effects of previous emissions take time to come through.

[2]A 'Cap and trade' scheme is where the government sets the maximum quantity of emissions and allows the market to find the price. An example of such a scheme is the EU Emissions Trading System (ETS).

[3]Here I define the natural real rate of interest as the rate of interest that would clear the market for loanable funds absent financial market or other frictions. That is, at this interest rate, desired savings equals desired investment.

extremes and Diebold and Rudebusch (2022) show how the seasonal pattern of daily temperature ranges across U.S. cities has changed over time. Zhang *et al.* (2013) showed that climate change has led to more intense extremes in daily rainfall. The question for this commentary is what that means for the macroeconomy?

Since climate change is a slow process, it is hard to assess the impact on the macroeconomy. As a result, economists have tended to use weather data as a way of inferring the macroeconomic impact of climate change. This work has identified a number of channels through which changes in, especially, temperature and rainfall can affect macroeconomic aggregates, including the economy's potential growth rate. High temperatures are known to reduce labour productivity given that humans simply cannot work as hard physically and mentally when the temperature is too hot. In fact, Dell *et al.* (2014) report that for each degree Celsius over 25°C productivity in various cognitive tasks falls by around 2 per cent. They also found that a 1°C rise in temperature in a given year in poorer countries reduced the growth rate by 1.3 percentage points in that year. Interestingly though, they did not find the same result for rich countries. Burke *et al.* (2015) found that the growth rate of GDP per head peaks at a temperature of around 13°C, while declining strongly at higher temperatures, and that this was true for both rich and poor countries. And Heal and Park (2015) find that hotter-than-average years are associated with lower output and TFP in hot countries.

There is also some evidence of an effect of higher temperatures on demand. Batten (2018) points out that unusual weather can damage the housing stock and affect consumption through wealth effects. Weather patterns also matter for 'shopping productivity' and for recreation, which can act as a substitute for shopping.[4] In terms of evidence for such an effect, Starr-McCluer (2000) finds a small but significant impact of unusual weather on retail sales, while Roth Tran (2019) finds evidence of long- and short-run adaptation to climate in shopping activities.

As shown in Fernando *et al.* (2021), an increase in the frequency and impact of extreme weather events such as droughts, floods and wildfires, will likely have effects on labour supply, productivity—particularly in the agricultural and electricity generation sectors—and output growth. Leaving aside the potential human cost of such events, an increase in their frequency is also likely to lead to much greater volatility in output. And, as these events become more frequent, it becomes harder for private insurance to cover firms and households against them. This creates a need for more active fiscal and monetary policy to dampen the effects of such shocks.

2. Transition risks from government policy

We can think of classifying government climate policy—which could be set at the national or international level—into three broad types.[5] The first is direct regulation, which we can think of as the most restrictive type since it limits the use of various inputs or mandates specific performance standards. An example would be, say, an outright ban on the use of coal in energy production. The second type of climate policy—'market-based' policy—is based around economic incentives, such as, for example, through pricing carbon. In turn, this could be done using a 'carbon tax'—that is a tax on the use of fossil fuels—or by a 'cap and trade' system. In the case of a carbon tax, the authority fixes the price of carbon, and lets the quantity of emissions be determined endogenously by agents' choices, whereas in a cap-and-trade system, the authority fixed the maximum amount of emissions, with the carbon price generated endogenously. The third type of climate policy is the 'institutional approach'. Here the idea is to internalise the climate externality via the use of, say, voluntary agreements and information programmes.

[4]The idea here is that there is a trade-off between enjoyable leisure and time spent in unpaid activities that we do not necessarily enjoy. For example, the less time we spend shopping (i.e. greater 'shopping productivity') the more time we spend doing enjoyable non-market activities with the result that welfare is increased.

[5]In this commentary, I shall be concentrating on policies to reduce carbon emissions, though clearly 'climate policy' is much broader, taking in such things as policy designed to reduce biodiversity loss and policies to protect food chains and water systems.

2.1. Regulation

Traditionally, stringent environmental policies are considered a burden to economic activity, at least in the short and medium term. However, there is no clear a priori direction of the effects of these policies on macroeconomic variables such as productivity, employment, trade and GDP. The famous 'Porter hypothesis' (Porter, 1991) suggests that well-designed environmental policies might enhance productivity and increase innovation, and therefore deliver direct economic benefits as well as the environmental ones.

Early studies found that environmental regulations hamper productivity but were based on narrowly defined subindustries within the manufacturing sector. Dechezleprêtre and Sato (2017), in a comprehensive review of the literature, found that environmental regulations can lead to statistically significant adverse effects on trade, employment, plant location and productivity in the short run. This was particularly the case for a well-identified subset of pollution- and energy-intensive sectors. But these impacts were small relative to general trends in production. At the same time, there is some evidence that environmental regulation has led to innovation in clean technologies, but it is not clear that the resulting benefits are large enough to outweigh the increase in costs faced by regulated entities.

2.2. Carbon taxes

Economic theory as first laid out in Pigou (1920) suggests that we should deal with externalities, such as global warming arising from carbon emissions, via a tax on the polluters. In the case of global warming, this means a tax on carbon emissions. But what effect would the imposition of such a tax have on the macroeconomy? The answer depends on whether we take a short, medium or long-run perspective.

In the short run, we would expect the imposition of a carbon tax to have a negative effect on output and labour productivity. Put simply, if you increase the cost of a production input then output can be expected to decline. Where this input—energy—is a complement to other factors of production, you would expect the productivity of those other inputs—such as labour—to fall. Estimates of the short-run elasticity of substitution between labour and energy and, indeed, between different sources of energy, suggest that these are complements in the short run. However, over time you would expect the taxed inputs—that is, fossil fuels—to become more easily substitutable with other untaxed inputs, such as labour and clean energy. Hence, in the medium run, the effects on output and productivity are less clear. In the long run, you might expect investment in clean energy to result in technological change that spilled over into other sectors and, so, raised productivity growth more generally.

Given the relative lack of evidence of the effects of carbon taxes, economists have used three approaches: computable general equilibrium (CGE) models, integrated assessment models (IAMs) and purely empirical models. The key to the IAMs is that, in these models, economic activity leads to climate change and climate change affects economic activity. In many respects, the approach is similar to that of CGE models, the difference being that they capture the dynamic effects of climate change in a way that CGE models do not. Against that, CGE models typically consider many sectors and many countries where IAMs tend to be much simpler in this respect.

Results using CGE models suggest that the output costs of a carbon tax may be relatively low. For example, Goulder and Hafstead (2017) found that imposing a $40 tax per ton of CO_2 in the United States in 2020 and letting it rise at 5 per cent in real terms annually left GDP 1 per cent lower in 2035 than it would otherwise have been. Importantly, as shown by Goulder *et al.* (2019), using a CGE model, carbon taxes have distributional effects as they raise the prices of goods and services bought by poorer households by more than those bought by richer households. This suggests that it is important for the government to offset the regressive impact of a carbon tax by recycling the revenues raised. More generally, the overall effects of the tax on the government's fiscal position and the economy more generally will depend to a large degree on whether and how the government recycles the money raised from the tax.

In contrast to the CGE results, some IAMs suggest that the output costs of a carbon tax could be large. For example, using an IAM, Fernando *et al.* (2021) examine the effects of carbon taxes set at a sufficiently high rate in each country to ensure net zero is achieved in all countries in 2050. They find that imposing such a tax results in large output costs varying from around 2 per cent of GDP in the G7 economies to around 8 per cent in OPEC countries and 10 per cent in Russia, relative to a baseline in which there is no tax. Importantly, the costs of the tax vary across sectors as well as across countries and, also, depend to a large degree on whether and how the government recycles the revenue raised from the tax.

In addition, the costs will depend on the extent to which different countries coordinate in setting carbon taxes. If one country imposes a carbon tax and their trading partners do not, then the country will suffer a competitive disadvantage. Domestic households will switch from relatively more expensive domestic production, which is subject to the tax, towards imports, which are not. Indeed, it could be argued that this has already happened as Western economies have reduced their carbon emissions by allowing high carbon emitting heavy manufacturing industry to migrate to developing economies. One way of dealing with this is the imposition of a carbon border adjustment (CBA), which taxes the carbon content of imports in line with the domestic tax. Arshad *et al.* (2022) examine the consequences of both a coordinated increase in carbon taxes across the world and a trade war resulting from a 'green club' of countries imposing a carbon tax on their domestic production as well as a CBA tax on imports. They find that a sudden and sharp coordinated rise in carbon prices from 2021 to 2025 of between \$130 and \$700 per tonne of CO_2 (depending on the country) leads to a fall in GDP growth of between 1 and 4 per cent in the first 2 years of the simulation. The effects of only a subset of countries imposing the carbon tax depend heavily on the extent to which the 'non-green club' countries impose retaliatory tariffs on the 'green club' as well as how the governments within 'green club' countries use the revenues raised from the carbon tax.

The long-run effects of a carbon tax will depend on the extent to which it encourages substitution to low-carbon technology and whether this switch has spillover effects that lead to faster technical change across the whole economy. Acemoglu *et al.* (2012) show in an endogenous growth model that a carbon tax (i.e. a tax on 'dirty' inputs or equivalently the flow of carbon emissions) can be used to redirect technical change and that such a tax, if combined with research subsidies and as long as the 'dirty' and 'clean' inputs are sufficiently substitutable, can achieve environmental goals without sacrificing much if any long-run growth.

Given the assumptions necessary for the modelling approach, it can be argued that a purely empirical approach might be a better way of assessing the effects of a carbon tax. Metcalf and Stock (2020) suggest that there are plenty of data from countries and regions that have implemented carbon taxes that could be used to do this. In their paper, they use data from 31 European countries and find essentially no evidence that carbon taxes have had a negative effect on GDP growth or employment. Dechezleprêtre *et al.* (2014) found that knowledge spillovers—measured by patent citations—are significantly greater for 'clean' technologies than for 'dirty' technologies and that 'clean' patents tend to be cited by more prominent patents. This provides some empirical support for the Acemoglu *et al.* (2012) results.

2.3. Cap-and-trade

While keeping to the 'market-based' approach, instead of setting the price of carbon emissions via a carbon tax, governments can instead set the quantity of carbon emissions. In a 'Cap and trade' scheme the government sets the maximum quantity of emissions and allows the market to find the price. The EU ETS is the world's first and largest multilateral cap-and-trade system for emissions, setting a cap on total emissions by the installations covered by the system, with the cap being reduced over time.[6] The installations themselves buy, receive and trade emission allowances with each other.

[6]The idea was to set the initial cap at a level slightly below total emissions in the European Union at the time the cap was introduced. However, in the absence of reliable emissions data, the cap was set based on estimates. As a result, the total amount

The effects on output of such a scheme are likely to be similar to those of a carbon tax. Känzig (2022) finds that higher carbon prices in the EU ETS led to a temporary but substantial fall in economic activity while Känzig and Konradt (2023) find that the economic costs of the EU ETS are larger than those of carbon taxes. Against this, however, there is likely to be a positive effect over time on innovation in green technology. Indeed, Calel and Dechezleprêtre (2016) found evidence that the ETS has increased low-carbon innovation among regulated firms by as much as 10 per cent.

3. Transition risks from investment

The transition to a net-zero carbon economy will require near-full electrification of economic activities and a move from using high carbon-emitting capital to low or zero carbon-emitting (green) capital. In turn, this will require large amounts of investment. For example, the UK government (HM Treasury, 2021) calculates that to achieve their net zero ambition, additional investment needs to reach around £50–60 billion per year in the late 2030s, equivalent to a total additional investment amount of around £660–791 billion to the end of 2037. In this section, I consider the effects on the macroeconomy that are likely to arise from this large increase in investment.

Increased investment, in and of itself, should have positive effects on output. And this is particularly important in the United Kingdom, where business investment has been low relative to similar countries for many years. To the extent that low business investment has been one of the causes of low UK productivity growth, we might expect that the increase in investment resulting from the need to 'green' the economy will help to bring us back to more reasonable rates of productivity growth. Of course, as discussed above, in the short run it may be that the investment will be in technology that is relatively inefficient compared with existing technologies based on fossil fuel usage, in which case it will take a while for any increase in productivity growth to appear.

From the point of view of monetary policymakers, though, perhaps the key issue is what effect this investment might have on the natural rate of interest, r^*. Intuitively, we might expect r^* to rise, at least in the short run, as we need to reduce consumption today relative to the future to free up the funds required for investment. Against that, however, we might expect the return on existing capital, powered by fossil fuels, to fall as using such fuels becomes more costly (as a result of a tax or 'cap-and-trade' scheme). We also might expect a temporary slowdown in growth—which acts to reduce r^*—given the negative effects on output caused by the increased cost of inputs discussed above. Which of these effects outweighs the other will depend on how fast the carbon-emitting capital becomes obsolete, how negative are the output effects in the short and medium run, and how fast the new investment can be put in place. It also depends on the extent to which changes in the relationship between investment and savings in the United Kingdom can affect the global real interest rate. For a small open economy, r^* will depend on the relationship between investment and savings at the global level. Of course, if all (or at least most) countries are moving towards net zero, then the effects described above will carry through into r^* at a global level.

In the long run, the effect on global r^* will depend on whether investment in green technology results in spillovers that affect the productivity of other sectors of the world economy. As argued above, there is some evidence for green investment leading to higher growth via spillovers. In this case, we would also expect to see a long-run rise in r^*. If growth were not higher in the long run, then neither would be r^*.

4. Conclusions

In this commentary, I have discussed the implications of climate change and the transition to net zero for the macroeconomy. I considered both physical risks and transition risks, as well as important policy

of allowances issued exceeded emissions and, with supply significantly exceeding demand, in 2007 the price of allowances fell to zero.

https://doi.org/10.1017/nie.2023.18 Published online by Cambridge University Press

questions around the effects of a carbon tax on GDP and the effects of investment in green technology on the natural rate of interest. I should note, though, that the area of climate and the macroeconomy is huge and, for reasons of space, there is much that I did not cover. In particular, I did not consider the issues of climate-induced migration and the possible conflicts and instability that could result. Nor did I consider the issue of biodiversity loss, which is linked to climate change and is likely to amplify its effects, for example, via threatening food chains and water systems.

I found that higher temperatures and more extreme weather events are likely to lead to lower, and more volatile, output. These results provide a strong incentive for governments to move as quickly as possible to net zero. That said, I also found that the transition itself is likely to negatively affect output, at least in the short run where it is hard for firms to switch out of using fossil fuels and into greener technologies. Looking over the medium to longer run, a large increase in investment in new green technologies could lead to higher output and possibly, depending on the degree of spillover from this investment to productivity in other sectors, to higher future output growth.

For this to happen in the United Kingdom, though, investment—both public and private—needs to start increasing, and sooner rather than later. So, maybe the key question for fiscal policymakers is how to finance the required public investment while ensuring that the public finances remain sustainable. One answer is to use the revenue raised via carbon taxes to finance the investment. Alternatively, they will need to raise taxes elsewhere or increase debt (with possible implications for fiscal sustainability) or both. Policymakers at the Bank of England need to consider the implications for financial stability of increased volatility, increased claims on the insurance industry and the possibility of 'stranded assets', as well as the effects of climate change and policy on growth and r^*.

Acknowledgements. Much of the material in this commentary is based on work I have carried out with Sandra Batten and Karen Mayhew at the Bank of England, and I am extremely grateful to them for their input. I should note, however, that the views expressed here are my own and should not be taken to represent those of the Bank of England or any of its Policy Committees. I am also grateful to Jagjit Chadha for his many useful comments.

References

Acemoglu, D., Aghion, P., Bursztyn, L. and Hemous, D. (2012), 'The environment and directed technical change', *American Economic Review*, **102**, pp. 131–66.

Arshad, M., Carlin, D., Holland, D., Hurst, I. and Liadze, I. (2022), 'Economic impacts of climate change: Exploring short-term climate related shocks for financial actors with macroeconomic models', United Nations Environment Programme Finance Initiative.

Batten, S. (2018), 'Climate change and the macroeconomy: A critical review,' Staff working paper no. 706, Bank of England.

Bindoff, N.L., **Stott, P.A.**, **Achuta Rao, K.M.**, **Allen, M.R.**, **Gillett, N.**, **Gutzler, D.**, **Hansingo, K.**, **Hegerl, G.**, **Hu, Y.**, **Jain, S.**, **Mokhov, I.I.**, **Overland, J.**, **Perlwitz, J.**, **Sebbari, R.** and **Zhang, X.** (2013), 'Detection and attribution of climate change: From global to regional,' in Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M. (eds), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge, UK: Cambridge University Press.

Burke, M., Hsiang, S.M. and Miguel, E. (2015), 'Global non-linear effect of temperature on economic production,' *Nature*, **527**, pp. 235–9.

Calel, R. and Dechezleprêtre, A. (2016), 'Environmental policy and directed technological change: Evidence from the European carbon market', *Review of Economics and Statistics*, **98**, pp. 173–91.

Dechezleprêtre, A., Martin, R. and Mohnen, M. (2014), 'Knowledge spillovers from clean and dirty technologies', Working paper no. 135, Grantham Research Institute on Climate Change and the Environment.

Dechezleprêtre, A. and Sato, M. (2017), 'The impacts of environmental regulations on competitiveness', *Review of Environmental Economics and Policy*, **11**, pp. 183–206.

Dell, M., Jones, B.F. and Olken, B.A. (2014), 'What do we learn from the weather? The new climate–economy literature,' *Journal of Economic Literature*, **52**, pp. 740–98.

Diebold, F.X. and Rudebusch, G.D. (2022), 'On the evolution of US temperature dynamics' in Essays in honor of M Hashem Pesaran: Prediction and macro modelling', *Advances in Econometrics*, **43**, pp. 9–28.

Fernando, R., Liu, W. and McKibbin, W.J. (2021), 'Global economic impacts of climate shocks, climate policy and changes in climate risk assessment', Working paper no. 37/2021, Centre for Applied Macroeconomic Analysis.

Goulder, L. and Hafstead, M. (2017), *Confronting the Climate Challenge: US Policy Options*, New York: Columbia University Press.

Goulder, L.H., Hafstead, M.A.C., Kim, G.-R. and Long, X. (2019), 'Impacts of a carbon tax across US household income groups: What are the equity-efficiency trade-offs?', *Journal of Public Economics*, **175**, pp. 44–64.

Heal, G. and Park, J. (2015), 'Goldilocks economies? Temperature stress and the direct impacts of climate change', Working paper no. 21119, National Bureau of Economic Research.

HM Treasury (2021), *Net Zero Strategy: Build Back Greener*.

Känzig, D.R. (2022), 'The unequal economic consequences of carbon pricing', Working paper no. 31221, National Bureau of Economic Research.

Känzig, D.R. and Konradt, M. (2023), 'Climate policy and the economy: Evidence from Europe's carbon pricing initiatives', Working paper no. 31260, National Bureau of Economic Research.

Metcalf, G.E. and Stock, J.H. (2020), 'The macroeconomic impact of Europe's carbon taxes', Working paper no. 27488, National Bureau of Economic Research.

Pigou, A. (1920), *The Economics of Welfare*, London: Macmillan and Co.

Porter, M. (1991), 'America's green strategy', *Scientific American*, **264**, p. 168.

Roth Tran, B. (2019), '"Sellin" in the rain: Adaptation to weather and climate in the retail sector', Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2019-067.

Starr-McCluer, M. (2000), 'The effects of weather on retail sales', Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 2000-08.

Stott, P.A. (2016), 'How climate change affects extreme weather events', *Science*, **352**, pp. 1517–8.

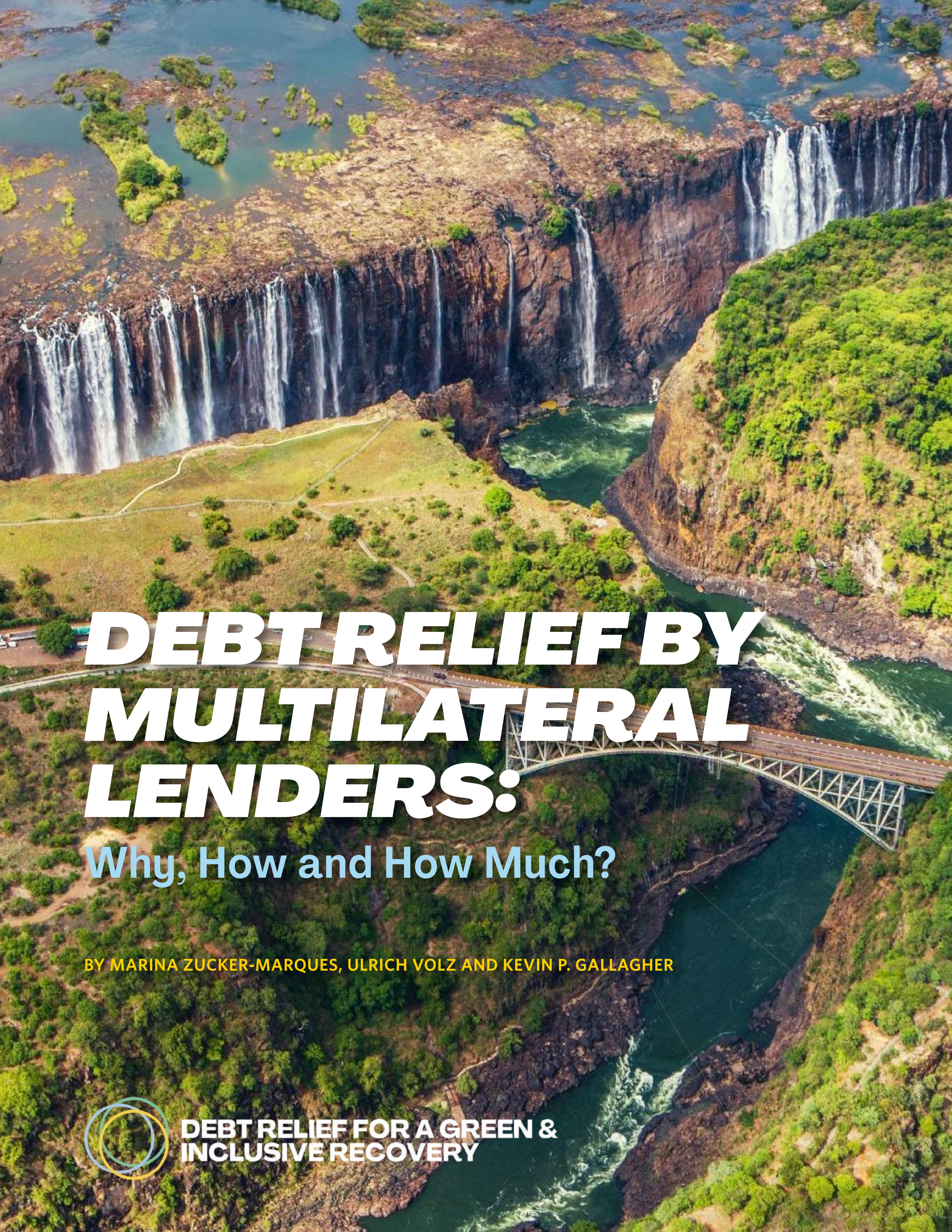
Stott, P.A., Christidis, N., Otto, F.E.L., Sun, Y., Vanderlinden, J.P., van Oldenborgh, G.J., Vautard, R., von Storch, H., Walton, P., Yiou, P. and Zwiers, F.W. (2016), 'Attribution of extreme weather and climate-related events', *WIREs Climate Change*, **7**, pp. 23–41.

Zhang, X., Wan, H., Zwiers, F.W., Hegerl, G.C. and Min, S.-K. (2013), 'Attributing intensification of precipitation extremes to human influence', *Geophysical Research Letters*, **40**, pp. 5252–7.

Cite this article: Millard, S. (2023), 'Macroeconomics and climate change', *National Institute Economic Review*, **264**, pp. 1–7. https://doi.org/10.1017/nie.2023.18

Annex 557

M. Zucker-Marques et el., "Debt Relief by Multilateral Lenders: Why, How and How Much?", *Boston University Global Development Policy Centre, Centre for Sustainable Finance SOAS University of London and Heinrich-Böll-Stiftung*, 2023, pp. 1-67



DEBT RELIEF BY MULTILATERAL LENDERS:

Why, How and How Much?

BY MARINA ZUCKER-MARQUES, ULRICH VOLZ AND KEVIN P. GALLAGHER

DEBT RELIEF FOR A GREEN & INCLUSIVE RECOVERY

DEBT RELIEF BY MULTILATERAL LENDERS:

Why, How and How Much?

BY MARINA ZUCKER-MARQUES, ULRICH VOLZ AND KEVIN P. GALLAGHER

SUGGESTED CITATION

Zucker-Marques, M., Volz, U. and Gallagher, K.P. (2023). Debt Relief By Multilateral Lenders. Why, How and How much? Boston, London, Berlin: Boston University Global Development Policy Center; Centre for Sustainable Finance, SOAS, University of London; Heinrich-Böll-Stiftung.

THE AUTHORS

Marina Zucker-Marques is a postdoctoral researcher in the Debt Relief for a Green and Inclusive Recovery project at SOAS, University of London.

Ulrich Volz, Professor of Economics and Director of the Centre for Sustainable Finance at SOAS, University of London; Senior Research Fellow at the German Institute of Development and Sustainability; and Visiting Professor at the London School of Economics and Political Science

Kevin P. Gallagher, Professor of Global Development Policy at the Frederick S. Pardee School of Global Studies and Director of the Boston University Global Development Policy Center

ACKNOWLEDGEMENTS

We thank Yan Wang, Brendan Harnoys-Vannier and Théo Marret for their feedback on an earlier version of this report. We also thank Maureen Heydt, Samantha Igo, and Sarah Ribbert for their support on communications and coordination. This report has been written with the input and guidance of the DRGR Co-Chairs, however, any shortcomings and errors are solely the writing team's.

ABOUT

A debt crisis is emerging in the Global South at the precise moment when substantial investment is needed to meet shared climate and development goals. Yet, the G20 Common Framework has been unable to engage all creditor classes or link debt relief to climate and development. The Debt Relief for Green and Inclusive Recovery (DRGR) Project, a collaboration between the Boston University Global Development Policy Center, Heinrich-Böll-Stiftung and the Centre for Sustainable Finance at SOAS, University of London, argues it is time for comprehensive debt reform. Utilizing rigorous research, DRGR seeks to develop systemic approaches to both resolve the debt crisis and advance a just transition to a sustainable, low-carbon economy in partnership with policymakers, thought leaders and civil society from around the world.

PROJECT CO-CHAIRS

Shamshad Akhtar, Former Governor of the State Bank of Pakistan and Finance Minister of Pakistan

María Fernanda Espinosa, Politician, Diplomat and Human Rights Advocate

Kevin P. Gallagher, Professor of Global Development Policy at the Frederick S. Pardee School of Global Studies and Director of the Boston University Global Development Policy Center

Jörg Haas, Head of International Politics at the Heinrich-Böll-Stiftung

Yuefen Li, Senior Advisor on South-South Cooperation and Development Finance at South Centre

Ulrich Volz, Professor of Economics and Director of the Centre for Sustainable Finance at SOAS, University of London; Senior Research Fellow at the German Institute of Development and Sustainability; and Visiting Professor at the London School of Economics and Political Science

BU Global Development Policy Center

HEINRICH BÖLL STIFTUNG

Centre for Sustainable Finance
SOAS University of London

DR GR

ABBREVIATIONS

ADB	Asian Development Bank
AfDB	African Development Bank
AFESD	Arab Fund for Economic and Social Development
CAF	Development Bank of Latin America and the Caribbean
CCRT	Catastrophe Containment and Relief Trust
COP21	21st Conference of the Parties
CoT	Comparability of Treatment
DSSI	Debt Service Suspension Initiative
EIB	European Investment Bank
EMDEs	Emerging market and developing economies
FTT	Financial transaction tax
G20	Group of 20
HIPC	Heavily Indebted Poor Countries Initiative
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IDB	Inter-American Development Bank
IFI	International financial institution
IFTT	International financial transaction tax
IMF	International Monetary Fund
LIC	Low-income country
MAC	Market Access Countries
MDB	Multilateral development bank
MDRI	Multilateral Debt Relief Initiative
NCF	New Common Framework countries
NPV	Net present value
NV	Nominal value
ODA	Official development assistance
PCDR	Post-Catastrophe Debt Relief Trust
PPG	Public and publicly guaranteed
PRGT	Poverty Reduction and Growth Trust
PV	Present value
SDGs	Sustainable Development Goals
SDRi	Special Drawing Rights interest rate
SDRs	Special Drawing Rights
SIDS	Small Island Developing States
UNDP	United Nations Development Programme

TABLE OF CONTENTS

EXECUTIVE SUMMARY

As the sovereign debt crisis in the Global South continues to unfold, the lack of involvement of multilateral development banks (MDBs) in debt relief efforts has become a contentious issue among major creditors. Although the Group of 20 (G20) has explicitly called for MDBs to develop options to share the burden of debt relief efforts, MDBs have not presented any concrete and systemic plan thus far on how to contribute to debt relief efforts to countries applying for the G20 Common Framework. Combined with other points of dispute, the ongoing negotiations within the Common Framework have yielded disappointing results with little to no substantial debt relief provided despite protracted discussions.

This report aims to contribute to the ongoing debate over debt relief negotiations and MDBs in three main areas. First, we assess whether there are compelling reasons for including multilateral lenders in debt relief, considering the point of view of debt-vulnerable developing countries, the efficiency of current debt relief negotiations and the sustainability of MDBs' operational model. Second, we estimate the adequate level of relief MDBs should provide should they partake in debt restructuring, considering the high levels of concessional lending they provide, which can be considered "ex ante" debt relief. Finally, bearing in mind the importance of maintaining MDBs' preferred creditor status and high credit ratings for a low cost of funding, we discuss policy options to cover MDBs losses. Our suggestions draw on historical experiences of MDB involvement in debt relief (the Heavily Indebted Poor Countries Initiative and the Multilateral Debt Relief Initiative), as well as emerging opportunities.

We argue there are four reasons to include MDBs in debt relief. First, debt-vulnerable countries rely substantially on these lending institutions. Second, providing debt relief is aligned with MDB goals and mandates, including achieving the UN 2030 Sustainable Development Goals (SDGs) and the Paris Agreement. Third, from the inception of the Common Framework, MDBs were explicitly requested by the G20 to be involved in relief efforts. The participation of MDBs allows for equitable distribution of the burden among creditors, thereby mitigating the perception of unfairness. Fourth, the prolongment of a debt crisis in the Global South is costly to MDBs, as their rules require them to increase the concessional/grant element as debt distress indicators of their most vulnerable countries deteriorate.

We find that MDB participation in debt restructuring could help unlock a multifold amount of relief by other creditors where debt relief would have greater leverage than new lending.

Main findings:

- For 61 countries identified as being in or at high risk of debt distress to achieve debt sustainability, we estimate more than $781 billion in debt (net present value) needs to be restructured across all creditor classes.
- Using a range of historical precedents for the size of relief needed (a reduction from 39 percent to 64 percent of net present value), we estimate that haircuts will have to amount to between $305 billion to $500 billion.
- The contribution of MDBs to the debt relief efforts can be less burdensome by adopting a "fair" comparability of treatment rule instead of a "flat" rate of debt relief.
- If all creditors of these 61 countries reduced their present value claims by the same proportion, the World Bank International Development Association (IDA) would bear $20 billion to $32 billion in losses. But under a "fair" comparability of treatment rule, IDA's contribution would account for only $3.5 billion to $23 billion, depending on the overall debt haircut needed by debtor countries.
- Considering the "fair" comparability of treatment, other MDBs (excluding IDA) would need to contribute between $33 billion and $75 billion, instead of $53 billion to $87 billion under a flat rate treatment.
- If all creditors were to participate in the debt restructuring of 61 countries in debt distress with an overall debt reduction of 39 percent, each dollar contributed by donors for debt relief through MDBs would translate into an additional $7 of total debt relief for countries in debt distress. This proportion exceeds average MDBs equity-to-loan leverage.

Key policy recommendations:

- All creditors, including MDBs, should participate in debt relief efforts and accept losses on their outstanding claims under a comparability of treatment rule that incorporates the cost of lending and concessionary elements.
- To compensate MDB losses, MDBs shareholders should:
    - **Revamp and expand existing debt relief initiatives:** Donor countries should contribute to a new round of debt relief through funds like the Debt Relief Trust Fund, which pools resources from donors and international financial institutions, and consider making debt relief

a regular component of concessional finance policies, with a dedicated portion of funding in each IDA replenishment specifically allocated to debt relief efforts.

- **Consider increasing MDB equity:** Explore avenues for increasing the equity of MDBs so that precautionary balances could be freed up and used partially for debt relief efforts without negatively impacting the institutions' credit ratings.
- **Revive efforts to establish an international financial transaction tax (IFTT):** While politically challenging, a well-designed IFTT on various financial transactions could generate substantial revenues, which could be directed toward MDBs to support debt relief and other development efforts. However, careful consideration is needed to avoid double taxation on private sector debt holders.

Including MDBs in debt relief is crucial to effectively addressing the mounting debt crisis in the Global South. Equitable burden-sharing among creditors is imperative to foster a fair and transparent process that encourages the participation of all stakeholders. While there are costs associated with providing debt relief, it is a prudent investment for the long-term stability and development of debt-vulnerable nations. Implementing policy options to support MDBs in shouldering these costs will be key to ensuring a sustainable future.

INTRODUCTION

Despite the worsening debt situation in developing countries, the ongoing debt relief negotiations within the Group of 20 (G20) Common Framework have yielded disappointing results. As of the writing of this report, there have been protracted discussions, but little to no substantial debt relief has been provided. One particularly contentious issue throughout the negotiations is the undecided participation of multilateral development banks (MDBs). The G20 has called on MDBs "to develop options for how best to help meet the longer term financing needs of developing countries, including by drawing on past experiences to deal with debt vulnerabilities such as domestic adjustment, net positive financial flows and debt relief," with explicit reference to past debt relief under the Heavily Indebted Poor Countries (HIPC) Initiative and the Multilateral Debt Relief Initiative (MDRI) (G20 and Paris Club 2020). However, views on this matter have been sharply divided. On one side, developed nations, including the United States and European countries, as well as institutions like the International Monetary Fund (IMF) and the World Bank, are resistant to the idea of MDBs incurring any losses. In contrast, China has consistently advocated for the involvement of MDBs, although there have been reports of a flexibilization in their stance during the 2023 IMF/World Bank Group Spring Meetings ("IMF's Georgieva Discusses" 2023; Cash 2023; G20 2020; van Staden 2023).

The resistance to MDBs participating in debt relief can be attributed to three main factors. First, it is argued that if MDBs absorbed losses, it would risk their preferred creditor status, an acknowledged practice to prioritize MDB repayment over other lenders. Accepting losses, it is argued, would adversely affect MDBs' credit rating, leading to increased borrowing costs that would ultimately be passed on to borrowing countries. While this risk could be eliminated by contributions from donor countries, there is often little willingness among advanced nations – the main shareholders of MDBs – to cover MDBs' losses.

Second, it is emphasized that MDBs' lending rates are significantly lower than commercial lending, and that a portion of their loans are often provided as grants that do not require repayment. From this perspective, MDBs argue that they already provide "ex-ante" debt relief and should not bear additional losses.

Lastly, MDBs highlight that their business operations are designed to be countercyclical as they provide financing even during crises. Instead of receiving debt write-offs from MDBs, developing countries could benefit more from fresh flows of funding, including increased grants and higher concessionary financing terms. Although MDBs' lending patterns differ significantly from private flows, which strongly respond to fluctuations in business cycles, it is not always countercyclical. Except for World Bank lending, whose lending is often countercyclical, lending from regional development banks can be described as acyclical at best (Galindo & Panizza 2018). Moreover, given the funding constrains and the impediments to expand MDB balance sheets, the promises that by avoiding write-offs MDB lending could increases in the coming years should be taken with caution.

Despite the arguments against the involvement of MDBs in debt relief, from the point of view of debt-vulnerable developing countries, there are compelling reasons for including these creditors in debt relief negotiations. This report contributes to this discussion, giving special attention to a group of 69 countries referred to as the New Common Framework (NCF) countries, which have been identified by the IMF and the United Nations Development Programme (UNDP) as having unsustainable levels of sovereign debt and needing debt relief (see Annex 1 for the list of countries) (Ramos et al. 2023).[1] Due to lack of data availability, in this report we restring our analysis to a sample of 61 countries. Given the imminent need to ramp up investments for green and inclusive development to achieve the UN 2030 Sustainable Development Goals (SDGs) and make economies more resilient against climate change, it is key that a broad range of countries benefit from a fair level of debt relief in order to increase their fiscal space. This report estimates the cost of MDB debt relief considering different approaches of comparability of treatment and proposes policy options to include MDBs in debt relief without harming their credit ratings and compromising their ability to raise capital at favorable rates.

The report is structured as follows. Section 2 discusses the case for involving MDBs in debt relief. Section 3 considers approaches to ensure comparability of treatment among different creditors, considering the respective financing terms, and provides estimates of losses that creditors would face under different scenarios. Section 4 subsequently discusses how losses of MDBs can be covered by their shareholders. Section 5 addresses the trade-offs between granting debt relief by MDBs and providing new MDB financing. Section 6 concludes with key policy recommendations.

1 The selection of these 69 countries is based on Ramos et. al (2023), who identified a group of countries that are either classified by the UNDP or the IMF as debt vulnerable. This comprises countries that were categorized by the IMF's recent Debt Sustainability Analyses as being in "high risk" of debt distress or in debt distress. From the UNDP, it includes all low- and middle-income countries that have a numeric credit rating under six or countries with sovereign bond spreads more than ten percentage points against US Treasury bonds.

THE CASE FOR MDB INVOLVEMENT

There are several political and economic reasons why it is crucial to consider the role of MDBs in the process of debt renegotiations. First, debt-vulnerable countries have a substantial reliance on these lending institutions. Second, providing debt relief is aligned with MDBs' goals and mandates, including achieving the SDGs and the Paris Agreement. Third, from the inception of the Common Framework, MDBs were explicitly requested by the G20 to be involved in relief efforts. The participation of MDBs allows for equitable distribution of the burden among creditors, thereby mitigating the perception of unfairness. Fourth, the prolongment of a debt crisis in the Global South is costly to MDBs, as their rules require them to increase the concessional/grant element as debt distress indicators of their most vulnerable countries deteriorate.[2] Lastly, the involvement of MDBs can facilitate the negotiation process and enhance debt restructuring for all creditor classes, ultimately leading to a more effective reduction of the overall debt burden. Including MDBs in debt negotiations can not only bring benefits to debt-vulnerable countries, but it can also have positive aspects for MDBs and their shareholders.

MULTILATERAL LENDERS AS KEY CREDITORS OF DEBT-VULNERABLE COUNTRIES

The first and main reason for including MDBs in the debt renegotiation is the size of exposure to these creditors. Considering the 61 NCF countries for which data is available, altogether they have an external public and publicly guaranteed (PPG) debt stock of $992 billion (at nominal value, NV),[3] of which 29 percent is owed to MDBs and 11 percent to the IMF. Debt stock from the World Bank International Development Association (IDA) alone – the soft loan window of the World Bank Group for low-income countries – represents $84 billion, or 8 percent of their total debt stock, which is even higher than debt stock from Paris Club countries ($76 billion). Apart from IDA, other key multilateral creditors to NCF countries are the World Bank Group's International Bank for Reconstruction and Development (IBRD) ($47 billion, or 5 percent), the Inter-American Development Bank (IDB) ($26 billion, or 3 percent), the African Development Bank (AfDB) ($26 billion, or 3 percent) and the Asian Development Bank (ADB) ($26 billion, or 3 percent).

2 Grant elements and concessionality rates are equivalent terms (Scott, 2017).

3 Excluding IMF credits, the total external PPG debt stock (face value) accounts for $879.2 billion, of which is equivalent to $781 billion in present value.

Figure 1: New Common Framework Countries, Public External Debt Stock Composition in 2021, in billions (at nominal value)

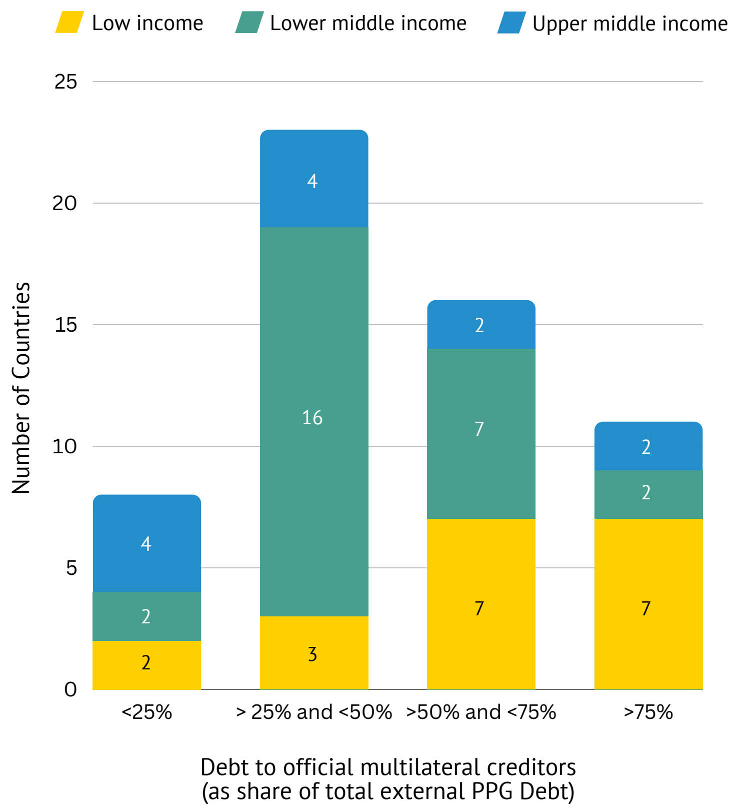
Source: Compiled with data from World Bank IDS 2022 and Ramos et al. (2023).

Note: IDA (International Development Association), IBRD (International Bank for Reconstruction and Development), IDB (Inter-American Development Bank), AfDB (African Development Bank), ADB (Asian Development Bank), EIB (European Investment Bank), CAF (Development Bank of Latin America and the Caribbean), AFESD (Arab Fund for Economic and Social Development), NCF (New Common Framework Countries).

The level of exposure to multilateral official lenders, including MDBs and the IMF, varies among countries, as shown in Figure 2a. For 27 debt-vulnerable countries, multilateral official lenders own at least half of their debt stock. This means that if the IMF's and MDBs' credit are excluded, these debtor countries would only have a limited portion of their total external debt available for restructuring. Consequently, even if bilateral and private debts were completely canceled, these countries may still face ongoing debt vulnerability. As Viterbo (2020) points out, excluding a high share of debt from restructuring would defeat the purpose of an international debt restructuring altogether. As she puts it, international debt restructuring aims "to give it a 'fresh start' that enables [the debtor country] to return to the path of economic growth in the long run. This is possible if, and only if, a significant portion of its total external debts is restructured" [emphasis added]. Moreover, as Figure 2a shows, given the higher exposure of low-income countries (LICs) to MDB lending, excluding MDBs from debt renegotiation would disproportionally affect the poorest nations. Of the 11 countries with over 75 percent of debt stock owned by multilateral lenders, seven are LICs. Moreover, there are eight Small Island Developing Economies (SIDs) with debt stock to MDBs or the IMF above 50 percent (Figure 2b).

Figure 2: Debt Stock Exposure of New Common Framework Countries to Official Multilateral Creditors by Income Group, as a Share of Total Official Outstanding Debt (December 2021)

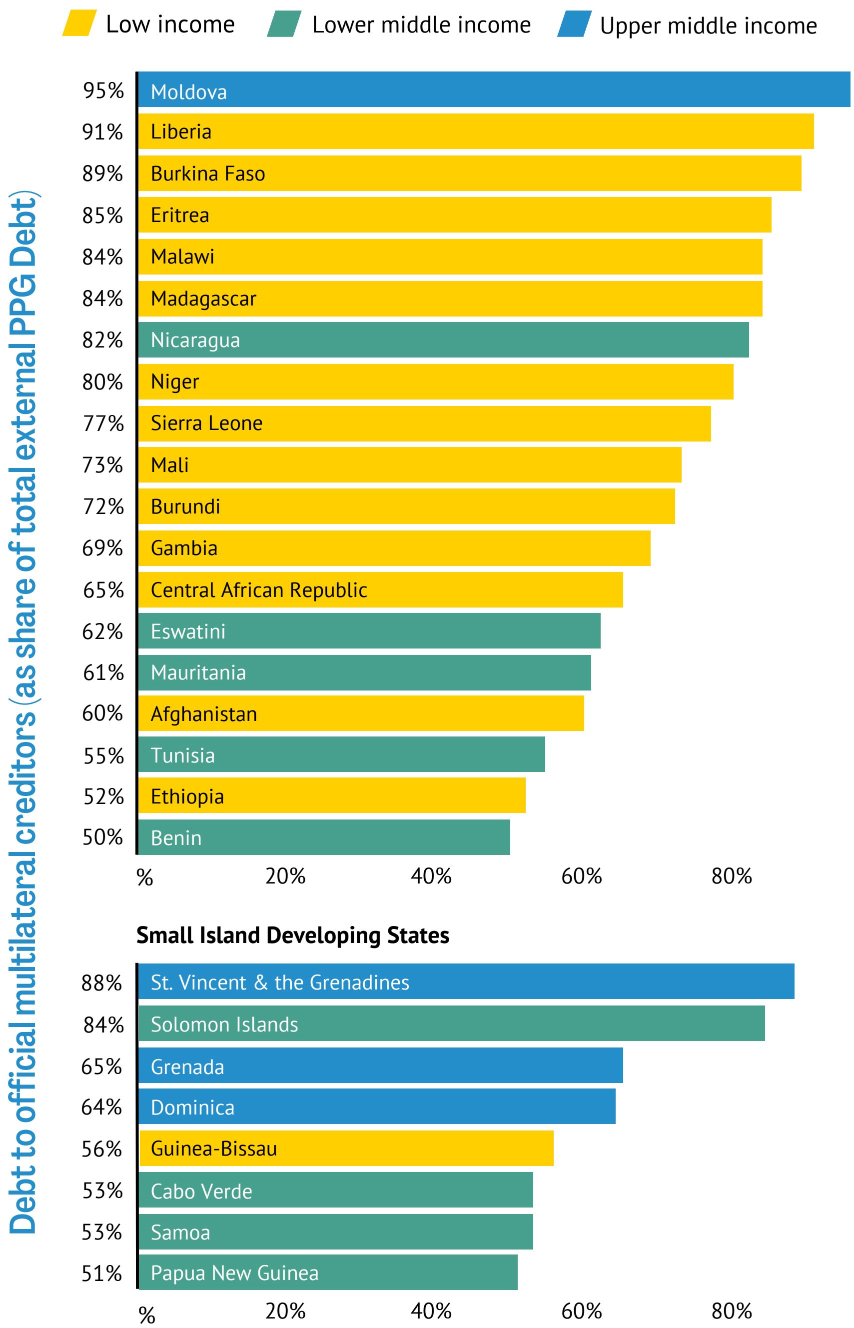
2a. Number of countries: up to 25%, between 25% and 50%, between 50% and 75%, above 75%



Source: Own elaboration based on WB IDS 2022. OBS. Income group as per 2022 WB classification

Note: Figure includes credits to the International Monetary Fund.

2b. Countries with debt stock to multilateral lenders above 50%



Source: Own elaboration based on WB IDS 2022. OBS. Income group as per 2022 WB classification

Note: Figure includes credits to the International Monetary Fund.

PROVIDING DEBT RELIEF IS ALIGNED WITH MDBS GOALS AND MANDATES

Including multilateral lenders in debt relief efforts would reinforce their core mandate of promoting economic development and poverty reduction, which is the second reason why they should participate in debt restructuring. To date, the HIPC Initiative from 1996, followed by the MDRI, were the largest debt relief programs implemented jointly by MDBs and the IMF. Although they cost multilateral creditors about $78 billion (in present value terms as of end-2017, $34 billion under HIPC and $44 billion under MDRI), studies suggest that such debt relief effort positively contributed to poverty reduction, public investments (Cassimon et. al 2015; Djimeu 2018) and growth (Hussain & Gunter 2005; Siddique et al. 2016) in developing countries.

MDBs are committed to the SDGs and the Paris Agreement[4] (AfDB et al. 2020), and they can reinforce their commitments not only by providing new lending but also through debt relief, as it would improve governments' fiscal space to spend on climate and development goals. Moreover, involving international financial institutions (IFIs) in debt renegotiation is compatible with the UN's *Guiding Principles on Foreign Debt and Human Rights*, according to which "[t]he renegotiation and restructuring [of sovereign debt] should be conducted in good faith and should cover all types of external debts owed to all types of external creditors, *including international financial institutions*" [emphasis added].[5]

FAIR BURDEN SHARING AND CONTRIBUTING TO THE G20 COMMON FRAMEWORK

A third reason for the involvement of multilateral lenders relates to a cornerstone of debt negotiations, which is "fair burden sharing." This principle posits that different creditors bear an equitable distribution of losses considering their exposure to risk, the terms of the loans and the creditor's financial capacity. At its inception in 2020, the G20 Common Framework has

4 Since 2015, during the 21st Conference of the Parties (COP21), a consortium of MDBs has expressed their support for the implementation of the outcomes of the Paris Conference. The COP21 declaration includes the African Development Bank Group, the Asian Development Bank, the European Bank for Reconstruction and Development, the European Investment Banks, the Inter-American Development Bank Group, and the World Bank Group (IFC, MIGA, World Bank). In recent declarations, the following MDBs also included the Asian Infrastructure Investment Bank, the Council of Europe Development Bank, the Islamic Development Bank, and the New Development Bank.

5 HRC, Guiding Principles on Foreign Debt and Human Rights (A/HRC/20/23), para 54.

mentioned the involvement of MDBs in debt negotiations within the section of "Comparability of Treatment with Other Creditors":

> *"Multilateral Development Banks will develop options for how best to help meet the longer-term financing needs of developing countries, including by drawing on past experiences to deal with debt vulnerabilities such as domestic adjustment, net positive financial flows and debt relief, while protecting their current ratings and low cost of funding" (G20 and Paris Club 2020, emphasize added).*

And although the G20 document mentions the lack of consensus on specifics regarding debt relief efforts, other previous experiences of MDB debt relief are referred to in the text:

> *"Different options were used in the past to deal with debt vulnerabilities, including domestic adjustment, increased net positive inflows or debt relief including through schemes such as the Heavily Indebted Poor Countries (HIPC) initiative and the Multilateral Debt Relief Initiative (MDRI). There is currently no consensus on how these previous options might apply to current circumstances" (G20 and Paris Club 2020).*

Recently, during the 2023 BRICS summit in Johannesburg II, BRICS member countries reinforced the importance of fair-burden sharing among all creditor classes within the Common Framework:

> *"One of the instruments, amongst others, to collectively address debt vulnerabilities is through the predictable, orderly, timely and coordinated implementation of the G20 Common Framework for Debt Treatment, with the participation of official bilateral creditors, private creditors and Multilateral Development Banks in line with the principle of joint action and fair" (BRICS 2023).*

As of today, MDBs have not developed a concrete and systematic approach on how to contribute to burden sharing under Common Framework restructurings. There was ad hoc involvement in the case of Zambia from the World Bank and the AfDB. However, in the case of the AfDB, new commitments account for merely $300 million for the period 2022-2025, which is lower than the average commitment the AfDB made over the past decade

(2012-2021).[6] In the case of the World Bank, new commitments for the period 2022-2025 amount to $1.4 billion. Although this is higher than its historical commitment to Zambia, only $175 million is in the form of grants (IMF 2023b). Despite these issues with AfDB and World Bank participation in the case of Zambia, there no indication that a similar pattern of involvement will be replicated in other cases.

The abstention of MDBs from debt restructuring in a systematic manner conveys an impression of unfairness and raises free-riding concerns to participating creditors. This perception can increase the resistance of other creditors to joining debt negotiations, making the overall process more challenging. For instance, MDBs are not the only financial institutions that have concerns over credit rating downgrades and funding costs when providing debt relief to their clients. Granting special treatment on these grounds sets a precedent for private creditors, who have their own unique concerns and financial limitations, to justify their exclusion from debt relief efforts (Rhodes & Lipsky 2023). Although credit ratings and funding concerns often set MDBs apart from other official lenders, the increasing complexity of the debt structure needs to be acknowledged and how exceptions can risk the success of the entire debt restructuring effort.

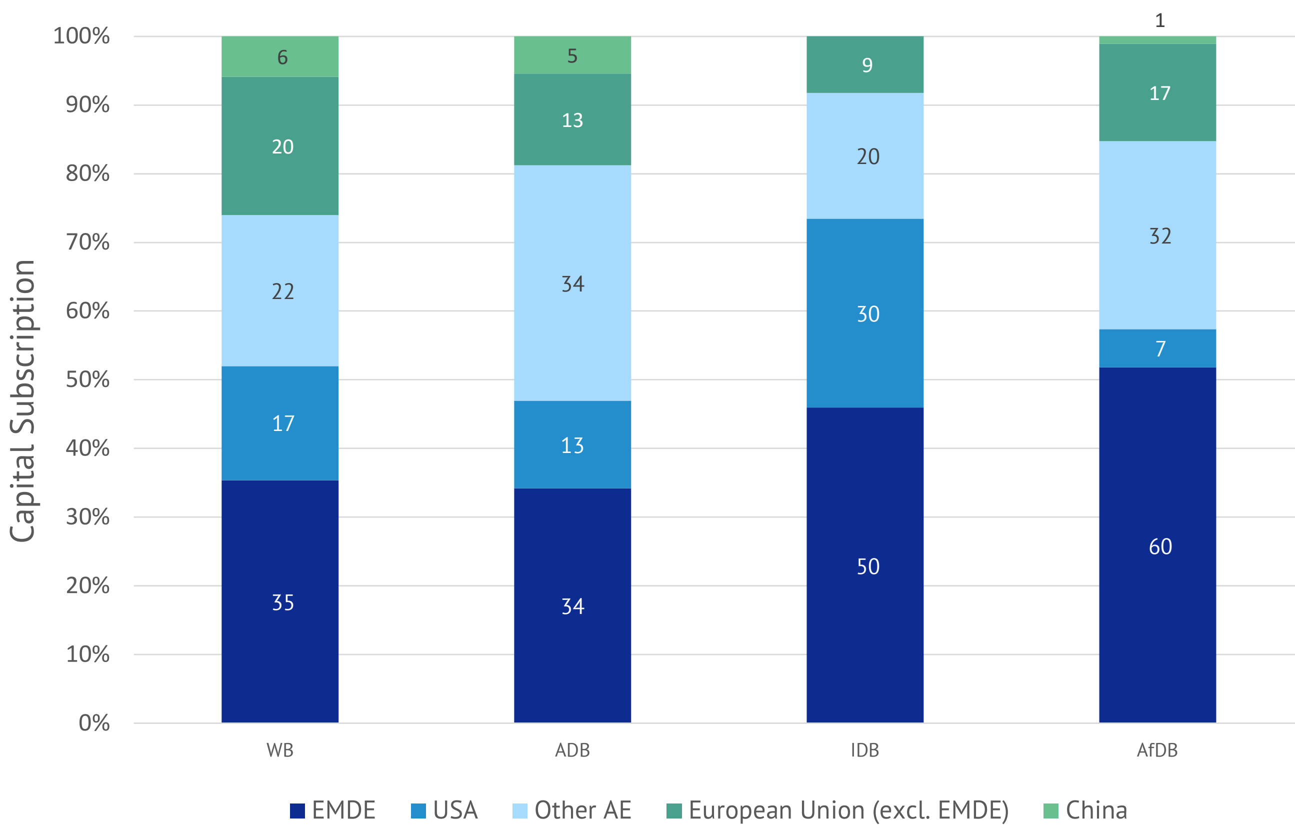
Another example concerns the recent involvement of China in debt negotiation: Brautigam and Huang (2023) note that the unequal participation of creditors in the G20 Debt Service Suspension Initiative (DSSI, valid between May 2020-December 2021) has generated an unfair impression to Chinese official lenders, which later reinforced Chinese demands for full creditor participation under the G20 Common Framework. Under the DSSI, private creditors were called to participate without any incentives (and on a voluntary basis), and MDBs were requested to "explore options," which left the *de facto* responsibility of providing support to poor nations only to official lenders. China was the largest contributor under the DSSI. Chinese participation accounted for 63 percent of all standstills, even though Chinese creditors held only 30 percent of debt service claims (Brautigam and Huang 2023). It should be noted, however, that MDBs contributed to the crisis responses to the COVID-19 pandemic by frontloading lending and increasing net flows to poor countries. However, the refusal of MDBs to participate in the DSSI and suspend debt payments generated an impression of unfairness.

6 The AfDB did not commit any resources in 2022 and 2025 but plans to disburse $150 in 2024 and another $150 in 2025 (IMF 2023). Between 2012 and 2012, on average AfDB committed $97 million per year according to data from WB IDR (2022).

According to Mingey and Wright (2023), China's total sovereign debt claims under negotiation between January 2020-March 2023 amount to over $78 billion, including both principal and deferred income. During the same period, China granted 16 write-offs to African nations, totaling $231 million.

Another issue that creates a perception of unfairness is related to the shareholder structure of large MDBs. Taking the World Bank as an example, although it has 189 members, the total subscription is concentrated in advanced economies, which together hold 59 percent of the subscribed capital. The largest shareholder is the United States, with 16.4 percent of subscribed capital. A similar distribution is found in other large MDBs, like the ADB, IDB and AfDB (see Figure 3). In that sense, the non-participation of MDBs may be interpreted as a bailout from creditors involved in debt relief efforts – including emerging market and developing economies (EMDEs) – to advanced economies that are the MDBs' main shareholders.

Figure 3: Capital Subscription of World Bank IBRD, Asian Development Bank, Inter-American Development Bank, African Development Bank

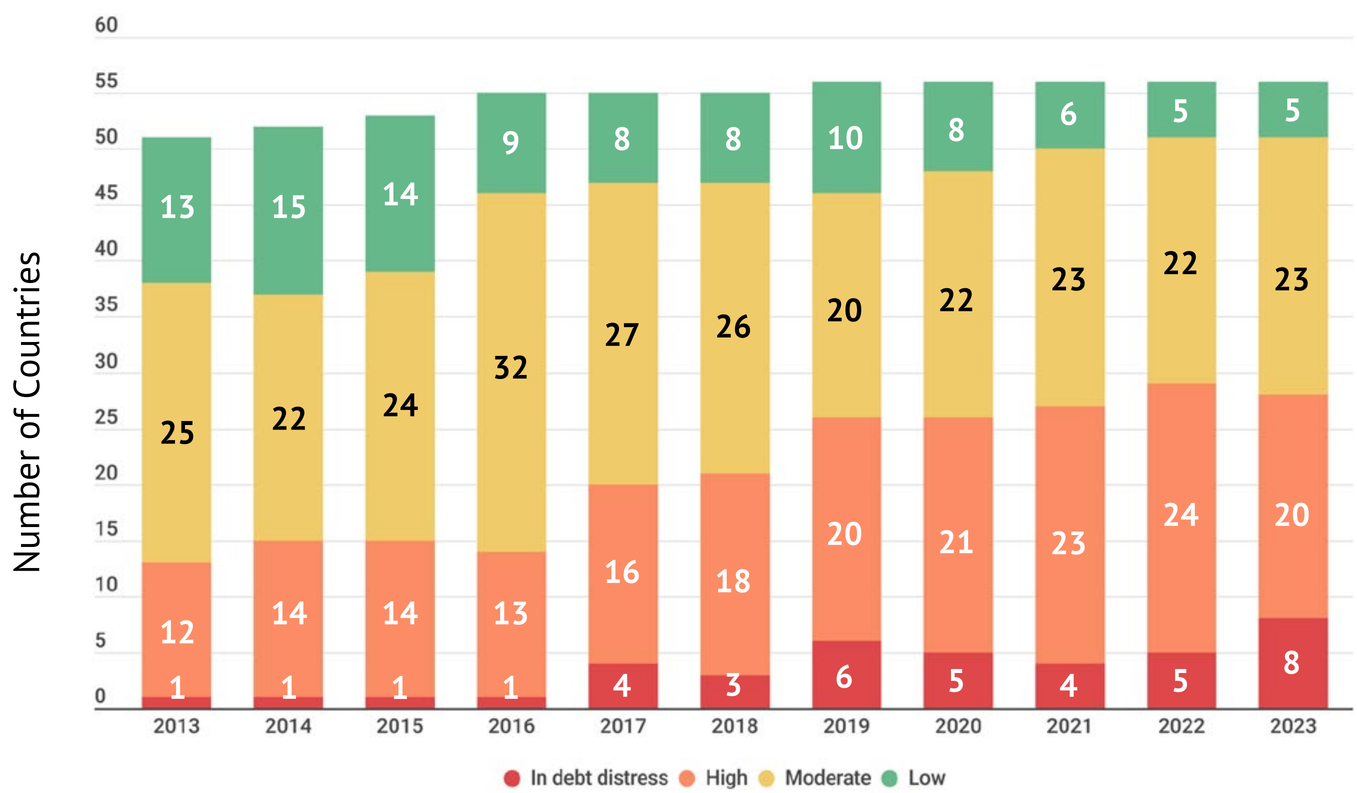


Source: Own elaboration based on WB (2023), IDB (2023), AfDB (2022), ADB (2018).

A PROLONGMENT OF A DEBT CRISIS IN THE GLOBAL SOUTH IS COSTLY TO MDBs

A fourth reason for the involvement of MDBs is that prolonging a debt crisis in the Global South is costly for MDBs. As part of their concessional policies, MDBs consider the debt distress classification of their clients – as per IMF/World Bank debt sustainability analyses – to determine the proportion of grants and credits. For instance, IDA adopts a "traffic light" system. Countries that are only eligible to IDA and are at high risk or in debt distress (red light) can benefit from 100 percent grants, medium-risk countries (yellow light) from 50 percent, while low-risk countries (green light) cannot benefit from grants and receive 100 percent of IDA credit (World Bank 2007; World Bank 2023). Similar policies are followed by the concessional window of other MDBs, including the AfDB, IDB and ADB (AfDB 2019; ADB 2021; IDB 2023).

Figure 4: Number of IDA-only Countries by Debt Distress Classification, as per IMF/World Bank Debt Sustainability Framework, 2013-2023



Source: IMF Debt Sustainability Analysis List for LICs PRGT eligible countries.

Note: Data from 2023 (May) is currently available at the IMF website, but earlier lists retrieved from Internet Archive website. Data available: November 2013, August 2014, January 2015, April 2016, September 2017, January 2018, November 2019, September 2020, June 2021, August 2022 and May 2023. DSA classification is not available for some IDA-only countries.

Considering debt distress indicators when allocating grants are viewed positively by client countries for maintaining their debt sustainability and avoiding debt overhangs. But once many of the MDBs' clients are in debt distress, a policy of providing grants considering debt distress indicators brings substantial cost to MDBs. As Figure 4 shows, between 2013-2023, the number of IDA-only eligible[7] countries that could benefit from 100 percent grants (red light, with high risk or in debt distress) increased from 13 to 28. As of May 2023, only five IDA-only eligible countries do not receive grants related to debt distress indicators.

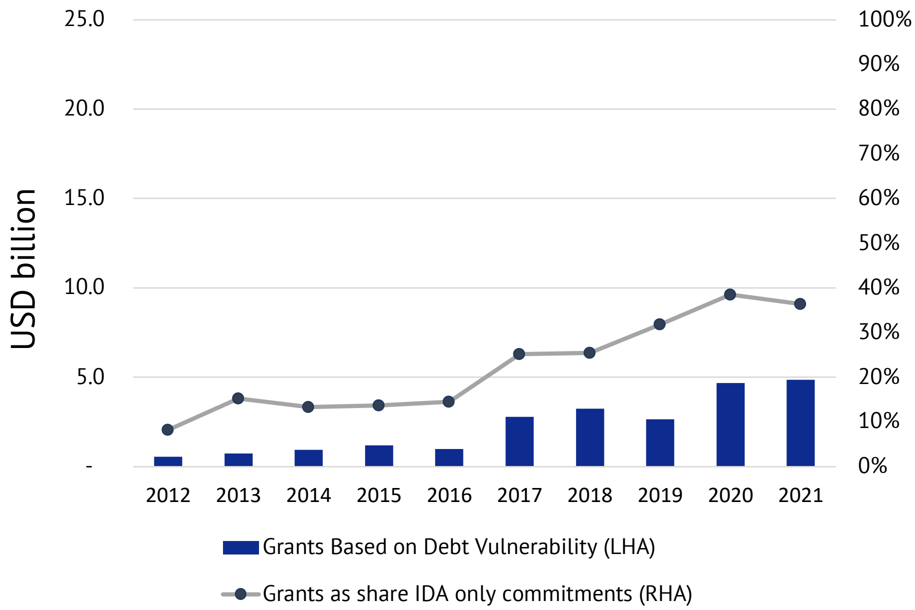
Diwan et al. (2023) estimate that since the inception of this concessional rule in 2005, IDA alone has provided $80 billion of grants to countries with debt vulnerability. According to our estimate for IDA-only countries shown in Figure 5a, IDA grants based on debt sustainability criteria grew from $0.6 billion (8 percent of IDA-only commitments) to $4.9 billion (36 percent of IDA-only commitments) between 2012-2021. In the 2012-2021 period, accumulated grants based on debt sustainability accounted for $22 billion.

If the current situation of debt vulnerability among IDA-only countries continues, grants linked to debt vulnerability from IDA could reach an accumulated amount of $24.3 billion over the next five years, assuming a steady IDA lending volume. Under a scenario where the trend observed from 2012-2021 persists, when grants linked to debt distressed increased by 27 percent per year, this type of grant could amount to $16 billion by 2026. In an extreme case, following a trend observed between 2019-2021, grants based on debt vulnerability could reach a staggering $22 billion in a single year by 2026 (assuming an annual increase rate of 35 percent). These projections illustrate that the prolongment of a debt distress situation among IDA clients – or even a further deterioration of the situation – poses a threat to the institution's business model, which relies in part on repayments from clients to support its capital base. As the debt situation worsens, IDA could become increasingly reliant on donor contributions to maintain the same lending capacity, let alone expanding it. Therefore, achieving the "green light" status (low risk of debt distress) for more countries is not only beneficial for the countries themselves but also crucial for maintaining a balanced model for IDA and other MDBs that adopt similar concessionally policies. Given the significant costs that prolonged debt distress in the Global South imposes on MDBs, it is in their best interest to prioritize the swift resolution of the current debt situation.

7 See annex 3 for the list of IDA eligible countries by lending terms (IDA-only or Blend)

Figure 5: Grants Based on Debt Vulnerabilities Indicators, World Bank-IDA to IDA-only Countries

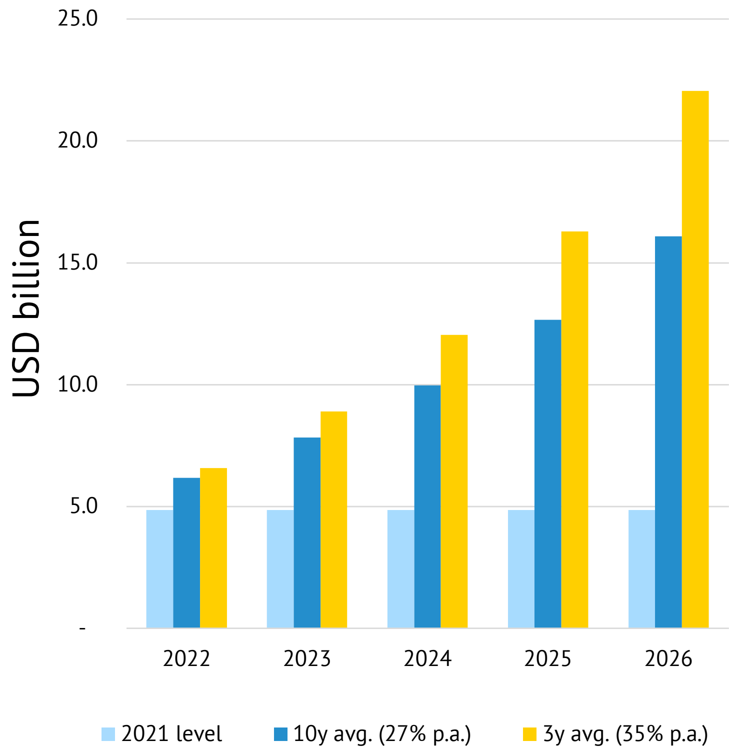
5a. Grants in USD billion (Based on Commitments) and as Share of Total Commitments to IDA-only Countries, 2012-2021



Source: Own elaboration based on World Bank IDS 2022, IMF Debt Sustainability Analysis List for LICs Poverty Reduction and Growth Trust (PRGT) eligible countries and WB (2023b).

Note: See Annex 3 for a list of IDA eligible countries based on lending terms. We do not include countries that can borrow from IBRD and IDA concomitantly (known as blend countries). Commitments to Sri Lanka were excluded from the estimation, as it was reclassified as IDA eligible during the 2023 Fiscal Year. For estimating grants based on sustainability indicators, it was accounted the debt distress classification of the previous year and IDA commitments of the following year. DSA list for 2012 not available, it was considered the DSA classification of 2011.

5b. Grants Volume in USD billion, 5-year Projection



Source: Own elaboration based on World Bank IDS 2022, IMF Debt Sustainability Analysis List for LICs Poverty Reduction and Growth Trust (PRGT) eligible countries and WB (2023b).

Note: See Annex 3 for a list of IDA eligible countries based on lending terms. We do not include countries that can borrow from IBRD and IDA concomitantly (known as blend countries). Commitments to Sri Lanka were excluded from the estimation, as it was reclassified as IDA eligible during the 2023 Fiscal Year. For estimating grants based on sustainability indicators, it was accounted the debt distress classification of the previous year and IDA commitments of the following year. DSA list for 2012 not available, it was considered the DSA classification of 2011.

FACILITATING THE NEGOTIATION PROCESS AND ENHANCING DEBT RESTRUCTURING FOR ALL CREDITOR CLASSES

The final reason for MDB participation in the current debt relief efforts is the potential to unlock the debt negotiation process and encourage the participation of all creditor classes. If MDBs agree to join – in terms that may vary, as the next section will show – not only will they be able to speed up the current debt negotiation, but they would also help preserve the long-term business model they depend on.

COMPARABILITY OF TREATMENT

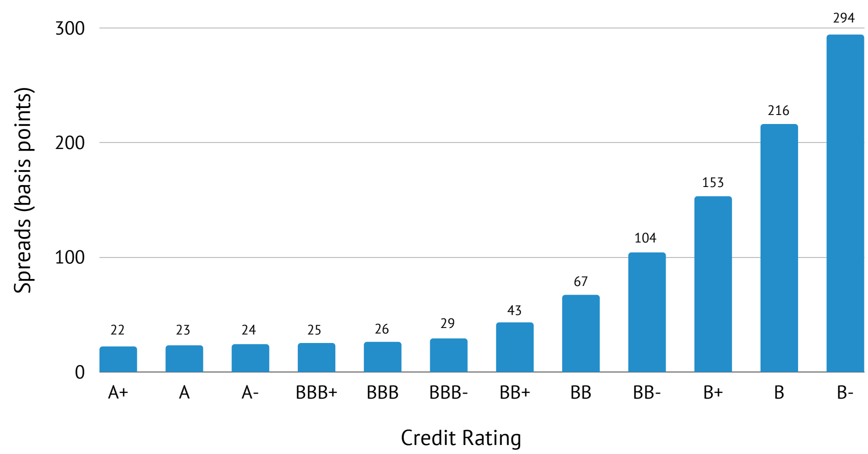
THE COST OF BORROWING

Defining the burden sharing among creditors during a debt relief process is a highly complex exercise (Iversen 2023). To start, lending conditions are diverse and vary in multiple dimensions including different financing objectives, maturities, grace period, interest rate, collateralization and conditionalities, to mention a few parameters. Comparing net present value (NPV) of debt reduction granted by different creditors or creditor group is a challenge by itself (Lazard 2022). To add to the complexity, different creditors classes face unique impediments and implications when providing debt relief (including financial, legal, bureaucratic and political). For instance, while the private sector and MDBs are concerned with potential credit rating downgrades and increasing funding costs, official creditors may face political and bureaucratic hurdles. All these instances make inter-creditor negotiation a very convoluted process, especially now with an increasingly diverse number of creditor classes.

This report does not aim to give a final answer to these complex questions. However, by acknowledging the complexity, from the point of view of efficiency and effectiveness of sovereign debt restructuring, it is impractical to offer preferential treatment to some creditor classes based on their unique impediments, regulatory regimes, status, underlying borrowing cost or even by the virtue of their mission. As Lazard (2022) highlights, simplicity and unambiguity criterion have merits when defining the comparability of treatment. In the spirit of providing simplicity but fairness, for the reasons outlined in the previous section, we agree that all creditor classes should be included in debt relief efforts but to define how much each creditor should contribute, it is important to account for *cost of borrowing* from different creditors.

On the one hand, private lenders incorporate default risks in their lending practices. To account for a more equitable distribution of losses among creditors, it is crucial to consider the incorporation of default risks in pricing of private sector lending practices, as well as the distinct level of conditionalities offered by official creditors. Apart from compensating for risks such as uncertainty, price volatility, liquidity and correlations with risky assets, investors are also specifically compensated for the risk of default. According to Bank of America (2022), emerging market spreads generally exceed what would be required to compensate investors for historical default risks. The historical five-year rate of default on foreign currency sovereign debt is about 2 percent for bonds rated up to BBB, about 5 percent to BB- and 14 percent for B-rated bonds. As Figure 6 shows, these risks are priced. For investment-grade countries, five-year spreads of about 20-30 basis points (bps) would be required to compensate for the historical probability of default, and it can reach 294 bps points for B- sovereign bonds. Moreover, it is observed that spreads generally exceed what would be required to compensate investors for historical default risks (Andritzky & Schumacher 2019; BofA, 2022; Meyer, Reinhart, & Trebesch 2022). Recent debt negotiations further support this notion. Taking the example of Zambia, it has been estimated that even if bondholders agreed to a 50 percent reduction in NPV, they could earn up to a 50 percent profit in comparison to what they would have gained from lending to the US government (Debt Justice 2023).

Figure 6: Five-year Spreads (bps) to Compensate for Historical Probability of Default by Rating



Source: Replicated from BofA, 2022.

Note from BofA (2022): Required spread calculated with simplified formula: Spread = [-(1-RR)/T]*[ln(1-PD)], where RR=Recovery Rate (in percent) and PD=Probability of Default (in percent). Calculation uses 25 percent Recovery Rate.

On the other hand, bilateral or multilateral creditors do not charge a premium associated to default risks. In contrast, official creditors – particularly IDA – often lend to developing countries at interest rates below market levels (hence, with grant element). Moreover, IDA specifically increases the grant element of loans as a country's debt distress situation worsens, as demonstrated by the traffic light policy discussed.

Figure 7 shows loan commitments and grant elements by creditor class for NCF countries. Although the private sector offered $653 billion of loan commitments from 2012-2021, its lending is often above the 10 percent per year rate, thereby yielding a "negative" grant element of 9 percent, or $56 billion, in that case. In contrast, official creditors provide positive grant elements at different levels. For the NCF countries, China provides the lowest share of grant element (14 percent), followed by other official bilateral (18 percent), multilateral lenders excluding IDA (28 percent), Paris Club (29 percent) and IDA (42 percent). One of the justifications why MDBs should be exempted from debt restructurings is the high grant element of loans to countries with debt vulnerabilities (referred to as "ex-ante" implicit debt relief) (World Bank 2023). But as Figure 7 shows, this practice is not exclusive to IDA or MDBs in general, but a feature common also among other official lenders.

Figure 7: NCF Countries: Accumulated Loan Commitments and Grants (billion USD) and Average Grant Elements by Creditor Classes (%), 2012-2021

Source: Own elaboration based on World Bank IDS 2022.

Note: The grant element of a loan is the grant equivalent expressed as a percentage of the amount committed. It is used as a measure of the overall cost of borrowing. To obtain the averages, the grant elements have been weighted by the amounts of the loans. The grant equivalent of a loan is its commitment (present) value, less the discounted present value of its contractual debt service; conventionally, future service payments are discounted at 10 percent. Commitments cover the total amount of loans for which contracts were signed in the year specified. Debt from private creditors includes bonds that are either publicly issued or privately placed; commercial bank loans from private banks and other private financial institutions; other private credits from manufacturers, exporters, and other suppliers of goods, and bank credits covered by a guarantee of an export credit agency. NCF (New Common Framework)

Despite private lenders charging higher costs (factoring in the risk of default upfront) compared to official lenders, Schlegl et al. (2019) shows that private debt is senior to official debt. Over the past 40 years, not only have arrears to private creditors been fewer, but they also face a smaller haircut in the event of debt restructuring (Schlegl, Trepesch, & Wright 2019).

BURDEN SHARING: LEGALIST VERSUS ECONOMIC APPROACHES[8]

When it comes to debt restructuring, the IMF/World Bank Debt Sustainability Framework defines the global debt relief quantum considered necessary to restore a country's debt sustainability.[9] The challenge then is to define how to distribute this total debt reduction among creditors.

The first and most common way to compute the "level of pain" in a debt restructuring process is by reducing each creditor's claims by the same rate based on their PV claims, as defined in the IMF/World Bank Debt Sustainability Framework for low-income countries. This approach is referred to by Lazard (2022) as the "economic" approach. For example, if the IMF defines that the country needs to reduce the total PV debt by half, all creditors will have to give a 50 percent discount on their PV claims. But as noticed by Lazard (2022), under the "economic" approach, creditors with concessional claims may end up subsidizing the debt restructuring in sharing the (remaining) grant element of their claims with the broader universe of creditors. Thus, the "economic" approach enhances private creditors' recovery.

Considering the different lending terms of creditors, it is possible to provide a more nuanced (but still direct) approach to burden sharing. In other words, by pricing the risk of default upfront, private lenders essentially acknowledge that they have capacity to absorb higher relative losses compared to other creditors. As for-profit organizations, private creditors not only incorporate their cost of capital in lending practices, but also an additional cost related to the risk of default. Therefore, allocating a larger share of the debt relief responsibility to private (as share of their PV claims) lenders seems justifiable, as it recognizes the differential risk assumed by various types of creditors. At the same time, grant elements provided by the official sector can be understood as a financial relief provided in advance, which justifies a smaller relative "ex post" contribution in debt restructuring efforts.

8 While there is a third approach called market-based, we have excluded it from our analysis due to its unrealistic application and potential to create uncollaborative behavior among creditors towards the debtor (Lazard 2022)

9 It is beyond the scope of this paper to discuss the issues with the current IMF/World Bank Debt Sustainability Framework. This topic is analyzed by Guzman & Heymann (2015); the need to integrate climate and nature into DSAs is analyzed by Maldonado & Gallagher, 2022; Kraemer & Volz, 2023.

The best approach that translates this difference in cost of borrowing would be the "legalist" approach, as referred to by Lazard (2022). Under this approach, every dollar of debt that has financed the government's budget should contribute equally to restoring the debt sustainability going forward. In that sense, the "legalist" approach computes the total debt relief efforts necessary to restore debt sustainability (as defined by the IMF's Debt Sustainability Analysis) not in terms of PV of individual creditors, but in terms of NV. Apart from allowing to account for "ex ante" and "ex post" debt relief efforts combined, other advantages of the "legalist" approach is simplicity and transparency of information. In other words, by using nominal values, it is possible to circumvent the confidentiality issues faced in an increasing number of sovereign debt agreements (Lazard 2022). Diwan et. al (2023) provide a method analogous to the "legalist" approach (Lazard 2022) – based on nominal value equalization – and the authors emphasize that such an approach proportionally weights larger losses with less concessional lenders, therefore providing a fairer distributional outcome.

ESTIMATING THE LEVEL OF RELIEF PROVIDED BY MDBS

In the following section, we estimate the debt relief efforts considering two approaches. The first one is the "economic" approach as defined by Lazard (2022), which we refer to as the "flat rate" Comparability of Treatment (CoT). The second approach is the "fair" CoT, the method of which was developed by Diwan et al. (2023), analogous to the "legalist" approach from Lazard (2022).

The "fair" CoT considers as the point of departure a necessary global effort to restore the country to sustainable levels (as share of total debt in PV terms, as potentially informed by an IMF/World Bank Debt Sustainability Analysis). It then distributes that burden considering a "ex ante" relief (the grant element) of different creditors and converges the "ex post" debt reduction needed towards a new average level of concessionality common to all creditors in terms of nominal values of the old debt. Creditors that are further away from this targeted average (e.g., the private sector) will bear a greater burden. Conversely, if a creditor is already more concessional than the average of all creditors (e.g., IDA), their required additional effort will be relatively smaller (or even unnecessary). In practical terms, if the necessary global debt relief is relatively small and some creditors have already offered high grant elements, their "ex ante" contributions may already suffice, and they might not need to contribute further. However, when total debt relief efforts are more significant (e.g., 70 percent of total PV debt, instead of 10 percent), even more "generous" creditors with high concessional elements in their lending would need to increase their contributions to achieve the required global debt relief for debtor countries. As highlighted by Diwan et. al (2023), this distribution considering "ex ante" cost of lending can provide a fairer overall distribution of burden.

In our estimation, we divide all creditors into six groups: private lenders,[10] China, Paris Club,[11] Other Official Bilateral,[12] MDBs (excluding IDA) and IDA. According to a comprehensive study of past sovereign debt restructurings, the average haircut on sovereign debt with foreign private creditors (comprising bank debt and bonds) in the "modern era" (post-1970) was 39 percent, while under the HIPC Initiative, debt restructuring reached up to 64 percent (Marchesi, Masi & Bomprezzi 2023; Meyer et al. 2022; Ramos et al. 2023; World Bank 2022). We consider these two historical debt reduction benchmarks for our scenarios: a 39 percent and a 64 percent reduction.

PV calculations are commonly used by the IMF/World Bank Debt Sustainability Analysis to measure necessary total debt relief efforts. Mathematically, the PV of debt is equal to the sum of all future debt service payments (principal and interest), discounted to the present using a given discount rate. There is no information publicly available on PV disaggregated by individual creditor or creditor group, neither complete data on future cash flows. To overcome this lack of data, we estimated PV by creditor groups based on weighted average of grant elements during the last ten years (between 2012-2021, following information as per Figure 7). As grant element of a debt is the difference between the PV of debt and its NV (expressed as a percentage of the NV of the debt), it was possible to estimate PV owned to specific creditor groups (Diwan et al. 2023; World Bank 2023). Apart from considering the whole group for which data is available (61 countries), we also estimated debt treatment for a subgroup of NCF countries, composed by countries that either are IDA-eligible or SIDS (41 countries).

10 Including bond holders, commercial lenders and other private creditors.

11 Paris Club permanent members include Australia, Austria, Belgium, Brazil, Canada, Denmark, Finland, France, Germany, Ireland, Israel, Italy, Japan, Korea, Netherlands, Norway, Russian Federation, Spain, Sweden, Switzerland, United Kingdom, United States (Paris Club 2023).

12 Saudia Arabia, Kuwait, India, United Arab Emirates and all other bilateral official creditors excluding China and Paris Club countries.

DEBT RELIEF FOR ALL NCF COUNTRIES

As Table 1 shows, NCF countries hold a total external PPG debt of $879.2 billion in nominal terms (excluding IMF credits). Given a total grant equivalent of $98.1 billion, the total external PPG debt accounts for $781.1 billion in NPV. A 39 percent "haircut" would imply a total PV reduction of $304.6 billion, while a 64 percent "haircut" would imply a reduction of $499.9 billion.

Table 1: NCF (61) Countries, PPG External Debt, as of 2021

	Nominal value (outstanding debt as of 2021) (a)	Grant element (b)	Grant equivalent (c= a*b)	Present value (a-c)
Private	379.1	-9%	-35.7	414.7
China	102.1	14%	14.3	87.8
Other bilateral	45.7	18%	8.0	37.7
Multilaterals (excl. IDA)	189.5	28%	53.5	135.9
Paris Club	76.4	29%	21.9	54.6
IDA	86.5	42%	36.1	50.4
Total	879.2		98.1	781.1

Source: Own elaboration based on WB IDS 2022 and authors' calculations.

Note: Estimation of grant element is based on commitment loans, and considering a ten years average (2012-2021).

Table 2 summarizes the results for burden sharing under "flat rate" and "fair" CoT. Considering a 39 percent haircut, if all creditor classes receive the same discount rate on their PV claims, MDBs (excluding IDA) would need to bear $53 billion in losses while IDA alone would be resposible for $19.7 billion. But with the "fair" CoT accounting for the grant element of the lending, their haircut would be 24 percent and 7 percent, respectivelly, instead of 39 percent each. This new ratio would save $35.8 billion to MDBs as a group, as the new contribution for MDBs (excluding IDA) would be $32.5 billion and IDA, $3.5 billion.

Among many contentious points delaying debt negotiations (e.g. domestic debt restructuring, sharing information on debt sustaintability analysis and debt carrying capacity), the participation of MDBs has been a crucial point. This means that, if IDA agreed to join debt relief efforts, it would need to provide only $3.5 billion of relief to help unlock the debt negotiation stalemate for IDA countries. By doing so, it could faciliate the participation of all creditors. This estimated contribution from IDA is smaller than the current annual expenditure on grants connected to debt vulnerabilities for

IDA-eligible countries of $4.9 billion (according to the traffic light system, as estimated earlier). In other words, by part-taking in debt relief, IDA would actually be better off than by abstaining if such a "fair" CoT were to enable debt relief involving all creditors. When considering MDBs as a group, each dollar contributed by donors for debt relief through MDBs translates into $7 of total debt relief for NCF countries. This proportion exceeds MDBs equity-to-loan leverage, suggesting that in pecuniary terms, support from MDBs through debt haircuts would have higher impact than additional lending.

Table 2: NCF (61) Countries, Inter-creditor Burden Sharing According to Distinct Comparability of Treatment Rules and Haircut Levels

			39% haircut					64% haircut				
			Flat Rate CoT		Fair CoT			Flat Rate CoT		Fair CoT		
	Grant element	Present value	Rate	USD bn	Rate	USD bn	Diff. CoT rules	Rate	USD bn	Rate	USD bn	Diff. CoT rules
Private	-9%	414.7	39%	161.7	50%	209.3	47.6	64%	265.4	71%	293.5	28.1
China	14%	87.8	39%	34.2	37%	32.5	-1.8	64%	56.2	63%	55.2	-1.0
Other bilateral	18%	37.7	39%	14.7	34%	12.9	-1.8	64%	24.1	61%	23.0	-1.0
Multi-laterals (excl. IDA)	28%	135.9	39%	53.0	24%	33.3	-19.7	64%	87.0	55%	75.4	-11.7
Paris Club	29%	54.6	39%	21.3	24%	13.1	-8.1	64%	34.9	55%	30.1	-4.8
IDA	42%	50.4	39%	19.7	7%	3.5	-16.1	64%	32.3	45%	22.7	-9.5
Total/ Average	**11%**	**781.1**	**39%**	**304.6**	**30%**	**304.6**	**-**	**64%**	**499.9**	**64%**	**499.9**	**-**

Source: Own elaboration based on WB IDS 2022 and authors' calculation.

On average, loans to NCF countries had a grant element of 11 percent, and the grant elements from all official creditor classes are higher than this average. Hence, according to the "fair" CoT rule, they would all contribute with a relatively smaller haircut compared to the flat rate CoT. In the case of China, contributions to debt relief would decline from $34.2 billion to $32.5 billion, for other bilateral official from $14.7 billion to $12.9 billion, and for Paris Club countries from $21.3 billion to $13.1 billion. To achieve the required overall debt reduction, the haircut from private lenders would increase from 39 percent to 50 percent, or from $161.7 billion to $209.3 billion.

In case NCF countries would receive a HIPC-like debt reduction of 64 percent NPV (Table 2, right side), the efforts from IDA following the "fair" CoT would account for $22.7 billion ($9.5 billion less than with the flat rate CoT), which would correspond to a 45 percent haircut instead of 64 percent. For MDBs excluding IDA, the contribution would be $75.4 billion (55 percent haircut) and $11.7 billion lower compared to the flat rate rule. The increase from the 39 percent case is substantially higher for IDA because, as the overall debt reduction increases, efforts from all creditors need to increase to avoid leaving one creditor (the least concessional) to completely write off their debt.

Table 3 demonstrates how the involvement of all creditors following a fair CoT can efficiently equalize debt relief efforts and incorporate the "ex ante" debt relief of all creditors. When no creditors participate in debt restructuring, debtors only receive support based on the concessionality rate in lending, with the private sector having a negative rate of 9.41 percent and IDA having the highest at 41.72 percent for the case of the NCF countries.

If NCF countries needed to reduce their PV debt by 64 percent, it would amount to a $499.9 billion reduction of their PV claims. In terms of NV of their claims, the same effort would result in a $598 billion, or 68.02 percent NV reduction. In case all official lenders were excluded from debt relief efforts, even if the private sector completely cancels its debt claims, it would not be sufficient to reduce the overall debt to sustainable levels. Such an approach would not only be inefficient (as debt sustainability cannot be achieved) but unfair, as the private sector's contribution would be disproportionately high compared to others who only contributed with an "ex ante" debt relief below the private sector share. If all creditors participate except IDA, their global individual effort would be 70.89 percent, and no creditor would need to completely cancel their debt. But this case would continue to be unfair because while IDA's "ex ante" debt relief would only account for 41.72 percent, all the others would be contributing with 70.68 percent. So, if IDA increases its "ex post" contribution to reach a total effort of 68.02 percent in nominal terms, it would lead to a situation where all creditors contribute equally, considering both their "ex ante" and "ex post" debt relief efforts.

The last column of Table 3 shows that with the "flat" CoT, even if all creditors participate, their efforts would differ in terms of the NV of the old debt. In this case, while the private sector would contribute 60.61 percent, IDA's contribution would end up being 79.02 percent.

Table 3: NCF Countries: Fairness in Comparability of Treatment
Considering a 64 percent haircut in PV, equivalent to 68 percent in nominal value of the old debt

Increasing Number of creditors →

	Conces-sionality rate in lending	Fair CoT						Flat rate CoT
		Only private	Only private & China	Only private & China & other bilateral	All cred-itors but Paris Club & IDA	All cred-itors but IDA	All creditors	All creditors
Private	-9.41%	122.47%	99.45%	92.36%	75.40%	70.89%	68.02%	60.61%
China	14.00%	14.00%	99.45%	92.36%	75.40%	70.89%	68.02%	69.04%
Other bilateral	17.54%	17.54%	17.54%	92.36%	75.40%	70.89%	68.02%	68.02%
Multilaterals (excl. IDA)	28.25%	28.25%	28.25%	28.25%	75.40%	70.89%	68.02%	74.17%
Paris Club	28.61%	28.61%	28.61%	28.61%	28.61%	70.89%	68.02%	74.30%
IDA	41.72%	41.72%	41.72%	41.72%	41.72%	41.72%	68.02%	79.02%
Result		**Not fair!**	**Not fair!**	**Not fair!**	**Not fair!**	**Not fair!**	**FAIR!**	**Not fair!**

Red Numbers: "ex ante" debt relief/nominal value of the old debt
Black Numbers: ("ex ante" + "ex post" debt relief)/nominal value of the old debt
Source: Authors' elaborations.

DEBT RELIEF FOR IDA-ONLY AND SIDS NCF COUNTRIES

In case the international community wants to prioritize debt relief for the most vulnerable groups, they could consider focusing debt relief efforts on IDA-eligible countries (the poorest group) or SIDS with debt vulnerabilities. Altogether, we identify 41 countries (see detailed list in Annex 2), of which 27 of them are IDA-only eligible countries, eight are both IDA-only and SIDs and six are SIDs but with IBRD or blended lending conditions.

As Table 4 shows, for this group of countries, total external PPG debt accounts to $186.8 billion in nominal terms (excluding IMF credits). Give a total grant equivalent of $46.9 billion, the total external PPG debt accounts for $140 billion in NPV. A 39 percent "haircut" would imply that $54.6 billion would have to be written off, while a 64 percent "haircut" would amount to $89.6 billion.

Table 4: NCF Countries Subgroup (IDA-only Eligible or SIDS, 41 countries) – PPG external debt (nominal value, grant element, grant equivalent and present value), as of 2021

	Nominal value (outstanding debt as of 2021) (a)	Grant element (b)	Grant equivalent (c=a*b)	Present value (a-c)
Private	45.5	-5%	-2.3	47.7
China	31.0	20%	6.3	24.6
Other bilateral	19.7	30%	5.9	13.7
Multilaterals (excl. IDA)	36.0	31%	11.3	24.7
Paris Club	13.8	40%	5.5	8.3
IDA	41.0	49%	20.2	20.8
Total	**186.8**		**46.9**	**140.0**

Source: Own elaboration based on WB IDS 2022 and authors' calculations.
Note: Estimation of grant element is based on commitment loans and considering a 10-year average (2012 to 2012).

Compared to the whole group of 61 NCF countries, for this subgroup of 41 countries, the costs of debt relief would be substantially lower, specifically for MDBs. As Table 5 shows, in the case where a 39 percent haircut is applied using the flat rate CoT, IDA would bear $8.1 billion in debt relief compared to $2.1 billion under the fair CoT. IDA's fair contribution is roughly a third of what it spent in grants to debt vulnerable countries in 2021 ($4.9 billion, according to estimation on the traffic light system). With a haircut of 64 percent, IDA would bear $9.8 billion in losses under a fair CoT ($3.6 billion less than with the flat rate CoT). IDA's contribution to debt relief would be less than the grants given to debt vulnerable countries in 2020 and 2021 combined.

Table 5: NCF Countries subgroup (IDA-only eligible or SIDS, 41 countries) – Inter-creditor Burden Sharing According to "Flat Rate" and "Fair" Comparability of Treatment Rules

			39% haircut					64% haircut				
			Flat rate CoT		Fair CoT			Flat rate CoT		Fair CoT		
	Grant element	Present value	Rate	USD bn	Rate	USD bn	Diff. CoT rules	Rate	USD bn	Rate	USD bn	Diff. CoT rules
Private	-5%	47.7	39%	18.6	56%	27.0	8.3	64%	30.6	74%	35.5	4.9
China	20%	24.6	39%	9.6	43%	10.5	0.9	64%	15.8	66%	16.3	0.5
Other bilateral	30%	13.7	39%	5.4	35%	4.7	-0.6	64%	8.8	61%	8.4	-0.4
Multi-laterals (excl. IDA)	31%	24.7	39%	9.6	33%	8.2	-1.4	64%	15.8	61%	15.0	-0.8
Paris Club	40%	8.3	39%	3.3	24%	2.0	-1.2	64%	5.3	55%	4.6	-0.7
IDA	49%	20.8	39%	8.1	10%	2.1	-6.0	64%	13.3	47%	9.8	-3.6
Total/ Average	25%	140.0	39%	54.6	39%	54.6	-	64%	89.6	64%	89.6	-

Source: Own elaboration based on WB IDS 2022 and authors' calculation.

For the other MDBs, a 39 percent haircut would imply $8.2 billion in losses considering the fair CoT ($1.4 billion less than with the flat rate CoT), and a global 64 percent debt reduction would account for $15 billion in the fair CoT ($0.8 billion less than with the flat rate CoT).

For this subgroup, the grant element from China (20 percent) is smaller than the average for the whole group of 61 NCF countries. Along with the private sector, China would then bear a higher cost for debt relief under the fair CoT rule than with the flat rate CoT. The difference is about $0.9 billion for the 39 percent haircut case and $0.5 billion under the 64 percent haircut case.

POLICY OPTIONS: HOW COULD MDB LOSSES BE COVERED?

Considering an involvement of multilateral creditors in debt restructuring requires not only an examination of the amount of their potential contribution but also the options to cover these losses. Since MDBs are crucial players in financing development and green transitions, it is important that they maintain a high credit rating to support a low-cost funding. This section explores policy options to cover MDB losses, based on previous experiences of debt restructuring and potential innovative policies.

LESSONS FROM PREVIOUS EXPERIENCES

The involvement of multilateral creditors in debt relief is not a novelty. In the past, multilateral debt restructuring has taken place, albeit in exceptional cases and through ad hoc procedures. Notably, there are three major debt relief efforts involving multilateral creditors: 1) The HIPC Initiative in 1996, 2) the MDRI in 2005 and 3) the IMF's Post-Catastrophe Debt Relief Trust (PCDR), which in 2010 was transformed into the Catastrophe Containment and Relief Trust (CCRT).

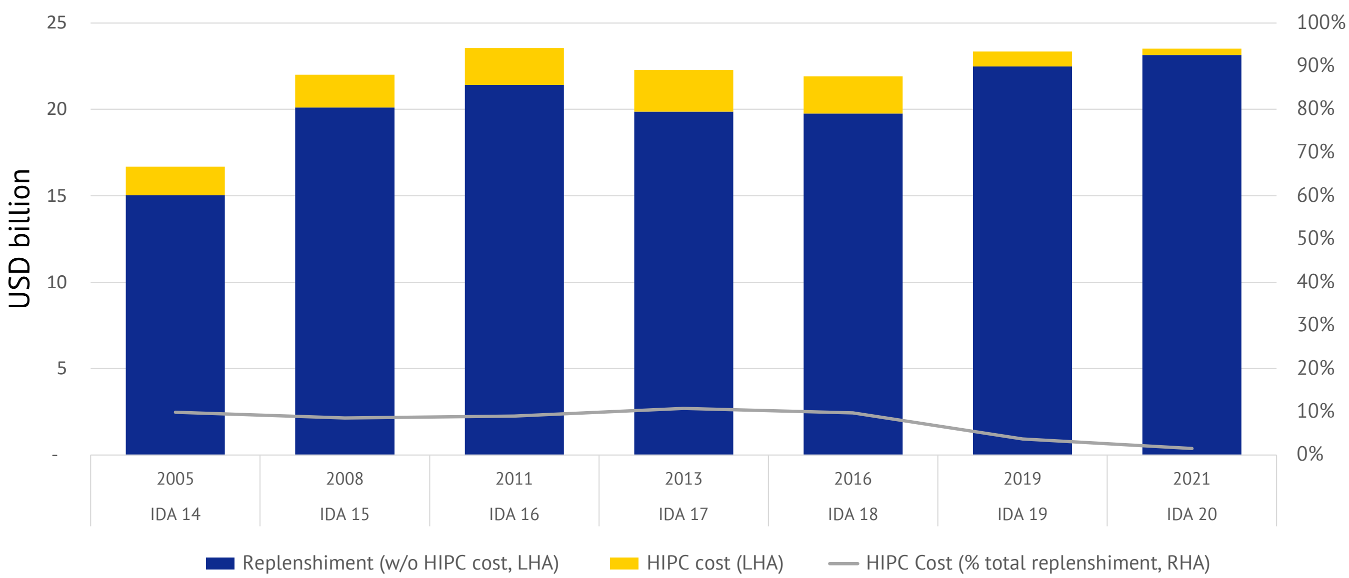
In all three cases, debt relief was made possible through a combination of donor contributions and the utilization of internal resources from international financial institutions. Essentially, debt repayments from countries in distress were shouldered by donor countries and the IFIs themselves (Viterbo 2020). An example of internal resource utilization is the IBRD operational profits (which was channeled to IDA via the Debt Relief Trust Fund, see the following). Apart from operational results, the IDB also used converted local currency assets, which had been previously donated by regional borrowing countries. Another example is the IMF, which used the proceedings of off-market gold sales[13] (IDB 2001; IDB 2006; IMF 2000).

Regarding donor contributions, resources came from three different channels. First, there were direct donations to MDBs. For instance, in the case of the IDB, Canada, the United States and other member countries outside the North American continent directly donated almost $500 million

13 Back in 1944, the IMF's initial quota was paid in gold, so as a historical legacy the fund is one of the world's largest official holders of gold with about around 90.5 million ounces (or 2,814.1 metric tons). Although based on historical cost, the IMF gold is valued at about $4.1 billion, at market prices it accounts for over $155 billion. In 1999, a total of 12.944 million troy ounces of gold, equivalent to SDR 2.680 billion, were sold and accepted back immediately at the same price, in settlement of Brazil and Mexico members' obligations to the IMF. Thus, despite the fact the gold sold by the IMF did not leave the bank, it was revalued with market prices, hence generating a profit, which was channelled to the HIPC Initiative. In addition to gold, the IMF participation was financed by bilateral contributions (International Monetary Fund 2000).

to the IDB to fund the HIPC Inititative (Inter-American Development Bank 2000). The second channel was through the Debt Relief Trust Fund (formerly the HIPC Debt Initiative Trust Fund), which pooled about $5.7 billion from donor countries and received $2.7 billion from the World Bank IBRD's operational results. This pool of resources was then redistributed among MDBs, mostly to IDA (about $3.5 billion), followed by the AfDB ($2.9 billion) and the remaining was distributed among ten other IFIs. Finally, in the case of IDA, which provided the highest volume of debt relief, donors continued to provide resources specific to meet the forgone credit reflows due to the HIPC Initiative. As Figure 8 shows, during the 2005 IDA replenishment, about 10 percent of resources were destined to cover HIPC costs. Over time, the total volume to HIPC and its share over the total resources is declining. During IDA's last round of replenishment (IDA 20, connected to the fiscal years from 2023-2025), IDA received $23.5 billion of which only 2 percent referred to HIPC costs (accounting for $360 million).

Figure 8: IDA Replenishment by Donor Countries, 2005-2021



Source: IDA replenishment reports.

In 2020, during G20 discussions on the DSSI, the Chinese Minister of Finance Liu Kun recommended the creation of a World Bank fund like the IMF's CCRT to support poor countries servicing their debt and flagged that China would be willing to contribute (Brautigam & Huang 2023). In practice, many institutional arrangements and practices used during the HIPC Initiative could be reactivated to the same purpose as recommended by China's Finance Minister. For instance, the Debt Relief Trust Fund, which gathered resources from donors and IBRD's operational resources, which still exists but at the writing of this report, has only $229 million available in its balance.

Donor countries, including China and advanced economies, could revamp contributions to this fund to finance a new round of MDB debt relief.

Moreover, MDBs' shareholders that provide donations to finance concessional finance could make debt relief specific contributions a common practice. For instance, in every IDA replenishment, donors could stipulate that 5 percent (or another appropriate share) would be dedicated to debt relief efforts and support reestablishing debt sustainability in developing countries. Because concessionary policies are attached to debt sustainability indicators (the traffic light system), a portion of IDA replenishment is used to support countries in debt distress situations, but there are serious problems with the current system. First, it continues to give support to debt-distressed countries but without any incentive to reestablish debt sustainability – with the implication that IDA money implicitly finances a bailout of private creditors of IDA countries, as suggested by Diwan and Le Houerou (2023). Second, IDA donors have highlighted that debt relief should not reduce IDA's capacity to support poverty reduction and development (World Bank 2008). But the current system does not record the support through the traffic light as debt relief, so in practice while IDA replenishment has been stagnant since 2008, resources available to new investments have been declining.

Regarding debt relief efforts from the IMF, the Catastrophe Containment and Relief Trust (CCRT) already represents an institutional layout to support debt relief from the IMF. The CCRT should be amplified to meet the needs of developing countries. In fact, during the pandemic, the IMF provided $965 million in debt service relief to 31 countries through the CCRT (International Monetary Fund 2022). But as a result of the COVID-19 crisis, the CCRT has been left "almost depleted" (IMF 2023). It is crucial that CCRT funding is replenished; one alternative is to make use of a modest share of IMF gold sales to that end. Currently, the IMF still holds around 90.5 million ounces (or 2,814.1 metric tons) of gold, which is equivalent to $162 billion at a market price of $1,800 per ounce (IMF 2023c). By selling only a tiny fraction of gold stocks, the IMF could not only provide more subsidized credit to low-income countries (as suggested by Sobel 2023), but also support debt relief to countries in need.

Apart from increasing the resources available to the CCRT, the IMF should overhaul the CCRT eligibility policies which are currently very restrictive. Countries need to be Poverty Reduction and Growth Trust (PRGT) eligible and have per capita income below the IDA cutoff, which currently makes only 29 countries eligible to IMF debt relief.[14] Moreover, although it is welcome that since 2015 the IMF has expanded the types of disasters triggering debt relief – including since then public health diseases – the Fund must be bolder. Given the context of increasing climate risks and development challenges, not only severe and intense shocks should trigger access to CCRT. Other cases should be considered too, including debt-vulnerable countries struggling to invest in climate adaptation, as well countries with milder but recurring climate shocks.

One may argue that supporting MDB debt relief is too costly to donor countries and to the IFIs themselves, indicating a "donor fatigue" among wealthy nations. Indeed, since the 1970s, advanced economies have not abided by their promise to donate 0.7 percent of their gross national income to developing countries as official development assistance (ODA). In the accumulated, high-income countries have failed to deliver a total of $5.7 trillion in aid, which could have been essential to improve the socio-economic conditions for many nations (Seery 2023). Moreover, donor contributions to IDA have been stagnant since 2011 (as shown in Figure 8) and giving the increasing volume of grant elements connected to debt distress factors, new lending to low-income countries has been in fact declining. IMF Managing Director Kristalina Georgieva has urged donor countries to step up and provide funding to the PRGT, which supports low-income countries with interest-free loans. Without such support, the PRGT cannot meet the high demand for concessional funding amid the global crisis (Reuters 2023). These are some examples of lack of support from wealthier nations to developing countries. Without question, solving the debt crisis in the Global South is going to be costly, but the price of inaction is much higher.

NEW OPPORTUNITIES

In addition to replicating past experiences, the international community can explore new ideas and seize new opportunities. One potential avenue for MDB shareholders to consider is increasing the equity of these institutions. By doing so, they would free precautionary balances that could be partially used for debt relief, without affecting their credit ratings. Currently, the World Bank alone has $30 billion in its balance sheet registered as precautionary balances. Potentially, a part of these resources could be used for

14 Considering countries eligible to PRGT and with income level below $1,255 of current IDA cut-off, countries eligible to PRGT include: Afghanistan, Burkina Faso, Burundi, Central African Republic, Chad, DR Congo, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Liberia, Madagascar, Malawi, Mali, Mozambique, Myanmar, Niger, Rwanda, Sierra Leone, Somalia, South Sudan, Sudan, Tajikistan, Tanzania, Togo, Uganda, Yemen, Zambia.

debt relief in case fresh funding is canalized. That way, debt write-offs would not impact MDBs' credit ratings or borrowing costs since a commitment of MDB shareholders to increase MDBs' equity would give a strong signal of support that could counterbalance the impact of debt relief.[15] Increases of the paid-in capital of MDBs by advanced economies would be the preferred way to raise equity, but given the thin support to inject "taxpayers'" money on MDBs, there are proposals to increase MDB equity through hybrid capital. For instance, the equity of MDBs could be increased through rechannelling Special Drawing Rights (SDRs) as suggested by the AfDB proposal (AfDB 2022), by SDR-denominated bonds (Paduano & Setser 2023) or by attracting foreign exchange reserves through Sustainable Future Bonds (Zucker-Marques & Gallagher 2023). Moreover, with a new capital injection, the overall lending capacity of the MDBs would increase leading to a future larger operational result. Part of the increased operational results could be designated for debt relief initiatives.

Theoretically, SDR resources could be directly used to support MDBs in their debt relief efforts. However, there are technical and regulatory obstacles that need to be addressed. The first technical challenge relates to the structure of SDR interest rates. When countries draw down their SDR holdings bellow allocation levels, they are required to pay an interest rate (referred to as SDRi) (Arauz, Cashman & Merling 2022). The SDRi is determined by the three-month yields of government bonds from SDR currencies, including the US dollar, UK pound sterling, Japanese yen, euro and Chinese yuan (IMF 2023a).

Between 2008 and mid-2022, SDRi remained low between 1 percent and 2 percent. But with the current interest rate rise in developed countries, in 2023, SDRi increased rapidly to about 4.5 percent. Consequently, if countries choose to redirect SDRs towards supporting MDBs' debt relief, and their SDR holdings are lower than the allocated amount, they would be required to pay perpetual interest rates on their contribution. The current structure of SDRi – which could be reformed in the future (Paduano 2022) – discourages the use of SDRs for debt relief purposes. Instead of rechanneling SDRs, countries could donate SDRs, but this brings even more hurdles. First, donating SDRs does not eliminate the need to pay SDRi on the difference between holdings and allocation. To avoid that, countries would need to replenish

15 Among many criteria to assess credit rating, agencies consider potential support from shareholders. Effectively providing new resources is not only an effective back up but a sign of commitment from shareholders. For details on the methodologies of rating agencies for supranational institutions, see, for instance, Fitch Ratings (2023).

their SDR account by either selling foreign exchange or, for countries that hold currencies that are part of the SDR basket, they could incur in a budgetary expenditure. In that case, SDR donations would account to a budgetary expenditure, requiring approval by the parliament (Plant 2021).

Another option that is technically viable but politically challenging, is the creation of a tax à *la Tobin* to finance MDBs debt relief. A Tobin tax is a financial transaction tax (FTT) originally proposed on currency exchange transactions to discourage speculative trading and stabilize financial markets. FTT could be broader than just currency trading, and the concept can encompass various types of financial transactions, such as stock trades, derivatives and other speculative activities in the financial markets. By enforcing a very marginal rate of 0.05 percent over foreign exchange transactions, an international financial transaction tax (IFTT) could yield annual revenues of around $650 billion per year (Kumar & Gallagher 2023). Resources generated from such IFTT could be channeled to MDBs, including to debt relief efforts. However, in case that an IFTT is chosen to finance MDBs debt relief, in practice some private sector participants would be "doubled taxed," as they would be directly providing debt relief on their debt and indirectly financing an official effort through the IFTT.

TRADE-OFFS BETWEEN MDB DEBT HAIRCUTS AND ADDITIONAL FUNDING

Debt relief can take various forms, such as partial or complete write-offs of outstanding debt obligations, extending repayment periods, reducing interest rates and others. NPV calculations are commonly used to measure debt relief efforts, providing a standardized framework for comparing different relief formats offered by diverse creditors. For instance, Wang and Qian's research (2022) shows that forgiving 15 percent of the debt obligation, referred to as a "haircut," can be similar to extending debt repayments by ten years (without altering the interest rate) when assessed in terms of NPV. Regarding MDBs' involvement in debt relief efforts, there is an ongoing debate regarding whether securing a future positive "net flow" of resources with higher levels of concessional funding and grants, could potentially offset the need for a haircut. In financial terms, to be considered equivalent to a haircut, the new financial flows from MDBs should consist of 100 percent grants.

But even if they are equal in NPV terms, different forms of debt relief can generate distinct economic consequences. For advanced and emerging market economies, Reinhart and Trebesch (2016) find that debtor countries see substantial economic improvements with direct debt write-offs, while softer forms of debt relief operations like maturity extensions and interest rate reductions usually do not lead to higher economic growth or improved credit ratings. Under soft forms of debt relief, countries may incur in a subsequent default, which can be reduced by directly providing principal haircuts (Schröder 2014). These findings indicate how creditors assess risks in distinct circumstances of debt relief and their willingness to provide fresh capital that promotes growth. As argued by Baqir et al. (2023), the success of debt restructuring hinges on unlocking growth prospects in a sustainable manner, which is especially challenging in a world economy with diverging growth rates between the Global North and South, loss of comparative advantages in developing economies, climate change and rising interest rates (Rodrik 2022; World Bank 2021). Under these circumstances, debt reduction not only needs to be deeper, but creditors need to provide new affordable finance with longer time horizons (Baqir et al. 2023). Hence, to help address this current twin crisis of debt and development, the first-best solution would be for MDBs to concede immediate debt relief and subsequently increase the volume of new grants and concessional finance. This would require substantive additional support from MDB shareholders and innovative ways to increase their capital base. The recent report from an Independent Expert Group commissioned by the G20 recommended MDBs at least triple their financing, and there are proposals to increase MDB equity by rechannelling SDRs and foreign exchange reserves which could give substantial lending headroom ("The Triple Agenda" 2023; AfDB 2022; Paduano & Setser 2023; Zucker-Marques & Gallagher 2023).

However, under a situation of limited funds available for MDBs, choosing between debt write-offs and additional funding present important trade-offs for debtor countries. These trade-offs can have varying implications depending on the size of debtor countries and their attractiveness to private investors. Table 6 provides a summary of the key aspects associated with each possibility for both Market Access Countries (MAC) and/or larger economies versus Non-Market Access Countries (Non-MAC) and/or smaller economies.

On the one hand, with a debt haircut, MAC countries would achieve a clean balance sheet that would help to improve their sovereign credit rating and reduce the cost of capital. Although they would not receive additional grants or concessional loans from MDBs, the restored debt sustainability situation could improve private investors' risk assessment, thereby fostering a new wave of private investment and spurring economic growth. For smaller countries without market access, while debt haircut would enhance their fiscal space, it may not necessarily stimulate investments from private creditors.

On the other hand, opting for additional grants would keep both groups of countries in a debt overhang situation, limiting their fiscal space and ability to attract private investors. Non-market access and smaller countries face even lower chances of attracting private investors under this scenario, but some projects may be financed with MDB resources in the short-term. The question that arises then is whether new grants would be sufficient to put the country onto a new development path. Clemens et al. (2012) shows that, despite being positive, the impact of aid on growth is modest. Moreover, according to Dreher et al. (2017), although aid from China, the United States and the Organisation for Economic Co-operation and Development's Development Assistance Committee produce similar impact on economic growth of recipient country, there is no such evidence for the World Bank. It may be the case that World Bank aid does support economic growth, but with much longer lag effect than that of other donors. Under any circumstance, the promise that new funding from MDBs will support countries to "grow out of their debt" should be taken with caution. Even by providing new loans in highly concessional terms, if MDB lending takes too long to impact economic growth, it can further deteriorate debt sustainability of recipient country, making the debt relief process all the more imperative.

Table 6: Comparative Analysis of MDB Debt Haircut or Additional Grants for Countries with and without Market Access

	Market access countries/ larger economies	Non-market access countries/small economy
Debt haircut	1. Reduced nominal debt burden, larger fiscal space. 2. Improved risk assessment may spur a new wave of private investment. 3. Although with higher cost compared to MDB financing, the country could receive new wave of private investment and spur economic growth.	1. Reduced nominal debt burden, larger fiscal space. 2. Improved risk assessment would not necessarily spur a new wave of private investment. 3. Green investments would be neither invested by private markets nor MDB grants.
Additional grants	1. Debt vulnerability indicators remain high. 2. Fails to attract private investment. 3. Some projects would be financed at low cost by MDBs, but they may not be enough to support the country to grow out of the debt.	1. Debt vulnerability indicators remain high. 2. Fails to attract private investment, but the pro bability of this occurring is low anyway. 3. Some projects would be financed at low cost by MDBs, which will not necessarily translate into sustainable development and higher growth rates.

Source: Authors' own elaboration.

It is important to consider that prioritizing an increase in future grant volumes instead of immediate debt relief does not eliminate the necessity of enhancing donor support. In order to sustain and augment the level of lending by MDBs on concessional terms, while simultaneously providing distressed countries with 100 percent grants, it would be imperative for donors to increase the volume of their contributions. By opting for a strategy that focuses on future grant allocations, it becomes crucial for donors to actively step in and amplify their financial contributions. This is necessary to ensure that MDBs can continue providing loans at favorable terms. while also accommodating the provision of grants to countries experiencing significant economic distress.

Moreover, it is essential to re-evaluate the current strategy for providing grants and loans, giving priority to lending that enhances the impact on economic development. Ball et al. (2021) argues that when borrowed funds are directed towards public investment (that generates cash flows), it results in a sounder debt sustainability situation compared to when financing is channeled to consumption spending. With the current debt sustainability framework, it is not possible to discriminate between different types of lending, but it would be possible by incorporating a balance sheet approach as suggested by Ball et al. (2021). In that sense, channeling borrowed funds specifically towards productive investments is potentially beneficial not just for supporting a green transition but also for maintaining debt sustainability (Wang & Xu 2022).

CONCLUSION: POSSIBLE WAYS FORWARD

The ongoing debt relief negotiations regarding the G20 Common Framework have been disappointing. Among the contentious issues in these negotiations is the involvement of MDBs, which have not yet put forward concrete and systematic plans for burden-sharing in the Common Framework debt relief efforts, despite direct requests from the G20.

Our report emphasizes the importance of including MDBs in debt restructurings. First, many debt-vulnerable countries have high exposure to MDB lending, making their inclusion necessary to solving the debt crisis. Second, involving MDBs ensures equitable burden sharing among creditors, which helps mitigate perceptions of unfairness and encourages the participation of all creditor classes in the debt negotiation process. Moreover, solving the debt crisis among low-income countries is paramount to the business model of MDBs, as a protracted debt crisis would have significant costs for the concessionary arm of these institutions. Apart from donor contribution and access to capital markets, MDBs rely on reflows from clients to maintain a balanced business model. Therefore, it is in the best interest of both debt-vulnerable countries and MDBs to have a swift debt resolution. MDB shareholders should consider that by actively contributing to the resolution of the current debt crisis they also contribute to a sustainable business model for their institutions. Finally, providing debt relief through MDBs would be an effective use of taxpayer money given the capacity to leverage resources. When considering MDBs as a group, each dollar contributed by donors for debt relief through MDBs translates into $7 of total debt relief for 61 countries in debt distress studied in this report. This proportion exceeds current MDB equity-to-loan leverage, suggesting that in pecuniary terms, support from MDBs through debt haircuts has higher impact than additional lending from MDBs.

Determining the burden sharing among creditors during a debt relief process is a complex task due to diverse lending conditions and unique impediments faced by different creditor classes. This report does not seek to provide final answers to this, but for the sake of simplicity and fairness, we suggest that inter-creditor burden sharing arrangements should consider the price of debt. By incorporating risk-based pricing and considering concessionality levels, a more nuanced and fair distribution of losses can be achieved across creditors. While debt relief does come with costs, it is economically efficient to support debt-vulnerable countries and steer them towards sustainable development. This not only benefits the countries themselves but also reduces the need for ongoing grants tied to debt distress indicators. By taking these measures, the international community can effectively navigate the complex landscape of debt relief and pave the way for a more sustainable future for all parties involved.

According to our estimations, in 2021 alone, IDA spent $4.9 billion in grants that would not be liable if less countries were debt vulnerable. This type of expenditure can increase even further in case the current debt crisis deteriorates. Considering the fair CoT rule adopted in this report, by accepting $37 billion in losses, MDBs including IDA could unlock $305 billion of overall debt relief to 61 countries when using the historical average of sovereign haircuts with foreign private creditors post-1970. In such a scenario, the cost of debt relief for IDA ($4 billion) would be smaller than its current grants tied to debt distress. If debt relief was provided only to a group of 41 IDA-eligible countries and SIDS facing sovereign debt distress, the costs to MDBs and IDA together would amount to only $10 billion – helping to achieve an overall debt write-off of $55 billion.

Finally, this report shows that there are viable options for shareholders to support MDBs' debt relief efforts, maintaining their high credit rating. Experiences with past debt restructurings show that a combination of donor contributions and internal resources from IFIs can enable debt relief without undermining the credit ratings of MDBs. Reviving institutional arrangements such as the World Bank's Debt Relief Trust Fund and increasing the equity of MDBs are practical approaches to generate resources for debt relief without compromising credit ratings.

To better reflect the current economic and political influence of developing countries in MDBs' shareholder structure, there is a clear need to enhance the voting power of these underrepresented economies. There have been longstanding calls for reforms within the Bretton Woods institutions, particularly the IMF and the World Bank. Augmenting the capital of these institutions could present an opportune moment to enact such reforms (Bretton Woods Project 2010).

Additionally, donors and MDBs could explore innovative alternatives. Among them, an FTT could fund MDBs' debt relief by targeting various financial transactions. Applying a 0.05 percent rate to foreign exchange transactions could generate roughly $650 billion annually (Kumar & Gallagher 2023). Although politically challenging to implement and adding costs to the private sector, an FTT has the potential to generate more than sufficient resources to finance debt relief in countries that most need it.

Ultimately, the decision between providing debt haircuts or increasing grants involves difficult trade-offs. Deciding against the participation of MDBs in debt restructuring risks that countries that urgently need debt relief will not get it, undermining their prospect for achieving the SDGs and the Paris Agreement. Moreover, there is a risk that the provision of new financial support by MDBs to debt-distressed countries whose debt is not restructured will not suffice to restart growth and that the transfers will effectively finance a bailout of other creditors. Prioritizing debt haircuts, coupled with increased grants and concessional finance, can effectively address debt distress and support sustainable development. To sustain these efforts, it is crucial for donors to actively contribute and enhance financial support to MDBs, ensuring the availability of concessional loans and grants for countries in need.

REFERENCES

African Development Bank, Asian Development Bank, Asian Infrastructure Investment Bank, Council of Europe Development Bank, European Bank for Reconstruction and Development, International Monetary Fund, et al. (2020). Financing the Sustainable Development Goals: The contributions of the Multilateral Development Banks, from https://www.un.org/ohrlls/sites/www.un.org.ohrlls/files/MDB.pdf.

African Development Bank Group (2019). Debt Sustainability and ADF Grant Eligibility. Retrieved 05-Jul-23, from https://www.afdb.org/en/projects-and-operations/financial-products/african-development-fund/debt-sustainability-and-adf-grant-eligibility.

African Development Bank Group (2022). Leveraging the power of Special Drawing Rights: how developed countries can help boost Africa's development. Retrieved 10-Jul-23, from https://www.afdb.org/en/news-and-events/interviews/leveraging-power-special-drawing-rights-how-developed-countries-can-help-boost-africas-development-51910.

AfDB (2022). Voting Power. https://www.afdb.org/en/documents/category/afdb-voting-powers

ADB (2018). Members, Capital Stock, and Voting Power. Available at: https://data.adb.org/sites/default/files/ar2018-oi-appendix1.pdf

Andritzky, J., & Schumacher, J. (2019). Long-Term Returns in Distressed Sovereign Bond Markets: How Did Investors Fare? (IMF Working Paper No. WP/19/138).

Arauz, A., Cashman, K., & Merling, L. (2022). Special Drawing Rights: The Right Tool to Use to Respond to the Pandemic and Other Challenges. Center for Economic and Policy Research.

Asian Development Bank (2021). Allocation of Concessional Resources. Retrieved 05-Jul-23, from https://www.adb.org/what-we-do/funds/adf/allocation-adf-resources.

Baqir, R., Diwan, I., & Rodrik, D. (2023). A Framework to Evaluate Economic Adjustment cum Debt Restructuring Packages. Retrieved 21-Jul-23, from https://findevlab.org/wp-content/uploads/2023/01/FDL_Working-Paper-2_A-Framework-to-Evaluate-Economic-Adjustment-cum-Debt-Restructuring-Packages.pdf.

BofA (2022). Emerging Market Sovereign Defaults Primer: A survival guide (GEMs FI Strategy Viewpoint). Retrieved 11-Jul-23, from https://debtcon6.princeton.edu/sites/g/files/toruqf3611/files/documents/brauer.pdf.

Boosting MDBs' investing capacity (2022). An Independent Review of Multilateral Development Banks' Capital Adequacy Frameworks. Retrieved 11-May-23, from https://www.dt.mef.gov.it/export/sites/sitodt/modules/documenti_it/rapporti_finanziari_internazionali/rapporti_finanziari_internazionali/CAF-Review-Report.pdf.

Brautigam, D., & Huang, Y. (2023). Integrating China into Multilateral Debt Relief: Progress and Problems in the G20 DSSI. China Africa Research Initiative. Retrieved April 08, 2023, from https://static1.squarespace.com/static/5652847de4b033f56d2bdc29/t/64303cd252cc4045dafc811f/1680882899126/Briefing+Paper+9+-+China+and+DSSI+-+April+2023+-+V5.pdf.

Bretton Woods Project (2010). Analysis of World Bank voting reforms. Retrieved 11-Aug-23, from https://www.brettonwoodsproject.org/doc/wbimfgov/wbgovreforms2010.pdf.

BRICS (2023). XV BRICS Summit Johannesburg II Declaration. 24th August. Retrieved August 29, 2023, from https://brics2023.gov.za/2023/07/05/summit-declarations/

Cash, J. (2023, June 22). Explainer: What is China's position on restructuring debt owed by poor nations? Reuters Media. Retrieved 04-Jul-23, from https://www.reuters.com/sustainability/what-is-chinas-position-restructuring-debt-owed-by-poor-nations-2023-06-22/.

Cassimon, D., van Campenhout, B., Ferry, M., & Raffinot, M. (2015). Africa: Out of debt, into fiscal space? Dynamic fiscal impact of the debt relief initiatives on African Heavily Indebted Poor Countries (HIPCs). International Economics, 144, 29–52. Retrieved 04-Jul-23.

Clemens, M. A., Radelet, S., Bhavnani, R. R., & Bazzi, S. (2012). Counting Chickens when they Hatch: Timing and the Effects of Aid on Growth. The Economic Journal, 122(561), 590–617.

Debt Justice (2023). Zambia's private creditors need to cut debt payments by more than 50%. 12th July. Retrieved September 20, from https://debtjustice.org.uk/press-release/zambias-private-creditors-need-to-cut-debt-payments-by-more-than-50

Diwan, I., Harnoys-Vannier, B., & Kessler, M. IDA in the debt crisis: Exploring feasible deals through comparability of treatments and new loans. Retrieved 25-May-23, from https://findevlab.org/wp-content/uploads/2023/05/FDL_DR_CoT_IDA_Formatted-vf.pdf.

Diwan, I., Kessler, M., & Properzi, E. (2023). IDA in the poorer countries' debt crisis. Retrieved 25-May-23, from https://findevlab.org/wp-content/uploads/2023/05/FDL_Note_IDA-in-the-poorer-countries-debt-crisis_May23.pdf.

Diwan, I., & Le Houerou, P. (24th May 2023). Growing Out of the Developing-Country Debt Crisis. Project Syndicate.

Djimeu, E. W. (2018). The impact of the Heavily Indebted Poor Countries initiative on growth and investment in Africa. World Development, 104, 108–127. Retrieved 04-Jul-23.

Dreher, A., Fuchs, A., Parks, B., Strange, A. M., & Tierney, M. J. AAid, China, and Growth: Evidence from a New Global Development Finance Dataset. Retrieved 22-Jul-23, from https://docs.aiddata.org/ad4/pdfs/WPS46_Aid_China_and_Growth.pdf.

Fitch Ratings (2023). Supranational. Available at: https://www.spglobal.com/ratings/en/sector/governments/supranationals

G20 (2020). Statement: Extraordinary G20 Finance Ministers and Central Bank Governors' Meeting.

G20 and Paris Club (2020). Common Framework for Debt Treatments beyond the DSSI. Retrieved 02-Jun-23, from G20 and Paris Club: https://clubdeparis.org/en/communications/press-release/endorsement-with-the-g20-of-a-common-framework-to-coordinated-debt.

Galindo, A. J., & Panizza, U. (2018). The cyclicality of international public sector borrowing in developing countries: Does the lender matter? World Development, 112, 119–135. Retrieved 13-Jul-23.

Hussain, N., & Gunter, B. (2005). External Shocks and the HIPC Initiative: Impacts on Growth and Poverty in Africa (Economic Research Working Paper Series). African Development Bank, from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/00363551-FR-ERWP-75.PDF.

IMF (2023a). SDR Interest Rate Calculation, from IMF: https://www.imf.org/external/np/fin/data/sdr_ir.aspx.

IMF (2023b). Zambia: 2023 Article IV Consultation, First Review Under the Extended Credit Facility Arrangement, and Financing Assurances Review-Press Release, from https://www.imf.org/en/Publications/CR/Issues/2023/07/13/Zambia-2023-Article-IV-Consultation-First-Review-Under-the-Extended-Credit-Facility-536340.

IMF (2023c). Gold in the IMF, from https://www.imf.org/en/About/Factsheets/Sheets/2022/Gold-in-the-IMF.

IMF's Georgieva Discusses Progress on Debt Restructuring Talks (2023a, February 27). Bloomberg, from https://www.bloomberg.com/news/videos/2023-02-27/imf-s-georgieva-discusses-debt-restructuring-video?sref=uMuyuNij.

Inter-American Development Bank (2000). Annual Report 1998.

Inter-American Development Bank (2001). Annual Report 2000.

Inter-American Development Bank (2006). Annual Report 2005.

Inter-American Development Bank (2023). Concessional Resources. Retrieved 05-Jul-23, from https://www.iadb.org/en/about-us/concessional-resources.

IDB (2023). Voting Power. Available at: https://www.iadb.org/en/about-us/capital-stock-and-voting-power

International Monetary Fund (2000). News Brief: IMF Completes Off-Market Gold Sales. Retrieved April 10, 2023, from https://www.imf.org/en/News/Articles/2015/09/29/18/03/nb0021.

International Monetary Fund (2022). IMF Financing and Debt Service Relief. Retrieved April 11, 2023, from https://www.imf.org/en/Topics/imf-and-covid19/COVID-Lending-Tracker.

International Monetary Fund (2023). 2023 Review of Resource Adequacy of the Poverty Reduction and Growth Trust, Resilience and Sustainability Trust, and Debt Relief Trusts (No. 23/112). Retrieved April 11, 2023, from International Monetary Fund: https://www.imf.org/en/News/Articles/2023/04/07/pr23112-2023-review-of-resource-adequacy-of-the-poverty-reduction-growth-trust.

Iversen, A. (2023). Intercreditor equity in sovereign debt restructuring (First edition). Oxford United Kingdom: Oxford University Press.

Kraemer, M., & Volz, U. (2023). Integrating Nature Into Debt Sustainability Analysis. Finance for Biodiversity. Retrieved 22-Jul-23, from https://www.naturefinance.net/wp-content/uploads/2022/09/IntegratingNatureIntoDebtSustainabilityAnalysis.pdf.

Kumar, N., & Gallagher, K. P. (2023). Reviving the international financial transactions tax (IFTT) agenda for the G20. T20. Retrieved 26-Jun-23, from https://www.orfonline.org/wp-content/uploads/2023/06/T20_PolicyBrief_TF5_RevivingIFTT.pdf.

Lazard (2022). How to make sovereign debt restructuring more effective: Hold warring parties to a better standard of "Comparability". Retrieved April 21, 2023, from https://www.lazard.com/media/c5bb0n11/lazard-policy-brief-on-comparability-of-treatment-may-2022.pdf.

Maldonado, F., & Gallagher, K. P. (2022). Climate Change and IMF Debt Sustainability Analysis, from https://www.bu.edu/gdp/files/2022/02/TF_WP_005_FIN.pdf.

Marchesi, S., Masi, T., & Bomprezzi, P. (2023). Is to Forgive to Forget? Sovereign Risk in the Aftermath of Private or Official Debt Restructurings. IMF Economic Review.

Meyer, J., Reinhart, C. M., & Trebesch, C. (2022). Sovereign Bonds Since Waterloo. The Quarterly Journal of Economics, 1615–1680.

Mingey, M., & Wright, L. (2023). China's External Debt Renegotiations After Zambia. Rhodium Group, from https://rhg.com/research/chinas-external-debt-renegotiations-after-zambia/.

Paduano, S. (2022). SDRs and The Global Financial Architecture: History, Economics, Mechanics and a Return to the Original System (LSE working paper). LSE Global Economic Governance Commission.

Paduano, S., & Setser, B. (2023, January 26). The magic of an SDR-denominated bond. Financial Times. Retrieved March 22, 2023, from https://www.ft.com/content/60a9e577-0bd3-4898-ac18-6ea9ff3573dd.

Paris Club (2023). Permanent Members. Retrieved 20-Jul-23, from https://clubdeparis.org/en/communications/page/permanent-members.

Plant, M. (2021). The Challenge of Reallocating SDRs A Primer Center For Global Development Ideas to Action. Center For Global Development, from https://www.cgdev.org/publication/challenge-reallocating-sdrs-primer.

Ramos, L., Ray, R., Bhandary, R. R., Gallagher, K. P., & Kring, W. (2023). Debt Relief for a Green and Inclusive Recovery: Guaranteeing Sustainable Development, from https://drgr.org/files/2023/05/DRGR_Report_2023.pdf.

Reinhart, C. M., & Trebesch, C. (2016). Sovereign debt relief and its Aftermath. Journal of the European Economic Association, 14(1).

Reuters (2023). IMF chief urges members to plug funding gap for poor country fund. Reuters Media, from https://www.reuters.com/business/sustainable-business/imf-chief-urges-members-plug-funding-gap-poor-country-fund-2023-03-31/.

Rhodes, W. R., & Lipsky, J. (2023). Private Sector Engagement and Equitable Burden Sharing: A New Paradigm. The Bretton Woods Committee. Retrieved 10-Jul-23, from https://www.brettonwoods.org/sites/default/files/documents/BWC-SDWG-Paper3-PrivSectorEng-2023-FNL-web1.pdf.

Rodrik, D. (2022). Prospects for global economic convergence under new technologies. Retrieved 24-Jul-23, from https://www.brookings.edu/wp-content/uploads/2022/05/Inclusive-future_Technology-new-dynamics-policy-challenges.pdf.

Schlegl, M., Trepesch, C., & Wright, M. L. J. The Seniority Structure of Sovereign Debt (Working Paper No. 759). Federal Reserve Bank of Minneapolis.

Scott, S. (2017). The grant element method of measuring the concessionality of loans and debt relief (339). The grant element method of measuring the concessionality of loans and debt relief. Retrieved 05-Jul-23, from https://one.oecd.org/document/DEV/DOC/WKP(2017)5/En/pdf.

Seery, E. (2020). 50 years of Broken Promises: The $5.7 trillion debt owed to the poorest people.

Siddique, A., Selvanathan, E. A., & Selvanathan, S. (2016). The impact of external debt on growth: Evidence from highly indebted poor countries. Journal of Policy Modeling. (38), 876–894.

The Triple Agenda (2023). Report of the Independent Expert Group, from https://icrier.org/g20-ieg/pdf/The_Triple_Agenda_G20-IEG_Report_Volume1_2023.pdf.

van Staden, C. (2023, February 23). Sharply Contrasting Views on Whether China is Right to Demand Multilateral Development Banks to Take Losses on Their Loans – The China Global South Project. China Global South Project, from https://chinaglobalsouth.com/2023/02/23/sharply-contrasting-views-on-whether-china-is-right-to-demand-multilateral-development-banks-to-take-losses-on-their-loans/.

Viterbo, A. (2020). Sovereingn debt restructuring: The role and limits of public international law: G. Giappichelli Editore.

Wang, Y., & Qian, Y. (2022). In Debt Restructuring, is a "Haircut" Better than "Rescheduling?" New Research Shows They are Comparable Approaches | Global Development Policy Center, from https://www.bu.edu/gdp/2022/09/21/in-debt-restructuring-is-a-haircut-better-than-rescheduling-new-research-shows-they-are-comparable-approaches/.

Wang, Y., & Xu, Y. (2023). China and Africa: A new narrative on debt sustainability and infrastructure financing. Journal of Infrastructure, Policy and Development, 7(1), 2181.

WB (2022). 5 lessons from past episodes of debt relief. Retrieved 15-Aug-23, from https://blogs.worldbank.org/developmenttalk/5-lessons-past-episodes-debt-relief#:~:text=Debt%20relief%20was%20substantial%2C%20with,before%20debt%20relief%20was%20provided.

World Bank (2023). Global Sovereign Debt Roundtable – Co-chairs Press Statement Washington DC – April 12, 2023. World Bank Group. Retrieved 10-May-23, from https://www.worldbank.org/en/news/statement/2023/04/12/global-sovereign-debt-roundtable-co-chairs-press-statement-washington-dc-april-12-2023.

World Bank (2007). IDA 15 The Role of IDA in ensiring debt sustaintability: A progress Report. Retrieved 10-Jul-23, from https://documents1.worldbank.org/curated/zh/792531468337151062/pdf/411430IDASecM200710590.pdf.

World Bank (2008). IDA15 report. Retrieved 04-Jun-23, from https://thedocs.worldbank.org/en/doc/415131d585283fb45eeb7348db847da0-0410012016/original/finalreportmarch2008.pdf.

World Bank (2023). Voting Powers. Available at: https://www.worldbank.org/en/about/leadership/votingpowers

Zucker-Marques M. & Gallagher P. K. (2023).). Boston University, Global Development Policy Center. GEGI Policy Brief 06.2023. Available at: https://www.bu.edu/gdp/2023/06/19/sustainable-future-bonds-boosting-MDB-lending-and-improving-the-global-reserve-system/

ANNEXES

Annex 1: List of New Common Framework Countries

Country name	
Afghanistan, Islamic Republic of	Lebanon
Angola	Liberia
Argentina	Madagascar
Belarus, Republic of	Malawi
Belize	Maldives
Benin	Mali
Burkina Faso	Marshall Islands**
Burundi	Mauritania
Cabo Verde	Micronesia, Federated States of**
Cameroon	Moldova, Republic of
Central African Republic	Mozambique
Chad	Nicaragua
Comoros	Niger
Congo, Democratic Republic of	Nigeria
Congo, Republic of	Pakistan
Cuba**	Papua New Guinea
Djibouti	St. Vincent and the Grenadines
Dominica	Samoa
Ecuador	Sao Tome & Principe
Egypt	Sierra Leone
El Salvador	Solomon Islands
Eritrea	Somalia
Eswatini, The Kingdom of	South Sudan**
Ethiopia	Sri Lanka
Gabon	Sudan
Gambia, The	Suriname**
Ghana	Tajikistan, Republic of
Grenada	Tonga
Guinea-Bissau	Tunisia
Haiti	Tuvalu**
Iraq	Ukraine
Kenya	Venezuela**
Kiribati**	Zambia
Kyrgyz Republic	Zimbabwe
Lao People's Democratic Republic	

Source: Ramos et al (2023).
Note: ** No International Debt Statistics data available.

Annex 2: List of New Common Framework Countries That are Eligible to IDA-only, or SIDS

Country name		
Afghanistan	Kyrgyz Republic	Solomon Islands
Benin	Laos	Somalia
Burkina Faso	Liberia	South Sudan*
Burundi	Madagascar	Sudan
Central African Republic	Malawi	Tajikistan, Republic of
Chad	Maldives	Tonga
Comoros	Mali	Tuvalu*
Congo, Democratic Republic of	Marshall Islands*	Zambia
Djibouti	Mauritania	Belize
Eritrea	Micronesia*	Cabo Verde
Ethiopia	Mozambique	Cuba*
Gambia, The	Nicaragua	Dominica
Ghana	Niger	Grenada
Guinea-Bissau	Samoa	Papua New Guinea
Haiti	Sao Tome & Principe	St. Vincent and the Grenadines
Kiribati*	Sierra Leone	Suriname*

Source: Authors' elaboration.

Note: *No International Debt Statistics data available.

Annex 3: World Bank IDA Borrowing Countries by Lending Terms

IDA-Only		Blend
Afghanistan	Mali	Cabo Verde
Bangladesh	Marshall Islands	Cameroon
Benin	Mauritania	Congo
Bhutan	Micronesia (Federated States of)	Dominica
Burkina Faso	Mozambique	Fiji
Burundi	Myanmar	Grenada
Cambodia	Nepal	Kenya
Central African Republic	Nicaragua	Nigeria
Chad	Niger	Pakistan
Comoros	Rwanda	Papua New Guinea
Congo, Dem. Rep. of the	Samoa	Saint Lucia
Côte d'Ivoire	Sri Lanka*	Saint Vincent and the Grenadines
Djibouti	Sao Tome and Principe	Timor-Leste
Eritrea	Senegal	Uzbekistan
Ethiopia	Sierra Leone	Zimbabwe
Gambia	Solomon Islands	
Ghana	Somalia	

Annex 3 continuation

Guinea	South Sudan
Guinea-Bissau	Sudan
Guyana	Syrian Arab Republic
Haiti	Tajikistan
Honduras	Tanzania, United Republic of
Kiribati	Togo
Kyrgyzstan	Tonga
Lao People's Dem. Rep.	Tuvalu
Lesotho	Uganda
Liberia	Vanuatu
Madagascar	Yemen
Malawi	Zambia
Maldives	Kosovo

Source: World Bank (2023b).
Note: *Sri Lanka was readmitted to IDA during the Fiscal Year 2023.


STAY CONNECTED
DEBT RELIEF FOR A GREEN &
INCLUSIVE RECOVERY

Annex 558

Z. Xing and Y. Wang, “Climate risk, climate risk distance and foreign direct investment”, *International Journal of Climate Change Strategies and Management,* 2023, pp. 41-57

Climate risk, climate risk distance and foreign direct investment

Zhaopeng Xing and Yawen Wang
School of Economics, Xiamen University, Xiamen, China

Received 3 September 2021
Revised 12 July 2022
26 September 2022
30 October 2022
Accepted 31 October 2022

Abstract

Purpose – Climate risk greatly increases the risk exposure of global investments. Both the climate risks of home countries and host countries may affect international investment behaviors. The purpose of this paper is to explore the impact of climate risk and climate risk distance on foreign direct investment (FDI) inflows and outflows. Targeted proposals are provided to promote international economic and trade cooperation and the authors provide suggestions for the FDI strategies of multinational enterprises.

Design/methodology/approach – The authors define "climate risk distance" as the difference in climate risks between two countries. This paper uses both a theoretical model and a generalized least squares test to investigate the impact of climate risk distance on FDI from the perspectives of FDI inflows and outflows. In addition, the authors subdivide the samples according to the sign of climate risk distance and rank the FDI share from home country to host country into four groups according to the host country's climate risk index. Finally, the authors undertake empirical tests with outward foreign direct investment (OFDI) data to support the empirical results.

Findings – Investors from countries with low climate risks have the upper hand due to their competitive advantages, like their skills, trademarks and patent rights, which they can transfer abroad to offset the disadvantage of being non-native. This is generally defined as ownership advantage. The impact of climate risk distance on FDI depends on the sign of climate risk distance. Specifically, host countries with higher climate risks compared with the climate risk levels of home countries may experience insignificant reductions in FDI inflows. For investors from home countries with higher climate risks, they are less likely to invest in host countries with lower climate risks. The results for samples from emerging market economies are shown to be more significant.

Originality/value – This study advances the O (ownership advantage) part of the ownership, location and internationalization (OLI) paradigm by incorporating the climate risk distance between the home country and the host country into the influencing factors of FDI. Both the O part and the L (location advantage, the advantage that host countries offers to make internationalization worthwhile to undertake FDI) part of the OLI paradigm concerning climate risks are validated with FDI and OFDI data.

Keywords Climate risk, Climate risk distance, Foreign direct investment, Outward foreign direct investment

Paper type Research paper

1. Introduction

Economic globalization has led to international production becoming an "economic bridge" (Li and Vashchilko, 2010) between countries or regions in the world economic system. Foreign direct investment (FDI) is a key distribution channel of international production. The inflow and outflow of FDI seeks to promote optimal allocation of production factors such as labor, capital and technological progress around the world. In recent years, the scale and speed of

International Journal of Climate Change Strategies and Management
Vol. 15 No. 1, 2023
pp. 41-57
Emerald Publishing Limited
1756-8692
DOI 10.1108/IJCCSM-09-2021-0100

international capital flows have shown a significant upward trend (Bhattacharya *et al.*, 1997), and links between international capital markets have strengthened. FDI is both profit seeking and wary of excessive risks. Significant market turmoil may cause international capital to seek a less risky environment. In addition, many, often complex factors, can also affect FDI flow.

Academia pays attention to the impact of institutional environmental differences on FDI inflows and outflows. Initially, many scholars used cultural distance instead of institutional environment differences to explore the impact of FDI on enterprises (Kogut and Singh, 1988; Shenkar, 2001). Some scholars argue that compared to cultural distance, institutional distance more accurately reflects key differences between national environments. Scholars explore the impact of various dimensions of institutional distance, including cultural differences, language differences, legal systems and macro and micro economic issues, in relation to FDI flow (Xu and Shenkar, 2002; Ionascu *et al.*, 2004; Estrin *et al.*, 2009). In sum, the impact of endogenous factors such as the institutional environment on FDI has been extensively analyzed. Yet, few scholars study the impact of exogenous factors such as climate risk on international capital flows.

Climate risk has always been a problem in relation to economic development faced by countries all over the world. In recent years, extreme weather and natural disasters, including torrential rains, floods, droughts, hurricanes and so on, have seriously threatened human life and health. The impact of climate change causes huge economic losses, and has attracted growing attention globally. According to a recent report from Germanwatch (Eckstein *et al.*, 2018), between 1998 and 2017 extreme weather led to more than 526,000 deaths and economic losses of more than $3.47tn, with a heavy global impact, especially in emerging market economies. In addition, climate change also causes both an indirect impact and a secondary economic risk. How to reduce the economic losses caused by climate disasters is an important issue for all countries as they seek to develop economically.

The degree of economic uncertainty caused by climate risks varies greatly from country to country. Not all multinational companies respond to climate risks in the same way. In addition to a direct impact on a host country's climate risk in relation to FDI, the scale of FDI may also vary depending on the home country's climate risks. According to ownership, location and internationalization (OLI) theory proposed by Dunning (1981), a company's international activities are determined by three factors: ownership (O) advantage location (L) advantage and internalization (I) advantage. Hypothetically, host countries with low climate risk reduce the uncertainty of capital return and lead to an "L" advantage, while enterprises in countries with high climate risk seek to develop an "O" advantage during a process of long-term risk adaptation. As a result, it appears that not all foreign investors are equally affected by a host country's climate risk. Specifically, companies located in high-climate-risk countries may not be excessively affected by high overseas climate risks. Based on the premise that the relative difference of climate risk between a home country and a host country may affect FDI, the authors establish both theoretical and empirical models to explore how climate risk distance affects FDI. Following that, the authors make relevant recommendations for the attention of both investors and governments.

2. Literature review

2.1 Climate risk and company development

Climate risk seriously threatens human life and health, causes huge economic losses to society, and the effect of climate change attracts global attention. Huang *et al.* (2018) use the Climate Risk Index published by Germanwatch (Eckstein and Kreft, 2013) to explore the global impact of climate-related risks on financing choices of listed companies. They discovered that the losses caused by storms, floods, heat waves and so on cause both lower and more unstable earnings which reduced cash flow. Lupton *et al.* (2021) examine the impact of climate risk on the success or failure of FDI in private participation infrastructure projects. They show that climate risk is a location disadvantage: the higher the climate risk of the host country, the greater the risk of investment failure. Kling *et al.* (2021) have constructed a new Climate Vulnerability Index and show that climate vulnerability limits financing channels, which directly or indirectly increases debt costs. In addition, enterprises in high climate risk countries may be subject to significant financial constraints.

The frequent occurrence of extreme weather has promoted enterprises to explore corresponding mitigation strategies. Kumarasiri and Gunasekarage (2017) conducted semistructured interviews with 39 executives of 18 large Australian listed companies directly involved in carbon emission management. From their interview data, it is clear that managers use management accounting technology as a risk management tool to mitigate risks related to climate change. Barbier and Burgess (2018) discuss how global enterprises, especially those in East Asia, seek to deal with climate risks via commitment, pricing mechanisms, scientific and technological innovation and other measures. Pinkse and Gasbarro (2019) investigate how enterprises in the oil and gas industry seek to improve cognitive ability to adapt to physical changes caused by climate risk. Finally, Daddi *et al.* (2020) have found that companies that are more sensitive to climate change are more likely to adopt mitigation and adaptation strategies.

2.2 Influencing factors of foreign direct investment

The existing literature on FDI is rich. The authors focus on various influencing factors which are grouped into two.

The first is that a country's or region's own institutional environment affects FDI inflows and outflows. Noorbakhsh *et al.* (2001) find that human capital is a significant determinant of FDI inflows, with its importance increasing over time. Emerging market economies can increase their attractiveness to FDI by improving local skills and enhancing human resource capabilities. Buthe and Milner (2008) suggest that emerging market economies that join the WTO and participate in Preferential Trade Agreements have more FDI inflows compared to other countries. International trade agreements provide foreign investors with a commitment mechanism on the return of their assets, thereby reducing the volatility of return rates. Luo *et al.* (2010) stress the importance of FDI promotion policies formulated by emerging market governments. Liu and Deseatnicov (2016) find that RMB appreciation has a negative impact on China's FDI inflows, while higher exchange rate volatility and expected depreciation encourage the country's FDI outflows.

The second aspect is the impact on FDI of differences in the institutional environment between a home country and a host country. Researchers have extensively examined differences in institutional environments. Multiple factors, including language distance, cultural distance, legal system and political environment are significant (Vidal-Suárez and López-Duarte, 2013). Some scholars focus on how a single factor in institutional environment differences affects the inflow and outflow of FDI. Eren and Jimenez (2015) examine the impact of corruption distance on the Turkey's inflow and outflow of FDI. Their empirical findings indicate that when the corruption distance between the home country and the host country is small, FDI flow is high. Conversely, countries whose corruption distance with Turkey is larger, find that FDI is diminished. O'Scawn (2018) studies the impact of cultural distance on China's FDI into 40 African countries. They indicate that cultural distance has a negative impact on China's FDI in the region. More generally, Li *et al.* (2021) suggest that cultural differences have a negative impact on the possibility and scale of Chinese FDI flowing into a host country. Nayak and Scheib (2020) discuss the relationship between cultural distance and FDI in Germany's service industry. In addition, some scholars have proposed that, compared to a single factor, institutional distance can more accurately explain the differences between national environments (Xu and Shenkar, 2002; Phillips *et al.*, 2009). Recently, studies have begun to explore the effect of institutional distance and its various subfactors on FDI. For example, Cezar and Escobar (2015) show that institutional distance reduces both possibility and scale of FDI, while compared to emerging market economies, enterprises in developed economies are more likely to adapt to institutional distance. Mohsin *et al.* (2021) have found that institutional distance promotes China's FDI in countries along "One Belt One Road." Overall, cultural distance inhibits FDI, and its inhibitory effect of is significantly greater than the promotion of institutional distance.

In summary, the impact of endogenous factors such as the institutional environment on FDI has been extensively analyzed. However, few scholars have studied the impact of exogenous factors, such as climate risk, on FDI. To fill gaps in the literature on international capital flows, this paper uses both a theoretical model and empirical tests to investigate the impact of climate risk distance on FDI from the perspectives of international direct investment inflows and outflows. In addition, the paper subdivides the samples between those with greater climate risk in the home country and those with greater climate risk in the host country. This classification is used to explore the impact of climate risk distance on FDI inflows in various national situations. The authors also rank the FDI share from home country to host country into four groups – from high to low quartile – according to the host country's Climate Risk Index. Then, based on the subdivided samples, the authors analyze how the climate risk distance affects FDI of various home countries. The authors also undertake empirical tests with outward foreign direct investment (OFDI) data to support the empirical results. The climate risks faced by countries all over the world have obvious heterogeneous characteristics, and this paper seeks to clarify the mechanisms of the influence of climate risk distance on the inflow and outflow of FDI. The paper also proposes targeted suggestions for promoting international economic and trade cooperation to achieve healthy development among countries. Finally, the authors offer advice for international investors and governments in relation to the topic of the paper.

3. Theoretical model and hypothesis development

3.1 Theoretical model

First, suppose that there is international capital i from country A, and its scale is fixed at 1. An investor must make a decision P whether or not to invest in country B. P = 1 indicates investing in B, and P = 0 indicates not investing in B:

$$P = \begin{cases} 1 & U(r_i) > U(\bar{r}) \\ 0 & U(r_i) \leq U(\bar{r}) \end{cases} \tag{1}$$

U represents utility. $\bar{r}$ is a constant, measuring the return to investors when they do not invest in B, and U (r_i) represents the expected utility of investors when they do invest in B. Obviously, investors choose to invest in country B only when $U(r_i) > U(\bar{r})$, and not to invest in country B when $U(r_i) \leq U(\bar{r})$. The authors further divide the investor's risk return into three parts based on the CAPM model:

$$r_i - r_f = \beta\left(E(r_m) - r_f\right) + cl_i + \varepsilon_i \tag{2}$$

$\beta(E(r_m) - r_f)$ represents a return related to market risk premium. cl_i is the change in investment return caused by climate disasters. e is the unpredictable income or loss caused in the host country by other unexpected conditions. The authors define the climate risk distance between A and B as D, and D is equal to the average climate disaster loss of the host country (cr_B) minus the average climate disaster loss of the home country (cr_A), where cr_A is known.

Dunning (1981) shows that FDI is determined by the three basic factors of O-advantage, L-advantage and I-advantage. O-advantages include the company's technical advantages and organizational management capabilities, while investors in high climate risk countries adopt risk-resistant technical means, hardware equipment and organization charters to increase long-term risks adaptation (Barbier and Burgess, 2018; Gasbarro and Pinkse, 2016; Pinkse and Gasbarro, 2019; Pinkse and Kolk, 2010; Weinhofer and Busch, 2013). The purpose is that they can then better identify climate risk (Todaro *et al.*, 2021), while gaining increased ability to deal with climate risk and so improve their O-advantage. Overall, this forms an advantage in competition with host country enterprises.

On the other hand, climate risk affects the rate of return on investment (Busch *et al.*, 2012; Huynh *et al.*, 2020). Low climate risk is an important factor for the host country to attract investment. By investing in countries with lower climate risks, companies can reduce the uncertainty of income, which can form an L-advantage. Therefore, the authors assume that cr_B reduces cl_i and increases variance of cl_i. If cl_i follows a normal distribution, then $cl_i \sim N(-cr_B + f(D), -cr_B\sigma^2)$, where σ^2 is a constant and f(D) is part of the O-advantage effect.

This paper uses a utility function with a constant absolute risk aversion coefficient of α:

$$U = \left(1 - \frac{1}{\alpha}\right)e^{-\alpha(1+r_i)} \tag{3}$$

To allow for cr_B that makes U the largest factor, the authors take the derivative of U to cr_B to get the optimal value of cr_B. This problem is equivalent to Max $U' = \left(1 - \frac{1}{\alpha}\right)e^{-\alpha(1+cl_i)}$ where $E\left[U'(cr_B)\right] = \left(1 - \frac{1}{\alpha}\right)e^{-\alpha\left(-cr_B + f(D) + \alpha^2\sigma^2 D/2\right)}$. The authors take the derivative of $E[U'(cr_B)]$ to cr_B:

$$\frac{\partial\left(E\left[U'(cr_B)\right]\right)}{\partial(cr_B)} = (-\alpha)E\left[U'(cr_B)\right]\left[f_{cr_B}(cr_B - cr_A) - \left(1 - \frac{\alpha^2\sigma^2}{2}\right)\right] \tag{4}$$

This equation reveals the influence of cr_B on both O-advantage and L-advantage. If cr_B^* maximizes $E[U'(cr_B)]$, then $f_{cr_B}\left(cr_B^* - cr_A\right) - \left(1 - \frac{\alpha^2\sigma^2}{2}\right) = 0$. If $cr_B > cr_B^*$, then O-advantage is surpassed by L-advantage. If $cr_B < cr_B^*$, then L-advantage is overtaken by O-advantage. Both situations lead to the reduction of U' and U. The utility of capital i invested in host country B first increases as the climate risk distance D grows. After reaching the critical value $cr_B^* - cr_A$, the utility of capital i invested in host country B decreases as the climate risk distance D diminishes.

This paper also examines how the host country's climate risk affects investment decisions. According to Figure 1, investors have no motivation to invest abroad when $U(\bar{r}) > U(r_j)_{Max}$. When $U(\bar{r}) < U(r_j)_{Max}$, investors have motivation to transfer assets overseas and invest in the country that makes $cr_B = cr_B^*$ to obtain the greatest return.

3.2 Hypothesis development

Based on the results of our theoretical model analysis, the authors believe that the impact of the host country's climate risk on investors depends on the climate risk of that country.

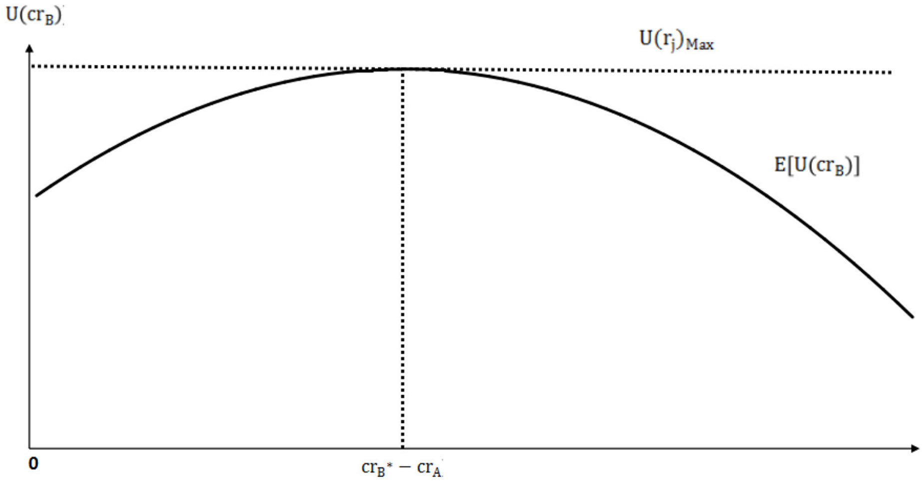


Figure 1.
Host country climate risk and utility of making investment

Specifically, if the climate risk of the home country is less than that of the host country, then the climate risk of the home country may have a great impact on investors' decision-making because investors' future returns face greater uncertainty. When the climate risk of the home country is relatively higher, its climate risk may not have a significant impact on investors. But overall, the host country's lower climate risk can be regarded as their L-advantage. After excluding the influence of other factors, investors should position their overseas investments in places with lower climate risks, so as to reduce the costs caused by risks and uncertainties. As a result, the authors propose *H1*:

H1. The climate risk of the host country is negatively correlated with inward FDI.

However, the various experiences of investors will generally determine their ability to deal with emergencies. Investors from countries with high climate risks may gain a competitive advantage through insurance, a comprehensive company management system, a stable industrial chain, a lower asset-liability ratio or more cash. Their experience may encourage other companies in the market, as their experience in their home country improves their location-bound O-advantage. As a result, they may also be more inclined to invest in countries where climate risk is relatively high. This leads to *H2a* and *H2b*:

H2a. If the climate risk distance between the home country and the host country is positive, then its impact on FDI is negative.

H2b. If the climate risk distance between the home country and the host country is negative, then its impact on FDI is positive.

4. Empirical strategy

4.1 The model

Climate disasters have shown an increasing trend in recent years, seriously increasing the risk exposure of various assets. As a result, the study of global samples is very important. To comprehensively analyze the impact of climate risk on FDI, the authors use the climate risk indicators of both the host and home countries in our empirical research. This paper first investigates how a host country's climate risk affects its country's attractiveness for FDI. The authors construct the following model (a):

$$FDI_{ijt} = \alpha_i + \beta_1 CRB_{jt} + \beta_2 D_{jt} + \beta_3 X_{jt} + \mu_{ijt} + \varepsilon_{ijt} \quad (a)$$

where the dependent variable is FDI_{ijt}, the FDI flow from a home country i to host country j at time t. The independent variables are CRB_{jt} and D_{jt}. X_{ijt} denotes control variables. μ is the between-entity error, and ε is the within-entity error.

According to the positive or negative impact of the climate risk distance, the full sample is divided into two subsamples for empirical analysis. In doing so, the authors can observe the impact of the positive and negative of climate risk distance on FDI. In addition, many emerging market economies are facing significant impacts from climate disasters. The geographical location of these countries can result in relatively frequent occurrence of natural disasters. Besides, such countries may not have sufficient capacity to deal with climate disasters. Therefore, the samples of emerging market economies are included separately in the study. The authors use random effect logistic regression to control the correlation between different samples.

4.2 Variables and measurements

The global sample the authors used includes 183 countries and territories. The time span is from 2006 to 2012, and the total number of observations is 14,586. The authors use the bilateral FDI data of UNCTAD as the dependent variable. These data include FDI data reported by both the host and home countries. To unify data sources, this paper uses the host country's FDI inflow sources to reflect its attraction to international capital. Included in these observations amount to 7,215 covering FDI data in relation to home country capital in countries with higher climate risk, and 7,371 relating to FDI data of home country capital to countries with lower climate risk.

The independent variables are the host country's Climate Risk Index and distance. Because there are many types of climate disasters globally, it seems too simplistic to consider only the impact of one climate disaster. In addition, economic losses do not include the huge impact of natural disasters on human capital. To comprehensively consider various factors, including measuring climate risk, this paper uses the Climate Risk Index published by Germanwatch covering 2006–2012. The index combines four indicators: deaths caused by extreme weather per year (DT), deaths per 100,000 residents (DP), economic losses calculated by purchasing power parity (AL) and the loss per unit of GDP (LP). The lower the Climate Risk Index, the more a country has suffered a severe impact from sudden climate disasters. To make a higher index represent a higher risk, the authors take the opposite number of the index as cr_B.

The authors use the climate risk of the host country to subtract the climate risk of the home country to get the climate risk distance. Therefore, a positive climate risk distance indicates that FDI is from a higher climate risk country to a lower climate risk country, and a negative climate risk distance indicates that FDI is from a lower climate risk country to a higher climate risk country. According to the climate risk distance, the samples are divided into those with greater climate risk in home country and those with greater climate risk in the host country. Adopting this method, the authors observe both the impact of climate risk on investors' ability to counter climate risks and of climate risk on FDI decision-making.

There are many studies covering factors influencing FDI decision-making, including the institutional environment and the degree of economic development. This paper integrates these findings into our research to observe the combined effects of both these variables and climate risk on FDI. This paper also adopts various characteristics of the home country as control variables. The authors use the natural logarithm of the host country's gross domestic product (GDP), the Human Development Index and the Economic Freedom Index. GDP data comes from the IMF. The Human Development Index, calculated by the United Nations, measures *inter alia* per capita GDP, education level and population life expectancy. The Economic Freedom Index is an index constructed by Heritage Foundation in 2012, which measures the degree of freedom of a country's fiscal, trade and monetary policies. Table 1 shows the description of each variable. The authors also use additional variables to represent the institutional differences between two countries, such as administrative distance, geographic distance and whether the residents belong to a common race. Administrative distance uses a comprehensive index constructed by Berry *et al.* (2010) that includes colonial background and various differences, of: language, religion and law. Geographical distance and common ethnicity data come from CEPII. Finally, to prevent significant multicollinearity between variables, the authors used the DW test. The test results reject the hypothesis of multicollinearity at the 1% level.

5. Results

5.1 FDI and climate risk: full sample

Model (a) draws on Godinez and Liu (2015) who uses random effects generalized least squares regression to control the correlation between data. The regression results are shown in Table 2. First, the authors do not add climate risk-related variables for regression, and the regression result is regression 1. Then, to explore the impact of climate risk on FDI, the authors compare the regression results with the regression results of regression 2 with climate risk. The regression coefficient of the development climate risk distance rejects the null hypothesis at a robust level of 1%. This shows that the higher the host country's climate risk, the lower FDI it will attract. FDI takes climate risk factors into consideration in terms of location selection. This supports *H1*.

To study separately the impact of positive climate risk distance and negative climate risk distance on FDI, the climate risk distance is divided into the home country high-risk group and the host country high-risk group in regression 3 and 4, respectively. The regression results indicate that when the home country risk is high, then the coefficient of climate risk distance does not reject the null hypothesis at the significance level of 10%, indicating that it has no impact on the size of FDI. The possible reason is that the risk dispersion effect of climate risk distance (L-advantage) and the comparative advantage effect (O-advantage) cancel each other out. When the host country's risk is higher, it is shown at a significance level of 5% that a higher climate risk distance increases the size of FDI. *H2a* is verified. If the climate risk distance between the home country and the host country is positive, then the impact of climate risk distance on FDI is negative.

5.2 FDI and climate risk: emerging market economies sample

Because emerging market economies have poor infrastructure and are more vulnerable to climate extremes than advanced economies (Eckstein *et al.*, 2018), the authors believe that a study of the impact of climate risk on the sample of developing countries is warranted. This paper excludes the sample of developed economies as host countries. Compared with developed economies, emerging market economies are generally less able to withstand climate risks. As a result, FDI inflows from these countries face greater uncertainty. In other words, risks may have a greater impact on FDI flows to emerging market economies. Using the same regression steps as described above, the authors find that the empirical results further verify the hypothesis. The regression results are shown in Table 3. The authors

Table 1. Model (a) variables, measurements and sources

Variable types	Variable	Measure	Source
Independent variable	FDI	FDI from home country A to host country B	UNCTAD
Dependent variables	CR_B	Climate Risk Index of host country B	Germanwatch
	D	Climate Risk Distance, Climate Risk Index of host country B minus Climate Risk Index of home country A	Germanwatch
	D1 (Climate Risk Index of host country B is lower)	Climate Risk Distance (Climate Risk Index of host country B is lower)	Germanwatch
	D2 (Climate Risk Index of host country B is higher)	Climate Risk Distance (Climate Risk Index of host country B is higher)	Germanwatch
Control variables	GDP	Natural logarithm of host country B's GDP	IMF
	ADIST	A comprehensive index of whether the two countries formerly had colonial relations, the proportion of people who speak the same language and have the same religion, and whether they share a legal system. The larger the index, the greater the distance	Berry *et al.* (2010)
	GDIST	Geographical distance between the political centers of the two countries (km)	CEPII
	COME	Whether the ethnic origins of the two countries are the same (it is 1 if they are same, otherwise it is 0)	CEPII
	HDI	An index that comprehensively measures GDP per capita, education and life expectancy per capita. From low to high (0–100)	United Nations
	EFI	An index reflecting the degree of freedom of a country's fiscal, trade and monetary policies. Not free to free (0–100)	Heritage Foundation

Table 2.
Model (a) results: full sample

Variables	(1) FDI	(2) FDI	(3) FDI	(4) FDI
CR_B		−35.850***	−24.435*	−50.431***
D		−23.355***		
D1 (Climate risk of home country is higher)			14.452	
D2 (Climate risk of host country is higher)				−28.821**
GDP	2,558.842***	2,471.742***	2,110.729***	2,860.417***
ADIST	−37.345***	−36.311***	−32.177***	−39.020***
GDIST	−0.512***	−0.542***	−0.390***	−0.721***
COME	3,465.293***	3,312.801***	6,097.711***	−138.919
HDI	−8,968.910***	−7,661.985***	−2,835.167	−13,566.836***
EFI	341.535***	339.673***	226.851***	487.067**
Constant	−71,607.641***	−67,778.709***	−57,288.799***	−80,264.010***
Wald test (χ^2)	1,427.41	1,446.82	757.46	753.90
Observations	14,586	14,586	7,371	7,215

Notes: *Significance of 10%; **significance of 5%; ***significance of 1%

Table 3. Model (a) results: emerging market economies sample

Variables	(5) FDI	(6) FDI	(7) FDI	(8) FDI
CR_B		−13.664**	−14.758*	−12.082
D		−23.140***		
D (Climate risk of home country is higher)			25.445***	
D (Climate risk of host country is higher)				−19.321*
GDP	1,666.792***	1,748.886***	1,884.837***	1,665.881***
ADIST	−8.723**	−7.379**	−11.452***	−3.080
GDIST	−0.156***	−0.175***	−0.291***	−0.0648
COME	2,064.902***	1,947.602***	2,494.443***	3,836.729***
HDI	−1,356.279	−1,956.686	−4,585.017	24.764
EFI	179.064**	181.673***	218.027***	153.555***
Constant	−48,439.650***	−49,290.248***	−51,647.739***	−48,284.907***
Wald test (χ^2)	613.29	638.51	434.56	277.93
Observations	9,168	9,168	4,714	4,454

Notes: *Significance of 10%; **significance of 5%; ***significance of 1%

observe that the regression coefficients of (6) and (8) CR_B and D are both significantly negative, and the coefficient of D in (7) is significantly positive at the 1% level, which validates our *H1*. It shows that emerging market economies have invested a lot of assets abroad due to their high climate risks.

In short, our analysis demonstrates that when investing overseas, foreign investors are affected not only by the climate risk of the host country, but also by the "climate risk distance." To study this problem, the authors put forward two hypotheses. Our first hypothesis suggests that, in general, the climate risk of the host country leads to a decrease in FDI inflows. Our second hypothesis is divided into two parts: the first proposes that the positive climate risk distance is negatively correlated with FDI inflows, and the second suggests that the negative climate risk distance is positively correlated with FDI inflows.

Our results support these two hypotheses. When the climate risk distance is positive, it hinders FDI. When the climate risk distance is negative, it does not significantly decrease FDI. This is consistent with our analysis results based on OLI theory. This paper further tests this conclusion by studying the relationship between climate risk and OFDI below.

6. Further discussion: OFDI and climate risk

6.1 The model and variables

To examine how climate risk in home countries affects OFDI, and to provide support for the results of model (a), model (b) was constructed. All countries are divided into four groups, 1, 2, 3, and 4 according to the quartile of climate risk from low to high. Then the proportions of OFDI from home country A to each group of host countries was calculated year by year. The authors employed them as dependent variables. The independent variables referred to the Climate Risk Index of the home country, and controlled the inflation rate, gross national product, Human Development Index, foreign trade scale, unemployment rate and economic freedom index. The description of each variable is shown in Table 4. Through such processing and regression, the authors can find out whether countries correspond to each other. This research adopts the panel data ordinary least square regression method to control the annual and national fixed effects to eliminate influence of individual differences:

$$\mathrm{OFDI_{ijt}} = \alpha_i + \beta_1 \mathrm{CRB_{it}} + \beta_3 \mathrm{X_{it}} + \mu_{ijt} + \varepsilon_{ijt} \tag{b}$$

6.2 The regression of OFDI on climate risk: full sample results

Table 5 shows the full sample regression results. The empirical research results show that climate risk of home countries significantly affects the proportion of FDI inflows to the host countries of Group 1 and Group 2. The regression result (9) shows that every time the home country's climate risk increases by 1, the home country's OFDI to the host country in the group decreases by 0.218%; while the regression result (10) shows that every time climate risk of home country increases by 1, the home country's OFDI to the host country of group 2 increases by 0.184%. Investors from home countries with different climate risks choose to invest in different groups of countries. For investors from countries with a higher climate risk, they are less likely to invest in group 1 and more likely to invest in group 2. This result proves the impact of climate risk distance on FDI from another perspective. Under the combined effect of the climate risk of home country and climate risk distance between home and host countries, OFDI presents the characteristic of being concentrated in a certain range.

Variable types	Variable	Measure	Source
Dependent variables	OFDI1	Percentage of OFDI flowing into countries with the lowest climate risk (Climate Risk Index in the 0%–25% quantile)	UNCTAD
	OFDI2	Percentage of OFDI flowing into countries with low climate risk (Climate Risk Index in the 25%–50% quantile)	UNCTAD
	OFDI3	Percentage of OFDI flowing into countries with high climate risk (Climate Risk Index in the 50%–75% quantile)	UNCTAD
	OFDI4	Percentage of OFDI flowing into countries with the highest climate risk (Climate Risk Index in the 75%–100% quantile)	UNCTAD
Independent variables	CR_A	Home Country Climate Risk Index	Germanwatch
Control variables	CPI	Consumer Price Index	IMF
	GDP	Natural logarithm of host country B's GDP	IMF
	HDI	An index that comprehensively measures GDP per capita, education, and life expectancy per capita. From low to high (0–100)	United Nations
	TRADE	Total foreign trade/GDP	IMF
	U	Unemployment rate	IMF
	EFI	An index reflecting the degree of freedom of a country's fiscal, trade, and monetary policies. Not free to free (0–100)	Heritage Foundation

Table 4.
Model (b) variables

Variables	(9) OFDI1	(10) OFDI2	(11) OFDI3	(12) OFDI4
CR_A	−0.00218**	0.00184***	0.000432	−8.82e-05
CPI	0.00221	0.00314	−0.00681**	0.00146
GDP	0.00902	0.769**	−0.0849	−0.693
HDI	4.575	−4.599**	0.638	−0.613
TRADE	−0.235	−0.0144	0.321***	−0.0718
U	0.0127	0.00812	0.00555	−0.0264***
EFI	−0.00692	0.000940	0.00528	0.000701
Constant	−1.533	−13.77**	0.901	15.41
Years	Yes	Yes	Yes	Yes
Countries	Yes	Yes	Yes	Yes
R-squared	0.314	0.443	0.350	0.292
N	493	493	493	493

Notes: **Significance of 5%; ***significance of 1%

Table 5.
Model (b) results: full sample

6.3 The regression of OFDI on climate risk: emerging market economies sample results

To test whether OFDI from emerging market economies is also affected by climate risk, the authors conduct the procedure of 6.1 on samples of such countries. The regression results are shown in Table 6. The empirical results show that the climate risk of home countries

Table 6.
Model (b) results: emerging market economies sample

Variables	(13) OFDI1	(14) OFDI2	(15) OFDI3	(16) OFDI4
CR_A	−0.00245*	0.000179	−0.000312	0.000355
CPI	0.000932	−0.00420	0.00236	−0.000942
GDP	−0.00164	−0.0359***	−0.0443***	−0.0790***
HDI	−0.271	−0.517**	−0.0961	−0.0265
TRADE	−0.108	−0.0870	0.0684	−0.156
U	0.00108	0.00214	−0.00300	0.000339
EFI	−0.00238	−0.00213	0.000819	−0.00637
Constant	−1.509	−1.414**	1.340*	2.582
Years	Yes	Yes	Yes	Yes
Countries	Yes	Yes	Yes	Yes
R-squared	0.3327	0.2780	0.2201	0.2813
N	310	310	310	310

Notes: *Significance of 10%; **significance of 5%; ***significance of 1%

significantly affects the proportion of FDI inflows to the host country of Group 1. The regression result (13) shows that every time the climate risk of the home country increases by 1, the FDI of the home country into the host country of group 1 is reduced by 0.245%. Combined with the results in 6.2, this further supports *H1* and *H2a* and *H2b*. Climate risk and climate risk distance do have an impact on capital flows in emerging market economies.

7. Conclusions

Climate risk increases the risk exposure of global investments. A growing body of research has shown that both home and host country factors influence the investment decisions of multinational investors. Therefore, the authors explore the impact of climate risk and climate risk distance on FDI, so as to provide investment advice for multinational investors.

In this study, the authors analyzed how the host country's climate risk affects FDI, that is, whether it is higher or lower than the home country's climate risk. This paper makes this distinction to examine whether investors from each group of countries react differently to the host country's climate risks. The authors also include the "climate risk distance" concept to assess how the difference in climate risk between the host and the home country affects FDI. Our research results show that when the climate risk of the home country is lower than that of the host country, the climate risk distance has a negative impact on FDI. Companies from high-climate risk countries are not affected by the climate risk distance when investing in the host country.

Based on the OLI theory, investors from countries with lower climate risks have the upper hand due to the unique advantages of their ownership. However, investors located in higher climate risk countries gain advantage by conducting their business in challenging locations. Specifically, the authors believe that companies located in countries with high climate risks have internalized knowledge of how to deal with climate risks. This O-advantage helps such companies reduce the costs associated with dealing with climate risks in foreign countries. So the authors advanced the O part of the OLI paradigm by incorporating the climate risk distance between the home country and the host country into the influencing factors of FDI.

Second, this paper incorporated FDI, OFDI and climate risk into the regression model of fixed effects and random effects. Empirical evidence was provided to supplement the evidence that when the company invests overseas, investors from countries with high climate risks are not affected by this concern. As a result, the authors enrich research on the relationship between climate risk and FDI. In addition, the authors believe that research in this field can be further refined going forward. This is because different industries have varying abilities to deal with climate risks, and so research on different industries may well lead to differing conclusions.

This paper contributes to the growing literature on FDI and climate risk. The impact of climate risk on economic activity is becoming more serious but few studies have addressed the topic. The authors expound the different impact mechanisms of national climate risk and climate risk distance on FDI based on the OLI theory. Besides, this paper provides empirical evidence to complement the studies. New researches can focus on the impact of different extreme climate types on FDI in different industries, so as to obtain more specific research conclusions.

Our work has a value both for investors and governments. For the former, when choosing FDI locations, they should not only consider the degree of climate risk in the target country, but also consider their own company's advantages in relation to climate risk prevention and resistance. From a government's point of view, it is necessary, first, to establish robust international cooperation to prevent the continuous deterioration of the climate. Second, it is necessary to establish a good prevention and confrontation mechanism so as to reduce the impact of extreme weather on a country and so increase its attractiveness for foreign investment. Especially for the emerging market economics with high climate risks, it is necessary to face this problem because FDI is an important driving force for their development. The authors suggest policy makers to provide foreign capital with ways to adapt to the climate, such as government–enterprise cooperation, company cooperation and providing consulting services.

References

Barbier, E.B. and Burgess, J.C. (2018), "Innovative corporate initiatives to reduce climate risk: lessons from east Asia", *Sustainability*, Vol. 10 No. 1, pp. 1-17.

Berry, H., Guillén, M.F. and Zhou, N. (2010), "An institutional approach to cross-national distance", *Journal of International Business Studies*, Vol. 41 No. 9, pp. 1460-1480.

Bhattacharya, A., Montiel, P. and Sharma, S. (1997), "Private capital flows to sub-Saharan Africa: an overview of trends and determinants", *External Finance for Low-Income Countries*, International Monetary Fund, Washington, DC.

Busch, T., Lehmann, N. and Hoffmann, V.H. (2012), "Corporate social responsibility, negative externalities, and financial risk: the case of climate change", Tinbergen Institute Discussion Paper.

Buthe, T. and Milner, H.V. (2008), "The politics of foreign direct investment into developing countries: increasing FDI through international trade agreements?", *American Journal of Political Science*, Vol. 52 No. 4, pp. 741-762.

Cezar, R. and Escobar, O.R. (2015), "Institutional distance and foreign direct investment", *Review of World Economics*, Vol. 151 No. 4, pp. 713-733.

Daddi, T., Bleischwitz, R., Todaro, N.M., Gusmerotti, N.M. and De Giacomo, M.R. (2020), "The influence of institutional pressures on climate mitigation and adaptation strategies", *Journal of Cleaner Production*, Vol. 244, p. 118879.

Dunning, J. (1981), *International Production and the Multinational Enterprise Allen and Unwin*, Vol. 339, Inversion Extranjera y Exportaciones, London.

Eckstein, D. and Kreft, S. (2013), *Global Climate Risk Index 2014*, Germanwatch, Bonn.

Eckstein, D., Hutfils, M.L. and Winges, M. (2018), *Global Climate Risk Index 2019*, Germanwatch, Bonn.

Eren, T.M. and Jimenez, A. (2015), “Institutional quality similarity, corruption distance and inward FDI in Turkey”, *Journal of East European Management Studies*, Vol. 20 No. 1, pp. 88-101.

Estrin, S., Baghdasaryan, D. and Meyer, K.E. (2009), “The impact of institutional and human resource distance on international entry strategies”, *Journal of Management Studies*, Vol. 46 No. 7, pp. 1171-1196.

Gasbarro, F. and Pinkse, J. (2016), “Corporate adaptation behaviour to deal with climate change: the influence of firm-specific interpretations of physical climate impacts”, *Corporate Social Responsibility and Environmental Management*, Vol. 23 No. 3, pp. 179-192.

Godinez, J.R. and Liu, L. (2015), “Corruption distance and FDI flows into Latin America”, *International Business Review*, Vol. 24 No. 1, pp. 33-42.

Huang, H.H., Kerstein, J. and Wang, C. (2018), “The impact of climate risk on firm performance and financing choices: an international comparison”, *Journal of International Business Studies*, Vol. 49 No. 5, pp. 633-656.

Huynh, T.D., Nguyen, T.H. and Truong, C. (2020), “Climate risk: the price of drought”, *Journal of Corporate Finance*, Vol. 65, p. 101750.

Ionascu, D., Meyer, K.E. and Estrin, S. (2004), “Institutional distance and international business strategies in emerging economies”, William Davidson Institute (WDI) – Working Papers.

Kling, G., Volz, U., Murinde, V. and Ayas, S. (2021), “The impact of climate vulnerability on firms’ cost of capital and access to finance”, *World Development*, Vol. 137, pp. 105-131.

Kogut, B. and Singh, H. (1988), “The effect of national culture on the choice of entry mode”, *Journal of International Business Studies*, Vol. 19 No. 3, pp. 411-432.

Kumarasiri, J. and Gunasekarage, A. (2017), “Risk regulation, community pressure and the use of management accounting in managing climate change risk: Australian evidence”, *The British Accounting Review*, Vol. 49 No. 1, pp. 25-38.

Li, Q. and Vashchilko, T. (2010), “Dyadic military conflict, security alliances, and bilateral FDI flows”, *Journal of International Business Studies*, Vol. 41 No. 5, pp. 765-782.

Li, S., Zhao, L. and Shen, H. (2021), “Foreign direct investment and institutional environment: the impact of bilateral investment treaties”, *Applied Economics*, Vol. 53 No. 30, pp. 3535-3548.

Liu, H.Y. and Deseatnicov, I. (2016), “Exchange rate and Chinese outward FDI”, *Applied Economics*, Vol. 48 No. 51, pp. 4961-4976.

Luo, Y., Xue, Q. and Han, B. (2010), “How emerging market governments promote outward FDI: experience from China”, *Journal of World Business*, Vol. 45 No. 1, pp. 68-79.

Lupton, N.C., Jiménez, A., Bayraktar, S. and Tsagdis, D. (2021), “Climate risk and private participation projects in infrastructure: mitigating the impact of locational (dis)advantages”, *Management Decision*, Vol. 59 No. 1, pp. 51-67.

Mohsin, A., Lei, H., Tushar, H., Hossain, S.F.A., Hossain, M.E. and Sume, A.H. (2021), “Cultural and institutional distance of China’s outward foreign direct investment toward the ‘belt and road’ countries”, *The Chinese Economy*, Vol. 54 No. 3, pp. 176-194.

Nayak, B.S. and Scheib, D. (2020), “Cultural logic of German foreign direct investment (FDI) in service sector”, *Journal of Economic Structures*, Vol. 9 No. 1, pp. 1-13.

Noorbakhsh, F., Paloni, A. and Youssef, A. (2001), “Human capital and FDI inflows to developing countries: new empirical evidence”, *World Development*, Vol. 29 No. 9, pp. 1593-1610.

O’Scawn, G. (2018), “Cultural distance and FDI: China Africa perspective”, *Open Journal of Business and Management*, Vol. 6 No. 2, pp. 382-399.

Phillips, N., Tracey, P. and Karra, N. (2009), “Rethinking institutional distance: strengthening the tie between new institutional theory and international management”, *Strategic Organization*, Vol. 7 No. 3, pp. 339-348.

Pinkse, J. and Gasbarro, F. (2019), "Managing physical impacts of climate change: an attentional perspective on corporate adaptation", *Business and Society*, Vol. 58 No. 2, pp. 333-368.

Pinkse, J. and Kolk, A. (2010), "Challenges and trade-offs in corporate innovation for climate change", *Business Strategy and the Environment*, Vol. 19 No. 4, pp. 261-272.

Shenkar, O. (2001), "Cultural distance revisited: towards a more rigorous conceptualization and measurement of cultural differences", *Journal of International Business Studies*, Vol. 32 No. 3, pp. 519-535.

Todaro, N.M., Testa, F., Daddi, T. and Iraldo, F. (2021), "The influence of managers' awareness of climate change, perceived climate risk exposure and risk tolerance on the adoption of corporate responses to climate change", *Business Strategy and the Environment*, Vol. 30 No. 2, pp. 1232-1248.

Vidal-Suárez, M. and López-Duarte, C. (2013), "Language distance and international acquisitions: a transaction cost approach", *International Journal of Cross Cultural Management*, Vol. 13 No. 1, pp. 47-63.

Weinhofer, G. and Busch, T. (2013), "Corporate strategies for managing climate risks", *Business Strategy and the Environment*, Vol. 22 No. 2, pp. 121-144.

Xu, D. and Shenkar, O. (2002), "Note: institutional distance and the multinational enterprise", *The Academy of Management Review*, Vol. 27 No. 4, pp. 608-618.

Further reading

Vincent, A.E., Salubi, I.L. and Timothy, P. (2017), "Evaluating the effect of exchange rate on foreign direct investment (FDI) in Nigeria", *Journal of Academic Research in Economics*, Vol. 9 No. 1, pp. 34-48.

Corresponding author

Yawen Wang can be contacted at: wyw_1002@163.com

Annex 559

T. Conlon et al., “Climate risk and financial stability: evidence from syndicated lending”, *The European Journal of Finance*, 2024

THE EUROPEAN JOURNAL OF FINANCE
https://doi.org/10.1080/1351847X.2024.2343111

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Climate risk and financial stability: evidence from syndicated lending

Thomas Conlon [a], Rong Ding[b], Xing Huan[c] and Zhifang Zhang[d]

[a]Smurfit Graduate Business School, University College Dublin, Dublin, Ireland; [b]NEOMA Business School, Paris, France; [c]EDHEC Business School, Nice, France; [d]Warwick Business School, University of Warwick, Coventry, UK

ABSTRACT

We study the impact of unexpected climate shocks on banks' individual and systemic risks. Employing climate risk measures developed using the Billion-Dollar Weather and Climate Disasters data from the National Oceanic and Atmospheric Administration (NOAA) and Dealscan syndicated lending data, we find that climate risk exposure acquired through cross-state lending increases banks' individual and systemic risks. We also find that bank profitability helps offset some of the adverse effects of climate risk. Banks reduce lending and increase loan loss reserves after the experience of an unexpected climate shock. The loan-level analysis reveals that the effect of climate risk exposure on bank risks is more pronounced for loans granted for operating and capital expenditures. We contribute to a growing literature on the impact of climate risk on financial stability and the development of robust measures of climate risk for banks.

ARTICLE HISTORY
Received 22 May 2023
Accepted 3 April 2024

KEYWORDS
Bank lending; climate change; climate risk; financial stability; systemic risk

JEL CLASSIFICATION:
G20; G21; G30; G32; N20

1. Introduction

What we have known simply as 'climate change' for the past thirty five years is now a global crisis. According to World Economic Forum (2021), climate action failure, extreme weather conditions, and environmental damage arising from human activities are among the most probable risks that the world will be exposed to over the next decade. Regulators are paying close attention to climate change and its implications for financial stability.[1] Central banks and financial regulators have started to design scenarios for climate stress tests to gauge how vulnerable the financial system is to climate change. Despite the sense of urgency and policy significance of this topic, considerable gaps remain in academic research. A major challenge facing both climate finance researchers and practitioners is the shortage of methodologies that facilitate robust measurement of climate risk and promote a successful assessment of the impact of climate change on financial stability (Bank for International Settlements 2021; Battiston, Dafermos, and Monasterolo 2021). The aim of this paper is to make progress in this matter by developing a method to calibrate climate risk and examine its impact on financial stability.

This paper makes several important contributions to the literature. First, we develop the literature on systemic risk by documenting borrower firms' exposure to climate risk as a source for lender banks' systemic risk contribution. Second, we add to the climate risk literature by proposing a climate risk measure that quantifies the extent to which banks are affected by extreme weather events, such as storms, floods, heat waves, and wildfires. In contrast to climate risk measures that focus on specific types of physical climate risks, such as heat exposure (Pankratz, Bauer, and Derwall 2023), or rises in sea levels (Bernstein, Gustafson, and Lewis 2019; Jiang, Li, and Qian 2020; Nguyen et al. 2022), our measure captures the impact of a comprehensive set of physical climate risks. We believe that this set of measures can create an avenue for future research that seeks to examine the impact of climate change on different aspects of social and economic life. Finally, this paper contributes to the ongoing regulatory efforts to measure climate risks and understand their implications for financial stability, providing

CONTACT Thomas Conlon conlon.thomas@ucd.ie

support for some recent developments in policy aimed at safeguarding monetary and financial stability against climate risk.

Climate risk would appear to meet the minimal definition of a systemic risk proposed by Benoit et al. (2017), as the risk that many market participants are simultaneously affected by severe losses, which then spread through the system.[2] In this paper, we exploit a setting where unexpected climate shocks transmit via bank lending and propagate through the system, generating financial contagion and elevated systemic risk once the unexpected exposure is priced. Prior studies have identified three primary channels through which shocks can be transmitted which, in turn, intensify systemic risk. The first channel is direct linkages between banks, which may propagate stress from distressed banks to other creditor banks (Allen and Gale 2000). The second channel is the commonality of asset holdings. Shocks can propagate via fire sales when distressed banks deleverage through selling assets (Shleifer and Vishny 1992, 2011). The final channel relies on information contagion (Chen 1999). When a bank is distressed, investors reassess the risk of other banks that are subject to similar exposures. When solvency risks are high, short-term investors may choose not to roll over their investments but engage in precautionary liquidity hoarding (Acharya and Skeie 2011).

We start with creating a bank-level climate risk measure using the Billion-Dollar Weather and Climate Disasters data from the National Oceanic and Atmospheric Administration (NOAA), in conjunction with syndicated lending data from the Dealscan database maintained by the Loan Pricing Corporation (LPC). We focus on syndicated loans for two main reasons: First, syndicated loans are a large and important source of corporate finance for nonfinancial firms in the US (Sufi 2007). Second, syndicated lending essentially operates as a risk-sharing mechanism, making it interesting to examine the transmission of climate risk exposure from borrower firms to banks within the syndication. Our identification strategy to determine the effect of banks' climate risk exposure on their individual and systemic risks consists of four key elements: (1) using an unexpected climate risk measure that cannot be accurately predetermined, thus presenting an exogenous source of variation in climate change and eliminating endogeneity concerns; (2) focusing on cross-state lending instead of within-state lending to isolate the mechanism through which climate risk exposure is transmitted from borrower firms to lender banks; (3) controlling for the book value of loans (i.e. loans-to-assets ratios) to isolate the incremental effect of syndicated lending; and (4) including borrower-firm fixed effects and loan fixed effects to control for latent constant characteristics of borrowers as well as loan demand around origination, allowing the bank-level climate risk measure to explain the remaining variation in banks' individual and systemic risks.

We find that unexpected climate risk exposure acquired through lending activity increases banks' individual and systemic risks. This effect is both statistically and economically significant: An increase of one standard deviation in the bank-level climate risk measure leads to an increase of 14.7% in the marginal expected shortfall, 1.3% in the long-run marginal expected shortfall, 5.9% in the 5% value at risk, 10.2% in the 1% value at risk, 2.7% in the 5% systemic risk contribution, and 6.1% in the 1% systemic risk contribution. We also find that banks reduce lending and increase loan loss reserves subsequent to the experience of a climate shock, and that more profitable banks are able to offset the risk effects of climate risk exposure. We conduct a thorough set of additional analyzes and find that our results are robust to many different specifications.[3]

Our paper relates to the prior literature documenting the effects of climate risks on both financial and nonfinancial firms. Firms that are more exposed to extremely high temperatures suffer lower revenues and operating income (Pankratz, Bauer, and Derwall 2023). Climate risk impacts the level and volatility of earnings in publicly listed companies, with firms in countries with higher climate risk holding more long-term debt and cash while paying lower cash dividends (Huang, Kerstein, and Wang 2017). Battiston et al. (2017) examine the propagation of climate policy risk through the financial system, finding that the proportion of banks' loan portfolios exposed to climate-policy-relevant sectors is similar to their level of capital held. A further strand of literature focuses on banks' reactions to climate change, showing that banks started pricing climate policy risk by charging marginally higher loan rates to fossil fuel firms after 2015 (Delis, de Greiff, and Ongena 2019), lender banks impose a higher cost of credit for fossil fuel firms that are subject to stricter climate policies and for firms exposed to greater sea level rise (SLR) risk (Jiang, Li, and Qian 2020), and lenders charge higher interest rates for mortgages on properties exposed to a greater risk of SLR (Nguyen et al. 2022).

The remainder of the paper is organized as follows. Section 2 describes the data and approach employed to measure climate risk. Section 3 presents the empirical design. Section 4 presents the main results. Section 5 reports robustness results. Section 6 concludes.

2. Measuring climate risk

Climate change can pose an impact on financial stability in two forms: physical risks and transition risks.[4] In this paper, we focus on physical climate risks, which adversely affect banks in two primary ways. First, physical climate risks can directly cause damage to physical assets and accelerate the depreciation of capital assets, for example, through a direct connection with extreme weather events such as floods, storms, or wildfires. Such impact can often be offset as insurance generally covers losses due to unexpected catastrophic events. Second, a more relevant impact arises from the fact that physical climate risks can alter (typically reducing) the outputs achievable with a given level of inputs, resulting in a change in the return on capital assets. Banks' credit risk increases and loan quality declines when borrower firms' ability to repay loans is weakened by climate losses. Dietz et al. (2016) document that the estimated impact of climate change on asset value (i.e. climate value at risk or climate VaR) is economically significant and mostly distributed in the tail. More importantly, it is difficult to model and hedge climate risks given the unexpected nature and the long horizon over which such risks may materialize (Financial Stability Board 2020).

2.1. Data

We use the Billion-Dollar Weather and Climate Disasters Data from the National Centers for Environmental Information (NCEI) database maintained by NOAA to measure the state-level climate risk. We employ extreme weather event data as physical climate risks are mostly driven by severe weather events (Li et al. 2024). The NCEI database reports weather and climate disasters where overall losses equaled or exceeded $1 billion. Climate risk events are classified into seven disaster categories: drought, flooding, freezing, severe storms, tropical cyclones, wildfires, and winter storms. For the 1980–2020 reporting cycle, it reports 290 events with total human deaths of 14,492 and total losses exceeding $1.98 trillion,[5] corresponding to an average of seven events and 353 deaths per year and a loss of $6.8 billion per event (NOAA 2020). In 2020, total losses amounted to $99.5 billion, which accounts for circa 0.5% of the annual GDP of the US for the same period (i.e. $20.94 trillion).

We map the raw climate risk loss data to provide an overview of the variation in climate risk across the states. Figure 1 displays the cumulative losses due to climate risk events during the period of 1980–2020. Figure 2 maps the total number of climate risk events for the same period. Georgia, Mississippi, North Carolina, and Texas are among the high-risk states in terms of both loss severity and frequency over the years.

We collect data on syndicated loans from the Dealscan database maintained by the LPC. Dealscan provides comprehensive information on syndicated loans at origination, including loan amount, maturity, pricing, and identity of lenders and borrowers. A syndicated loan is facilitated by a syndicate of lenders jointly providing funding to a single borrower. The unit of observation in the Dealscan database is a facility (or tranche). A typical syndicated loan deal (or package) consists of multiple facilities initiated at the same time. A deal is arranged by a sole or a few lead lenders who solicit the syndicated members and define the lending arrangement.

We place several restrictions on the Dealscan data to align the climate risk measures with the subsequent analysis requirements. First, we require that the data on the deal value and the date of origination be nonmissing and remove transactions with deal status 'canceled', 'suspended', or 'rumour'. Second, since we require information on a bank's allocation share in a loan, we exclude packages with facilities missing information on any lender shares. However, if a package has just one lender and its allocation information is missing, we set the lender share to 100%. Since most loans in Dealscan are syndicated, they are typically associated with one or more lead banks and several participant banks. We retain both lead and participant banks and obtain lender shares for both. Third, we exclude packages with inaccurate lender share information; for instance, when the total of all lender shares exceeds 101%, a threshold that is set to account for minor rounding errors. Lastly, as our focus is on lending made by banks to nonfinancial firms in the United States, we exclude loans made by non-US banks or loans to non-US firms or those in the financial sector (two-digit Standard Industrial Classification (SIC) codes 60–69). Table 1 reports the above sample selection procedure. After four data screening restrictions, we obtain a dataset with 54,642 bank share observations contributed by 571 lender banks and 6,524 borrower firms.

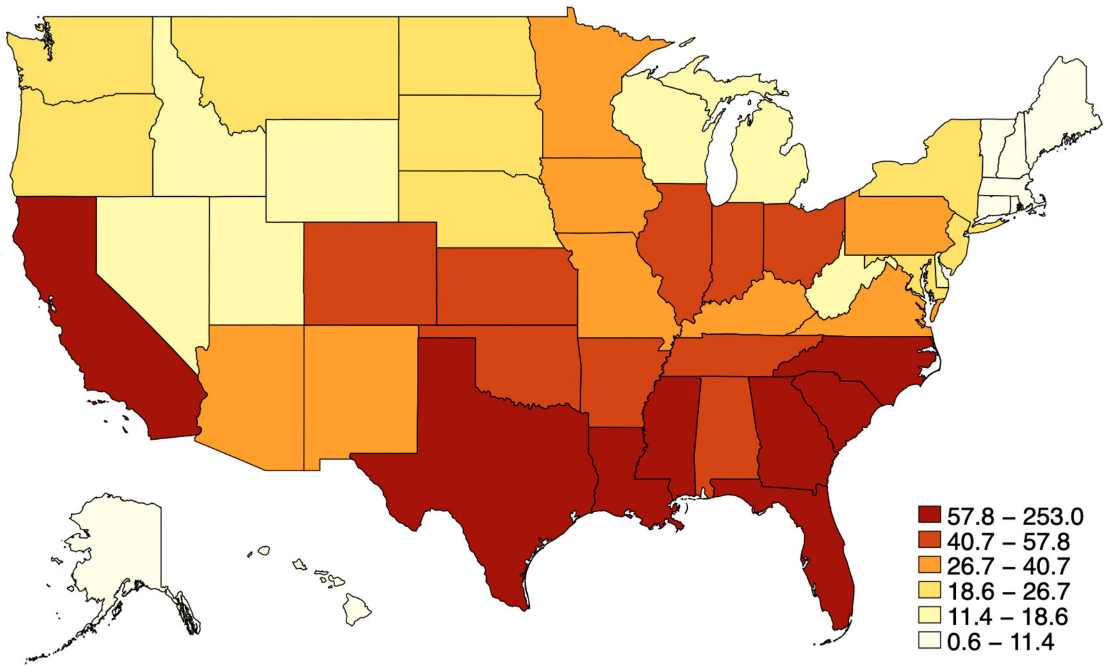


Figure 1. Cumulative losses (USD bn) of climate risk events 1980–2020.

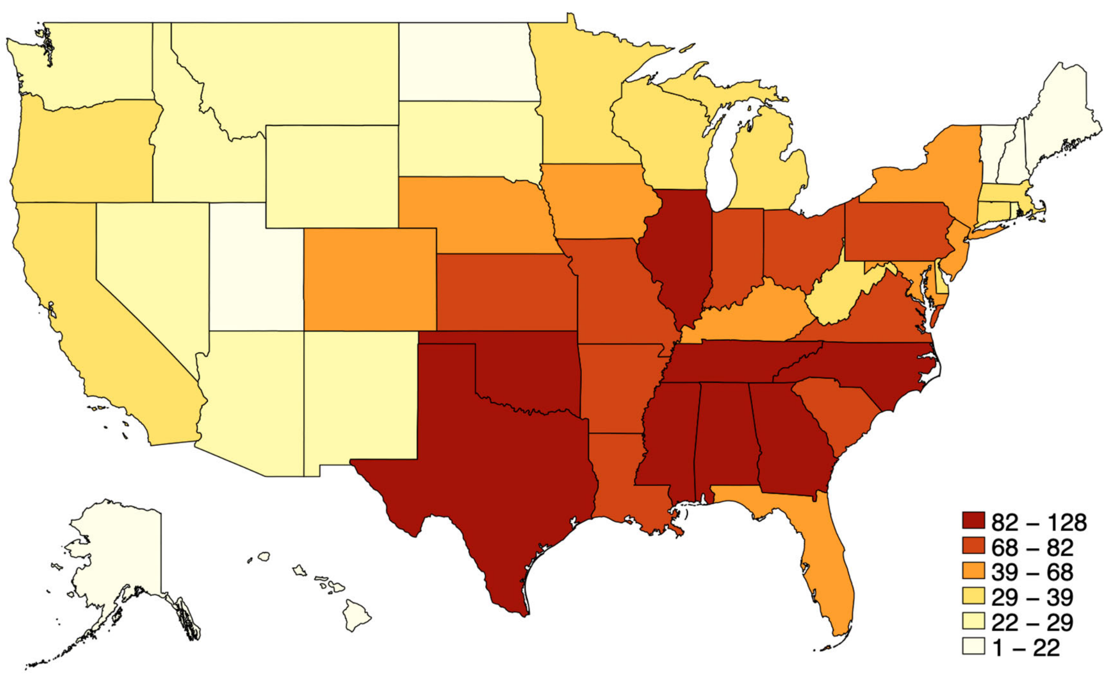


Figure 2. Cumulative frequency of climate risk events 1980–2020.

Table 1. Sample selection for climate risk measurement.

	# of lender banks	# of borrower firms	# of bank share observations
Initial Dealscan sample	10, 428	73, 430	1, 747, 705
1. Removing deals that are ‘canceled’, ‘suspended’, or ‘rumour’.	10, 402	73, 074	1, 739, 874
2. Excluding deals with missing lender share information.	5218	32, 272	410, 904
3. Excluding deals with inaccurate lender share information.	5164	31, 828	396, 647
4. Excluding loans made by non-US banks or loans made to non-US firms or financial firms.	571	6524	54, 642

This table presents the sample selection procedure undertaken for measuring climate risk.

Table 2. Principal component analysis results.

Component	Eigenvalues	Percentage of variance
1	2.802	0.467
2	1.428	0.238
3	0.917	0.153
4	0.630	0.105
5	0.121	0.020
6	0.103	0.017

This table reports the eigenvalues and the proportion of the variance explained by the six components.

2.2. Measurement

Our approach to climate risk measurement is largely informed by the methodological framework developed by the Bank for International Settlements (2021), which involves scoring climate risk on the basis of accounting for portfolio and sectoral exposures. The measurement of climate risk comprises two major steps: We first create a state-level climate risk index (CRI_State), and then compute bank-level climate risk exposure (CRI_Bank) by weighting bank lending to a state by the climate risk index of the borrower's state.

CRI_State quantifies the extent to which states have suffered unexpected losses associated with extreme weather events such as storms, floods, and heat waves. CRI_State is indicative of the severity of losses that a state suffers due to climate change, and is based on the following six key climate risk indicators: (1) number of deaths, (2) number of deaths per 100,000 inhabitants, (3) sum of losses in USD at purchasing power parity (PPP), (4) losses per unit of Gross Domestic Product (GDP), (5) number of events, and (6) loss per event. CRI_State is constructed in four steps: First, we perform principal component analysis of these six factors and report the eigenvalues and proportion of the variance explained by the six components in Table 2. As shown in Figure 3, we identify two components with eigenvalues greater than one, explaining 70% of the total variance. Second, we compute the state-level climate risk exposure as the weighted sum of these two significant components, where the weight is given by the eigenvalues. Third, CRI_State is obtained from the residuals from regressing the climate risk exposure of the current year on this variable in the previous three years. CRI_State captures the unexpected variations in climate change, which present credible exogenous shocks as they cannot be accurately predetermined and thus imply that endogeneity issues arising from reverse causality and self selection are unlikely to be a major concern (Auffhammer et al. 2020; Dell, Jones, and Olken 2014; Rao et al. 2022). Finally, we rank CRI_State and scale it by -1 so that a higher score corresponds to greater climate risk for state j in year t.

The bank-level climate risk is the sum of a bank's lending share to an individual state weighted by the climate risk of the borrower's state, which can be expressed as follows:

$$\text{CRI\_Bank}_{i,t} = \sum \frac{L_{i,j,t}}{TL_{i,t}} \text{CRI\_State}_{j,t}, \tag{1}$$

where $L_{i,j,t}$ are the total outstanding loans made by bank i to borrowers in state j in year t. $TL_{i,t}$ are the total outstanding loans of bank i in year t. $\frac{L_{i,j,t}}{TL_{i,t}}$ measures a bank's lending share in state j in year t. $CRI\_State_{j,t}$ is the climate risk index for state j in year t as defined above. For example, JP Morgan's lending share to borrowers in Texas and Florida is 17% and 6% out of its total syndicated lending in 2016, respectively. We construct two

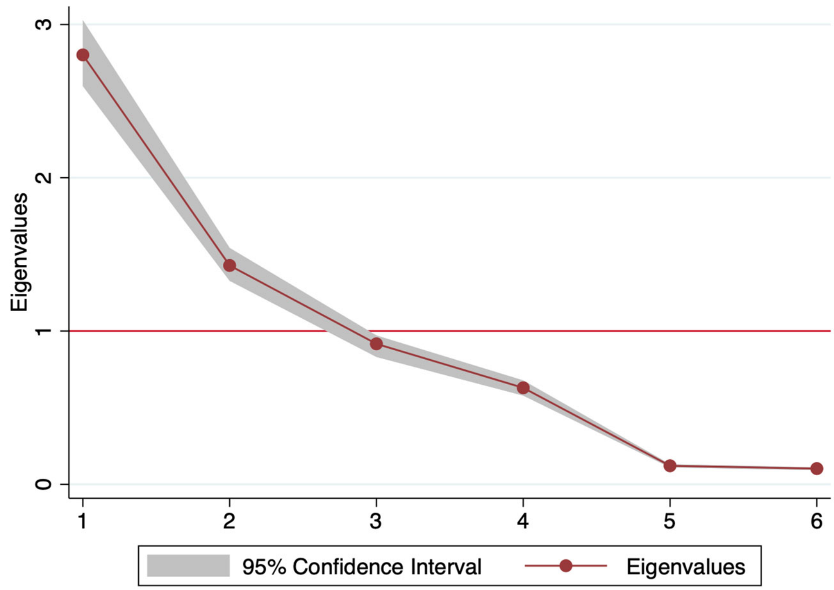


Figure 3. Scree plot of eigenvalues after PCA.

variations of CRI_Bank: CRI_Bank_Cross, and CRI_Bank_Home. The former quantifies unexpected climate risk exposure banks acquire through lending to firms located in a different state (i.e. cross-state lending) while the latter captures unexpected climate risk exposure banks acquire through lending to firms located in the same state (i.e. within-state lending).

3. Empirical design

3.1. Methodology

To examine the impact of bank-level climate risk on financial stability, we exploit the economic link between a lender bank and its borrower firms, and analyze how the exposure of a bank's borrowers to climate risk affects the bank's individual risk and systemic risk contribution. We specify our baseline model as follows:

$$\text{Risk}_{i,t} = \beta_0 + \beta_1 \text{CRI\_Bank\_Cross}_{i,t-1} + \sum_{j=2}^{27} \beta_j \text{Control}_{i,t-1} + \text{FE} + \epsilon_{i,t}, \tag{2}$$

where $\text{Risk}_{i,t}$ is a set of variables of bank i at time t that is one of the following risk measures: Marginal Expected Shortfall (MES), Long-run Marginal Expected Shortfall (LRMES), VaR5, VaR1, ΔCoVaR5, and ΔCoVaR1.

Following Acharya, Engle, and Richardson (2012), we compute MES as follows:

$$\text{MES}_t^i = E[R_t^i | R_t^m \leqslant q_\alpha], \tag{3}$$

where R_t^i is the same as previously defined; R_t^m represents the daily financial sector market return at time t; and q_α is the α quantile of market returns. Setting $\alpha = 5\%$, MES measures the average bank equity return during the 5% worst return days for the banking industry in a year. MES quantifies the extent to which an individual bank's stock returns are low when market returns are low.

LRMES is the long-run marginal expected shortfall (Acharya, Engle, and Richardson 2012), which measures the co-movement of a bank's stock price with the banking industry's market index during its worst 2% return days in a year, and calculated as:

$$\mathrm{LRMES}_t^i = 1 - \exp(-18 \times \mathrm{MES}_t^i). \tag{4}$$

$\mathrm{VaR}_t^i(q)$ focuses on the risk of an individual bank in isolation and is defined as the qth percentile of the potential asset return in percentage R^i that can occur to bank i during a given time period t (Jorion 2006):

$$P(R^i \leqslant \mathrm{VaR}_t^i(q)) = q. \tag{5}$$

Following Brunnermeier, Dong, and Palia (2020) and Adrian and Brunnermeier (2016), t is set at a weekly interval. Setting q at 5% or 1%, VaR thus measures the worst expected loss of bank i on a weekly basis at either 5% or 1%. The weekly interval is also well-suited for capturing variations in the impact of climate change on stock returns, as the duration of events in our sample ranges from days to months. We then convert weekly VaR to an annual frequency by multiplying the mean weekly VaR during a year by 52.

ΔCoVaR is a statistical measure of tail dependency that does not rely on causality. It captures the direct spillover effects through contractual links, as well as the indirect spillover effects arising from market-wide externalities and the shared exposure of multiple financial institutions to the same risk factors (Adrian and Brunnermeier 2016). Consistent with the approach detailed in Adrian and Brunnermeier (2016), we estimate the time-varying ΔCoVaR for each bank at the 5% and 1% levels. Our estimation is based on quantile regressions using weekly data calculated using CRSP daily stock files for all financial institutions with two-digit Standard Industrial Classification (SIC) code between 60 and 67 inclusive.[6] We remove daily observations with missing or negative prices and retain banks with nonmissing stock return data on their ordinary common shares for a minimum of 260 weeks. We then merge the weekly stock data with quarterly balance sheet data from the CRSP/Compustat Merged dataset and remove banks with book-to-market and leverage ratios that are less than zero or greater than 100.[7] The following models are estimated:

$$X_t^i = \alpha^i + \gamma^i M_{t-1} + \epsilon_t^i, \tag{6}$$

$$X_t^{\mathrm{system}} = \alpha^{\mathrm{system|i}} + \beta^{\mathrm{system|i}} X_t^i + \gamma^{\mathrm{system|i}} M_{t-1} + \epsilon_t^{\mathrm{system|i}}, \tag{7}$$

where X_t^i is the weekly equity return for bank i at time t; $\mathrm{X}_t^{\mathrm{system}}$ is the weekly return on the market equity of the financial system, calculated as the average market equity weighted by lagged market equity. M_{t-1} is a set of state variables that include the change in the three-month Treasury bill rate, the change in the slope of the yield curve (i.e. the spread between the composite long-term bond yield and three-month Treasury bill rate), a short-term TED spread (i.e. the difference between the three-month LIBOR rate and the three-month Treasury bill rate), the change in credit spread between Moody's seasoned BAA corporate bond yield and the ten-year Treasury rate, the weekly market return computed from the S&P 500 index, the weekly real estate sector return in excess of the financial sector return, and equity volatility calculated as the 22–day rolling standard deviation of the daily CRSP stock market return.

From the estimation of Equations (5) and (6) we obtain:

$$\mathrm{VaR}_t^i(q) = \hat{\alpha}_q^i + \hat{\gamma}_q^i M_{t-1}, \tag{8}$$

$$\mathrm{CoVaR}_t^i(q) = \hat{\alpha}_q^{\mathrm{system|i}} + \hat{\beta}_q^{\mathrm{system|i}} \mathrm{VaR}_t^i(q) + \hat{\gamma}_q^{\mathrm{system|i}} M_{t-1}, \tag{9}$$

where $\hat{\alpha}_q^i$, $\hat{\gamma}_q^i$, $\hat{\beta}_q^{\mathrm{system|i}}$ and $\hat{\gamma}_q^{\mathrm{system|i}}$ are coefficients obtained from quantile regressions at the 1% and 5% confidence levels. $\Delta\mathrm{CoVaR}_t^i(q)$, which measures the marginal contribution of bank i to the risk of the system at time t, is computed as the difference between $\mathrm{CoVaR}_t^i(q)$ conditional on the distress of the institution (i.e. $q = 5\%$ or 1%) and $\mathrm{CoVaR}_t^i(50\%)$ (i.e. the normal state of the institution):

$$\Delta\mathrm{CoVaR}_t^i(q) = \mathrm{CoVaR}_t^i(q) - \mathrm{CoVaR}_t^i(50\%). \tag{10}$$

We obtain weekly $\Delta\mathrm{CoVaR}_t^i(q)$ from the quantile regressions and convert it to an annual frequency by first taking the mean of $\Delta\mathrm{CoVaR}_t^i(q)$ and then applying a multiplier of 52 for each bank year. We multiply MES, LRMES, VaR5, VaR1, ΔCoVaR5, and ΔCoVaR1 by -1 so that higher values correspond to greater risk.

As discussed in Section 2.2, we create two variations of bank-level climate risk measures: CRI_Bank_Cross and CRI_Bank_Home. The former quantifies unexpected climate risk exposure banks acquire through lending to firms located in a different state (i.e. cross-state lending) while the latter captures unexpected climate risk exposure banks acquire through lending to firms located in the same state (i.e. within-state lending). In our analyzes, the variable of interest is CRI_Bank_Cross because it enables us to pinpoint the mechanism through which climate risk exposure is transmitted from borrower firms to lender banks. This is not the case with CRI_Bank_Home, as it does not facilitate a clear identification of the transmission channel for climate risk. This is because shared climate risk environments among borrower firms and lender banks, when located in the same state, make it difficult to isolate this transmission mechanism. Nevertheless, we include CRI_Bank_Home as an additional control to address concerns about omitted variable bias when not accounting for the effect of within-state lending.

We further control for a set of bank characteristics that are found to be relevant in explaining bank systemic risk (Anginer et al. 2018; Brunnermeier, Dong, and Palia 2020; De Jonghe, Diepstraten, and Schepens 2015; Gauthier, Lehar, and Souissi 2012; Laeven, Ratnovski, and Tong 2016). We include bank size (SIZE_Bank) to control for economies of scale, equity ratio (EQRAT_Bank) to control for bank capital position, market-to-book ratio (MTB_Bank) to control for bank growth opportunities, loans-to-assets ratio (LTA_Bank), loan loss reserves ratio (LLR_Bank) to control for bank loan risk, deposit ratio (DEPO_Bank) to control for bank funding structure, noninterest income ratio (NII_Bank) to control for bank business model, and return on assets (ROA_Bank) to control for bank profitability. Notably, since our CRI_Bank_Cross has an element of bank lending share, controlling for the book value of loans (LTA_Bank) thus allows us to gauge the incremental effect of syndicated lending in addition to bank loan books, on banks' systemic risk. At the borrower firm level, we control for a set of firm characteristics commonly included in debt covenants and relevant for explaining lending decisions and loan quality (Demerjian and Owens 2016), which in turn may affect banks' systemic risk via lending: firm size (SIZE_Borrower), interest coverage (COVER_Borrower), debt-to-EBITDA ratio (DEBT_Borrower), and current ratio (CURRENT_Borrower). We control for GDP per capita and its annual growth rate (ΔGDP) for both lender and borrower states. Variable definitions are detailed in Appendix 1. We also include year fixed effects in all regressions to account for economy-wide shocks on bank risk. We include borrower firm fixed effects to control for latent constant characteristics of each borrower. All continuous independent variables are winsorized at the 1st and 99th percentiles of their empirical distribution.[8] Standard errors are adjusted for clustering at the bank-borrower lending relationship level.[9]

3.2. Sample and descriptive statistics

We match borrower firms in the Dealscan database with annual financial statement information from Compustat using the linking table provided by Beyhaghi et al. (2021). We use data from the financial year prior to the year of loan origination to ensure that the accounting information is publicly available at the time of loan origination. Using the linking table provided by Schwert (2018), we merge lender banks active in Dealscan with financial statement data from Compustat. We then aggregate all data at lender banks' and borrower firms' parent level to construct the lender-borrower-year sample structure. After applying these two linking tables, the number of lender banks is reduced from 571 to 42[10] and the number of borrower firms decreases from 6,524 to 1,314, resulting in a total of 12,142 lender-borrower-year observations. Table 3 reports composition of the final sample used in our empirical analyzes. Panel A reports sample composition by year. Panel B reports sample composition by lender bank state. Panel C reports sample composition by borrower firm state.

Table 4 presents descriptive statistics for all variables used in our analysis. For our key dependent variables, the average bank has marginal expected shortfall (−MES) of 3.35%, long-run marginal expected shortfall (−LRMES) of 0.48%, value at risk at the 5% level (−VaR5) of 2.65 %, value at risk at the 1% level (−VaR1) of 4.43%, a systemic risk contribution at the 5% level (−ΔCoVaR5) of 0.87%, and systemic risk contribution at the 1% level (−ΔCoVaR1) of 0.78%. For the key independent variable, the average value of CRI_Bank_Cross is −24.30, with a standard deviation of 9.61. CRI_Bank_Cross ranges from −37.16 to 0, with a higher value indicating greater climate risk. Similarly, CRI_Bank_Home has a mean of −26.39 and ranges from −49 to 0. The average bank in our sample has log of total assets (SIZE_Bank) of 12.44 (mean total assets of $560.82 billion),

Table 3. Sample composition.

Year	Frequency	Percent	Cumulative
Panel A. Sample Composition by Year			
1999	677	5.58	5.58
2000	640	5.27	10.85
2001	691	5.69	16.54
2002	687	5.66	22.20
2003	761	6.27	28.46
2004	807	6.65	35.11
2005	874	7.20	42.31
2006	622	5.12	47.43
2007	555	4.57	52.00
2008	282	2.32	54.32
2009	325	2.68	57.00
2010	722	5.95	62.95
2011	840	6.92	69.86
2012	766	6.31	76.17
2013	602	4.96	81.13
2014	556	4.58	85.71
2015	685	5.64	91.35
2016	492	4.05	95.40
2017	185	1.52	96.93
2018	197	1.62	98.55
2019	176	1.45	100.00
Total	12, 142	100.00	
State	Frequency	Percent	Cumulative
Panel B. Sample Composition by Lender State			
Alabama	271	2.23	2.23
California	1, 086	8.94	11.18
Connecticut	38	0.31	11.49
Georgia	836	6.89	18.37
Hawaii	20	0.16	18.54
Illinois	925	7.62	26.16
Louisiana	47	0.39	26.54
Massachusetts	195	1.61	28.15
Minnesota	1, 393	11.47	39.62
Mississippi	6	0.05	39.67
New Jersey	23	0.19	39.86
New York	2, 206	18.17	58.03
North Carolina	2, 167	17.85	75.88
Ohio	1, 353	11.14	87.02
Pennsylvania	1, 051	8.66	95.68
Rhode Island	25	0.21	95.88
Texas	407	3.35	99.23
Utah	49	0.40	99.64
Wisconsin	44	0.36	100.00
Total	12, 142	100.00	
Panel C. Sample Composition by Borrower State			
Alabama	62	0.51	0.51
Arizona	243	2.00	2.51
Arkansas	98	0.81	3.32
California	592	4.88	8.19
Colorado	237	1.95	10.15
Connecticut	208	1.71	11.86
Delaware	44	0.36	12.22
District of Columbia	107	0.88	13.10
Florida	557	4.59	17.69
Georgia	388	3.20	20.89
Idaho	74	0.61	21.50
Illinois	797	6.56	28.06
Indiana	192	1.58	29.64
Iowa	28	0.23	29.87

Table 3. Continued.

Kansas	61	0.50	30.37
Kentucky	205	1.69	32.06
Louisiana	95	0.78	32.84
Maryland	160	1.32	34.16
Massachusetts	304	2.50	36.67
Michigan	459	3.78	40.45
Minnesota	409	3.37	43.81
Mississippi	11	0.09	43.91
Missouri	496	4.08	47.99
Montana	7	0.06	48.05
Nebraska	56	0.46	48.51
Nevada	61	0.50	49.01
New Hampshire	18	0.15	49.16
New Jersey	342	2.82	51.98
New Mexico	12	0.10	52.08
New York	631	5.20	57.27
North Carolina	291	2.40	59.67
North Dakota	12	0.10	59.77
Ohio	761	6.27	66.04
Oklahoma	193	1.59	67.62
Oregon	103	0.85	68.47
Pennsylvania	605	4.98	73.46
Rhode Island	99	0.82	74.27
South Carolina	63	0.52	74.79
South Dakota	33	0.27	75.06
Tennessee	480	3.95	79.01
Texas	1,620	13.34	92.36
Utah	28	0.23	92.59
Vermont	5	0.04	92.63
Virginia	391	3.22	95.85
Washington	170	1.40	97.25
West Virginia	5	0.04	97.29
Wisconsin	329	2.71	100.00
Total	12,142	100.00	

This table reports the sample composition. Panel A reports the sample composition by year. Panel B reports the sample composition by lender bank state. Panel C reports the sample composition by borrower firm state.

equity ratio (EQRAT_Bank) of 9%, market-to-book ratio (MTB_Bank) of 1.59, deposit ratio (DEPO_Bank) of 63%, loans-to-assets ratio (LTA_Bank) of 51%, nonperforming loans ratio (NPL) of 1%, noninterest income ratio (NII_Bank) of 3%, and return on assets (ROA_Bank) of 1%. These statistics suggest that the average bank tends to be very large and well-capitalized although these averages may mask substantial cross-sectional and time-varying differences. Turning to the borrower controls, we find that the average borrower firm in our sample has a log of total assets (SIZE_Borrower) of 8.08 (mean total assets of \$12.41 billion), interest coverage (COVER_Borrower) of 20.29, debt-to-EBITDA ratio (DEBT_Borrower) of 2.44, and current ratio (CURRENT_Borrower) of 0.41. We also note that the average value of log GDP per capita is 10.76 and 10.73 for lender banks' and borrower firms' states, respectively. The average value of annual growth in GDP per capita (ΔGDP) for both lender banks' and borrower firms' states is 3% and 4% for lender banks' and borrower firms' states, respectively.

4. Results

4.1. Univariate analysis

We report the Pearson correlation between climate risk and banks' individual and systemic risk measures in Panel A of Table 5. All measures for banks' individual and systemic risks are positively correlated at the 1% of statistical significance. CRI_Bank_Cross is positively and significantly correlated with −MES, −LRMES, −VaR5, −VaR1, $-\Delta$CoVaR5, and $-\Delta$CoVaR1, which provides preliminary support to our expected relationship about the unexpected climate risk exposure gained through cross-state lending and banks' individual and systemic

Table 4. Descriptive statistics.

	N	Mean	S.D.	Min	Median	Max
−MES	12,142	3.35	2.20	0.57	2.97	14.65
−LRMES	12,142	0.48	0.18	0.04	0.48	0.97
−VaR5	12,142	2.65	0.84	1.18	2.47	7.36
−VaR1	12,142	4.43	1.34	2.19	4.11	14.12
−ΔCoVaR5	12,142	0.87	0.32	0.26	0.84	2.43
−ΔCoVaR1	12,142	0.78	0.45	0.17	0.70	3.18
CRI_Bank_Cross	12,142	−24.30	9.61	−37.16	−26.79	0.00
CRI_Bank_Home	12,142	−26.39	13.62	−49.00	−28.00	0.00
SIZE_Bank	12,142	12.44	1.29	8.69	12.30	14.67
EQRAT_Bank	12,142	0.09	0.02	0.04	0.09	0.13
MTB_Bank	12,142	1.59	0.76	0.39	1.52	4.11
DEPO_Bank	12,142	0.63	0.10	0.28	0.65	0.86
LTA_Bank	12,142	0.51	0.14	0.12	0.55	0.77
NPL_Bank	12,142	0.01	0.01	0.00	0.00	0.03
NII_Bank	12,142	0.03	0.01	0.01	0.02	0.07
ROA_Bank	12,142	0.01	0.01	−0.01	0.01	0.02
GDP_Bank	12,142	10.76	0.20	10.10	10.75	11.23
ΔGDP_Bank	12,142	0.03	0.02	−0.03	0.04	0.10
SIZE_Borrower	12,142	8.08	1.65	2.56	8.06	11.74
COVER_Borrower	12,142	20.29	41.28	−6.96	8.78	284.68
DEBT_Borrower	12,142	2.44	2.37	−7.04	2.02	16.54
CURRENT_Borrower	12,142	0.41	0.33	0.00	0.33	2.16
GDP_Borrower	12,142	10.73	0.22	10.13	10.71	11.28
ΔGDP_Borrower	12,142	0.04	0.02	−0.03	0.04	0.10

This table presents descriptive statistics of the variables studied. N refers to the number of observations. S.D. is the standard deviation. Min and Max refer to the minimum and maximum values, respectively. Variables are defined in Appendix 1.

risks. In Panel B of Table 5, we review the correlation between the climate risk measures and all control variables and find nothing that would indicate issues with multicollinearity.

4.2. *The effects of climate risk on banks' individual and systemic risks*

Table 6 reports the baseline results from regressions of banks' individual and systemic risks on our climate risk measure and control variables. The variable of interest is CRI_Bank_Cross. We find that β_1, the coefficient for CRI_Bank_Cross, is statistically significant at the 1% level across all model specifications. For the purpose of interpretation, we normalize all variables so that the coefficient captures the effect of a unit (one standard deviation) change in the respective variable on *Risk*. β_1 thus represents the percentage of additional *Risk* generated, away from the mean *Risk*, associated with a one standard deviation increase in the pertinent CRI_Bank_Cross. A unit increase in CRI_Bank_Cross leads to an increase of 14.7% in −MES, 1.3% in −LRMES, 5.9% in −VaR5, 10.2% in −VaR1, 2.7% in −ΔCoVaR5, and 6.1% in −ΔCoVaR1. The average variance inflation factor (VIF) of 1.94 indicates that multicollinearity among the regressors should not be a concern. Adjusted R^2 ranges from 0.49 to 0.91, suggesting that a substantial proportion of the variation in the dependent variables is explained in the models identified.[11]

Many of our bank-specific control variables, chosen to align with the extant literature, are found to be significant. Bank size and equity ratio have a positive and significant association with the risk measures examined, with the exception of −ΔCoVaR1, where there is a reversal of sign.[12] To try to understand the changes in sign for bank size and equity ratio, two contributing factors must be considered. First, the level of aggregate systemic risk spiked to unprecedented levels following the collapse of Lehman Brothers. Second, subsequent to this event, not all banks were bailed out, and those that were tended to be the very largest and most systemically important ones.[13] Combining these contributors may explain the changes in sign. During the most significant period of systemic risk, where the focus is on the quantile of most extreme returns, certain banks were more likely to be bailed out. These bailouts, in turn, altered the bank-level systemic risk, as larger, too-big-to-fail banks found themselves in a stronger position, thereby helping to explain the change in sign. The market-to-book ratio, MTB_Bank is positive and significant for the systemic risk measures and negative and significant for −VaR1.

Table 5. Correlation.

	CRI_Bank_Cross	CRI_Bank_Home	−MES	−LRMES	−VaR5	−VaR1	−ΔCoVaR5	−ΔCoVaR1
Panel A. Correlation Between Climate Risk and Systemic Risk Measures								
CRI_Bank_Cross	1							
CRI_Bank_Home	−0.088***	1						
−MES	0.102***	−0.051***	1					
−LRMES	0.151***	−0.022*	0.909***	1				
−VaR5	0.371***	−0.060***	0.777***	0.741***	1			
−VaR1	0.278***	−0.069***	0.710***	0.683***	0.894***	1		
−ΔCoVaR5	0.269***	−0.161***	0.560***	0.558***	0.660***	0.540***	1	
−ΔCoVaR1	0.205***	−0.136***	0.249***	0.285***	0.333***	0.276***	0.780***	1

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel B. Correlation Between Climate Risk and Control Variables									
(1) CRI_Bank_Cross	1								
(2) CRI_Bank_Home	−0.088***	1							
(3) SIZE_Bank	−0.220***	0.037***	1						
(4) EQRAT_Bank	−0.284***	0.080***	−0.037***	1					
(5) MTB_Bank	0.400***	−0.001	−0.474***	−0.362***	1				
(6) DEPO_Bank	−0.018*	0.037***	−0.640***	0.359***	0.160***	1			
(7) LTA_Bank	0.110***	0.056***	−0.370***	0.237***	0.021*	0.473***	1		
(8) NPL_Bank	−0.200***	0.002	0.109***	0.168***	−0.461***	0.118***	0.314***	1	
(9) NII_Bank	0.144***	−0.037***	−0.183***	−0.126***	0.504***	−0.042***	−0.412***	−0.188***	1
(10) ROA_Bank	0.198***	0.059***	−0.309***	0.104***	0.616***	0.255***	0.210***	−0.438***	0.380***
(11) GDP_Bank	−0.404***	0.080***	0.432***	0.241***	−0.389***	0.029**	−0.367***	−0.029**	−0.105***
(12) ΔGDP_Bank	0.057***	0.037***	−0.076***	0.104***	0.164***	0.059***	−0.071***	−0.208***	0.100***
(13) SIZE_Borrower	−0.157***	0.027**	0.097***	0.102***	−0.100***	0.047***	−0.204***	−0.013	0.078***
(14) COVER_Borrower	−0.013	−0.007	0.036***	0.024**	−0.037***	−0.01	0.002	0.021*	−0.032***
(15) DEBT_Borrower	0.015	−0.001	0.003	0.018*	−0.016	0.011	0.013	0.004	−0.003
(16) CURRENT_Borrower	0.039***	−0.009	0.011	−0.018*	−0.007	−0.041***	0.017	0.040***	−0.002
(17) GDP_Borrower	−0.383***	0.060***	0.289***	0.397***	−0.464***	0.137***	−0.082***	0.125***	−0.189***
(18) ΔGDP_Borrower	0.081***	−0.054***	−0.070***	0.030**	0.168***	−0.037***	−0.012	−0.153***	0.087***

Table 5. Continued.

	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Panel B. Correlation Between Climate Risk and Control Variables									
(1) CRI_Bank_Cross									
(2) CRI_Bank_Home									
(3) SIZE_Bank									
(4) EQRAT_Bank									
(5) MTB_Bank									
(6) DEPO_Bank									
(7) LTA_Bank									
(8) NPL_Bank									
(9) NII_Bank									
(10) ROA_Bank	1								
(11) GDP_Bank	−0.120***	1							
(12) ΔGDP_Bank	0.228***	0.078***	1						
(13) SIZE_Borrower	−0.056***	0.286***	−0.023*	1					
(14) COVER_Borrower	−0.014	0.030***	0.004	−0.139***	1				
(15) DEBT_Borrower	−0.013	−0.003	0.005	0.126***	−0.307***	1			
(16) CURRENT_Borrower	−0.016	−0.052***	−0.025**	−0.083***	−0.013	0.050***	1		
(17) GDP_Borrower	−0.158***	0.588***	−0.043***	0.254***	0.058***	0.007	−0.057***	1	
(18) ΔGDP_Borrower	0.197***	−0.097***	0.467***	−0.057***	0.003	0.020*	−0.045***	−0.028**	1

Panel A reports Pearson correlation coefficients between climate risk and systemic risk measures. Panel B reports correlation coefficients between climate risk measures and control variables. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Variables are defined in Appendix 1.

Table 6. The effects of climate risk on banks' individual and systemic risks.

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) −ΔCoVaR5	(6) −ΔCoVaR1
CRI_Bank_Cross	0.147***	0.013***	0.059***	0.102***	0.027***	0.061***
	(7.671)	(7.502)	(6.435)	(4.339)	(5.273)	(6.633)
CRI_Bank_Home	−0.006	0.000	0.007**	−0.016**	−0.039***	−0.035***
	(−0.935)	(0.055)	(2.246)	(−2.031)	(−18.777)	(−8.882)
SIZE_Bank	0.087***	0.003**	0.070***	0.154***	0.049***	−0.049***
	(6.094)	(2.122)	(10.051)	(9.295)	(9.962)	(−5.793)
EQRAT_Bank	−0.000	0.003***	0.034***	0.093***	0.025***	−0.019***
	(−0.006)	(3.922)	(7.360)	(7.672)	(7.084)	(−2.905)
MTB_Bank	0.013	0.009***	−0.080***	0.012	0.046***	0.084***
	(0.735)	(6.236)	(−10.024)	(0.593)	(6.840)	(7.429)
DEPO_Bank	−0.077***	−0.004***	0.033***	0.078***	0.108***	0.212***
	(−4.535)	(−2.713)	(4.940)	(4.674)	(22.098)	(24.845)
LTA_Bank	0.048***	0.001	−0.150***	−0.080***	−0.056***	−0.126***
	(3.322)	(0.517)	(−22.624)	(−4.470)	(−10.872)	(−14.980)
NPL_Bank	0.222***	0.023***	0.012*	−0.034*	−0.008*	−0.060***
	(14.676)	(19.586)	(1.813)	(−1.710)	(−1.904)	(−8.316)
NII_Bank	0.130***	0.015***	−0.050***	−0.086***	0.040***	0.045***
	(11.872)	(13.146)	(−9.558)	(−6.202)	(9.070)	(6.422)
ROA_Bank	−0.267***	−0.030***	−0.024***	−0.041**	−0.012***	−0.089***
	(−19.828)	(−26.157)	(−3.885)	(−2.439)	(−2.891)	(−11.816)
GDP_Bank	−0.169***	−0.013***	−0.120***	−0.420***	0.013***	−0.057***
	(−12.915)	(−11.407)	(−16.047)	(−25.258)	(2.824)	(−6.685)
ΔGDP_Bank	−0.156***	−0.004***	−0.006	−0.080***	−0.004	−0.023***
	(−12.997)	(−4.790)	(−1.378)	(−6.758)	(−1.399)	(−4.968)
SIZE_Borrower	0.047	0.005	−0.013	−0.056	0.007	0.012
	(1.221)	(1.361)	(−0.787)	(−1.364)	(0.741)	(0.671)
COVER_Borrower	0.006	−0.000	−0.004	−0.011	0.003	0.007
	(0.470)	(−0.392)	(−0.917)	(−0.833)	(1.079)	(1.453)
DEBT_Borrower	0.008	0.002	0.005	0.015	−0.002	−0.003
	(0.707)	(1.585)	(0.959)	(1.405)	(−0.870)	(−0.642)
CURRENT_Borrower	−0.002	0.001	−0.003	−0.000	0.002	−0.004
	(−0.147)	(0.565)	(−0.484)	(−0.003)	(0.518)	(−0.750)
GDP_Borrower	−0.002	−0.001	0.024	−0.029	0.024*	0.049**
	(−0.031)	(−0.310)	(1.051)	(−0.487)	(1.766)	(2.084)
ΔGDP_Borrower	−0.007	0.000	0.003	0.009	−0.001	−0.002
	(−0.628)	(0.232)	(0.689)	(0.766)	(−0.520)	(−0.364)
Constant	3.351***	0.477***	2.653***	4.425***	0.873***	0.778***
	(580.371)	(960.696)	(860.958)	(567.684)	(362.269)	(181.959)
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,142	12,142	12,142	12,142	12,142	12,142
VIF	1.92	1.92	1.92	1.92	1.92	1.92
Adjusted R^2	0.914	0.903	0.887	0.712	0.662	0.494

This table reports baseline results of the impact of the banks' climate risk exposure on their individual and systemic risks. The regressions include borrower and year fixed effects (not reported). Standard errors are adjusted for clustering at the bank-borrower (lending relationship) level. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust t-statistics are reported in parentheses. Variables are defined in Appendix 1.

The ratio of deposits is negatively related to −MES and −LRMES, and has a positive relationship with the other dependent variables. The positive relationship found for $-\Delta$CoVaR may relate to its reliance on a series of interest rate variables connected to the attractiveness of deposits. Both loans to assets and nonperforming loans exhibit different relationships with −MES and $-\Delta$CoVaR in terms of their signs. Net interest income is found to be associated with reduced systemic risk, pointing to the lower risk exposures associated with a traditional loan book. Higher return on assets is linked with a reduction in risk across all measures examined. The GDP and change in GDP of the home state of the bank is associated with a reduction in risk, with the exception of $-\Delta$CoVaR5, which has a positive sign. This surprising outcome may be linked to possible lags in changes in GDP relative to the more market-based systemic risk. For the extreme changes in systemic risk observed during the global financial crisis, this lag effect might be less evident due to the extended downturn. The only significant effect for the borrower-level variables is in the case of GDP for the $-\Delta$CoVaR measures.[14]

Table 7. The effects of climate risk on banks' individual and systemic risks: the moderating role of bank profitability.

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) −ΔCoVaR5	(6) −ΔCoVaR1
CRI_Bank_Cross	0.146***	0.013***	0.117***	0.216***	0.068***	0.117***
	(6.298)	(5.667)	(9.417)	(6.942)	(9.279)	(8.692)
Profit	−0.251***	−0.022***	0.009	0.115***	−0.006	0.122***
	(−12.785)	(−10.347)	(0.677)	(3.418)	(−0.766)	(9.847)
CRI_Bank_Cross × Profit	0.005	−0.000	−0.065***	−0.131***	−0.047***	−0.065***
	(0.282)	(−0.103)	(−6.955)	(−5.995)	(−7.591)	(−5.897)
CRI_Bank_Home	−0.009	−0.000	0.008**	−0.013*	−0.039***	−0.032***
	(−1.378)	(−0.354)	(2.561)	(−1.666)	(−18.412)	(−8.328)
Constant	11.446***	1.121***	7.752***	27.218***	−2.446***	1.249
	(3.828)	(4.715)	(6.521)	(8.908)	(−3.337)	(1.001)
CRI_Bank_Cross+	0.151***	0.013***	0.052***	0.085***	0.021***	0.052***
CRI_Bank_Cross × Profit	(7.750)	(7.640)	(5.600)	(3.650)	(4.110)	(5.530)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.915	0.904	0.888	0.713	0.665	0.500

This table reports test results of the moderating role of bank profitability on the impact of climate risk on banks' individual and systemic risks. The regressions include borrower and year fixed effects (not reported). Standard errors are adjusted for clustering at the bank-borrower (lending relationship) level. *** ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

Overall, these results provide evidence that a higher level of unexpected climate risk acquired through cross-state lending leads to greater individual and systemic risks for banks. We next examine the moderating effect of bank profitability on the relationship.

4.3. The moderating role of bank profitability

A large literature considers the relevance of profitability to bank risk-taking, with differing inferences. Early literature conjectures a reduction in risk-taking incentives from higher profitability (Keeley 1990; Repullo 2004). To generate profits, however, banks need to take risks (Blum 1999), and those banks that generate excess profits can build up capital, allowing them to absorb losses (Calem and Rob 1999). Building on this latter notion, Anginer, Demirgüç-Kunt, and Mare (2018) highlight that more capital impacts the risk of individual banks but also a bank's contribution to the risk of the financial system. In light of these arguments, we are investigating whether bank profitability moderates the relationships between climate risk and the systemic risk contribution of banks.

Using an interaction between CRI_Bank_Cross and bank profitability (Profit), we examine the moderating effect of profitability in Table 7. Profit is a dummy variable that is equal to one when a bank's return on assets exceeds the yearly sample median. For −MES and −LRMES, we find no evidence of a moderating impact of bank profitability. For −VaR and −ΔCoVaR measures, the impact of climate risk is mitigated during periods of higher bank profitability. Assessing the aggregated impact of climate risk along with the interaction, the effect of climate risk is significantly reduced. For example, for −ΔCoVaR1, the aggregate coefficient is more than halved from 0.117 to 0.052 during times when banks are more profitable. The difference in findings between −MES and −ΔCoVaR may result from the latter's reliance on state variables, such as interest rates, which affect bank profitability. From a policy perspective, these results highlight the importance of maintaining robust bank profitability as a safeguard against the increasing climate risk to financial stability. Regulators and policymakers should consider bank profitability as a vital factor in enhancing financial system resilience against climate risk.

4.4. Business cycle and financial crisis

The nature of systemic risk leads to extended periods of low systemic risk followed by relatively brief states of excessive systemic risk (He and Krishnamurthy 2019). The implication for our work is that the observed positive

Table 8. The effects of climate risk on banks' individual and systemic risks: business cycle and financial crisis.

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) −ΔCoVaR5	(6) −ΔCoVaR1
Panel A. Controlling for Inflation Rate						
CRI_Bank_Cross	0.381***	0.043***	0.225***	0.269***	0.057***	0.058***
	(19.203)	(26.042)	(26.145)	(16.210)	(16.372)	(11.274)
CRI_Bank_Home	−0.034**	0.002*	0.005	−0.028***	−0.040***	−0.039***
	(−2.480)	(1.919)	(0.863)	(−2.917)	(−15.404)	(−10.311)
Inflation	0.029	0.009***	0.172***	0.244***	0.049***	0.042***
	(0.944)	(4.777)	(14.444)	(12.670)	(11.757)	(9.194)
Constant	3.351***	0.477***	2.653***	4.425***	0.873***	0.778***
	(337.363)	(619.146)	(595.880)	(495.515)	(332.038)	(179.031)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No	No
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.628	0.635	0.578	0.467	0.454	0.441
Panel B. Interaction Test Results						
CRI_Bank_Cross	0.287***	0.039***	0.183***	0.204***	0.048***	0.053***
	(21.473)	(26.205)	(26.572)	(14.318)	(15.230)	(10.732)
Crisis	6.238***	0.276***	1.829***	2.671***	0.650***	0.425***
	(64.068)	(46.814)	(37.646)	(32.176)	(39.371)	(19.064)
CRI_Bank_Cross × Crisis	0.826***	0.066***	1.657***	2.461***	0.302***	0.213***
	(5.801)	(7.125)	(16.749)	(14.584)	(10.276)	(4.832)
CRI_Bank_Home	0.014	0.004***	0.009*	−0.023***	−0.036***	−0.037***
	(1.499)	(3.850)	(1.911)	(−2.696)	(−15.625)	(−9.931)
Constant	3.040***	0.463***	2.565***	4.296***	0.841***	0.757***
	(423.884)	(612.512)	(636.333)	(501.169)	(336.232)	(170.875)
CRI_Bank_Cross+	1.113***	0.105***	1.840***	2.665***	0.350***	0.265***
CRI_Bank_Cross × Crisis	(7.850)	(11.540)	(18.640)	(15.850)	(12.040)	(6.080)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No	No
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.823	0.694	0.715	0.583	0.553	0.460

This table reports subsample analysis results of business cycle and financial crisis. The regressions include borrower fixed effects (not reported). Standard errors are adjusted for clustering at the bank-borrower (lending relationship) level. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

relationship between climate risk exposure and banks' individual and systemic risks may be influenced by the business cycle. For this reason, we further control for inflation rate to account for the effect of the business cycle. Results, reported in Panel A of Table 8, remain unchanged.

In addition, during our sample period the global financial crisis (GFC) stands out, with many banks requiring public and private bailouts and a number of financial institutions failing outright. To test the relevance of the GFC to our findings, we interact our variable of interest, CRI_Bank_Cross, with a crisis dummy variable equal to one during the years 2008 and 2009, and zero otherwise. Results are detailed in Panel B of Table 8. For each of the risk measures examined, we find that the baseline findings are consistent: climate risk exposure has a positive and significant relationship with both individual and systemic risks. When considering the combined effect during the crisis period, as indicated by the linear combination of CRI_Bank_Cross and CRI_Bank_Cross × Crisis, we observe an increase in the contribution of climate risk to bank risks during the GFC. Specifically, during the crisis period, there is a substantial increase in the magnitude of the coefficient associated with climate risk. However, this does not necessarily suggest a sizable increase in the influence of climate risk during this period; rather, it reflects a significant increase in bank risk at this time. These findings indicate that climate risk influences banks' individual and systemic risks during both normal and crisis periods.

4.5. The effects of climate risk on banks' subsequent lending behavior

To verify whether unexpected climate risk exposures have a material impact on banks, we perform additional tests to understand the changes in banks' subsequent lending behavior. We employ the following set of outcome

Table 9. The effects of climate risk on banks' subsequent lending behavior.

	(1) LTA	(2) ΔLTA	(3) LLP	(4) ΔLLP
CRI_Bank_Cross	−0.021***	−0.017***	0.029**	0.903***
	(−9.126)	(−7.167)	(1.998)	(5.781)
CRI_Bank_Home	−0.002***	−0.006***	0.049***	−0.162***
	(−2.712)	(−6.616)	(10.501)	(−4.707)
SIZE_Bank	−0.022***	0.004**	0.163***	0.176**
	(−10.861)	(2.476)	(15.837)	(2.563)
EQRAT_Bank	0.009***	0.014***	−0.032***	−0.176***
	(6.243)	(10.133)	(−3.178)	(−3.850)
MTB_Bank	−0.013***	0.009***	−0.059***	0.780***
	(−5.673)	(4.336)	(−4.815)	(6.719)
DEPO_Bank	0.026***	0.003	−0.086***	−0.315***
	(12.001)	(1.619)	(−7.743)	(−2.754)
NPL_Bank	0.076***	0.008***	0.255***	0.949***
	(47.163)	(6.355)	(22.478)	(8.464)
NII_Bank	−0.080***	−0.023***	−0.001	−0.988***
	(−57.868)	(−20.906)	(−0.139)	(−10.523)
ROA_Bank	0.068***	−0.007***	0.021**	0.099*
	(46.198)	(−4.839)	(1.999)	(1.746)
GDP_Bank	−0.041***	0.016***	−0.003	−0.006
	(−25.253)	(9.933)	(−0.269)	(−0.044)
ΔGDP_Bank	0.002*	−0.007***	−0.076***	0.053
	(1.746)	(−5.649)	(−8.025)	(0.748)
SIZE_Borrower	0.005	−0.000	0.032	0.236
	(1.078)	(−0.121)	(1.133)	(1.317)
COVER_Borrower	0.002	−0.001	−0.003	−0.063
	(1.300)	(−0.373)	(−0.291)	(−0.823)
DEBT_Borrower	0.000	−0.003*	0.004	−0.025
	(0.104)	(−1.927)	(0.408)	(−0.437)
CURRENT_Borrower	0.000	−0.002	−0.004	−0.002
	(0.040)	(−1.439)	(−0.426)	(−0.036)
GDP_Borrower	0.005	−0.008	−0.033	−0.068
	(0.780)	(−1.439)	(−0.778)	(−0.214)
ΔGDP_Borrower	0.000	−0.000	0.000	−0.044
	(0.137)	(−0.247)	(0.048)	(−0.642)
Constant	0.501***	−0.015***	0.853***	−0.177***
	(624.223)	(−24.276)	(195.247)	(−5.053)
Borrower FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	12,103	12,103	12,103	12,103
Adjusted R^2	0.769	0.243	0.731	0.070

This table reports test results of the impact of the banks' climate risk exposure on their subsequent lending behavior. The regressions include borrower and year fixed effects (not reported). Standard errors are adjusted for clustering at the bank-borrower (lending relationship) level. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

variables: the loans-to-asset-ratio (LTA), annual changes in LTA (ΔLTA), the loan loss provision ratio (LLP), and annual changes in LLP (ΔLLP). All independent variables are lagged by one year as we do for the baseline models. Based on the results reported in Table 9, we find that banks reduce lending (Models 1 and 2) and increase loan loss provisions (Models 3 and 4) subsequent to the experience of an unexpected climate shock. These results can be interpreted as either banks adopting more prudent climate risk management after experiencing unexpected climate shocks or climate losses constraining banks' lending capacity. It remains an open empirical question as to whether both effects are at play jointly or whether one is more dominant than the other. This question is out of the scope of the current paper but deserves attention from future research.

5. Robustness tests

5.1. Alternative climate risk measures

Extreme weather events may systematically influence stock market performance (Lanfear, Lioui, and Siebert 2019). In order to rule out the possibility that our climate risk measure captures predominantly or

Table 10. Alternative climate risk measures.

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) $-\Delta$CoVaR5	(6) $-\Delta$CoVaR1
Panel A. Residual Climate Risk						
CRI_Bank_Cross_Res	0.097***	0.008***	0.040***	0.072***	0.015***	0.039***
	(7.816)	(7.355)	(6.760)	(4.698)	(4.547)	(6.649)
CRI_Bank_Home_Res	−0.011	−0.001	0.007**	−0.020**	−0.043***	−0.038***
	(−1.630)	(−0.976)	(2.145)	(−2.379)	(−19.837)	(−9.756)
Constant	11.741***	1.131***	7.622***	26.717***	−2.382***	0.816
	(3.737)	(4.640)	(6.133)	(8.370)	(−3.144)	(0.635)
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,768	11,768	11,768	11,768	11,768	11,768
Adjusted R^2	0.915	0.904	0.887	0.714	0.669	0.502
Panel B. Germanwatch Method						
CRI_Bank_Cross_GW	0.019***	0.001***	0.006***	−0.003	0.006***	0.011***
	(9.364)	(5.818)	(6.097)	(−1.020)	(10.103)	(10.096)
CRI_Bank_Home_GW	−0.028***	0.001	−0.000	−0.019***	−0.035***	−0.024***
	(−4.395)	(0.873)	(−0.032)	(−2.663)	(−16.934)	(−6.426)
Constant	12.579***	1.204***	7.944***	27.186***	−1.948***	1.590
	(4.216)	(5.026)	(6.651)	(8.872)	(−2.666)	(1.278)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.915	0.903	0.887	0.711	0.663	0.495

This table reports test results of the impact of the banks' climate risk exposure on their individual and systemic risks based on the use of alternative climate risk measures. Panel A reports results based on an alternative climate risk measure computed as a residual of common risk factors. Panel B reports results using an alternative climate risk measure computed using the Germanwatch method. The regressions include borrower and year fixed effects (not reported). Standard errors are adjusted for clustering at the bank-borrower (lending relationship) level. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

acts as a proxy for the systematic effect of climate risk events on the stock market, we create an alternative climate risk measure, CRI_Bank_Res, that is orthogonal to common risk factors identified in prior studies (Bessler and Kurmann 2014; Bessler, Kurmann, and Nohel 2015; Fabrizi, Huan, and Parbonetti 2021), including interest rate risk, credit risk, commodity risk, foreign exchange risk, market risk, political risk, real estate risk, sovereign risk, and the VIX Index. A detailed description of these common risk factors is reported in Appendix 2. CRI_Bank_Cross_Res is computed as the residual from the regression of CRI_Bank_Cross on these common risk factors. We find consistent results based on CRI_Bank_Cross_Res and report them in Panel A of Table 10. The climate risk residual has a consistent and significant positive relationship with bank systemic and individual risks.

Our main construct for state-level climate risk is based on two principal components of six key climate risk indicators: (1) number of deaths, (2) number of deaths per 100,000 inhabitants, (3) sum of losses in USD at purchasing power parity (PPP), (4) losses per unit of Gross Domestic Product (GDP), (5) number of events, and (6) loss per event. To check the sensitivity of our results to the method of calibrating climate risk, we also apply the Germanwatch method. Each state's climate risk index is the sum of the state's score in the first four indicating categories (i.e. indicators 1 to 4):

$$\text{CRI\_State\_GW} = \frac{1}{6} \times \text{Death} + \frac{1}{3} \times \frac{\text{Death}}{\text{Population}} + \frac{1}{6} \times \text{Loss} + \frac{1}{3} \times \frac{\text{Loss}}{\text{GDP}}. \tag{11}$$

We then calculate the bank-level climate risk exposure based on the above Germanwatch state-level climate risk index. Panel B of Table 10 reports results based on this alternative climate risk measure. We find a consistent positive link across all model specifications except for −VaR1, which is found to be insignificant.

Table 11. Alternative loan samples.

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) −ΔCoVaR5	(6) −ΔCoVaR1
Panel A. Term Loans and Credit Lines Only						
CRI_Bank_Cross	0.121***	0.010***	0.058***	0.052**	0.031***	0.084***
	(6.520)	(5.975)	(6.151)	(2.198)	(5.757)	(8.788)
CRI_Bank_Home	−0.009	−0.000	0.004	−0.022***	−0.042***	−0.037***
	(−1.353)	(−0.277)	(1.442)	(−2.812)	(−19.632)	(−9.486)
Constant	12.138***	1.144***	7.503***	25.911***	−2.396***	1.030
	(3.957)	(4.678)	(6.144)	(8.318)	(−3.234)	(0.823)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,774	11,774	11,774	11,774	11,774	11,774
Adjusted R^2	0.914	0.903	0.887	0.713	0.664	0.497
Panel B. Lead Banks Only						
CRI_Bank_Cross	0.131***	0.015***	0.058**	0.157***	0.029***	0.056***
	(2.695)	(2.836)	(2.561)	(2.827)	(2.667)	(3.119)
CRI_Bank_Home	0.018	0.002	0.011	−0.002	−0.023***	−0.025**
	(0.554)	(0.800)	(0.722)	(−0.045)	(−3.315)	(−2.440)
Constant	20.409*	1.976**	9.747**	41.394***	4.091**	8.065***
	(1.925)	(2.508)	(2.510)	(4.294)	(2.390)	(2.905)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,387	1,387	1,387	1,387	1,387	1,387
Adjusted R^2	0.947	0.934	0.943	0.848	0.861	0.755

This table presents the test results regarding the impact of banks' climate risk exposure on their individual and systemic risks, using alternative loan samples. Panel A reports results based on a sample of term loans and credit lines. Panel B reports results based on a sample comprising lead banks only. The regressions include borrower and year fixed effects (not reported). Standard errors are adjusted for clustering at the bank-borrower (lending relationship) level. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

5.2. Alternative loan samples

In additional analyzes using alternative loan samples, we first focus on term loans and revolvers because they are the dominant types of loans made by banks to nonfinancial firms in the US (Colla, Ippolito, and Li 2013; Jiang, Li, and Shao 2010; Sufi 2009). A term loan facility entails a loan of a defined sum, with a predetermined repayment schedule and maturity, often fully funded at origination. Revolver facilities usually have shorter maturities compared to term loan facilities and are drawn down at the discretion of the borrower (Lim, Minton, and Weisbach 2014). Following Chu, Zhang, and Zhao (2019), we define a lending observation as a credit line or term loan if it falls within one of the following categories: 364–day facility, revolver/line < 1 year, revolver/line ≥ 1 year, revolver/term loan, term loan, and term loan A. Results, reported in Panel A of Table 11, show a positive and significant link between climate risk and bank systemic and individual risk, highlighting the robustness of our findings to the the choice of loans.

To check the robustness of our findings to loan share sales by participating banks, we focus solely on lead banks. Lead banks, also referred to as lead arrangers, originate a loan and then market it to other participant banks (Ivashina and Sun 2011). Lead banks maintain ongoing relationships with borrowers, liaise between borrowers and participant banks, make loan pricing decisions, and bear reputational costs if they misprice loans (Bushman, Williams, and Wittenberg-Moerman 2017; François and Missonier-Piera 2007). For signaling purposes, lead banks tend to retain a larger share in a loan (Sufi 2007). We follow Ivashina (2009) to identify the lead bank(s) of a facility. If a lender is reported as the 'administrative agent', we designate it as the lead bank. If no lender is reported as the 'administrative agent', we define a lender as the lead bank if it assumes roles of 'agent', 'arranger', 'book-runner', 'lead arranger', 'lead bank', or 'lead manager'. As reported in Panel B of Table 11, our main findings remain unchanged using the alternative loan sample of lead banks only.

Table 12. Weighted least squares.

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) −ΔCoVaR5	(6) −ΔCoVaR1
Panel A. Weighted Least Squares (by State Population)						
CRI_Bank_Cross	0.147***	0.012***	0.060***	0.103***	0.027***	0.061***
	(7.707)	(7.504)	(6.510)	(4.407)	(5.180)	(6.552)
CRI_Bank_Home	−0.006	0.000	0.007**	−0.015**	−0.039***	−0.035***
	(−0.954)	(0.028)	(2.251)	(−2.019)	(−18.755)	(−8.836)
Constant	11.972***	1.181***	7.825***	27.395***	−2.357***	1.116
	(4.013)	(4.974)	(6.636)	(9.001)	(−3.207)	(0.891)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.915	0.903	0.887	0.713	0.663	0.494
Panel B. Weighted Least Squares (by Bank Market Capitalization)						
CRI_Bank_Cross	0.149***	0.011***	0.059***	0.099***	0.025***	0.058***
	(7.518)	(7.013)	(6.768)	(4.452)	(4.933)	(6.456)
CRI_Bank_Home	−0.004	0.001*	0.005*	−0.018**	−0.039***	−0.032***
	(−0.577)	(1.776)	(1.779)	(−2.509)	(−20.627)	(−9.071)
Constant	12.576***	1.278***	8.779***	29.630***	−1.704**	2.749**
	(4.057)	(5.591)	(7.461)	(9.934)	(−2.440)	(2.347)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.918	0.910	0.895	0.729	0.678	0.493

This table reports test results of the impact of the banks' climate risk exposure on their individual and systemic risks using Weighted Least Squares (WLS) estimation. Panel A reports results using state population of lender banks as the weight in the estimation. Panel B reports results using banks' market capitalization as the weight in the estimation. The regressions include bank, borrower and year fixed effects (not reported). Standard errors are adjusted for clustering at the bank-borrower (lending relationship) level. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

5.3. Weighted least squares

Panel B of Table 3 indicates a substantial variation in the number of observations across states where lender banks are headquartered. For this reason, we use state-weighted least squares estimation to control for the different weights of lender bank states in the sample. State population is used as the weight. Results for this specification test are reported in Panel A of Table 12. We further employ a capitalization-weighted least squares specification to account for possible greater contributions to systemic risk by larger banks. Laeven, Ratnovski, and Tong (2016) find that larger banks have significantly higher systemic risk contributions. The weight is computed as a bank's end-of-year market capitalization divided by the total capitalization of the financial industry at the same point in time. We report results for this specification in Panel B of Table 12. Results provide further consistent support that climate risk is linked with bank systemic and individual risk.

5.4. Standard errors

We perform three additional tests to check the robustness of our results to the method standard errors are computed. First, we cluster standard errors at borrowers' state level and obtain similar results as reported in Panel A of Table 13. Second, we cluster standard errors at the borrowers' firm level. Our results, reported in Panel B of Table 13, remain unchanged. Lastly, we follow Newey and West (1987) to compute heteroskedasticity- and autocorrelation-consistent (HAC) standard errors that allow for up to two periods of autocorrelation, and report results in Panel B of Table 13. Overall, these results confirm that our main results are robust to different methods of calculating standard errors.

5.5. Alternative fixed effects specifications

In our baseline model specifications, we include both year and borrower firm fixed effects. We also examine our results using alternative fixed effects specifications. In one specification, we include only the year fixed effect,

Table 13. Standard errors.

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) −ΔCoVaR5	(6) −ΔCoVaR1
Panel A. Standard Errors Clustered at Borrower State Level						
CRI_Bank_Cross	0.147***	0.013***	0.059***	0.102***	0.027***	0.061***
	(7.279)	(5.666)	(5.466)	(4.193)	(4.769)	(6.221)
CRI_Bank_Home	−0.006	0.000	0.007	−0.016	−0.039***	−0.035***
	(−1.148)	(0.068)	(1.593)	(−1.548)	(−13.416)	(−6.918)
Constant	12.024***	1.173***	7.819***	27.126***	−2.370**	1.051
	(3.713)	(7.370)	(8.955)	(13.888)	(−2.603)	(0.757)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.914	0.903	0.887	0.712	0.662	0.494
Panel B. Standard Errors Clustered at Borrower Firm Level						
CRI_Bank_Cross	0.147***	0.013***	0.059***	0.102***	0.027***	0.061***
	(7.219)	(7.732)	(6.688)	(4.442)	(5.623)	(6.832)
CRI_Bank_Home	−0.006	0.000	0.007**	−0.016**	−0.039***	−0.035***
	(−0.975)	(0.055)	(2.399)	(−2.116)	(−18.897)	(−8.956)
Constant	12.024***	1.173***	7.819***	27.126***	−2.370***	1.051
	(4.446)	(6.781)	(8.681)	(12.508)	(−3.589)	(0.983)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.914	0.903	0.887	0.712	0.662	0.494
Panel C. Newey-West Standard Errors						
CRI_Bank_Cross	0.147***	0.013***	0.059***	0.102***	0.027***	0.061***
	(7.741)	(7.548)	(6.387)	(4.281)	(5.157)	(6.420)
CRI_Bank_Home	−0.006	0.000	0.007**	−0.016**	−0.039***	−0.035***
	(−0.936)	(0.056)	(2.284)	(−2.072)	(−19.183)	(−9.435)
Constant	11.885***	1.150***	8.321***	27.096***	−2.242***	0.941
	(4.300)	(5.128)	(6.837)	(8.706)	(−2.989)	(0.719)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.914	0.903	0.887	0.712	0.662	0.494

This table reports test results of the impact of the banks' climate risk exposure on their individual and systemic risks. Panel A reports results with standard errors adjusted for clustering at the borrower state level. Panel B reports results with standard errors adjusted for clustering at the borrower's firm level. Panel C reports results with heteroskedasticity- and autocorrelation-consistent (HAC) standard errors computed following the Newey and West (1987) procedure that allows for up to two periods of autocorrelation. The regressions include bank, borrower and year fixed effects (not reported). ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

and in another, we do not include any fixed effects. Results for these two specifications are reported in Panel A and B of Table 14, respectively, and remain consistent with our baseline findings, showing that climate risk is linked with bank systemic and individual risks. Of particular note, the adjusted R-squared is found to decrease substantially when year fixed effects are excluded, suggesting that the high R-squared observed in our baseline models are at least partially a consequence of year fixed effects.

5.6. Loan-level analyzes

We perform several additional tests using the loan-level sample to check if our baseline results hold at the deal level. The loan-level sample includes 2,918 deal packages and 3,699 facilities with available bank share information, which correspond to 15,037 bank share observations. We report the main results of the loan-level analysis in Table 15. Panel A, B, and C report results with standard errors clustered at the lending relationship level, the package level, and the facility level, respectively. Results remain consistent with the baseline results under different specifications of standard error clustering.

Table 14. Alternative fixed effects specifications.

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) −ΔCoVaR5	(6) −ΔCoVaR1
Panel A. Year Fixed Effects Only						
CRI_Bank_Cross	0.147***	0.013***	0.064***	0.111***	0.029***	0.060***
	(8.156)	(8.275)	(6.688)	(4.727)	(5.578)	(6.348)
CRI_Bank_Home	−0.009	−0.001	0.007**	−0.015**	−0.040***	−0.036***
	(−1.428)	(−0.903)	(2.337)	(−1.965)	(−19.547)	(−9.301)
Constant	11.225***	1.055***	9.058***	26.288***	−1.609***	2.493***
	(13.317)	(13.996)	(18.211)	(22.889)	(−4.850)	(4.096)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.914	0.903	0.883	0.706	0.655	0.484
Panel B. No Fixed Effects						
CRI_Bank_Cross	0.352***	0.044***	0.266***	0.296***	0.066***	0.060***
	(24.172)	(36.589)	(40.044)	(23.030)	(22.566)	(13.085)
CRI_Bank_Home	−0.056***	0.001	−0.001	−0.040***	−0.043***	−0.043***
	(−3.961)	(1.047)	(−0.229)	(−3.855)	(−16.156)	(−11.419)
Constant	−15.011***	−1.259***	8.487***	15.243***	−1.327***	0.165
	(−12.109)	(−12.780)	(13.767)	(14.205)	(−5.190)	(0.432)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	No	No	No	No	No	No
Year FE	No	No	No	No	No	No
Observations	12,142	12,142	12,142	12,142	12,142	12,142
Adjusted R^2	0.537	0.552	0.445	0.354	0.361	0.406

This table reports test results of the impact of the banks' climate risk exposure on their individual and systemic risks based on different fixed effects choices. Panel A reports results using state population of lender banks as the weight in the estimation. Panel B reports results using banks' market capitalization as the weight in the estimation. The regressions include bank, borrower and year fixed effects (not reported). Standard errors are adjusted for clustering at the bank-borrower (lending relationship) level. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

The loan-level data structure also enables us to exploit the variation across different types of loans categorized by their intended purpose. We classify syndicated loans into three primary categories: (1) Operating and capital expenditures: if a loan is granted for capital expenditures, equipment purchase, real estate, or working capital; (2) Capital structure: if a loan is made for initial public offering, recapitalization, securities purchase, or stock buyback; and (3) M&A and buyouts: if a loan is granted for acquisitions, mergers, takeover, leveraged buyout, management buyout, or secondary buyout. We then create dummy variables based on these categories and interact them with our bank-level climate risk measure. The resulting interaction term captures the moderating role of specific loan purposes on the effects of climate risk on banks' individual and systemic risks. We report the test results in Table 16. We find that the coefficient for the interaction term is significant and positive for loans made for operating and capital expenditures (columns 2, 3, 4, 5, and 6 of Panel A), indicating that the effect of climate risk exposure on bank risks is more pronounced for loans earmarked for operating and capital expenditures. This finding is in line with the underlying premise of this study, which posits that as climate losses weaken borrower firms' ability to repay loans, banks' credit risk increases and loan quality deteriorates. Results for loans granted for capital structure (Panel B) and M&A and buyouts (Panel C) are not significant, except for −MES in column 1 for both tests.

Table 17 reports the loan-level analysis results based on alternative fixed effects specifications. Panel A reports results with package (or loan) and year fixed effects included. Package fixed effects help control for loan demand and remove any confounding borrower characteristics that are otherwise unobservable (Chu, Zhang, and Zhao 2019). Once the package fixed effects are included, borrower characteristics drop out. Therefore, any remaining variation in the individual and systemic risks across banks is explained by the bank-level climate risk exposure. Panel B reports results with the use of bank, borrower, and year fixed effects. The inclusion of bank fixed effects allows us to control for the correlation between the bank- level climate risk measures and

Table 15. Loan-level analyzes: main results.

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) −ΔCoVaR5	(6) −ΔCoVaR1
Panel A. Standard Errors Clustered at the Lending Relationship Level						
CRI_Bank_Cross	0.144***	0.013***	0.063***	0.112***	0.028***	0.064***
	(6.532)	(6.663)	(6.033)	(4.022)	(4.974)	(6.071)
CRI_Bank_Home	−0.007	0.000	0.006*	−0.016*	−0.042***	−0.038***
	(−0.972)	(0.032)	(1.885)	(−1.884)	(−18.424)	(−8.968)
Constant	13.569***	1.310***	7.530***	25.517***	−2.224***	0.746
	(4.373)	(5.044)	(6.145)	(8.205)	(−2.748)	(0.540)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,037	15,037	15,037	15,037	15,037	15,037
Adjusted R^2	0.913	0.901	0.889	0.711	0.663	0.497
Panel B. Standard Errors Clustered at the Package Level						
CRI_Bank_Cross	0.144***	0.013***	0.063***	0.112***	0.028***	0.064***
	(5.857)	(6.638)	(6.139)	(4.011)	(5.040)	(6.034)
CRI_Bank_Home	−0.007	0.000	0.006**	−0.016**	−0.042***	−0.038***
	(−0.962)	(0.031)	(1.964)	(−1.981)	(−18.671)	(−9.707)
Constant	13.569***	1.310***	7.530***	25.517***	−2.224***	0.746
	(5.835)	(7.642)	(8.102)	(11.526)	(−3.807)	(0.773)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,037	15,037	15,037	15,037	15,037	15,037
Adjusted R^2	0.913	0.901	0.889	0.711	0.663	0.497
Panel C. Standard Errors Clustered at the Facility Level						
CRI_Bank_Cross	0.144***	0.013***	0.063***	0.112***	0.028***	0.064***
	(6.864)	(8.224)	(7.324)	(5.017)	(5.751)	(7.043)
CRI_Bank_Home	−0.007	0.000	0.006**	−0.016**	−0.042***	−0.038***
	(−1.129)	(0.038)	(2.302)	(−2.392)	(−22.194)	(−11.558)
Constant	13.569***	1.310***	7.530***	25.517***	−2.224***	0.746
	(6.242)	(8.787)	(8.871)	(12.765)	(−4.355)	(0.877)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,037	15,037	15,037	15,037	15,037	15,037
Adjusted R^2	0.913	0.901	0.889	0.711	0.663	0.497

This table reports the loan-level analysis results of the impact of the banks' climate risk exposure on their individual and systemic risks. The regressions include borrower and year fixed effects (not reported). ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

unobservable time-invariant bank characteristics. Results remain broadly consistent, with the only exception being $-\Delta$CoVaR5.

6. Conclusions

This paper provides evidence that unexpected climate risk exposure acquired through cross-state lending increases banks' individual and systemic risks. This effect is both statistically and economically significant: An increase by one standard deviation in the bank-level climate risk measure leads to an increase of 14.7% in the marginal expected shortfall, 1.3% in the long-run marginal expected shortfall, 5.9% in value at risk at a 5% confidence level, 10.2% in value at risk at 1%, 2.7% in systemic risk contribution at 5%, and 6.1% in systemic risk contribution at 1%. We also find that banks reduce lending and increase loan loss reserves subsequent to the experience of an unexpected climate shock.

Our analysis starts with crafting a bank-level climate risk measure using the NOAA Billion-Dollar Weather and Climate Disasters data and Dealscan syndicated lending data, followed by tests of the impact of banks' climate risk exposure on their individual and systemic risks based on a sample of 12,142 lender-borrower-year

Table 16. Loan-level analyzes: the moderating role of loan purposes

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) −ΔCoVaR5	(6) −ΔCoVaR1
Panel A. Operating and Capital Expenditure						
CRI_Bank_Cross	0.140***	0.012***	0.055***	0.090***	0.025***	0.056***
	(5.533)	(5.650)	(5.075)	(3.034)	(4.277)	(5.077)
CapEx	0.016	−0.001	0.006	0.031	0.006	0.012
	(0.733)	(−0.821)	(0.629)	(1.555)	(1.253)	(1.397)
CRI_Bank_Cross × CapEx	0.017	0.004*	0.037***	0.097***	0.013*	0.033**
	(0.637)	(1.882)	(2.817)	(3.009)	(1.708)	(2.360)
CRI_Bank_Home	−0.007	0.000	0.006*	−0.016**	−0.042***	−0.038***
	(−0.981)	(0.000)	(1.895)	(−2.055)	(−18.703)	(−9.763)
Constant	13.593***	1.309***	7.540***	25.568***	−2.214***	0.766
	(5.837)	(7.652)	(8.119)	(11.594)	(−3.797)	(0.793)
CRI_Bank_Cross+	0.157***	0.016***	0.092***	0.187***	0.038***	0.089***
CRI_Bank_Cross × CapEx	(4.930)	(6.860)	(6.350)	(5.190)	(4.840)	(5.960)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,037	15,037	15,037	15,037	15,037	15,037
Adjusted R^2	0.913	0.901	0.889	0.711	0.663	0.497
Panel B. Capital Structure						
CRI_Bank_Cross	0.143***	0.013***	0.063***	0.112***	0.028***	0.064***
	(6.517)	(6.646)	(6.018)	(4.008)	(4.982)	(6.085)
CS	−0.166	−0.016*	−0.002	0.041	−0.026	−0.033
	(−1.523)	(−1.784)	(−0.059)	(0.377)	(−1.082)	(−0.925)
CRI_Bank_Cross × CS	0.125*	0.009	0.033	0.072	−0.011	−0.038
	(1.758)	(1.360)	(1.046)	(0.815)	(−0.495)	(−1.027)
CRI_Bank_Home	−0.007	0.000	0.006*	−0.016*	−0.042***	−0.038***
	(−0.978)	(0.023)	(1.892)	(−1.875)	(−18.426)	(−8.974)
Constant	13.717***	1.322***	7.561***	25.576***	−2.229***	0.718
	(4.420)	(5.084)	(6.173)	(8.228)	(−2.753)	(0.518)
CRI_Bank_Cross+	0.268***	0.022***	0.096***	0.184**	0.017	0.026
CRI_Bank_Cross × CS	(3.580)	(3.210)	(2.910)	(2.020)	(0.800)	(0.690)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,037	15,037	15,037	15,037	15,037	15,037
Adjusted R^2	0.913	0.901	0.889	0.711	0.663	0.497
Panel C. M&A and Buyouts						
CRI_Bank_Cross	0.150***	0.013***	0.063***	0.108***	0.028***	0.064***
	(6.925)	(6.801)	(6.151)	(4.012)	(4.846)	(6.033)
M&A	−0.004	0.000	−0.003	−0.017	−0.001	−0.010
	(−0.148)	(0.165)	(−0.262)	(−0.591)	(−0.141)	(−0.887)
CRI_Bank_Cross × M&A	−0.053**	−0.002	−0.002	0.032	0.004	0.001
	(−2.149)	(−0.997)	(−0.153)	(0.890)	(0.465)	(0.066)
CRI_Bank_Home	−0.007	0.000	0.006*	−0.016*	−0.042***	−0.038***
	(−0.979)	(0.029)	(1.884)	(−1.882)	(−18.425)	(−8.971)
Constant	13.308***	1.298***	7.524***	25.702***	−2.204***	0.766
	(4.302)	(5.017)	(6.156)	(8.274)	(−2.734)	(0.557)
CRI_Bank_Cross+	0.097***	0.011***	0.061***	0.140***	0.032***	0.065***
CRI_Bank_Cross × M&A	(2.980)	(3.710)	(3.710)	(2.990)	(3.460)	(3.720)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,037	15,037	15,037	15,037	15,037	15,037
Adjusted R^2	0.913	0.901	0.889	0.711	0.663	0.497

This table reports the loan-level analysis results of the moderating role of loan purpose on the impact of the banks' climate risk exposure on their individual and systemic risks. The regressions include borrower and year fixed effects (not reported). Standard errors are adjusted for clustering at the lending relationship level. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

Table 17. Loan-level analyzes: alternative fixed effects specifications.

	(1) −MES	(2) −LRMES	(3) −VaR5	(4) −VaR1	(5) −ΔCoVaR5	(6) −ΔCoVaR1
Panel A. Package and Year Fixed Effects						
CRI_Bank_Cross	0.141***	0.013***	0.064***	0.109***	0.032***	0.070***
	(5.472)	(6.145)	(6.029)	(3.672)	(5.505)	(6.487)
CRI_Bank_Home	−0.006	0.000	0.005*	−0.015*	−0.043***	−0.041***
	(−0.839)	(0.154)	(1.808)	(−1.860)	(−19.121)	(−10.309)
Constant	11.706***	1.134***	8.910***	25.213***	−1.377***	3.125***
	(15.277)	(15.030)	(26.161)	(29.899)	(−5.518)	(7.636)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Package FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,037	15,037	15,037	15,037	15,037	15,037
Adjusted R^2	0.912	0.899	0.887	0.702	0.648	0.474
Panel B. Bank, Borrower, and Year Fixed Effects						
CRI_Bank_Cross	0.125***	0.009***	0.047***	0.083***	0.001	0.009**
	(5.167)	(4.980)	(6.119)	(4.646)	(0.675)	(2.194)
CRI_Bank_Home	−0.016**	−0.000	0.004	−0.021***	0.003***	−0.000
	(−2.317)	(−0.223)	(1.551)	(−2.907)	(3.930)	(−0.021)
Constant	15.606***	2.299***	−13.896***	−12.788***	−3.039***	−0.064
	(5.096)	(6.617)	(−13.515)	(−4.214)	(−10.097)	(−0.165)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,037	15,037	15,037	15,037	15,037	15,037
Adjusted R^2	0.924	0.914	0.941	0.841	0.968	0.965

This table reports the loan-level analysis results based on alternative fixed effects specifications. Panel A reports results with the use of package and year fixed effects. Panel B reports results with the use of bank, borrower, and year fixed effects. Standard errors are adjusted for clustering at the package level. ***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Robust *t*-statistics are reported in parentheses. Variables are defined in Appendix 1.

observations comprised of 42 lender banks and 1,314 borrower firms for the period of 1999–2019. Our results are robust to several alternative climate risk measures, including a residual climate risk measure that is orthogonal to common risk factors and an alternative climate risk measure computed following the Germanwatch method, weighted least squares estimators, and alternative methods to compute standard errors. Our results also hold based on the use of a loan-level sample.

This paper addresses a recent call for the development of methodologies that facilitate a successful assessment of the risks posed by climate change to financial stability (Battiston, Dafermos, and Monasterolo 2021), rationalizing recent developments in policy practices aimed at safeguarding monetary and financial stability against climate risk. We focus on the impact of physical climate risks on banks' individual risk and systemic risk contributions while not addressing the effects of transition climate risks. We acknowledge that the latter represents an interesting avenue for future research. Future work could, for instance, aim to delineate the dynamics of the interaction between physical and transition climate risks, as well as their outcomes at various levels. Nevertheless, a major challenge in this regard is designing an identification strategy for assessing the 'double materiality' of climate physical and transition risks.

The effectiveness of the current macroprudential framework in mitigating systemic climate-related financial risks is the subject of much debate. The macroprudential framework, in addressing systemic climate-related risks, necessitates two main objectives: increasing the financial system's resilience and directly influencing banks' credit policies to contain systemic risks. However, it is uncertain whether this framework is essential to ensure the financial system can absorb climate-related shocks. Additionally, prudential tools may not effectively steer banks away from climate-related risks, as changes in capital requirements have little impact on banks' investment policies unless they are calibrated at a very high level (Bank for International Settlements 2022). Note that avoiding bank systemic risk from climate change is distinct from any attempts to incorporate *net zero* transition plans into bank prudential policy, an area where further research is warranted.

Notes

1. For example, the Financial Stability Board's (FSB) Task Force on Climate-related Financial Disclosures (TCFD) released its recommendations on climate risk management and disclosure for financial institutions in June 2017 with the objective of developing voluntary disclosure on climate risk. In November 2017, the Economic and Monetary Affairs Committee (EMAC) of the European Parliament issued a proposal that would amend the European Union's Capital Requirements Regulation to make climate risk management and disclosures mandatory. In July 2021, the FSB drew up a roadmap for addressing climate-related financial risks, which highlights four key interconnected blocks namely disclosures, data, vulnerabilities analysis, and regulatory practices and tools.
2. Significant variation in levels of systemic risk has been determined conditional on the institution's noninterest income (Brunnermeier, Dong, and Palia 2020), corporate governance (Anginer et al. 2018), jurisdiction (Bostandzic and Weiss 2018), size (De Jonghe, Diepstraten, and Schepens 2015; Laeven, Ratnovski, and Tong 2016; Pais and Stork 2013), competition (Anginer, Demirgüç-Kunt, and Zhu 2014), network interdependence (Hautsch, Schaumburg, and Schienle 2015), capital (Gauthier, Lehar, and Souissi 2012), and the provision of government aid (Berger, Roman, and Sedunov 2020).
3. For example, we examine a residual climate risk measure that is orthogonal to common bank risk factors and an alternative climate risk measure computed following the Germanwatch method. Our results are consistent for alternative loan samples, including a sample comprising term loans and credit lines only, as well as a sample restricted to lead banks. Lastly, our results are robust to weighted least squares estimators, alternative standard errors estimates, and alternative fixed effects specifications.
4. Physical climate risks arise when climate change causes damage to physical assets and disruption to the operations of firms, generating increased credit risk for lender banks, increasing claims for insurance companies, and impairing the financial position of governments. Transition climate risks relate to unanticipated and sudden adjustments of asset prices (both positive and negative) and changes in default rates for entire asset classes due to shifts in policies, technology, and sentiment in the process of adjustment towards a low-carbon economy (Financial Stability Board 2020).
5. CPI-adjusted to 2020.
6. We adjust the changes in SIC code due to conversions of several large institutions into bank holding companies.
7. Both equity return and balance sheet data are adjusted for mergers and acquisitions.
8. Results remain the same without winsorization.
9. We refrain from clustering the standard errors at the lender bank level because it is a very conservative way to compute standard errors given that there are only 42 lender banks in our sample (Gatev and Strahan 2009).
10. The number of lender banks is comparable to prior studies (e.g. Cai et al. 2018).
11. Similarly, high R^2 values are found in other studies examining the determinants of systemic risk. For example, when examining the determinants of systemic risk using a syndicated lending dataset, Cai et al. (2018) also reported adjusted R^2 values of around 0.96. Lopez-Espinosa et al. (2012) report adjusted R^2 values of between 0.80 and 0.88 in their assessment of the determinants of systemic risk. In Section 5.5, we explore the range of adjusted R^2 for alternative fixed effects specifications and find that year fixed effects are responsible for a large proportion of explained variation in systemic risk.
12. Differences in sign also appear in the literature. For example, Anginer et al. (2018) find a negative relationship between $-\Delta$CoVaR1 and size, while Anginer, Demirgüç-Kunt, and Mare (2018) find a positive relationship.
13. Beltratti and Stulz (2012) contrast the characteristics associated with banks with the highest and lower performance during the financial crisis. Conlon and Cotter (2014) demonstrate the ex-ante funding mechanisms used by nationalized and bailed-out banks differed significantly from those of surviving banks.
14. In Table 14, we examine the robustness of our findings in the absence of borrower fixed effects. Without borrower fixed effects, several borrower-level variables, including size, debt-to-EBITDA ratio, and GDP, become significant across multiple model specifications. Coefficients associated with borrower-level variables are not shown in Table 14 for brevity.

Acknowledgments

We thank Chris Adcock (the editor), two anonymous referees, Abhinav Anand, Christoph Herpfer, Arthur Krebbers, Francesco Mazzi, Shashidhar Murthy, Alessia Paccagnini, Bharat Raj Parajuli (discussant), Sébastien Pouget (discussant), Srinivasan Rangan, Lingxia Sun (discussant), and Leon Vaks for helpful comments and suggestions. This paper also benefited from participant comments at seminars in the Indian Institute of Management Bangalore and Strathclyde Business School. Earlier versions of this paper were presented at the 38th International Conference of the French Finance Association (AFFI), European Financial Management Association 2022 Annual Meeting, Financial Management and Accounting Research Conference 2022, and International Finance and Banking Society 2023 Conference.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

Conlon acknowledges the support of Science Foundation Ireland under Grant Number 16/SPP/3347, 13/RC/2106 and 17/SP/5447.

Notes on contributors

Thomas Conlon is Professor of Finance in University College Dublin with research interests including sustainable finance, risk management, banking and asset pricing. He has published extensively in leading international journals such as *Journal of Banking & Finance, Journal of Financial Econometrics, European Journal of Operational Research, Journal of Empirical Finance* and the *Journal of Financial Stability*.

Rong Ding is Professor of accounting at NEOMA Business School, France. Rong's research interests are in financial reporting, auditing and market-based tax research, and he has published in peer-reviewed journals including Abacus, *British Accounting Review, Journal of Business Ethics, Journal of Accounting and Public Policy, Journal of Business Research, Journal of Financial Markets and Management Accounting Research*, among others.

Xing Huan joined EDHEC Business School as an Associate Professor of Accounting in 2022. Prior to that he was an Assistant Professor of Accounting at Warwick Business School, Research Fellow in Banking and Finance at University College Dublin, and visiting scholar at Case Western Reserve University. He earned his PhD from Ca' Foscari University of Venice and MA from Durham University Business School. His research is at the intersection of financial accounting and empirical banking, covering a broad range of topics including disclosure, financial regulation, climate risk, and operational risk. His research was funded by Irish Research Council (IRC) and Italian Ministry of Education, Universities and Research (MIUR).

Zhifang Zhang is an Associate Professor of Accounting at Warwick Business School. She holds a PhD in Accounting and Finance from Lancaster University. Her research interests are in the areas of corporate governance and financial accounting. She has published papers in leading journals, including *Management Science, Journal of Corporate Finance, British Journal of Management*, and *Journal of Business Ethics* among others.

ORCID

Thomas Conlon http://orcid.org/0000-0002-9187-5173

References

Acharya, V. V., R. F. Engle, and M. Richardson. 2012. "Capital Shortfall: A New Approach to Ranking and Regulating Systemic Risks." *American Economic Review* 102 (3): 59–64. https://doi.org/10.1257/aer.102.3.59.

Acharya, V. V., and D. Skeie. 2011. "A Model of Liquidity Hoarding and Term Premia in Inter-bank Markets." *Journal of Monetary Economics* 58 (5): 436–447. https://doi.org/10.1016/j.jmoneco.2011.05.006.

Adrian, T., and M. K. Brunnermeier. 2016. "CoVaR." *American Economic Review* 106 (7): 1705–1741. https://doi.org/10.1257/aer.20120555.

Allen, F., and D. Gale. 2000. "Financial Contagion." *Journal of Political Economy* 108 (1): 1–33. https://doi.org/10.1086/262109.

Anginer, D., A. Demirgüç-Kunt, H. Huizinga, and K. Ma. 2018. "Corporate Governance of Banks and Financial Stability." *Journal of Financial Economics* 130 (2): 327–346. https://doi.org/10.1016/j.jfineco.2018.06.011.

Anginer, D., A. Demirgüç-Kunt, and D. S. Mare. 2018. "Bank Capital, Institutional Environment and Systemic Stability." *Journal of Financial Stability* 37:97–106. https://doi.org/10.1016/j.jfs.2018.06.001.

Anginer, D., A. Demirgüç-Kunt, and M. Zhu. 2014. "How Does Competition Affect Bank Systemic Risk?." *Journal of Financial Intermediation* 23 (1): 1–26. https://doi.org/10.1016/j.jfi.2013.11.001.

Auffhammer, M., S. M. Hsiang, W. Schlenker, and A. Sobel. 2020. "Using Weather Data and Climate Model Output in Economic Analyses of Climate Change." *Review of Environmental Economics & Policy*7 (2): 181–198. https://doi.org/10.1093/reep/ret016.

Bank for International Settlements. 2021. "Climate-Related Financial Risks – Measurement Methodologies." https://www.bis.org/bcbs/publ/d518.pdf.

Bank for International Settlements. 2022. "The Regulatory Response to Climate Risks: Some Challenges." https://www.bis.org/fsi/fsibriefs16.pdf.

Battiston, S., Y. Dafermos, and I. Monasterolo. 2021. "Climate Risks and Financial Stability." *Journal of Financial Stability* 54:100867. https://doi.org/10.1016/j.jfs.2021.100867.

Battiston, S., A. Mandel, I. Monasterolo, F. Schütze, and G. Visentin. 2017. "A Climate Stress-test of the Financial System." *Nature Climate Change* 7 (4): 283–288. https://doi.org/10.1038/nclimate3255.

Beltratti, A., and R. M. Stulz. 2012. "The Credit Crisis Around the Globe: Why Did Some Banks Perform Better?." *Journal of Financial Economics* 105 (1): 1–17. https://doi.org/10.1016/j.jfineco.2011.12.005.

Benoit, S., J.-E. Colliard, C. Hurlin, and C. Pérignon. 2017. "Where the Risks Lie: A Survey on Systemic Risk." *Review of Finance* 21 (1): 109–152. https://doi.org/10.1093/rof/rfw026.

Berger, A. N., R. A. Roman, and J. Sedunov. 2020. "Did TARP Reduce Or Increase Systemic Risk? The Effects of Government Aid on Financial System Stability." *Journal of Financial Intermediation*43:100810. https://doi.org/10.1016/j.jfi.2019.01.002.

Bernstein, A., M. T. L. Gustafson, and R. Lewis. 2019. "Disaster on the Horizon: The Price Effect of Sea Level Rise." *Journal of Financial Economics* 134 (2): 253–272. https://doi.org/10.1016/j.jfineco.2019.03.013.

Bessler, W., and P. Kurmann. 2014. “Bank Risk Factors and Changing Risk Exposures: Capital Market Evidence Before and During the Financial Crisis.” *Journal of Financial Stability* 13:151–166. https://doi.org/10.1016/j.jfs.2014.06.003.

Bessler, W., P. Kurmann, and T. Nohel. 2015. “Time-varying Systematic and Idiosyncratic Risk Exposures of US Bank Holding Companies.” *Journal of International Financial Markets, Institutions & Money* 35:45–68. https://doi.org/10.1016/j.intfin.2014.11.009.

Beyhaghi, M., R. Dai, A. Saunders, and J. Wald. 2021. “International Lending: The Role of Lender’s Home Country.” *Journal of Money, Credit & Banking* 53 (6): 1373–1416. https://doi.org/10.1111/jmcb.v53.6.

Blum, J.. 1999. “Do Capital Adequacy Requirements Reduce Risks in Banking?.” *Journal of Banking & Finance* 23 (5): 755–771. https://doi.org/10.1016/S0378-4266(98)00113-7.

Bostandzic, D., and G. N. F. Weiss. 2018. “Why Do Some Banks Contribute More to Global Systemic Risk?.” *Journal of Financial Intermediation* 35:17–40. https://doi.org/10.1016/j.jfi.2018.03.003.

Brunnermeier, M. K., G. N. Dong, and D. Palia. 2020. “Banks’ Noninterest Income and Systemic Risk.” *Review of Corporate Finance Studies* 9 (2): 229–255.

Bushman, R. M., C. D. Williams, and R. Wittenberg-Moerman. 2017. “The Informational Role of the Media in Private Lending.” *Journal of Accounting Research* 55 (1): 115–152. https://doi.org/10.1111/1475-679X.2017.55.issue-1.

Cai, J., F. Eidam, A. Saunders, and S. Steffen. 2018. “Syndication, Interconnectedness, and Systemic Risk.” *Journal of Financial Stability* 34:105–120. https://doi.org/10.1016/j.jfs.2017.12.005.

Calem, P., and R. Rob. 1999. “The Impact of Capital-based Regulation on Bank Risk-taking.” *Journal of Financial Intermediation* 8 (4): 317–352. https://doi.org/10.1006/jfin.1999.0276.

Chen, Y.. 1999. “Banking Panics: The Role of the First-come, First-served Rule and Information Externalities.” *Journal of Political Economy* 107 (5): 946–968. https://doi.org/10.1086/250086.

Chu, Y., D. Zhang, and Y. Zhao. 2019. “Bank Capital and Lending: Evidence From Syndicated Loans.” *Journal of Financial & Quantitative Analysis* 54 (2): 667–694. https://doi.org/10.1017/S0022109018000698.

Colla, P., F. Ippolito, and K. Li. 2013. “Debt Specialization.” *The Journal of Finance* 68 (5): 2117–2141. https://doi.org/10.1111/jofi.2013.68.issue-5.

Conlon, T., and J. Cotter. 2014. “Anatomy of a Bail-in.” *Journal of Financial Stability* 15:257–263. https://doi.org/10.1016/j.jfs.2014.04.001.

De Jonghe, O., M. Diepstraten, and G. Schepens. 2015. “Banks’ Size, Scope and Systemic Risk: What Role for Conflicts of Interest?.” *Journal of Banking & Finance* 61 (1): S3–S13. https://doi.org/10.1016/j.jbankfin.2014.12.024.

Delis, M. D., K. de Greiff, and S. Ongena. 2019. “Being Stranded with Fossil Fuel Reserves? Climate Policy Risk and the Pricing of Bank Loans.” Swiss Finance Institute Research Paper Series No.18-10.

Dell, M., B. F. Jones, and B. A. Olken. 2014. “What Do We Learn From the Weather? The New Climate-economy Literature.” *Journal of Economic Literature* 52 (3): 740–798. https://doi.org/10.1257/jel.52.3.740.

Demerjian, P. R., and E. L. Owens. 2016. “Measuring the Probability of Financial Covenant Violation in Private Debt Contracts.” *Journal of Accounting & Economics* 61 (2–3): 433–447. https://doi.org/10.1016/j.jacceco.2015.11.001.

Dietz, S., A. Bowen, C. Dixon, and P. Gradwell. 2016. “‘Climate Value At Risk’ of Global Financial Assets.” *Nature Climate Change* 6 (7): 676–679. https://doi.org/10.1038/nclimate2972.

Fabrizi, M., X. Huan, and A. Parbonetti. 2021. “When LIBOR Becomes LIEBOR: Reputational Penalties and Bank Contagion.” *Financial Review* 56 (1): 157–178. https://doi.org/10.1111/fire.v56.1.

Financial Stability Board. 2020. “Stocktake of Financial Authorities’ Experience in Including Physical and Transition Climate Risks as Part of Their Financial Stability Monitoring.” https://www.fsb.org/wp-content/uploads/P220720.pdf.

François, P., and F. Missonier-Piera. 2007. “The Agency Structure of Loan Syndicates.” *Financial Review*42 (2): 227–245. https://doi.org/10.1111/fire.2007.42.issue-2.

Gatev, E., and P. E. Strahan. 2009. “Liquidity Risk and Syndicate Structure.” *Journal of Financial Economics* 93 (3): 490–504. https://doi.org/10.1016/j.jfineco.2008.10.004.

Gauthier, C., A. Lehar, and M. Souissi. 2012. “Macroprudential Capital Requirements and Systemic Risk.” *Journal of Financial Intermediation* 21 (4): 594–618. https://doi.org/10.1016/j.jfi.2012.01.005.

Hautsch, N., J. Schaumburg, and M. Schienle. 2015. “Financial Network Systemic Risk Contributions.” *Review of Finance* 19 (2): 685–738. https://doi.org/10.1093/rof/rfu010.

He, Zhiguo, and Arvind. Krishnamurthy. 2019. “A Macroeconomic Framework for Quantifying Systemic Risk.” *American Economic Journal: Macroeconomics* 11 (4): 1–37.

Huang, H. H., J. Kerstein, and C. Wang. 2017. “The Impact of Climate Risk on Firm Performance and Financing Choices: An International Comparison.” *Journal of International Business Studies* 49 (5): 633–656. https://doi.org/10.1057/s41267-017-0125-5.

Ivashina, V.. 2009. “Asymmetric Information Effects on Loan Spreads.” *Journal of Financial Economics*92 (2): 300–319. https://doi.org/10.1016/j.jfineco.2008.06.003.

Ivashina, V., and Z. Sun. 2011. “Institutional Demand Pressure and the Cost of Corporate Loans.” *Journal of Financial Economics* 99 (3): 500–522. https://doi.org/10.1016/j.jfineco.2010.10.009.

Jiang, F., C. W. Li, and Y. Qian. 2020. “Do Costs of Corporate Loans Rise with Sea Level?.” Working Paper.

Jiang, W., K. Li, and P. Shao. 2010. “When Shareholders are Creditors: Effects of the Simultaneous Holding of Equity and Debt by Non-commercial Banking Institutions.” *Review of Financial Studies* 23 (10): 3595–3637. https://doi.org/10.1093/rfs/hhq056.

Jorion, P. 2006. *Value at Risk: The New Benchmark for Managing Financial Risk*. New York: McGraw-Hill.

Keeley, M. C.. 1990. “Deposit Insurance, Risk, and Market Power in Banking.” *American Economic Review* 80 (5): 1183–1200.

Laeven, L., L. Ratnovski, and H. Tong. 2016. “Bank Size, Capital, and Systemic Risk: Some International Evidence.” *Journal of Banking & Finance* 69 (1): S25–S34. https://doi.org/10.1016/j.jbankfin.2015.06.022.

Lanfear, M. G., A. Lioui, and M. G. Siebert. 2019. “Market Anomalies and Disaster Risk: Evidence From Extreme Weather Events.” *Journal of Financial Markets* 46:100477. https://doi.org/10.1016/j.finmar.2018.10.003.

Li, Q., H. Shan, Y. Tang, and V. Yao. 2024. “Corporate Climate Risk: Measurements and Responses.” *The Review of Financial Studies*

Lim, J., B. A. Minton, and M. S. Weisbach. 2014. “Syndicated Loan Spreads and the Composition of the Syndicate.” *Journal of Financial Economics* 111 (1): 45–69. https://doi.org/10.1016/j.jfineco.2013.08.001.

López-Espinosa, Germán, Antonio Moreno, Antonio Rubia, and Laura Valderrama. 2012. “Short-term Wholesale Funding and Systemic Risk: A Global CoVaR Approach.” *Journal of Banking & Finance* 36 (12): 3150–3162. https://doi.org/10.1016/j.jbankfin.2012.04.020.

Newey, W. K., and K. D. West. 1987. “A Simple, Positive Semi-definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix.” *Econometrica* 55 (3): 703–708. https://doi.org/10.2307/1913610.

Nguyen, D. D., S. Ongena, S. Qi, and V. Sila. 2022. “Climate Change Risk and the Cost of Mortgage Credit.” *Review of Finance* 26 (6): 1509–1549. https://doi.org/10.1093/rof/rfac013.

NOAA. 2020. “National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters.” https://www.ncdc.noaa.gov/billions/summary-stats.

Pais, A., and P. A. Stork. 2013. “Bank Size and Systemic Risk.” *European Financial Management* 19 (3): 429–451. https://doi.org/10.1111/eufm.v19.3.

Pankratz, N., R. Bauer, and J. Derwall. 2023. “Climate Change, Firm Performance, and Investor Surprises.” *Management Science* 69 (12): 7151–7882. https://doi.org/10.1287/mnsc.2023.4685.

Rao, S., S. Koirala, C. Thapa, and S. Neupane. 2022. “When Rain Matters! Investments and Value Relevance.” *Journal of Corporate Finance* 73:101827. https://doi.org/10.1016/j.jcorpfin.2020.101827.

Repullo, R.. 2004. “Capital Requirements, Market Power, and Risk-taking in Banking.” *Journal of Financial Intermediation* 13 (2): 156–182. https://doi.org/10.1016/j.jfi.2003.08.005.

Schwert, M.. 2018. “Bank Capital and Lending Relationships.” *The Journal of Finance* 73 (2): 787–830. https://doi.org/10.1111/jofi.2018.73.issue-2.

Shleifer, A., and R. W. Vishny. 1992. “Liquidation Values and Debt Capacity: A Market Equilibrium Approach.” *The Journal of Finance* 47 (4): 1343–1366. https://doi.org/10.1111/jofi.1992.47.issue-4.

Shleifer, A., and R. W. Vishny. 2011. “Fire Sales in Finance and Macroeconomics.” *Journal of Economic Perspectives* 25 (1): 29–48. https://doi.org/10.1257/jep.25.1.29.

Sufi, A.. 2007. “Information Asymmetry and Financing Arrangements: Evidence From Syndicated Loans.” *The Journal of Finance* 62 (2): 629–668. https://doi.org/10.1111/jofi.2007.62.issue-2.

Sufi, A.. 2009. “Bank Lines of Credit in Corporate Finance: An Empirical Analysis.” *Review of Financial Studies* 22 (3): 1057–1088. https://doi.org/10.1093/revfin/hhm007.

World Economic Forum. 2021. “The Global Risks Report.” https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2021.pdf.

Appendices

Appendix 1. Variable definition

Variable	Definition	Source
Climate Risk Measures		
CRI_State	State-level climate risk calculated based on the Billion-Dollar Weather and Climate Disasters data by the National Centers for Environmental Information (NOAA). It is defined as the first principal component of six key climate risk indicators: (1) number of deaths, (2) number of deaths per 100,000 inhabitants, (3) sum of losses in USD at purchasing power parity (PPP), (4) losses per unit of Gross Domestic Product (GDP), (5) number of events, and (6) loss per event.	BEA NOAA
CRI_State_GW	State-level climate risk calculated using the Germanwatch method. It is defined as the sum of the state's score in all four indicating categories: (1) number of deaths, (2)number of deaths per 100,000 inhabitants, (3) sum of losses in USD at PPP, (4) losses per unit of GDP, (5) number of events, and (6) loss per event.	As above
CRI_Bank_Cross	Bank-level unexpected climate risk acquired through cross-state lending. The sum of a bank's lending to a foreign state as a percentage of its total lending weighted by the unexpected component of CRI_State of the specific state for each year.	BEA NOAA Dealscan
CRI_Bank_Home	Bank-level unexpected climate risk acquired through within-state lending. The sum of a bank's lending to its home state as a percentage of its total lending weighted by CRI_State of its home state for each year.	As above

CRI_Bank_Cross_Res	Bank-level residual climate risk related to cross-state lending. The residual imputed from regressing CRI_Bank_Cross on a set of market-based common risk factors including market risk, market risk for the banking industry, credit risk, commodity risk, political risk, real estate risk, and sovereign risk.	As above
CRI_Bank_Home_Res	Bank-level residual climate risk related to within-state lending. The residual imputed from regressing CRI_Bank_Home on a set of market-based common risk factors including market risk, market risk for the banking industry, credit risk, commodity risk, political risk, real estate risk, and sovereign risk.	As above
CRI_Bank_Cross_GW	Bank-level climate risk related to cross-state lending calculated based on CRI_State_GW.	As above
CRI_Bank_Home_GW	Bank-level climate risk related to within-state lending calculated based on CRI_State_GW.	As above
Dependent Variables		
MES	Marginal expected shortfall. The average return for a bank during the 5% worst return days for the banking industry in a year.	CRSP
LRMES	Long-run marginal expected shortfall during the 2% worst return days for the banking industry in a year.	As above
VaR5	Value at risk at the 5%. The annual average of the 5th percentile of a bank's asset return in a weekly interval.	As above
VaR1	Value at risk at the 1%. The annual average of the 1st percentile of a bank's asset return in a weekly interval.	As above
ΔCoVaR5	A measure of a bank's marginal contribution to the risk of the system, computed as the difference between the value at risk of the system when the institution's return is at the 5th percentile and the value at risk of the system when the institution' return is at the median.	As above
ΔCoVaR1	A measure of a bank's marginal contribution to the risk of the system, computed as the difference between the value at risk of the system when the institution's return is at the 1st percentile and the value at risk of the system when the institution' return is at the median.	As above
Variable	Definition	Source
LTA	Loans-to-assets ratio. Loans net of total allowance for loan losses (*lntal*) divided by total assets (*at*).	Compustat
ΔLTA	Annual changes in LTA.	As above
LLP	Loan loss provision ratio. Provision for loan or asset losses (*pll*) divided by total loans (*lntal*).	As above
ΔLLP	Annual changes in LLP.	As above
Lender Characteristics		
SIZE_Bank	Bank size. Natural logarithm of total assets (*at*).	As above
EQRAT_Bank	Equity ratio. Book value of equity (*ceq*) divided by total assets (*at*).	As above
MTB_Bank	Market-to-book ratio. Market value of equity ($prccm \times cshom$) divided by book value of equity (*ceq*).	As above
DEPO_Bank	Deposit ratio. Total deposits (*dptc*) divided by total assets (*at*).	As above
LTA_Bank	Loans-to-assets ratio. Loans net of total allowance for loan losses (*lntal*) divided by total assets (*at*).	As above
NPL_Bank	Nonperforming loans ratio. Nonperforming assets (*npat*) divided by total assets (*at*).	As above
NII_Bank	Noninterest income ratio. Total noninterest income (*tnii*) divided by total assets (*at*).	As above
ROA_Bank	Return on assets. Net income (*ni*) divided by total assets (*at*).	As above
Borrower Characteristics		
SIZE_Borrower	Firm size. Natural logarithm of total assets (*at*).	As above
COVER_Borrower	Interest coverage. Earnings before interest (*ebitda*) divided by total interest expense (*xint*).	As above
DEBT_Borrower	Debt-to-EBITDA ratio. Debt ($dltt+dlc$) divided by earnings before interest, taxes, depreciation, and amortization (*ebitda*).	As above
CURRENT_Borrower	Current ratio. Current assets (*aco*) divided by current liabilities (*lco*).	As above
State-Level Variables		
GDP_Bank	Natural logarithm of annual gross domestic product (GDP) per capita of the lender bank's state.	BEA
ΔGDP_Bank	Annual growth rate of GDP per capita of the lender bank's state.	As above
GDP_Borrower	Natural logarithm of annual GDP per capita of the borrower firm's state.	As above
ΔGDP_Borrower	Annual growth rate of GDP per capita of the borrower firm's state.	As above
Inflation	Annual inflation rate of the United States.	As above
Other Variables		
Profit	A dummy variable that takes a value of one if a bank's ROA is above the yearly sample median.	Compustat
Crisis	A dummy variable that takes a value of one if the year is within the 2008–2009 financial crisis period, and zero otherwise.	
CapEx	A dummy variable that takes a value of one if the loan is used for operating and capital expenditures, and zero otherwise.	Dealscan
CS	A dummy variable that takes a value of one if the loan is used to manage capital structure, and zero otherwise.	As above
M&A	A dummy variable that takes a value of one if the loan is used for mergers, acquisitions, or buyouts, and zero otherwise.	As above

Appendix 2. Common risk factors

Risk Factor	Description	Source
Interest rate risk	Percentage changes in the market value of long-term assets. The factor is based on market prices of 10-year government bonds.	Datastream
Credit risk	Changes in the default premium between BAA– and AAA–rated corporate bonds. The factor is based on the time series maintained by Moody's.	Datastream
Commodity risk	Percentage changes in the S&P GSCI Total Return Index.	Datastream
Foreign exchange risk	Percentage changes in the trade-weighted currency baskets. The factor measures the currency value with respect to the currency values of the major trade partners.	Bank of England
Market risk	Percentage changes in the market value of S&P 500.	Datastream
Market risk (banking industry)	Percentage changes in the market value of the banking sector stock market portfolios.	Datastream
Political risk	Percentage changes in gold price against U.S. dollars.	Bank of England
Real estate risk	Percentage changes in the market value of the REIT investments.	Datastream
Sovereign risk	Changes in the difference of the (mean) of yields on the 10-year government bonds (Greece, Portugal, Spain, Italy) and 10-year German Government bonds.	Datastream
VIX	Chicago Board Options Exchange volatility index. The index measures market expectations of short-term volatility based on S&P 500 stock-index option prices.	Datastream

Annex 560

K. K. Agoraki et al., "The relationship between firm-level climate change exposure, financial integration, cost of capital and investment efficiency", *Journal of International Money and Finance*, 2024

Journal of International Money and Finance 141 (2024) 102994

Contents lists available at ScienceDirect

Journal of International Money and Finance

journal homepage: www.elsevier.com/locate/jimf

The relationship between firm-level climate change exposure, financial integration, cost of capital and investment efficiency

Konstantina K. Agoraki [a], Maria Giaka [b,c], Dimitrios Konstantios [d,*], Ioannis Negkakis [e]

[a] Department of Tourism Studies, University of Piraeus, Greece
[b] Department of Biomedical Sciences, University of West Attica, Greece
[c] Hellenic Open University, School of Social Sciences, Greece
[d] ALBA Graduate Business School, The American College of Greece, 6-8 Xenias Str, 115 28, Athens, Greece
[e] Plymouth Business School, University of Plymouth, UK

ARTICLE INFO

JEL classification:
F36
E22
G30
G32

Keywords:
Firm level Climate change exposure
Cost of capital
Investment efficiency
Financial integration

ABSTRACT

This paper investigates the impact of firm-level climate change exposure on corporate cost of capital, growth opportunities and new investment across 67 countries with varying degrees of financial integration from 2002 to 2021. The analysis documents that firms with high climate change exposure have a negative outlook, face increased cost of capital, and have reduced investment activity. Moreover, firms with climate change exposure are characterised by investment inefficiency and slower speed of adjustment towards the target investment. These findings become more pronounced for companies which operate in countries with high levels of financial integration. Our results are robust to alternative estimation techniques that address model sensitivity, endogeneity, and selection bias issues.

1. Introduction

There is increasing evidence that climate change has become an important factor with large effects for modern enterprises (Bansal, et al., 2017; Hong, et al., 2019; Krueger et al., 2020; Addoum, et al., 2020; Hossain and Masum, 2022). For instance, the U.S. National Oceanic and Atmospheric Administration (NOAA) has documented a surge in extreme weather events across the United States in recent years. The costs associated with these calamities are often borne by taxpayers, consumers, and businesses. In 2020 alone, the U.S. economy suffered $95 billion in damages from climate-related disasters, while such catastrophic events have accrued a staggering cost of over $2 trillion since 1980. Additionally, the U.S. National Climate Assessment report projects that climate change could incur expenses amounting to 10 % of the country's GDP within this century. These expenses demonstrate that climate change has significant economic impact in the modern economic environments.

Corporate industries and financial institutions (Heinkel et al., 2001; Hoepner et al., 2022) have proactively taken measures to mitigate the effects of climate risk. This includes the identification of climate risks and the development of comprehensive plans and strategies aimed at fostering competitiveness and profitability through sustainable practices (Chasiotis et al., 2023). Therefore,

* Corresponding author.
E-mail addresses: kagoraki@unipi.gr (K.K. Agoraki), mgiaka@uniwa.gr (M. Giaka), dkonstantios@alba.acg.edu (D. Konstantios), ioannis.negkakis@plymouth.ac.uk (I. Negkakis).

https://doi.org/10.1016/j.jimonfin.2023.102994

Available online 19 November 2023

decision-making processes have integrated risk analysis and strategies that enable the determination and evaluation of exposure to climate risk (Matsumura et al., 2014).

Certain businesses directly experience the financial burdens associated with climate change, such as extreme weather events or rising sea levels (Krueger et al., 2020; Murfin and Spiegel, 2020). This includes increased risks for properties located in coastal areas and prolonged droughts impacting food producers. However, laws and regulations implemented to mitigate climate change can have adverse effects on other industries. For instance, carbon pricing or emission caps may negatively impact fossil fuel companies. Moreover, climate change-related technological advancements pose a threat to well-established industry business structures of various portfolio companies (El Ghoul et al., 2018; Painter, 2020).

According to Ridley (2023), a significant London lawsuit involving institutional investors from across Europe has been filed against the board of energy giant Shell, raising allegations of climate mismanagement. This lawsuit has the potential to have far-reaching effects on how businesses approach emissions management. The case asserts that Shell's eleven directors have violated company law by neglecting to address the "*substantial and predictable*" risks associated with climate change that could impact the company. Notably, this is the first notable legal action taken by shareholders against a board for alleged failure to adequately prepare for a transition away from fossil fuels. Shell, in response, refuted the accusations, stating that its climate goals were on track, and asserting that its directors acted lawfully and in the best interests of the company.

Our study is motivated by the growing recognition of climate change's impact on businesses and the increasing legal and regulatory scrutiny surrounding climate risk management. With an urgent need for comprehensive research on effective approaches to address these challenges, understanding the implications of climate change and developing sustainable business strategies are vital for long-term success and mitigating its adverse effects. Therefore, this study aims to address a significant research gap in the literature by examining how firm-level climate change exposure, affects firms' cost of capital and growth opportunities and thus corporate new investment and its speed of adjustment towards the optimal point. Previous literature documents that the degree of a country financial integration is crucial factor that can have significant role in economic growth, and economic stability (Borensztein et al., 1998; Edwards, et al., 2001; Arteta,et al., 2003; Durham, 2004; Woo, 2009; Alfaro et al., 2009; Baltabaev, 2014). Moreover, Caballero et al. (2006) emphasizes in the role of heterogeneous domestic financial systems in explaining global imbalances and business heterogeneity. We built and expand this literature by investigating the role of financial integration in the aforementioned relationships using an international sample of 67 countries for the time period between 2002 and 2021.

We present empirical evidence that highlights a negative relationship between climate change exposure and both firms' cost of capital and growth opportunities. Our findings reveal that companies exposed to climate risk face difficulties in securing capital and financing their investments. Moreover, these firms demonstrate a higher likelihood of underinvestment and a slower adjustment towards the optimal investment levels. Notably, the impact of these findings is particularly significant for companies operating in countries with high financial integration.

It is worth emphasizing the substantial economic significance of our findings, as they provide crucial implications for both investors and policymakers. Specifically, they offer valuable insights for assessing corporate valuation and understanding the intricate interplay between financial integration, climate risk, and investment efficiency.

The rest of the study is structured as follows. The theory and hypothesis development for the current study is provided in section 2, and the data and methodology in section 3. In section 4, we then go on to a detail empirical analysis. In section 5, we assess protentional endogeneity concerns and in section 6 we use alternative measures of financial integration to provide further robustness. Last but not least, section 7 presents the study's conclusions.

2. Theory and hypotheses development

2.1. Firm level climate risk exposure and corporate investment activity

The literature recognizes three major dimensions of climate risk exposure. The first is the physical risk which stems from a firm's exposure to CO_2 emissions or natural climate issues such as sea levels rising (Chava, 2014; Hong, et al., 2019; Painter, 2020). This type of risk is directly linked with large scale corporate losses related to assets and operations. The second is the transitional risk and relates with climate-oriented disruptive innovation in the transition process that firms follow in order to become "green" (Delis, et al., 2020; Johnston, et al., 2020; Bolton and Kacperczyk, 2021). The third is the regulatory risk which originates from the changes in regulations and policies which aim to minimize the corporate footprint on climate change concerns (Sautner et al., 2022).

Previous studies, highlight the negative impact of climate risk exposure, on corporate financial outcomes such as firm valuation, corporate governance, and market reaction (Matsumura, et al., 2014; Chava, 2014; Lee et al., 2015; Dessaint and Matray, 2017; Hong, et al., 2019; Painter, 2020; Huynh and Xia, 2021; Javadi and Masum, 2021; Bolton and Kacperczyk, 2021). Climate risk exposure is expected to raise businesses' need for investment capital, in order to improve their adaptability in net-zero activities and a desire for carbon neutrality (Busch et al., 2016; Drempetic et al., 2020), and at the same time reduce their ability to finance themselves given that investors ask for risk premium to undertake this type of investments. Huang et al., (2022) document that heightened exposure to extremely high temperatures has adverse effects on firms' revenues and operating income. Pankratz et al. (2023) report that firms facing climate hazards encounter unfavourable financing terms when seeking bank loans. These terms include higher interest rates, greater collateral requirements, and increased covenant constraints. However, firms that take proactive steps to address climate risk, such as implementing a corporate climate strategy, adopting specific or integrated approaches to manage climate change, are able to alleviate the adverse effects of climate risk on loan contracting. Moreover, strategic investments which aim to address climate risk, increase firms' sustainable performance, reduce capital expenses, and enhance financial performance and valuation (Giese et al., 2019;

Fafaliou et al., 2022; Economidou et al., 2022).

The ability of a corporation to raise internal cash or obtain outside funding affects the materialization of the potential investment (Fazzari et al., 1988; Campello et al., 2010; Lambrecht and Myers, 2012). Climate risk exposure, reduce firms' capacity to raise money from both internal and external sources (Huang et al., 2018; Huynh et al., 2020; Kling et al., 2021). As a result, we contend that businesses under climate risk exposure face difficulties to finance their investment. Therefore, we formalize our first hypotheses:

H1: Firm level climate risk exposure is negative associated with firms' growth opportunities and increases the cost of corporate financing.

H2: Firm level climate risk exposure is negative associated with firms' investment activity.

2.2. Financial integration

The existing literature mainly examines the effects of financial integration on macro level. Levine (1997, 2005) and Wachtel (2001) argue that financial integration impacts positively the economic growth and the efficient of banking systems. In the same direction, Goldsmith (1969), King and Levine (1993) and Levine and Zervos (1996) document a positive relationship between financial integration and the GDP per capita and the liquidity of stock markets. Levine et al. (2000) and Huang and Lin (2009) also report a positive relationship between the different degrees of financial development and growth which is due to the country differences in legal, accounting, and income level. Moreover, several studies argue for a positive impact of the financial deepening on income (Backé et al., 2007; Égert et al., 2007), and on capital accumulation and productivity (de Haas, 2001; Levine, 2005). In this direction, Arcand et al. (2012) report a positive association between financial depth and economic growth, which for increased financial depth becomes weaker with diminisher returns.

Another strand of the literature focusing on the Central and Eastern Europe transition economies, supports a positive association between financial deepening and economic growth (Hermes and Lensink, 2000; Bonin and Wachtel, 2003; Bonin et al., 2005; Kenourgios and Samitas, 2007; Fink et al., 2009; Zagorchev et al., 2011). Hermes and Lensink (2000) and Agoraki et al., (2023) underline the importance of regulation in stock markets in the process of financial intermediation which improves the stability of the banking sector.

A related stream of the literature examines the effect of regulatory quality in financial markets. Benbouzid,et al., (2017a,2017b) show that high quality of economic and legal institutions reduces banks' credit risk while Lombardo and Pagano (2002) document that better disclosures lessen investors monitoring costs. Their findings support that efficiency legal systems protect investors and improve firms' financial ability by lower the risk premium (Hail and Leuz, 2006). Moreover, they show that investors raise capital in better terms in strong regulatory environments. La Porta, et al. (2008), argue that legal institutions, security enhance equity markets and legal protection reduce firms' overall risk and increase investors engagement. Finally, it's important to note that financial integration and institutional quality improve capital mobility and investment activity (Younas, 2009).

The present study aims to extend this literature and study the effect of financial integration at a microeconomic dimension, by examining its role as a moderator on the relationship between firm level climate risk and financial outcomes such as cost of capital, investment efficiency, and financial performance. We expect that climate risk exposure in countries with higher degrees of financial integration can influence more investors sentiment and the market valuation of companies. Specifically, as awareness of climate-related risks grows, investors may reassess the value of companies exposed to such risks. This can lead to lower market valuations and reduced access to equity financing (Pankratz et al., 2023), affecting investment efficiency. Therefore, we formalize our third hypothesis:

H3: Financial integration amplifies the relationship between firm level climate risk exposure, corporate investment, and investment inefficiency.

3. Data and methodology

3.1. Sample construction

Our sample is constructed using a range of sources. We obtain global financial and accounting data from *Compustat – Capital IQ database* while information on firm-level climate risk exposure is abstained from Sautner et al. (2022). From *Institutional Brokers' Estimate System (IBES)* database, we take analysts' earnings forecast and financial development indicators, while from *International Monetary Fund* (*Financial Development Index Database*). We exclude financial and utility sectors (SIC codes 6000–6999 and 4900–4999) and clean our sample from all observations with missing values in our estimating equations. The final sample consists of 8,551 firms (42,605 firm-year observations) distributed over 67 countries,[1] for the time period between 1 January 2002 and 31 December 2021. All variables are winsorized at the conventional 1st and 99th percentiles to reduce the protentional impact of outliers.

[1] In Appendix Table A4, we present the comprehensive list of countries included in the study.

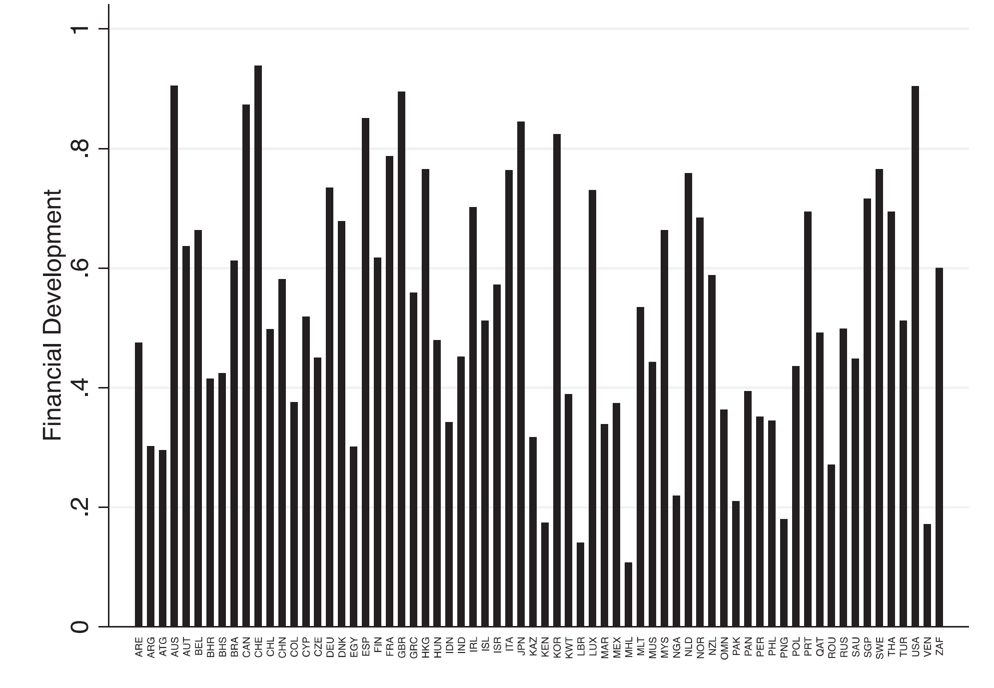


Fig. 1. Financial integration by Country.

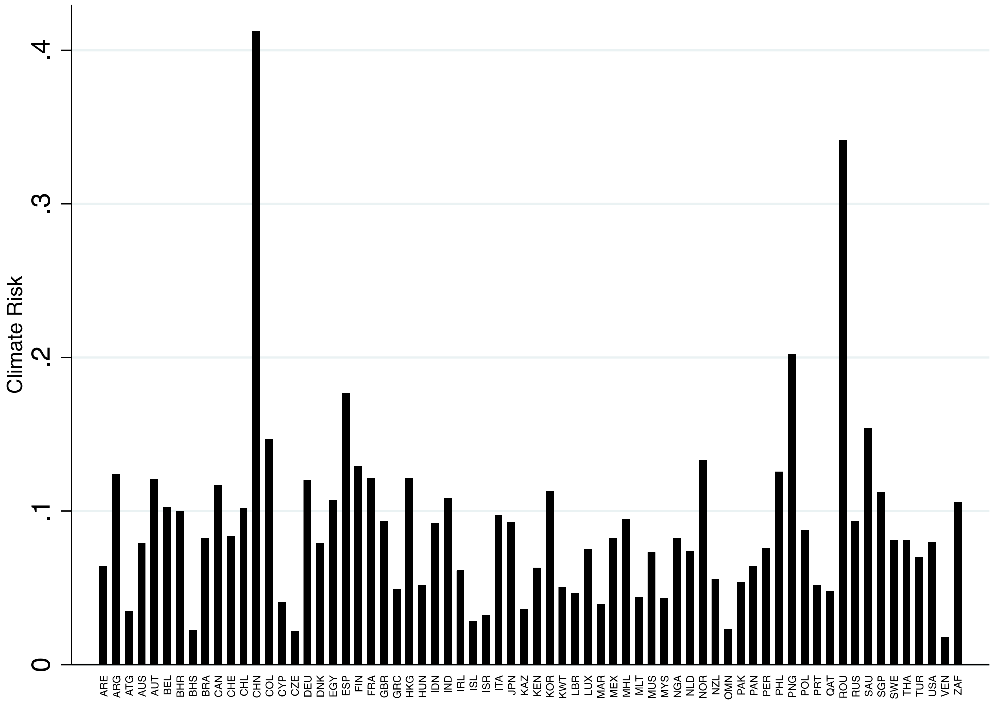


Fig. 2. Climate risk by Country.

3.1.1. Firm level climate risk exposure measurement

Our main variable of interest is firm-level climate risk exposure (*Climate risk*) constructed and provided[2] using bigram analysis on quarterly earnings conference calls by Sautner et al. (2022). The variable captures information considering firm level climate risks that arising from regulatory, physical, and transitional climate change shocks (See Fig. 2).[3] Earnings conference calls have evolved over the past 20 years into a key method of firm's communication between its stakeholders, investors, and analysts. The *climate risk index* developed by Sautner et al. (2022) quantifies information considering the firm level climate exposure based on the communication of these parties having good firm-time variation. Firm level climate risk exposure (*Climate risk*) is made similarly as the measure of Hassan et al. (2019) that captures information for firms' level political risks, using bigram analyses focusing on the frequency of key words (e. g., such as climate risk, climate risk uncertainty) that convey information about possible firm climate risk exposure. The construction of the measure follows a multidimension approach (i.e., firm-level climate risk considering physical, regulatory, and transitional firm climate issues) and according to the authors is positively correlated with other measures such as CO_2 emissions index of Engle et al. (2020). It's important to note that recent literature recognizes and adopts this measure (Cook and Luo, 2021; Ben-Amar et al., 2022; Hossain and Masum, 2022; Wu et al., 2022). Collectively, these studies provide valuable insights into the diverse impacts of climate risk on firm value, financing choices, cost of capital, and innovation, highlighting the relevance and importance of considering climate risk in corporate decision-making processes. However, one limitation of this measure is that it is possible some firms to ignore climate change issues in their conference calls and consequently having zero climate risk exposure for those particular firm-year observations.[4]

3.1.2. Cost of capital measurement

To calculate the cost of capital[5] for our firms, we closely follow the existing literature (Damodaran, 1994; Fama & French,1999; Brealey et al.,2017) using the weighted average of the cost of equity and the cost of debt as described in equation (1). By weighing the cost of equity and the cost of debt based on their respective proportions in the firm's capital structure, the cost of capital provides a benchmark for evaluating investment opportunities and determining the minimum required return on investment to satisfy the expectations of both equity and debt holders (Ross et al., 2016).

$$Costofcapital = \frac{\text{Total Interest and Related Expense}}{\text{Total Debt in Current Liabilities}} \tag{1}$$

3.1.3. Calculating investment adjustments

We quantify yearly businesses' investment expenditures to new projects (I_{New}), using Richardson's (2006)[6] methodology. Where (I_{New}) is defined as the difference between total capital expenditures and acquisitions and sales of property, plant, and equipment.[7] To calculate the speed of adjustment of firm's which may vary from the optimal investment level, we employ a dynamic panel regression of the following equation.

$$I_{New_{i,t}} - I_{New_{i,t-1}} = \lambda\left(\widehat{I}_{New_{i,t}} - I_{New_{i,t-1}}\right) + \varepsilon_{it} \tag{2}$$

The divergence between the target investment, $\left(\widehat{I}_{New_{i,t}}\right)$ *and the* lagged investment $\left(I_{New_{i,t-1}}\right)$ is called speed of adjustment (SOA), takes values in the interval zero to one and symbolized as λ. A value of SOA, close to one indicates an immediate response from the target investment, while a value close to zero denotes no modification. In our model, we include a vector X to control for firm specific characteristics and also add firm and year fixed effects as shown in the next equation.

$$\widehat{I}_{New_{i,t}} = \beta X_{i,t} + y_t + f_i + \varepsilon_{i,t} \tag{3}$$

We obtain equation (4) by adding (2) and (3) together.

[2] Firm level climate risk data are available online at https://osf.io/fd6jq/.

[3] In Fig. 2 presents the variation in climate risk across different countries. This figure allows us to visually analyze the extent to which firms in various countries face significant climate risks. By illustrating the differences in climate risk exposure, Fig. 2 contributes to our understanding of the heterogeneity in climate-related challenges faced by firms operating in different regions.

[4] Our findings have tested excluding those particular firm-year observations and remain in the same direction.

[5] In addition, we calculate the cost of capital for our firms following the existing literature (Francis, et al., 2005; Hail and Leuz, 2006; Li, 2010) using the ex-ante cost of capital implied in current stock price and analyst's forecasts of future earnings. In line with Francis et al. (2005), we employ a price–earnings growth (*Price Earnings Growth*) ratio model. In doing so, firm-specific ex ante cost of capital is defined as described by the following equation: $CostofCapital_{(PriceEarninggrowth)} = \sqrt{\frac{EarningsPerShare_{(t+2)} - EarningsPerShare_{(t+1)}}{MarketPrice_t}}$; Where, the (*Market Price*) is firms stock price that corresponds to the current period, (*Earnings Per Share*) are defined as the expected future earnings per share for the two forward periods and (*Cost of Capital*) stands for the estimation of cost of capital solved as internal rate of return. When we follow this methodology, we construct the cost of capital for a reduce sample of 36,605 observations. However, our estimates remain in the same direction for both specifications of cost of capital.

[6] A number of subsequent studies investigated the impact of overinvestment/underinvestment on firm performance and stock performance (Liu and Bredin, 2010; Fu, 2010).

[7] Investment expenditure to new projects, I_{New}, is equal to total investment, I_{TOTAL} (=cash paid for the purchase and construction of fixed assets, intangible assets and other long-term assets minus net cash recovered from disposal of fixed assets, intangible assets, and other long-term assets) minus investment expenditure to maintenance, $I_{MAINTENANCE}$ (=depreciation and amortization expenses).

$$I_{New_{i,t}} = (1-\lambda)I_{New_{i,t-1}} + \lambda\beta X_{i,t} + y_t + f_i + \varepsilon_{i,t} \tag{4}$$

We take equation (5) by denoting α equal to $1 - \lambda$ and γ equal to λβ.

$$I_{New_{i,t}} = aI_{New_{i,t-1}} + \gamma X_{i,t} + y_t + f_i + \varepsilon_{i,t} \tag{5}$$

In our model, we assume constant time invariance for both the speed of adjustment λ and the impact of firm-specific features on target investment β. We follow Drobetz et al. (2013) and apply a sensitive regime-switching partial adjustment model to capture the fluctuation of adjustment speed and the relative firm specific characteristics associated to target investment over the two different regimes as described in equations (6) and (7).

$$\text{Regime}A\ :\quad I^{A}{}_{New_{i,t}} = a_1 \mathrm{I}^{\mathrm{A}}{}_{New_{i,t-1}} + \gamma_1 \mathrm{X}^{\mathrm{A}}{}_{i,t} + y_{1t} + f_{1i} + \varepsilon^{\mathrm{A}}{}_{i,t} \tag{6}$$

$$\text{Regime}B\ : I^{\mathbf{B}}{}_{New_{i,t}} = a_2 \mathrm{I}^{\mathrm{B}}{}_{New_{i,t-1}} + \gamma_2 \mathrm{X}^{\mathrm{B}}{}_{i,t} + y_{2t} + f_{2i} + \varepsilon^{\mathrm{B}}{}_{i,t} \tag{7}$$

Taken together the previous two equations, we construct a partial adjustment regime-switching model (equation (8). The two regimes D_A and D_B take the value of one if firm i is in the respective regime at time t and zero otherwise.

$$\mathrm{I}_{New_{i,t}} = D_{\mathrm{A}}\left(a_1 I_{New_{i,t-1}} + \gamma_1 X_{i,t} + y_t + f_i + \varepsilon_{i,t}\right) + D_{\mathrm{B}}\left(\alpha_2 I_{New_{i,t-1}} + \gamma_2 X_{i,t} + y_t + f_i + \varepsilon_{i,t}\right) \tag{8}$$

We transform equation (8) and take equation (9) as follows:

$$\mathrm{I}_{New_{i,t}} = \alpha_1 I_{New_{i,t-1}} + (\alpha_2 - \alpha_1) D_{\mathrm{B}} I_{New_{i,t-1}} + \gamma_1 X_{i,t} + (\gamma_2 - \gamma_1) D_{\mathrm{B}} X_{i,t} + y_t + f_i + \varepsilon_{i,t} \tag{9}$$

In accordance with Elsas and Florisiak (2015), we estimate equation (9) to model the fractional nature of the normal investment ratio using the doubly censored Tobit - fractional dependent variable (DPF) estimator. To account for the unobserved and time-invariant characteristics of the firms, we incorporate company and year fixed effects in all calculations.

3.1.4. Estimating underinvestment

We follow Richardson (2006) to assess the over- and under-investment of firms on our sample. In doing so, we calculate the share of investment (I_{New}) over total assets and estimate the the following equation.

$$\mathrm{I}_{New_{i,t}} = \delta + \zeta I_{New_{i,t-1}} + \xi X_{i,t} + y_t + f_i + \varepsilon_{i,t} \tag{10}$$

We control in our model for firm level characteristics that may affect firms' investment activity. Specifically, we include Tobin's Q and firms *Growth (Growth),* age *(Age)* and size *(Size)* to capture firms' Growth opportunities, and asymmetric information. Similarly, as in Richardson (2006), we also include Cash, Leverage, Returns. We estimate equation (9) and keep the residuals to proxy the "deviation from the target investment". In particular, we construct underinvestment (overinvestment) as a dummy variable that takes the value of one (zero) in the case that the residuals the estimated equation are negative (positive).

3.1.5. Financial integration measurement

We obtain financial development index *(FD)* by International Monetary Fund database (See Fig. 1). The index was created as the aggregation of subindexes which denote the development of financial Institutions *(FI)* including banks, insurance companies, mutual funds, pension funds, and financial markets *(FM)* which are defined as the stock and bond markets.

The index[8] quantifies information for the size and liquidity of markets "depth", for the ability of individuals and companies to access financial services "access" and for the ability of institutions to provide financial services at low cost and with sustainable revenues, and the level of activity of capital markets "*efficiency*". Each indicator is scaled by the database between zero to one and normalized. As a result, the highest (lowest) value of a given variable across time and nations is equal to one (zero), and all other values are compared to these maximum (minimum) values. Higher values of the indicators are defined to imply stronger financial integration.

3.2. Methodology

3.2.1. The impact of firm level climate risk exposure on firms cost of capital and growth opportunities

We investigate the relationship between firms' level climate risk exposure, corporate growth opportunities and cost of capital by estimating models (11) and (12). We employ a variety of estimators to secure our findings. Specifically, we use *Pooled OLS*, *High Dimension Fixed Effects* and *High Dimension Fixed Effects with entropy balanced weighting scores*.

$$Tobins'Q_{i,t} = a_0 + a_1 \text{Climate } Risk_{i,t-1} + \ a_2 X_{i,t-1} \ + \ Y_t + F_i \ + C_j \ + u_{i,t,j} \tag{11}$$

$$CostofCapital_{i,t} = b_0 + b_1 ClimateRisk_{\ i,t\ -1} + b_2 X_{i,t-1} + Y_t + F_i + C_j + \varepsilon_{i,t,j} \tag{12}$$

[8] Fig. 1 illustrates the variation in financial development across different countries, allowing us to visually examine the diverse levels of financial integration and sophistication in different economies. This figure provides insights into the varying degrees of access to financial resources, institutional quality, and stability across countries, which are crucial factors influencing firms' investment decisions.

To account for possible factors that may affect firms' investment, we include a vector X of control variables in our model. In particular, we include Tobin's q (*TobinsQ*) and firms age (*Firms Age*) and size (*Size*) to control for firm's growth opportunities and asymmetric information. We control for asymmetric information and agency costs by including leverage (*Leverage*) (Denis and Osobov, 2008; Blouin et al., 2011), and for market dynamics by including firms market competition (*HHI*) (Hoberg et al., 2014; Grullon et al., 2019). To capture firms' risk, we control for firm's cash (*Cash*). In addition, to account for the heterogeneity of the macroeconomic environment that may affect corporate sustainable plans, we include in our model the country's GDP growth and the inflation. In our estimations, we also add firm, year and country fixed effects.

3.2.2. The impact of firm level climate risk exposure on firms' new investment and investment efficiency

We use a probit model to evaluate the likelihood of a company's underinvestment due to Climate Risk exposure. In doing so, we construct the dependent variable (*Underinvestment*) as a dummy variable that takes the value of one when a firm underinvests and the value of zero otherwise. Therefore, to examine the impact of firm level climate risk on investment efficiency, we estimate the following model:

$$Prob(Underinvestment)_{i,t} = c_0 + c_1 ClimateRisk_{i,t-1} + cX_{i,t-1} + Y_t + F_i + C_j + u_{\iota,t,j} \tag{13}$$

Moreover, we estimate equation (14) to investigate for the impact of climate risk on corporate investment.

$$Investment_{i,t} = \beta_0 + \beta_1 ClimateRisk_{i,t-1} + \beta_2 X_{i,t-1} + Y_t + F_i + C_j + u_{\iota,t,j} \tag{14}$$

Where Vector X includes the same controls as described in the previous section.

3.3. Entropy-balanced regressions

To enhance the robustness of our findings and address potential endogeneity concerns, we employ entropy-balancing regressions (Hainmueller, 2012). This technique allows us to calibrate the unit weights in our model, mitigating potential variations in moment distributions between firms with high climate risk (treatment sample) and those without (control sample). It is worth noting that the entropy balancing method does not involve "matching or discarding" individual units, as seen in propensity-score matching algorithms. Instead, it improves covariate balance while minimizing information loss. By utilizing this method, we effectively address potential inequalities in the covariance distributions of second, or even higher, moments.

3.4. Heckman selection model

In this section, we employ the two-stage Heckman (1979) procedure to secure that our OLS estimates are not driven by sample selection mechanisms which may lead to a non-zero covariance between the random error and the firm level climate risk. Our motivation is that under certain circumstances there is higher probability for firms to have higher climate risk. Moreover, it is possible confound variables to influence climate risk and at the same time to affect firms' new investment activity. In such a case, the estimated coefficient of climate risk would be bias.

To account for potential selection bias, we follow the two-stage Heckman model. The first stage of this model uses a probit regression to estimate the probability that firms' climate risk exposure is above the sample average (*High_Climate_Risk)* and the second stage uses the individual predicted probabilities of first stage to correct for potential selection bias. We presented below the selection equations of the Heckman model:

$$DC^*_{i,t} = kZ_{i,t} + \varepsilon_{\iota,t}, DC_{i,t} = \begin{cases} 1, if High\_Climate\_Risk^*_{i,t} \\ 0, if Low\_Climate\_Risk^*_{i,t} \end{cases} \tag{15}$$

To control for the intensity of firm level climate risk exposure, we use a dummy variable DC^*_i that captures its latent characteristics. The estimated coefficients and a set of $DI_{i,t}$ predictor variables are included in vectors K and $Z_{i,t}$ respectively, while $\varepsilon_{\iota,t}$ is the error term of the model. The first stage of the methodology retains the same regressors as the baseline model and in addition, we add the same additional variables known as exclusion restrictions to account for selection bias on firm level climate risk.

Following prior literature (Deng et al., 2013; Hoi et al., 2013; Dutordoir et al., 2018), we use variables based on the location of firms' headquarters as exclusion restrictions, which are the country Political Orientation (*Political Orientation*) and the Religion Strength (*Religion Strength*) of the country that a firm belongs (Angelidis and Ibrahim, 2004; Dutordoir et al., 2018). We use the variable State Religion as our first exclusion restriction since firm level climate risk appears to be influenced by the level of religiosity of the country that a firm belongs. As a second restriction we use the left- right Political Orientation *(Political Orientation)* as specific political agendas may show less tolerance to climate risk issues, and thus the probability to punish the responsible firms with fines may be higher. There is no theoretical justification for anticipating a correlation between religion and Political Orientation and the response of climate risk on the vector $\vec{O}$ which includes the regressands *(Cost of capital, Tobin's Q, Investment new, Underinvestment*). Finally, we calculate the industry share by dividing the number of firms belonging to each of the Fama French 48 industries by the total number of firms in the sample. This allows us to account for the distribution of firms in each industry in the dataset. We provide definitions for the former variables in the appendix A1.

We build equations (16) and (17) to capture firms with high and low climate risk, respectively.

$$E\left[\vec{O}\middle|DC_{i,t}=1\right]=\beta'X+\delta+E\left[e\middle|DC_{i,t}=1\right]=\beta'X+\delta+\rho\sigma_e\frac{\varphi(\omega'A)}{\Phi(\omega'A)} \tag{16}$$

$$E\left[\vec{O}\middle|DC_{i,t}=0\right]=\beta'X+\rho\sigma_e\frac{-\varphi(\omega'A)}{1-\Phi(\omega'A)} \tag{17}$$

In equation (17) ω' is a vector with the estimated coefficients, φ symbolizes the function of normal distribution, and Φ stands for the distribution function of the cumulative distribution function. We calculate the effect of climate risk on the vector $\vec{O}$ by subtracting equation (16) from equation (17).

$$E\left[\vec{O}\middle|DC_{i,t}=1\right]-E\left[\vec{O}\middle|DC_{i,t}=0\right]=\delta+\rho\sigma_e\frac{\varphi(\omega'A)}{\Phi(\omega'A)(1-\Phi(\omega'A))} \tag{18}$$

Equation (19) captures the impact of climate risk exposure on the regressands of via the δ coefficient, which is related to the a_1 coefficient of equation (11). The Mills ratio (IMR) presented below, is a corrective term that can be used to identify and correct of the risk of selection bias.

$$IMR=\frac{\varphi(\omega'A)}{\Phi(\omega'A)}\ if\ DC_{i,t}=1\ \text{or}\ IMR=\frac{-\varphi(\omega'A)}{1-\Phi(\omega'A)}\ if\ DC_{i,t}=0 \tag{19}$$

3.5. Descriptive statistics

In Table 1, we provide the descriptive statistics for the variables in our study. The average (median) climate risk exposure in our sample is equal to 0.09 (0.034) and its percentile range is between 0.012 and 0.085 which suggests that the majority of firms do not have serious climate risk exposure. Firms' growth opportunities and leverage in our sample are on average (median) equal to 1.461 (1.227) and 0.020 (0.012) respectively and the average firm is in the market is 7.473 years. Firms, cash and cost of capital on average (median) equal to 0.139 (0.088) and 0.278 (0.175) respectively. Last but not least, the firm's new investment over its total assets is on average (median) 0.128 (0.078). For all the variables included in our analysis, we provide the definitions and the correlation matrix in the appendix A1.

Table 1
Summary statistics. Variable definitions are provided in Appendix.

Variables	N	Mean	Median	SD	p25	p75
Climate Risk	42,605	0.096	0.034	0.217	0.012	0.085
Cost of Capital	42,605	0.275	0.175	0.328	0.104	0.316
Investment new	42,605	0.128	0.078	0.192	0.021	0.172
Underinvestment	42,605	0.128	0	0.334	0	0
Tobin's Q	42,605	1.461	1.227	0.928	0.714	1.963
ROA	42,605	0.066	0.107	0.245	0.158	−2.808
Cash	42,605	0.139	0.088	0.153	0.037	0.181
Leverage	42,605	0.264	0.225	0.491	0.068	0.374
HHI	42,605	0.147	0.088	0.168	0.186	0.015
Size	42,605	304316.23	1569.4	5522833.5	353.617	7257.6
Firms Age	42,605	17.363	17	8.546	10	24
GDP Growth	42,605	1.885	2.281	2.494	2.796	−6.596
Inflation	42,605	2.163	2.069	1.563	1.262	2.912
Business Freedom Index	42,605	86.088	88.8	8.333	83.3	91.3
LMF	42,605	5.713	5.678	0.614	5.51	5.757
KAOPEN	42,605	2.216	2.347	0.59	2.347	2.347
FD	42,605	0.851	0.905	0.119	0.871	0.909
FI	42,605	0.848	0.885	0.112	0.871	0.894
FM	42,605	0.823	0.889	0.135	0.818	0.899

Table 2
Climate risk and firms' growth opportunities, This table presents the impact of firm level climate on firms' growth opportunities. In column (1) we estimate our model using polled OLS, while in columns (2) and (3) we employ high dimensional fixed effects and high dimensional fixed effects with entropy matching weights including firm year and country fixed effects. One, two, and three asterisks indicate statistical significance at the 10 %, 5 %, and 1 % levels, respectively. All variables are defined in appendix.

	(1)	(2)	(3)
VARIABLES	Tobin's Q	Tobin's Q	Tobin's Q
	Pooled OLS	HDFE	HDFE with entropy matching
Climate Risk$_{(t-1)}$	−0.912***	−0.327***	−0.539*
	(0.223)	(0.116)	(0.330)
ROA	0.026**	0.038**	0.046***
	(0.012)	(0.017)	(0.011)
Cash$_{(t-1)}$	1.159***	1.021***	0.234***
	(0.028)	(0.026)	(0.050)
Leverage$_{(t-1)}$	1.463***	2.156***	0.077
	(0.114)	(0.154)	(0.134)
HHI$_{(t-1)}$	−0.085***	−0.017	−0.012
	(0.018)	(0.017)	(0.031)
Size$_{(t-1)}$	−0.112***	0.017***	−0.215***
	(0.001)	(0.002)	(0.010)
Firms Age$_{(t-1)}$	−0.000	−0.054***	−0.210***
	(0.006)	(0.005)	(0.028)
GDP Growth$_{(t-1)}$	0.018***	0.012***	0.010
	(0.001)	(0.002)	(0.008)
Inflation$_{(t-1)}$	−0.024***	−0.000	0.022
	(0.002)	(0.003)	(0.015)
Constant	2.166***	1.315***	3.299***
	(0.020)	(0.020)	(0.089)
Observations	42,605	42,605	42,605
R-squared	0.178	0.491	0.772
Firm FE	NO	YES	YES
Year FE	NO	YES	YES
Country FE	NO	YES	YES
Entropy	NO	NO	YES

4. Empirical analysis

In this section, we first look at the relationship between firm level climate risk exposure and new investment. We then delve deeper and examine the effect of climate risk exposure on corporate investment efficiency and the speed of adjustment (SOA) to target investment.

4.1. The impact of firm level climate risk exposure on firms' growth opportunities

Table 2 displays the estimates of equation (11), which assesses the impact of firm-level climate risk exposure on growth opportunities measured by Tobin's Q. In columns (1) to (3), we present the results of our analysis. Our estimates consistently reveal a statistically significant and negative relationship between climate risk and firm growth opportunities at the conventional levels. These findings hold substantial economic significance, as they indicate that the market discounts the negative impact of climate risk exposure on firms' growth prospects. Thus, our results support hypothesis (H1) and underscore the importance of considering climate risk in evaluating and valuing companies' growth potential.

4.2. Firm level climate risk exposure and cost of capital

Table 3 presents our findings regarding the impact of firm level climate risk exposure on the firm's cost of capital. In columns (1) to (3), we present the estimates from our models. Notably, the coefficient of climate risk (*Climate Risk)* consistently exhibits a negative and statistically significant relationship across all estimators, providing direct support for our first hypothesis (H1). These results carry significant economic implications, as they indicate that the market imposes a risk premium on the cost of borrowing for firms exposed to climate risk. Therefore, our findings underscore the importance of considering climate risk when assessing the cost of capital and highlight the financial consequences faced by firms operating in a climate-risk environment.

4.3. The association between a firm's climate risk exposure and new investment

Table 4 showcases the estimates of equation (14), which investigates the relationship between firm level climate risk exposure and investment activity. In column (1), we utilize Pooled OLS, while in columns (2) and (3), we employ the High dimensional fixed effects (HDFE) and High dimensional fixed effects with entropy matching weights, respectively. Our findings, derived from all estimation

Table 3
The relation between firm level climate risk and Cost of Capital, This table documents the impact of firm level climate on firms' cost of capital. In column (1) we estimate our model using polled OLS, while in columns (2) and (3) we employ high dimensional fixed effects and high dimensional fixed effects with entropy matching weights including firm year and country fixed effects. One, two, and three asterisks indicate statistical significance at the 10 %, 5 %, and 1 % levels, respectively. All variables are defined in appendix.

VARIABLES	(1) Cost of Capital Polled OLS	(2) Cost of Capital HDFE	(3) Cost of Capital HDFE With Entropy Matching
Climate Risk$_{(t-1)}$	0.022*	0.025***	0.060**
	(0.012)	(0.008)	(0.027)
Tobin's Q$_{(t-1)}$	−0.110***	−0.110***	−0.121***
	(0.003)	(0.003)	(0.010)
Cash$_{(t-1)}$	0.063***	0.038**	0.014
	(0.017)	(0.018)	(0.059)
Leverage$_{(t-1)}$	0.766***	0.731***	0.852***
	(0.167)	(0.164)	(0.198)
HHI$_{(t-1)}$	0.007	0.035***	0.023
	(0.012)	(0.013)	(0.030)
Size$_{(t-1)}$	−0.026***	−0.030***	−0.047***
	(0.001)	(0.001)	(0.004)
Firms Age$_{(t-1)}$	−0.018***	−0.019***	−0.021**
	(0.004)	(0.004)	(0.010)
GDP Growth$_{(t-1)}$	0.011***	0.004	0.012
	(0.001)	(0.003)	(0.009)
Inflation$_{(t-1)}$	0.005**	0.003	−0.022
	(0.002)	(0.005)	(0.019)
Constant	0.654***	0.701***	0.879***
	(0.015)	(0.020)	(0.058)
Observations	42,605	42,605	42,605
R-squared	0.250	0.322	0.855
Year FE	YES	YES	YES
Firm FE	NO	YES	YES
Country FE	NO	YES	YES
Entropy	NO	NO	YES

Table 4
The relation between firm level climate risk and corporate investment, This table presents the results from estimating (14) with OLS, high dimensional fixed effects and high dimensional fixed effects with entropy matching using firm, year, and country fixed effects. Robust standard errors clustered at the firm level are reported in parentheses. Variable definitions are reported in appendix. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

VARIABLES	(1) Investment new Polled OLS	(2) Investment new HDFE	(3) Investment new HDFE With Entropy Matching
Climate Risk$_{(t-1)}$	−0.072***	−0.043***	−0.064*
	(0.013)	(0.012)	(0.037)
Tobin's Q$_{(t-1)}$	−0.005***	−0.004***	−0.000
	(0.001)	(0.001)	(0.002)
Cash$_{(t-1)}$	−0.036***	−0.032***	−0.048***
	(0.004)	(0.006)	(0.008)
Leverage$_{(t-1)}$	0.169***	0.154**	0.010
	(0.059)	(0.060)	(0.029)
HHI$_{(t-1)}$	0.019***	0.001	0.045
	(0.001)	(0.001)	(0.032)
Size$_{(t-1)}$	−0.003***	−0.004***	−0.010***
	(0.000)	(0.000)	(0.001)
Firms Age$_{(t-1)}$	−0.003***	−0.000	−0.001
	(0.001)	(0.001)	(0.002)
GDP Growth$_{(t-1)}$	−0.000	−0.001	0.000
	(0.000)	(0.001)	(0.001)
Inflation$_{(t-1)}$	−0.000	−0.001**	−0.000
	(0.000)	(0.001)	(0.002)
Constant	−0.072***	−0.043***	−0.064
	(0.013)	(0.012)	(0.039)
Observations	42,605	42,605	42,605
R-squared	0.011	0.040	0.097
Year FE	YES	YES	YES
Firm FE	NO	YES	YES
Country FE	NO	YES	YES
Entropy	NO	NO	YES

Table 5
Firm level climate risk and investment activity for different levels of financial integration across countries. This table presents the impact of firm level climate risk on firm new investment across countries with different levels of financial integration. In column (1) we use financial development index (*FD*), while in columns (2) and (3) financial institutions (*FI*) and financial markets (*FM*) indexes. In all specifications we estimate our model using high dimensional fixed effects on firm, year, and country. One, two, and three asterisks indicate statistical significance at the 10 %, 5 %, and 1 % levels, respectively. All variables are defined in appendix.

VARIABLES	(1) Investment new HDFE	(2) Investment new HDFE	(3) Investment new HDFE
Climate Risk$_{(t-1)}$	−0.088*	−0.057	−0.087*
	(0.048)	(0.040)	(0.047)
FD$_{(t-1)}$	0.010		
	(0.007)		
Climate Risk$_{(t-1)}$ x *FD*$_{(t-1)}$	−0.157**		
	(0.075)		
FI$_{(t-1)}$		0.001	
		(0.007)	
Climate Risk$_{(t-1)}$ x *FI*$_{(t-1)}$		−0.120*	
		(0.066)	
FM$_{(t-1)}$			0.009**
			(0.004)
Climate Risk$_{(t-1)}$ x *FM*			−0.161**
			(0.075)
Tobin's Q$_{(t-1)}$	−0.008***	−0.008***	−0.008***
	(0.001)	(0.001)	(0.001)
Cash$_{(t-1)}$	−0.031***	−0.031***	−0.031***
	(0.004)	(0.004)	(0.004)
Leverage$_{(t-1)}$	−0.017	−0.017	−0.017
	(0.035)	(0.035)	(0.035)
HHI$_{(t-1)}$	0.003*	0.003*	0.003*
	(0.001)	(0.001)	(0.001)
Size$_{(t-1)}$	−0.003***	−0.003***	−0.003***
	(0.001)	(0.001)	(0.001)
Firms Age$_{(t-1)}$	0.005***	0.005***	0.005***
	(0.001)	(0.001)	(0.001)
GDP Growth$_{(t-1)}$	−0.000***	−0.000***	−0.000***
	(0.000)	(0.000)	(0.000)
Inflation$_{(t-1)}$	−0.001***	−0.001***	−0.001***
	(0.000)	(0.000)	(0.000)
Constant	0.082***	0.072***	0.080***
	(0.007)	(0.006)	(0.006)
Total Effect Climate Risk	−0.221***	−0.157***	−0.219***
	(0.052)	(0.028)	(0.054)
Observations	42,605	42,605	42,605
R-squared	0.533	0.532	0.533
Firm FE	YES	YES	YES
Year FE	YES	YES	YES
Country FE	YES	YES	YES

techniques, consistently reveal a negative and statistically significant impact of climate risk on corporate investment. These results hold substantial economic significance as they highlight the adverse effects of climate risk exposure on firms' investment decisions. Thus, our findings lend empirical support to hypothesis (H2) and emphasize the importance of considering climate risk in understanding and evaluating firms' investment behaviour.

4.4. The impact of financial integration on firm's climate risk exposure and investment nexus

In Table 5, we present our estimates examining the impact of financial integration on the relationship between firm level climate risk exposure and investment. Column (1) utilizes the financial development index (*FD*) as a measure of financial integration, while columns (2) and (3) focus on its subindexes, financial institutions (*FI*) and financial markets (*FM*), respectively. Our findings consistently reveal a negative and statistically significant interaction between all financial integration indexes and firm level climate risk exposure. This indicates that financial integration amplifies the adverse relationship between climate risk exposure and corporate investment.

Importantly, these results hold significant economic implications as they underscore the role of financial integration in shaping the impact of climate risk on investment decisions. By intensifying the negative association, financial integration exacerbates the challenges faced by firms exposed to climate risk when making investment choices. Consequently, our findings directly support hypothesis (H3) and emphasize the necessity of considering financial integration in assessing the effects of climate risk exposure on firms' investment behaviour.

Table 6

The impact firm level climate risk on investment efficiency, This table presents the impact of firm level climate risk on firm investment efficiency across countries with different level of financial integration. In column (1) we present the impact of firm level climate risk on investment efficiency while in columns (2), (3) and (4) we study this relationship accounting for the degree of development (*FD*), financial institutions (*FI*) and financial markets (*FM*). In all specifications we estimate our model using high dimensional fixed effects on firm, year, and country. One, two, and three asterisks indicate statistical significance at the 10 %, 5 %, and 1 % levels, respectively. All variables are defined in appendix

	(1)	(2)	(3)	(4)
VARIABLES	Underinvestment	Underinvestment	Underinvestment	Underinvestment
Climate Risk$_{(t-1)}$	0.351***	0.234**	0.169*	0.244***
	(0.042)	(0.119)	(0.099)	(0.106)
FD$_{(t-1)}$		−0.102*		
		(0.061)		
Climate Risk$_{(t-1)}$ *x FD*$_{(t-1)}$		0.218***		
		(0.075)		
FI$_{(t-1)}$			−0.184	
			(0.122)	
Climate Risk$_{(t-1)}$ *x FI*$_{(t-1)}$			0.592*	
			(0.336)	
FM$_{(t-1)}$				−0.113*
				(0.064)
Climate Risk$_{(t-1)}$ *x FM*				0.545***
				(0.181)
Tobin's Q$_{(t-1)}$	0.325***	0.322***	0.324***	0.321***
	(0.012)	(0.012)	(0.012)	(0.012)
Cash$_{(t-1)}$	2.973***	2.985***	2.979***	2.984***
	(0.064)	(0.064)	(0.064)	(0.064)
Leverage$_{(t-1)}$	−2.032***	−2.009***	−2.023***	−2.001***
	(0.262)	(0.261)	(0.261)	(0.260)
HHI$_{(t-1)}$	−0.026***	−0.026***	−0.026***	−0.026***
	(0.006)	(0.006)	(0.006)	(0.006)
Size$_{(t-1)}$	−0.426***	−0.425***	−0.426***	−0.426***
	(0.014)	(0.014)	(0.014)	(0.014)
Firms Age$_{(t-1)}$	−0.778***	−0.783***	−0.779***	−0.784***
	(0.020)	(0.020)	(0.020)	(0.020)
GDP Growth$_{(t-1)}$	−0.097***	−0.076***	−0.083***	−0.076***
	(0.020)	(0.022)	(0.021)	(0.022)
Inflation$_{(t-1)}$	0.198***	0.222***	0.216***	0.217***
	(0.019)	(0.022)	(0.022)	(0.021)
Total Effect climate risk		0.419***	0.667**	0.690**
		(0.130)	(0.333)	(0.363)
Observations	42,605	42,605	42,605	42,605
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES

4.5. *The impact firm level climate risk exposure on investment efficiency*

Table 6 presents the estimates of equation (13), which examines the relationship between firm level climate risk exposure and investment efficiency across different levels of financial integration. In column (2), we use the financial development index (*FD*) as a proxy for financial integration, while in columns (3) and (4), we utilize financial institutions (*FI*) and financial markets (*FM*) as alternative measures. Our models are estimated using the probit estimator. Our findings indicate that firms with climate risk exposure tend to have investment levels below the target. Additionally, the coefficients of the interaction between the financial integration indexes and firm-level climate risk are positive and statistically significant. These results suggest that climate risk firms in countries with high levels of financial development are more likely to fall below the target investment levels. Consequently, our estimates provide support for hypothesis (H3), indicating that financial integration plays a role in influencing the association between climate risk exposure and investment efficiency. Overall, these findings contribute to our understanding of the relationship between climate risk exposure, financial integration, and investment efficiency. They highlight the challenges faced by climate risk exposured firms, particularly in countries with high financial development, in achieving their target investment levels.

4.6. *The impact firm level climate risk exposure on the investment speed of adjustment*

In this section, we empirically assess the relationship between firm level climate risk exposure and the relative to the target investment adjustment using a partial adjustment regime switching model. By examining the effect of climate risk on SOA, we aim to understand how climate risk factors influence the pace at which firms respond to deviations from their desired investment levels. This analysis sheds light on the dynamics of investment decision-making under climate risk scenarios, and it helps us comprehend the potential implications of climate risk on firms' investment strategies and capital allocation.

In Table 7, column (1), we consider the total sample while in columns (2) and (3), we estimate our model in subsamples including firms with high climate risk exposure belonging in countries with high and low financial integration, respectively. The coefficient of lagged investment (*New Investment$_{(t-1)}$)* is positive and statistically significant at the conventional levels across all columns but also higher for climate risk firms who belong in countries with higher financial integration. It's important to note that our estimates reveal significant differences in the rate of adjustment between the two groups corresponding to firms with high climate risk and high (low) financial integration. The speed investment of adjustment (SOA) is equal to the difference of 1 – λ where λ is defined as the coefficient of the lagged investment (*New Investment$_{(t-1)}$*). In particular, in column (1) the speed of adjustment is equal to 0.480 while in columns (2) and (3) is 0.434 and 0.591, respectively. One potential explanation is that in countries with high financial integrating the social and regulatory pressure is higher, and consequently climate risk issues cost more. Overall, these findings show that climate risk exposued firms belonging in countries with high financial integration have a slower speed of adjustment towards the target (optimal) investment. Overall, these findings highlight the dynamics of investment adjustment in response to climate risk exposure and financial integration. They indicate that climate risk exposure firms in countries with high financial integration face a slower speed of adjustment towards their target (optimal) investment levels.

5. Addressing protentional endogeneity

5.1. Instrumental variable approach

In this section, we employ an instrumental variable method (2SLS) to ensure that our estimates do not suffer from potentially

Table 7
The impact of firm level climate risk on firms' investment speed of adjustment (SOA).

	(1)	(2)	(3)
VARIABLES	Investment new	Investment new	Investment new
Panel A	All Firms	High Climate risk & High FD	High Climate risk & Low FD
New Investment$_{(t-1)}$	0.520***	0.566***	0.409***
	(0.019)	(0.111)	(0.012)
Tobin's Q$_{(t-1)}$	0.012***	0.005	0.023***
	(0.001)	(0.012)	(0.002)
Cash$_{(t-1)}$	0.151***	0.149**	0.209***
	(0.009)	(0.059)	(0.011)
Leverage$_{(t-1)}$	0.226***	0.459***	0.052***
	(0.078)	(0.151)	(0.014)
HHI$_{(t-1)}$	−0.003	−0.006	0.025***
	(0.005)	(0.057)	(0.009)
Size$_{(t-1)}$	−0.004***	−0.007	−0.004***
	(0.001)	(0.006)	(0.001)
Firms Age$_{(t-1)}$	−0.003*	−0.065***	−0.005*
	(0.002)	(0.023)	(0.003)
GDP Growth$_{(t-1)}$	−0.000	0.005	0.004
	(0.002)	(0.006)	(0.004)
Inflation$_{(t-1)}$	0.003	−0.000	0.003
	(0.003)	(0.005)	(0.006)
Tobin's Q$_{(t-1)}$ x D_B	−0.009***	−0.014***	−0.008***
	(0.003)	(0.003)	(0.002)
Cash$_{(t-1)}$ x D_B	−0.045**	−0.043**	−0.047**
	(0.021)	(0.020)	(0.023)
Leverage$_{(t-1)}$ x D_B	−0.579***	−0.056**	−0.087***
	(0.132)	(0.021)	(0.021)
HHI$_{(t-1)}$ x D_B	−0.023*	−0.019	−0.022*
	(0.012)	(0.016)	(0.013)
Size$_{(t-1)}$ x D_B	−0.004*	−0.009*	−0.008*
	(0.002)	(0.005)	(0.005)
Firms Age$_{(t-1)}$ x D_B	−0.018***	−0.017***	−0.018***
	(0.005)	(0.004)	(0.005)
GDP Growth$_{(t-1)}$ x D_B	−0.002	−0.003	−0.002
	(0.002)	(0.002)	(0.002)
Inflation$_{(t-1)}$ x D_B	0.010***	0.013***	0.011***
	(0.003)	(0.003)	(0.003)
Observations	42,605	30,205	12,400
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Country FE	YES	YES	YES
Panel B			
SOA (below target investment)	0.480	0.434	0.591
	(1)	(2)	(3)
	All Firms	High Climate risk & High FD	High Climate risk & Low FD
SOA (below target investment)	0.480	0.434	0.591
Observations	42,605	30,205	12,400

Table 8
Instrumental variables estimations of the effect of firm level climate risk on cost of capital, new investment, and underinvestment. Robust standard errors are in parentheses. Variable definitions are provided in appendix. *** p < 0.01, ** p < 0.05, * p < 0.1.

VARIABLES	First stage	(1) Cost of Capital Second stage	(2) Tobin's Q	(3) Investment new	(4) Underinvestment
Climate Risk$_{(t-1)}$		0.643***	−0.829**	−0.643**	0.159 ***
		(0.234)	(0.391)	(0.309)	(0.003)
Tobin's Q$_{(t-1)}$		−0.081***		−0.006***	0.303***
		(0.004)		(0.000)	(0.013)
Cash$_{(t-1)}$		−0.100***	0.360***	−0.027***	3.076***
		(0.018)	(0.026)	(0.001)	(0.066)
Leverage$_{(t-1)}$		0.423***	0.822***	0.013	−2.126***
		(0.163)	(0.199)	(0.020)	(0.254)
HHI$_{(t-1)}$		0.021*	−0.019	0.001**	−0.026
		(0.012)	(0.013)	(0.001)	(0.070)
Size$_{(t-1)}$		−0.008	−0.141***	−0.001***	−0.466***
		(0.006)	(0.004)	(0.000)	(0.009)
Firms Age$_{(t-1)}$		0.008	−0.144***	0.005***	−1.008***
		(0.013)	(0.013)	(0.001)	(0.020)
GDP Growth$_{(t-1)}$		−0.002	0.013***	−0.000***	−0.119***
		(0.003)	(0.001)	(0.000)	(0.023)
Inflation$_{(t-1)}$		0.001	0.004**	−0.000***	0.256***
		(0.004)	(0.002)	(0.000)	(0.023)
ROA$_{(t-1)}$			0.084***		
			(0.030)		
Population density	0.011***				
	(0.002)				
W_Cash	−0.061***				
	(0.020)				
W_Leverage	0.415***				
	(0.093)				
W_HHI	0.005				
	(0.020)				
W_Size	0.009***				
	(0.001)				
W_Firms Age	0.010**				
	(0.005)				
W_GDP Growth	−0.020***				
	(0.002)				
W_Inflation	−0.006***				
	(0.002)				
W_ROA	−0.005				
	(0.004)				
Observations		42,605	42,605	42,605	42,605
Year FE		YES	YES	YES	YES
Firm FE		YES	YES	YES	YES
Country FE		YES	YES	YES	YES

endogeneity, which can arise by reverse causality, omitted factors, and measurement error. Our first instrument population density *(PopulationDensity)* comes from the World Data Bank and measures population density as the number of people per square kilometres. Furthermore, in our analysis, we incorporate heteroskedasticity-based instruments following the approach suggested by Lewbel (2012). This econometric technique proves useful in situations where external instruments are either unavailable or as a supplement to external instruments to enhance the efficiency of the instrumental variable (IV) estimator. The key requirement for identification using this method is that the regressors should not exhibit correlation with the product of heteroskedastic errors. This condition holds in models where error correlations arise from an unobserved common factor. The instruments proposed by Lewbel (2012) are derived from the existing model, specifically by leveraging heterogeneity in the error term of the first-stage regression.

The endogenous variable is the firm's climate risk, which is regressed in the first stage together with the instruments and control variables.

$$Climaterisk_{i,t} = a_0 + a_1 Instrument_{i,t} + a_2 Z_{i,t} + F_i + Y_t + C_j + u_{i,t,j} \tag{20}$$

In the second stage, we regress our baseline models' dependent variables; cost of capital, growth opportunities, investment, and underinvestment inefficiency; on the control variables, which also include the first stage's estimates residuals.

$$dependentvariables_{i,t} = \gamma_0 + \gamma_1 Predicted(ClimateRisk)_{i,t-1} + \gamma_2 Z_{i,t-1} + F_i + Y_t + C_j + e_{i,t,j} \tag{21}$$

Table 9
Heckman, The impact of climate risk on firms' cost of capital, growth opportunities, new investment and investment efficiency accounting for sample selection using 2 stage Heckman selection Model. In columns (1), (3) (5) and (7) we show the first step of Heckman estimations while in columns (2), (4), (6) and (8) we provide the second step. Variable definitions are provided in Appendix. *** p < 0.01, ** p < 0.05, * p < 0.1. Standard errors are reported in the parenthesis. All specifications include firms and year and country fixed effects.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Cost of Capital		Tobin's Q		Investment new		Underinvestment	
	First step	Second step	First step	Second step	First step	Second step	First step	Second step
Climate Risk$_{(t-1)}$		0.102***		−0.960***		−0.109***		0.721**
		(0.009)		(0.239)		(0.031)		(0.362)
Tobin's Q$_{(t-1)}$	0.136***	0.112**			0.007	−0.003***	0.133***	0.369***
	(0.011)	(0.046)			(0.008)	(0.000)	(0.008)	(0.032)
Cash$_{(t-1)}$	−0.215***	1.538***	−0.133***	1.243***	−0.100**	−0.034***	−0.294***	2.945***
	(0.068)	(0.561)	(0.047)	(0.071)	(0.049)	(0.003)	(0.051)	(0.268)
Leverage$_{(t-1)}$	−0.564	0.005	−0.698*	1.986***	0.056	0.048**	−0.432	−2.038**
	(0.560)	(0.030)	(0.358)	(0.553)	(0.303)	(0.020)	(0.367)	(0.982)
HHI$_{(t-1)}$	0.042	−0.017***	0.018	−0.061	0.005	0.013***	0.101***	0.290
	(0.047)	(0.003)	(0.034)	(0.046)	(0.035)	(0.002)	(0.035)	(0.184)
Size$_{(t-1)}$	0.054***	−0.035***	0.058***	−0.139***	0.055***	−0.002***	0.025***	−0.309***
	(0.005)	(0.009)	(0.003)	(0.008)	(0.003)	(0.000)	(0.004)	(0.037)
Firms Age$_{(t-1)}$	0.052***	−0.102***	0.055***	−0.028*	0.044***	−0.002***	0.062***	−0.624***
	(0.016)	(0.009)	(0.010)	(0.016)	(0.011)	(0.001)	(0.012)	(0.043)
ROA$_{(t-1)}$			−0.115***	−0.049				
			(0.021)	(0.042)				
GDP Growth$_{(t-1)}$	−0.003	0.010**	−0.021***	0.012**	−0.021***	−0.000	−0.013***	−0.134***
	(0.006)	(0.004)	(0.004)	(0.005)	(0.004)	(0.000)	(0.004)	(0.022)
Inflation$_{(t-1)}$	0.010	0.011*	0.004	−0.017***	0.003	0.000	0.011**	0.262***
	(0.008)	(0.006)	(0.004)	(0.006)	(0.004)	(0.000)	(0.006)	(0.029)
Political Orientation $_{(t-1)}$	0.043***		0.008***		0.007***		0.037***	
	(0.003)		(0.001)		(0.001)		(0.002)	
Religion Strength$_{(t-1)}$	1.759***		−0.567***		−0.567***		−0.076	
	(0.173)		(0.073)		(0.074)		(0.101)	
Industry Share	−0.016***		−0.020***		−0.022***		−0.022***	
	(0.003)		(0.002)		(0.002)		(0.003)	
lambda		0.012		−0.603***		−0.031***		
		(0.045)		(0.224)		(0.012)		
athrho								0.162
								(0.184)
Observations	42,605	42,605	42,605	42,605	42,605	42,605	42,605	42,605
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Sector FE	YES	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES	YES

Standard errors in parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.1.

The first and second stages of our 2SLS technique are described by equations (20) and (21). In Table 9, we provide our estimates which are in the same direction as those of our baseline models providing additional support for the validity of our estimates. We utilize the under- identification test by Kleibergen and Paap (LM statistic) to determine whether the number of instruments is sufficient in comparison to the number of the endogenous variables in order to give validity in our 2SLS estimations. The null hypothesis of under- identification is rejected when *p*-value is lower than 0.05 and 0.1 at the 5 % and 10 % level, respectively. We also examine any potential correlation between the instruments and the error term using the Hansen over-identification (p-value) test. The instruments are not taken as acceptable if there is any association. Over identifying constraints are justified under the null hypothesis, and a value greater than 0.05 is needed to reject the null hypothesis at the 5 % level. A weak identification test is used to evaluate the instrument's explanatory power. The instruments are weak or lack explanatory power if the critical values of this test are grater of those of the Cragg-Donald Wald F-statistic. The aforementioned tests demonstrate that we appropriately employed the 2sls operation. It's important to note that we fail to reject the join null hypothesis of the Hansen test (Hansen's J-statistic), that our instruments are proper and uncorrelated with the error term. In Table 8, we present the estimates from the two-stage least squares estimation. Overall, our results further support those of the baseline model, by showing that climate risk increases the cost of corporate financing and is negative associated with firms' growth opportunities new investment activity.

5.2. Accounting for selection bias

In Table 9, we employ Heckman (1979) two-step estimator. We use this method to correct any protentional selection bias, that could arise from unobservable factors with an impact on both the regression outputs and the firm level climate risk. Our results, after addressing selection bias, are in line with those of our baseline estimations, providing further support for our hypothesis that firm level

Table 10
The table presents the findings of an analysis examining the influence of firm's level climate risk on firms' new investment. The study utilizes a quasi-natural experiment approach, focusing on the exogenous shock resulting from the adoption of the Paris Agreement. The dependent variable across all specifications in firms' new investment while in columns (1) to (3), we utilize financial development index (*FD*), financial institutions (*FI*), and and financial markets (*FM*) as proxies for financial development, respectively. In all specifications we include firm year and country fixed effects. Standard errors are displayed in parentheses to indicate the precision of the estimates. For detailed definitions of the variables, please refer to Appendix. Statistical significance is denoted as follows: $p < 0.01$*** $p < 0.05$* $p < 0.1$.

	(1)	(2)	(3)
VARIABLES	Investment new	Investment new	Investment new
Climate Risk$_{(t-1)}$	−0.100*	−0.081*	−0.104
	(0.061)	(0.048)	(0.123)
FD	−0.033***		
	(0.006)		
ParisAgreement	0.001***	0.001***	0.002***
	(0.000)	(0.000)	(0.000)
Climate Risk$_{(t-1)}$ *x FD x ParisAgreement*	−0.363***		
	(0.118)		
FI		−0.001	
		(0.006)	
Climate Risk$_{(t-1)}$ *x FI x ParisAgreement*		−0.369***	
		(0.119)	
FM			−0.027***
			(0.004)
Climate Risk$_{(t-1)}$ *x FM x ParisAgreement*			−0.376***
			(0.122)
Tobin's Q$_{(t-1)}$	−0.006***	−0.006***	−0.006***
	(0.000)	(0.000)	(0.000)
Cash$_{(t-1)}$	−0.026***	−0.026***	−0.026***
	(0.001)	(0.001)	(0.001)
Leverage$_{(t-1)}$	0.004	0.004	0.004
	(0.021)	(0.021)	(0.021)
HHI$_{(t-1)}$	−0.001***	−0.001***	−0.001***
	(0.000)	(0.000)	(0.000)
Size$_{(t-1)}$	−0.001***	−0.001***	−0.002***
	(0.000)	(0.000)	(0.000)
Firms Age$_{(t-1)}$	0.004***	0.003***	0.003***
	(0.001)	(0.001)	(0.001)
GDP Growth$_{(t-1)}$	−0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)
Inflation$_{(t-1)}$	−0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)
Constant	0.093***	0.065***	0.088***
	(0.005)	(0.005)	(0.004)
Observations	42,605	42,605	42,605
R-squared	0.764	0.763	0.764
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Country FE	YES	YES	YES

climate risk exposure is positive associated with the corporate cost a capital and underinvestment, and negative associated with firms' growth opportunities and new investment activity.

5.3. The role of Paris Agreement on the relationship between firm-level climate risk exposure and investment: A natural experiment approach

The Paris Agreement represents a legally binding global treaty addressing climate change, which was adopted during the UN Climate Change Conference held in Paris, France, on 12 December 2015 (Acemoglu & Akcigit, 2015; Aldy et al., 2017). Its primary objective is to reducing greenhouse gas emissions and limit the rise in average global temperature to well below 2 °C above pre-industrial levels, with additional efforts aimed at achieving a temperature increase of 1.5 °C or less. This precautionary approach is based on scientific evidence from the Intergovernmental Panel on Climate Change, which warns that surpassing the 1.5 °C threshold could lead to more severe climate change consequences, such as increased occurrences of droughts, heatwaves, and heavy rainfall (Keohane et al., 2017).

In our study, we utilize the Paris Agreement as an external factor that directly influences the relationship between firm-level climate risk exposure and investment decisions. By incorporating the Paris Agreement into our research design, we aim to establish a causal connection between firm-level climate risk exposure and investment behaviour within different financial development contexts (Dietz et al., 2020). We argue that this international climate change treaty strengthens the negative impact of climate risk on investment, particularly across various levels of financial integration. Consequently, we anticipate that the enactment of the Paris

Table 11
Alternative proxies of financial integration, This table presents the impact of firm level climate risk on firm new investment across countries with different levels of financial integration. In column (1) we use financial development index (Business Freedom Index), while in columns (2) and (3) we use Milesi-Ferretti's de facto financial openness index (LMF) and Chinn and Ito, (2006) financial openness (KAOPEN) indexes. In all specifications we estimate our model using high dimensional fixed effects on firm, year, and country. One, two, and three asterisks indicate statistical significance at the 10 %, 5 %, and 1 % levels, respectively. All variables are defined in appendix.

	(1)	(2)	(3)
VARIABLES	Investment new	Investment new	Investment new
Climate Risk$_{(t-1)}$	−0.130*	−0.190*	−0.018
	(0.076)	(0.107)	(0.014)
Business Freedom Index$_{(t-1)}$	0.021***		
	(0.001)		
Climate Risk$_{(t-1)}$ *x Business Freedom Index*$_{(t-1)}$	−0.032***		
	(0.012)		
LMF$_{(t-1)}$		−0.023	
		(0.004)	
Climate Risk$_{(t-1)}$ *x LMF*$_{(t-1)}$		−0.026**	
		(0.013)	
KAOPEN			0.025*
			(0.013)
Climate Risk$_{(t-1)}$ *x KAOPEN*			−0.038***
			(0.013)
Tobin's Q$_{(t-1)}$	−0.008***	−0.008***	−0.008***
	(0.001)	(0.001)	(0.001)
Cash$_{(t-1)}$	−0.031***	−0.031***	−0.032***
	(0.004)	(0.006)	(0.004)
Leverage$_{(t-1)}$	−0.017	−0.036	−0.018
	(0.035)	(0.035)	(0.037)
HHI$_{(t-1)}$	0.003*	0.003*	0.003**
	(0.001)	(0.001)	(0.001)
Size$_{(t-1)}$	−0.003***	−0.003***	−0.003***
	(0.001)	(0.001)	(0.001)
Firms Age$_{(t-1)}$	0.005***	0.006***	0.006***
	(0.001)	(0.002)	(0.001)
ROA$_{(t-1)}$	−0.000***	−0.000**	−0.000
	(0.000)	(0.000)	(0.000)
GDP Growth$_{(t-1)}$	−0.001***	−0.001**	−0.000**
	(0.000)	(0.000)	(0.000)
Inflation$_{(t-1)}$	0.002	−0.000	0.005
	(0.003)	(0.005)	(0.006)
Total Effect climate risk	−0.157*	−0.338**	−0.216***
	(0.093)	(0.169)	(0.065)
Constant	0.084***	0.093***	0.076***
	(0.007)	(0.028)	(0.007)
Observations	42,605	42,605	42,605
R-squared	0.533	0.524	0.530
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Country FE	YES	YES	YES

Agreement will amplify the negative effect of firm-level climate risk exposure on investment. To test this hypothesis, we adopt a methodology similar to previous studies that employ natural experiments involving regulatory changes (Heath and Mace, 2020). We estimate the following regression equation to examine our hypothesis:

$$\begin{aligned} Investment_{i,t} = {} & b_0 + b_1 ClimateRisk_{i,t-1} * FinancialDevelopment * PostParisAgreement + b_2 ClimateRisk_{i,t-1} \\ & + b_3 PostParisAgreement + b_4 FinancialDevelopment + b_5 X_{i,t-1} + Y_t + F_i + C_j + u_{i,t,j} \end{aligned} \quad (22)$$

We introduce the variable "PostParisAgreement" which takes the value of one for firms operating after 2015, and the vector "FinancialDevelopment" which includes FD, FI, and FM depending on the specification we use. We anticipate that the interaction term (Climate Risk$_{i,t-1}$ x FinancialDevelopment $_{j,t-1}$ x PostParisAgreement) will display a negative coefficient, denoted as a_1, and will be statistically significant. The results of our estimation are presented in Table 10. In columns (1) to (3), we utilize financial development index (*FD*), financial institutions (*FI*), and and financial markets (*FM*) as proxies for financial development, respectively. Across all columns, the dependent variable is firms' investment. Notably, the coefficient of the interaction term consistently exhibits a negative and statistically significant value across all specifications, indicating a causal relationship between firm-level climate risk exposure and investment under different levels of financial integration.

Table 12
The relation between firm level climate risk sub-indexes and corporate investment, This table reports the estimates of the three main firm-level climate change exposure sub-indexes (*Climate change opportunity exposure, Climate change regulation exposure, Climate change regulation exposure*) on firms' new investment. In all specifications we use high dimensional fixed effects including firm, year, and country fixed effects. Robust standard errors clustered at the firm level are reported in parentheses. Variable definitions are reported in appendix. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

VARIABLES	(1) Investment new	(2) Investment new	(3) Investment new
Climate change opportunity exposure	−0.005*		
	(0.003)		
Climate change regulation exposure		−0.023***	
		(0.008)	
Climate change physical exposure			−0.089***
			(0.021)
Tobin's $Q_{(t-1)}$	−0.004***	−0.004***	−0.004***
	(0.001)	(0.001)	(0.001)
$Cash_{(t-1)}$	−0.032***	−0.032***	−0.032***
	(0.006)	(0.006)	(0.006)
$Leverage_{(t-1)}$	0.154**	0.154**	0.156***
	(0.060)	(0.060)	(0.060)
$HHI_{(t-1)}$	0.001	0.001	0.000
	(0.001)	(0.001)	(0.001)
$Size_{(t-1)}$	−0.004***	−0.004***	−0.004***
	(0.000)	(0.000)	(0.000)
Firms $Age_{(t-1)}$	−0.000	−0.000	−0.000
	(0.001)	(0.001)	(0.001)
GDP $Growth_{(t-1)}$	−0.001	−0.001	−0.001
	(0.001)	(0.001)	(0.001)
$Inflation_{(t-1)}$	−0.001**	−0.001**	−0.001**
	(0.001)	(0.001)	(0.001)
Constant	0.097***	0.097***	0.097***
	(0.006)	(0.006)	(0.006)
Observations	42,605	42,605	42,605
R-squared	0.401	0.401	0.402
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Country FE	YES	YES	YES

6. Robustness with alternative proxies of financial integration and climate risk exposure

6.1. Alternative proxies of financial integration

Prior literature documents that financial openness enhances the availability of foreign capital, which lowers domestic capital costs and lowers net risk as a result of risk sharing (Bekaert et al., 2005, Bechlioulis et al., 2023). International financial integration stimulates domestic private investment by opening up foreign capital inflows to the private sector (Henry, 2000; Alfaro and Hammel, 2007). Moreover, the advantages of financial integration may not stem only from financial openness but also from its externalities, which include improvements in institutional and regulatory quality as well as in both private and public governance (Kose et al., 2006). These benefits of financial integration's externalities increase allocative efficiency, which in turn promotes a stronger cross-border flow of financial capital, amplifying the advantages of financial integration.

In this section, we use as alternative proxy to measure financial integration the de facto, and de jure financial openness standards.[9] In doing so: i) We retrieve form the AREAR database of the IMF, Chinn and Ito (2006) de jure measure to proxy financial openness. The database offers the laws and ordinances that various nations employ to regulate financial and capital operations. These are then translated for each regulation into binary variables. These binary indicators are used by KAOPEN to offer a thorough indicator of financial openness at the national level. Principal component analysis is used extensively in this indicator to examine different facets of financial globalization. It is open to the public and covers a large portion of the nation. The index has been adjusted to lie within the interval of 0 and 1. ii) We incorporate a measure of de facto financial openness in the model since the actual volume of capital flows is influenced by factors other than capital controls (such as the quality of the regulatory framework). We employ Lane and Milesi-Ferretti's (2007) index as the de facto measure. Their index, which is a frequently used indicator of financial integration, calculates a nation's total assets + liabilities in relation to its GDP. All varieties of portfolio equity, FDI, debt, and financial derivatives are included in the assets and liabilities. The measure adjusts for the size of the economy because it is divided by the GDP. iii) We utilize the Heritage Foundation's Business Freedom Index as a gauge of regulatory effectiveness. The index assesses the effectiveness of governmental rules and rates how difficult it is to open, run, and shut down a firm. A country could receive a score between 0 and 100, with 100 signifying

[9] The de jure method does not give information on actual capital flows between countries and may not accurately depict the level of economic financial integration.

the most liberal business environment. The number of procedures, length of time, and cost of doing business are used to determine each country's ranking. The World Bank's doing business report is the source of the information. The Heritage index has been widely used by academics to evaluate the effectiveness of institutions and economic freedom (Chortareas et al., 2013).

In Table 11, we present our results focusing on the impact of the interaction between financial integration and firm level climate risk exposure on new investment. In column (1), we use the Business Freedom Index as a proxy for financial integration, while in columns (2) and (3), we employ the Lane and Milesi-Ferretti's (LMF) and Chinn and Ito capital openness (CAOPEN) indexes, respectively. Across all specifications, we find that the coefficients of the interaction terms between financial integration indexes and firm-level climate risk exposure are consistently negative and statistically significant. This implies that financial integration amplifies the negative relationship between firm-level climate risk and corporate investment. These findings provide direct support for our hypothesis (H3), which suggests that financial integration plays a role in intensifying the impact of climate risk on investment decisions.

By demonstrating the amplifying effect of financial integration, our results underscore the importance of considering the interaction between climate risk exposure and financial integration when analyzing investment behavior. These findings highlight the challenges faced by climate risk exposed firms within integrated financial systems, where the negative consequences of climate risk on investment are exacerbated. Overall, our findings provide empirical evidence supporting the hypothesis (H3) and contribute to a deeper understanding of the relationship between financial integration, climate risk, and corporate investment.

6.2. Alternative proxies of climate risk exposure

In this section we perform aditional analyses using the subindexes of climate risk exposure, namely Opportunity, Physical, and Regulatory exposure. The inclusion of these subindexes provides a more nuanced understanding of the different dimensions of climate risk exposure and their impact on firms' new investment. By examining the effects of opportunity shocks, we can assess how firms respond to climate-related market opportunities and their implications for firm performance and investment decisions. The analysis of physical shocks allows us to explore the direct impacts of climate-related events, such as natural disasters or extreme weather patterns, on firms' financial and operational performance. Lastly, the examination of regulatory shocks helps us understand how firms navigate the evolving landscape of climate-related regulations and policy changes and their effects on corporate behaviours. By incorporating these additional analyses, we aim to enhance the comprehensiveness and robustness of our study, providing a more comprehensive understanding of the multifaceted nature of climate risk and its implications for firms. In Table 12, we document the estimates of our analysis. Our estimates, across all the specifications incorporating the subindexes of climate risk, consistently demonstrate a significant and negative impact of climate risk on corporate investment. These results further bolster and reinforce the validity of our baseline findings.

7. Conclusion

In modern economies, climate risk is driving fundamental changes with adverse impacts on human livelihoods and corporates. This study builds and extents the current literature (Huang et al., 2022; Pankratz et al., 2023), by showing that climate risk has important impact on corporate financial decisions. Moreover, we recognize that there is significant variation of the uncertainty arising from climate risk exposure, as well as its impact on corporate decisions, across countries with different level of financial integration.

We investigate the impact of climate risk exposure on a firm's cost of capital, growth opportunities, new investment, corporates investment efficiency and its speed of adjustment towards the optimal investment in countries with varying levels of financial integration. The findings demonstrate that higher climate risk exposure adversely affects a firm's ability to secure capital on favourable terms, leading to a reduction in investment activity. Moreover, firms with higher climate risk exposure have increase probability for underinvestment and slower speed of adjustment (SOA) to the optimal level of investment These effects are particularly amplified in countries with strong financial integration.

The findings of our study have important managerial, economic, and practical implications. To address these challenges, managers should actively assess and manage climate-related risks, integrate climate considerations into decision-making processes, and develop adaptive strategies. Policymakers should also enhance regulatory frameworks and provide incentives to support climate-resilient investments. By taking these actions, firms can improve their investment activity and contribute to sustainable economic growth. Lastly, our research findings hold relevance for the general public, as they shed light on the financial implications of climate risk. Increased awareness of the potential impacts of climate change on businesses can empower individuals to make more informed choices as consumers, employees, and citizens. It also emphasizes the need for collective action to address climate change and promote sustainable development.

Overall, our research will help investors, regulators, managers, police makers and general public to formulate their opinions about the relationship between financial integration, firm level climate risk exposure, corporate new investment, and investment efficiency.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

Konstantina K. Agoraki is at the Department of Tourism Studies, University of Piraeus, Greece kagoraki@unipi.gr, Maria Giaka is at the Department of Biomedical Sciences, University of West Attica, Greece mgiaka@uniwa.gr and Dimitrios Konstantios* (corresponding author) is at the ALBA Graduate Business School, The American College of Greece dkonstantios@alba.acg.edu, Ioannis Negkakis is at Plymouth Business School, University of Plymouth, UK ioannis.negkakis@plymouth.ac.uk. We would like to express our appreciation to the co-editor, Mark Spiegel, the discussant, and the two anonymous referees for their constructive comments and suggestions that have improved the paper irrevocably . We are grateful to conference participants at the 27th International Conference on Macroeconomic Analysis and International Financ e, Department of Economics, University of Crete, Rethymno, Greece, 25 – 27 May 2023, for helpful comments and discussions. We are also grateful for the insightful feedback received from seminar participants at both the Athens University of Economics and Business and the School of Management, University of Bath. Additionally, we would like to acknowledge the support and resources provided during Dimitrios Konstantios' visit to the University of Bath, which facilitated the progress of this research. Lastly, we would like to note that the usual caveats apply.

Appendix A

(See Tables A1–A4).

Table A1
Variable definitions.

Variable	Definition	Source
Investment new	Total capital expenditures and acquisitions subtracting sale of property, plant and equipment share of total assets.	Authors estimations based on Richardson's (2006) methodology
Overinvestment	Positive residuals of the estimated regression capture the "unexpected investments" (misinvestment).	Authors estimations based on Richardson's (2006) methodology
Underinvestment	Negative residuals of the estimated regression capture the "unexpected investments" (misinvestment).	Authors estimations based on Richardson's (2006) methodology
Inefficiency	Firm's investment efficiency is a dummy variable that takes the value of one is a firm invests inefficient, otherwise 0.	Constructed by the authors following the methodology of Demerjian et al. (2012) and using Compustat data.
Climate Risk	A company's current level of climate risk exposure to regulatory, physical, and opportunity climate change shocks. Higher value of this index indicates more climate risk exposure.	(*Climate risk*) constructed and provided using bigram analysis on quarterly earnings conference calls by Sautner et al. (2022) https://osf.io/fd6jq/files/osfstorage?view_only=
Climate change opportunity exposure	A company's current level of climate risk exposure to opportunity climate change shocks. Higher value of this index indicates more climate risk exposure.	(*Climate risk*) constructed and provided using bigram analysis on quarterly earnings conference calls by Sautner et al. (2022) https://osf.io/fd6jq/files/osfstorage?view_only=
Climate change regulation exposure	A company's current level of climate risk exposure to regulatory climate change shocks. Higher value of this index indicates more climate risk exposure.	(*Climate risk*) constructed and provided using bigram analysis on quarterly earnings conference calls by Sautner et al. (2022) https://osf.io/fd6jq/files/osfstorage?view_only=
Climate change physical exposure	A company's current level of climate risk exposure to physical climate change shocks. Higher value of this index indicates more climate risk exposure.	(*Climate risk*) constructed and provided using bigram analysis on quarterly earnings conference calls by Sautner et al. (2022)
TobinsQ	Market-to-book ratio, calculated as the market value of assets((PRCC_F*CSHO) + AT – CEQ)) divided by the book value of assets (AT)	Compustat
ROA	Return on assets defined as operating income before depreciation divided by book value of total assets	Compustat
Leverage	Total debt scaled by the book value of total assets	Compustat
Firms Age	Number of years elapsing from a firm's foundation day.	Orbis database, J.R. Ritter (https://site.warrington.ufl.edu/ritter/ipo-data/)
Size	The natural logarithm of firm's total assets	Compustat
HHI	Herfindahl-Hirschman index of industry concentration calculated using 3-digit SIC codes	Compustat
Political Orientation	Political party ideology (Left- Right)	The World Bank: Database of Political Institution
Religion Strength	The strength of religion based on expert surveys and a similarly broad in-house coded variable from CLD	World Data Bank
Industry Share	We calculate the industry share by dividing the number of firms belonging to each of the Fama French 48 industries	Authors calculations; Compustat

(*continued on next page*)

Table A1 (*continued*)

Variable	Definition	Source
	by the total number of firms in the sample. This allows us to determine the proportion of firms accounted for by each industry in the dataset.	
GDP Growth	GDP growth (annual %)	World Data Bank
Inflation	Inflation, consumer prices (annual %)	World Data Bank
Business Freedom Index	Business Freedom Index, as a measure of regulatory quality, from the heritage foundation	https://www.heritage.org/index/explore?view = by-region-country-year&countryids=&regionids=&yearids=
LMF	The natural logarithm of Lane and Milesi-Ferretti's de facto financial openness index	https://graebnerc.github.io/OpennessDataR/data.html
KAOPEN	Indicator of financial openness at the national level.	AREAR database of the IMF, (Chinn and Ito, 2006)
PopulationDensity	Population density is calculated by dividing the midyear population of an area by its land area measured in square kilometers. The population measure is based on the de facto definition, which includes all residents irrespective of their legal status or citizenship. The only exception is made for refugees who have not yet permanently settled in their country of asylum, as they are typically considered part of the population of their country of origin.	World Bank

Table A2

Entropy Matching Weighting, This table documents the entropy balancing method. Panel A present the mean, variance, and skewness between the treated and control groups before and after weighting. Panel B reports the entropy balancing regression estimates. Variable definitions are reported in appendix. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Panel A: Entropy Balancing Weighting						
Before: Without weighting	Treat			Control		
	mean	variance	skewness	mean	variance	skewness
Tobin'sQ	0.803	0.615	2.226	1.575	0.971	0.629
Cash	0.142	0.031	2.212	0.159	0.030	1.951
Leverage	0.020	0.018	8.129	0.002	0.001	31.930
HHI	0.175	0.037	2.081	0.146	0.032	2.803
Size	6.875	11.840	0.073	7.129	5.785	0.559
Firm Age	2.225	0.608	−0.789	2.642	0.369	−0.712
GDP Growth	3.126	10.380	−0.262	1.968	5.146	−0.838
Inflation	2.602	7.005	1.913	2.146	2.254	1.677
After: Weighting variables	Treat			Control		
	mean	variance	skewness	mean	variance	skewness
Tobin'sQ	0.803	0.615	2.226	0.803	0.363	2.046
Cash	0.142	0.031	2.212	0.142	0.027	2.190
Leverage	0.020	0.018	8.129	0.020	0.022	7.702
HHI	0.175	0.037	2.081	0.175	0.043	2.285
Size	6.875	11.840	0.073	6.875	6.269	0.270
Firm Age	2.225	0.608	−0.789	2.225	0.485	−0.676
GDP Growth	3.126	10.380	−0.262	3.126	5.813	0.442
Inflation	2.602	7.005	1.913	2.602	4.126	2.2

Table A3

Pairwise correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) *Tobin'sQ*	1.000							
(2) Cash	0.117***	1.000						
(3) *Leverage*	0.372***	0.078***	1.000					
(4) *HHI*	0.021***	−0.046***	0.014***	1.000				
(5) Size	−0.311***	−0.215***	−0.316***	−0.061***	1.000			
(6 *Firm Age*	−0.001	−0.048***	−0.055***	−0.083***	0.224***	1.000		
(7) *GDP Growth*	−0.076***	−0.073***	−0.037***	0.014***	0.018***	−0.109***	1.000	
(8) *Inflation*	−0.039***	−0.155***	−0.023***	0.012***	0.006***	−0.113***	0.300***	1.000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A4
List of Countries including in the study.

Country code	Country name	Country code	Country name
ARG	Argentina	MEX	Mexico
ATG	Antigua and Barbuda	MHL	Marshall Islands
AUS	Australia	MLT	Malta
AUT	Austria	MUS	Mauritius
BEL	Belgium	MYS	Malaysia
BHR	Bahrain	JPN	Japan
BHS	Bahamas	KAZ	Kazakhstan
BRA	Brazil	KEN	Kenya
CAN	Canada	KOR	South Korea
CHE	Switzerland	KWT	Kuwait
CHL	Chile	LBR	Liberia
CHN	China	NLD	Netherlands
COL	Colombia	NOR	Norway
CYP	Cyprus	NZL	New Zealand
CZE	Czech Republic	OMN	Oman
DEU	Germany	PAK	Pakistan
DNK	Denmark	PAN	Panama
EGY	Egypt	PER	Peru
ESP	Spain	PHL	Philippines
FIN	Finland	PNG	Papua New Guinea
FRA	France	POL	Poland
GBR	United Kingdom	PRT	Portugal
GRC	Greece	QAT	Qatar
HKG	Hong Kong	ROU	Romania
HUN	Hungary	RUS	Russia
IDN	Indonesia	SAU	Saudi Arabia
IND	India	SGP	Singapore
IRL	Ireland	SWE	Sweden
ISL	Iceland	THA	Thailand
ISR	Israel	TUR	Turkey
ITA	Italy	USA	United States of America
LUX	Luxembourg	VEN	Venezuela
MAR	Morocco	ZAF	South Africa
NGA	Nigeria		

References

Acemoglu, D., & Akcigit, U. (2015). Climate change, irreversible investments, and stranded assets. NBER Working Paper No. 21747.
Addoum, J.M., Ng, D.T., Ortiz-Bobea, A., 2020. Temperature shocks and establishment sales. Rev. Financ. Stud. 33 (3), 1331–1366.
Agoraki, M.-E.-K., Giaka, M., Konstantios, D., Patsika, V., 2023. Firms' sustainability, financial performance, and regulatory dynamics: Evidence from European firms. J. Int. Money Financ. 131, 102785.
Aldy, J.E., Pizer, W.A., Tavoni, M., 2017. Economic tools to promote transparency and comparability in the Paris Agreement. Nat. Clim. Chang. 7 (12), 895–898.
Alfaro, L., Hammel, E., 2007. Capital flows and capital goods. J. Int. Econ. 72, 128–150.
Alfaro, L., Kalemli-Ozcan, S., Sayek, S., 2009. FDI, productivity and financial development. World Econ. 32 (1), 111–135.
Angelidis, J., Ibrahim, N., 2004. An exploratory study of the impact of degree of religiousness upon an individual's corporate social responsiveness orientation. J. Bus. Ethics 51 (2), 119–128.
Arcand, J.L., Berkes, E., & Panizza, U., (2012). Too much finance? IMF Working Paper WP/12/161. *International Monetary Fund*, Washington, D.C.
Arteta, C., Eichengreen, B., & Wyplosz, C. (2003) *When does capital account liberalization help more than it hurts?* In: Helpman E, Sadka E (eds) *Economic policy in the international economy: essays* in honor of Assaf Razin. Cambridge University Press, Cambridge.
Backé, P., Égert, B., & Walko, Z., (2007). Credit growth in Central and Eastern Europe. Policy Research Working Paper Series 4638, The World Bank.
Baltabaev, B., 2014. FDI and total factor productivity growth: new macro evidence. World Econ. 37 (2), 311–334.
Bansal, R., Kiku, D., & Marcelo, O. (2017), Price of long-run temperature shifts in capital markets, Working Paper, Duke University.
Bechlioulis, A., Economidou, C., Karamanis, D., Konstantios, D., 2023. How important are capital controls in shaping innovation activity? J. Int. Money Financ. 131, 102768.
Bekaert, G., Harvey, C.R., Lundblad, C., 2005. Does financial liberalization spur growth? J. Financ. Econ. 77 (1), 3–55.
Ben-Amar, W., Gomes, M., Khursheed, H., Marsat, S., 2022. Climate change exposure and internal carbon pricing adoption. Bus. Strateg. Environ. 31 (7), 2854–2870.
Benbouzid, N., Mallick, S., Sousa, R., 2017a. Do country-level financial structures explain bank-level CDS spreads? J. Int. Financ. Mark., *Inst. Money* 48, 135–145.
Benbouzid, N., Mallick, S., Sousa, R., 2017b. An international forensic perspective of the determinants of bank CDS spreads. J. Financ. Stab. 33, 60–70.
Blouin, J.L., Raedy, J.S., Shackelford, D.A., 2011. Dividends, share repurchases, and tax clienteles: Evidence from the 2003 reductions in shareholder taxes. Account. Rev. 86 (3), 887–914.
Bolton, P., Kacperczyk, M., 2021. Do investors care about carbon risk? J. Financ. Econ. 142, 517–549.
Bonin, J., Wachtel, P., 2003. Financial sector development in transition economies: lessons from the first decade. Financ. Mark. Inst. Instrum. 12 (1), 1–66.
Bonin, J., Hasan, I., Wachtel, P., 2005. Privatisation matters: bank performance in transition countries. J. Bank. Financ. 29, 2153–2178.
Borensztein, E., De Gregorio, J., Lee, J., 1998. How does foreign direct investment affect growth? J. Int. Econ. 45 (1), 115–135.
Brealey, R.A., Myers, S.C., Allen, F., Mohanty, P., 2017. Principles of corporate finance. McGraw-Hill Education.
Busch, T., Bauer, R., Orlitzky, M., 2016. Sustainable development and financial markets: Old paths and new avenues. Bus. Soc. 55 (3), 303–329.
Caballero, R.J., Farhi, E., & Gourinchas, P.O. (2006). An Equilibrium Model of Global Imbalances and Low Interest Rates. NBER Work-ing Paper No. 11996, February 2006.
Campello, M., Graham, J.R., Campbell, R.H., 2010. The real effects of financial constraints: evidence from a financial crisis. J. Financ. Econ. 97 (3), 470–487.
Chasiotis, I., Gounopoulos, D., Konstantios, D., Patsika, V., 2023. ESG reputational risk, corporate payouts and firm value. Br. J. Manag.
Chava, S., 2014. Environmental externalities and cost of capital. Manag. Sci. 60, 2223–2247.

Chinn, M.D., Ito, H., 2006. What matters for financial development? Capital controls, institutions, and interactions. J. Dev. Econ. 81 (1), 163–192.
Chortareas, G., Girardone, C., Ventouric, A., 2013. Financial freedom and bank efficiency: Evidence from the European Union. J. Bank. Financ. 37 (4), 1223–1231.
Cook, D.O., Luo, S., 2021. Does perception of social issues affect portfolio choices? Evidence from the MeToo Movement. *Financ. Manage.* 51, 613–634.
Damodaran, A., 1994. Estimating the cost of capital: A survey. J. Appl. Corp. Financ. 6 (4), 60–73.
de Haas, R.T.A., (2001). Financial development and economic growth in transition economies. A Survey of the Theoretical and Empirical Literature. Research Series Supervision 35, Netherlands Central Bank.
Delis, M.D., de Greiff, K., & Ongena, S. (2020). Being stranded with fossil fuel reserves? Climate policy risk and the pricing of bank loans, EBRD Working Paper 231.
Deng, X., Kang, J.K., Sin Low, B., 2013. Corporate social responsibility and stakeholder value maximization: Evidence from mergers. J. Financ. Econ. 110 (1), 87–109.
Denis, D., Osobov, I., 2008. Why do firms pay dividends? International evidence on the determinants of dividend policy. J. Financ. Econ. 89 (1), 62–82.
Dessaint, O., Matray, A., 2017. Do managers overreact to salient risks? Evidence from hurricane strikes. J. Financ. Econ. 126, 97–121.
Dietz, S., Bowen, A., Dixon, C., 2020. Climate value at risk of global financial assets. Nat. Clim. Chang. 10 (7), 637–643.
Drempetic, S., Klein, C., Zwergel, B., 2020. The influence of firm size on the ESG score: Corporate sustainability ratings under review. J. Bus. Ethics 167, 333–360.
Drobetz, W., Gounopoulos, D., Merikas, A.G., Schröder, H., 2013. Capital structure decisions of globally listed shipping companies. Transport. Res. Part E: Log. Transport. Rev. 52, 49–76.
Durham, J.B., 2004. Absorptive capacity and the effects of foreign direct investment and equity foreign portfolio investment on economic growth. Eur. Econ. Rev. 48 (2), 285–306.
Dutordoir, M., Strong, N.C., Sun, P., 2018. Corporate social responsibility and seasoned equity offering. Finance 50 (C), 158–179.
Economidou, C., Gounopoulos, D., Konstantios, D., Tsiritakis, E., 2022. Is sustainability rating material to the market? Financ. Manag. 00, 1–53.
Edwards S, Levine R, Ricci L, & Torsten, S. (2001) Capital mobility and economic performance: are emerging economies different? NBER Working Paper No. 8076. National Bureau of Economic Research, Cambridge, Massachusetts.
Égert, B., Backé, P., Zumer, T., 2007. Private-sector credit in Central and Eastern Europe: new (over) shooting stars? Comp. Econ. Stud. 49 (2), 201–231.
El Ghoul, S., Guedhami, O., Kim, H., Park, K., 2018. Corporate environmental responsibility and the cost of capital: International evidence. J. Bus. Ethics 149, 335–361.
Elsas, R., Florysiak, D., 2015. Dynamic capital structure adjustment and the impact of fractional dependent variables. J. Financ. Quant. Anal. 50 (5), 1105–1133.
Engle, R.F., Giglio, S., Kelly, B., Lee, H., Stroebel, J., 2020. Hedging climate change news. Rev. Financ. Stud. 33, 1184–1216.
Fafaliou, I., Giaka, M., Konstantios, D., Polemis, M., 2022. Firms' ESG reputational risk and market longevity: A firm-level analysis for the United States. J. Bus. Res. 149, 161–177.
Fama, E.F., French, K.R., 1999. The corporate cost of capital and the return on corporate investment. J. Financ. 54 (6), 1939–1967.
Fazzari, S., Hubbard, R., Petersen, B., Blinder, A., Poterba, J., 1988. Financing constraints and corporate investment. Brook. Pap. Econ. Act. 1, 141–206.
Fink, G., Haiss, P., Vuksic, G., 2009. Contribution of financial market segments at different stages of develop- ment:transition, cohesion and mature economies compared. J. Financ. Stab. 5 (4), 431–455.
Fu, F., 2010. Overinvestment and operating performance of SEO firms. Financ. Manag. 39 (1), 249–272.
Giese, G., Lee, L.E., Melas, D., Nagy, Z., Nishikawa, L., 2019. Foundations of ESG investing: How ESG affects equity valuation, risk, and performance. J. Portfolio Manage. 45 (5), 69–83.
Goldsmith, R.W., 1969. Financial structure and development. Yale University Press, New Haven.
Grullon, G., Larkin, Y., Michael, R., 2019. Are US industries becoming more concentrated? Eur. Finan. Rev. 23 (4), 697–743.
Hail, L., Leuz, C., 2006. International differences in the cost of equity capital: Do legal institutions and securities regulation matter? J. Account. Res. 44 (3), 485–531.
Hainmueller, J., 2012. Entropy balancing for causal effects: A multivariate reweighting method to produce balanced samples in observational studies. Polit. Anal. 20 (1), 25–46.
Hassan, T.A., Hollander, S., Van Lent, L., Tahoun, A., 2019. Firm-level political risk: measurement and effects. Q. J. Econ. 134, 2135–2202.
Heath, R., Mace, B., 2020. The impact of climate change on corporate investment decisions: A systematic review. Bus. Strateg. Environ. 29 (7), 2734–2750.
Heckman, J., 1979. Sample selection bias as a specification error. Econometrica 47 (1), 153–161.
Heinkel, R., Kraus, A., Zechner, J., 2001. The effect of green investment on corporate behavior. J. Financ. Quant. Anal. 36, 431–449.
Henry, P.B., 2000. Do stock market liberalizations cause investment booms? J. Financ. Econ. 58 (1), 301–334.
Hermes, N., Lensink, R., 2000. Financial system development in transition economies. J. Bank. Financ. 24 (4), 507–524.
Hoberg, G., Philips, G., & Prabhala, N. (2014). Product market threats, payouts and financial flexibility. *Journal of Finance,* 69, 293-324.
Hoepner, A., Oikonomou, I., Sautner, Z., Starks, L., & Zhou, X. (2022). ESG shareholder engagement and downside risk. Working Paper, University College Dublin.
Hoi, C.H., Qiang, W., Hao, Z., 2013. Is Corporate Social Responsibility (CSR) associated with tax avoidance? Evidence from irresponsible CSR activities. Account. Rev. 88.
Hong, H., Li, F., Xu, J., 2019. Climate risks and market efficiency. J. Econ. 208, 265–281.
Hossain, A.T., Masum, A.A., 2022. Does corporate social responsibility help mitigate firm-level climate change risk? Financ. Res. Lett. 47, 102791.
Huang, H.H., Kerstein, J., Wang, C., 2018. The impact of climate risk on firm performance and financing choices: An international comparison. J. Int. Bus. Stud. 49, 633–656.
Huang, H.H., Kerstein, J., Wang, C., Wu, F., 2022. Firm climate risk, risk management, and bank loan financing. Strateg. Manag. J. 43 (13), 2849–2880.
Huang, H.C., Lin, S.C., 2009. Non-linear finance–growth nexus: a threshold with instrumental variable approach. Econ. Transit. 17 (3), 439–466.
Huynh, T.D., Xia, Y., 2021. Climate change news risk and corporate bond returns. J. Financ. Quant. Anal. 56, 1985–2009.
Huynh, T.D., Nguyen, T.H., Truong, C., 2020. Climate risk: The price of drought. Finance 65, 101750.
Javadi, S., Masum, A.A., 2021. The impact of climate change on the cost of bank loans. Finance 69, 102019.
Johnston, R., Blakemore, R., & Bell, R. (2020). The Role of Oil and Gas Companies in the Energy Transition. Atlantic Council, Report.
Kenourgios, D., Samitas, A., 2007. Financial development and economic growth in a transition economy: evidence for Poland. J. Financ. Decis. Making 3 (1), 35–48.
Keohane, N.O., Revesz, R.L., Stavins, R.N., 2017. The choice of regulatory instruments in environmental policy. Harvard Environ. Law Rev. 41 (2), 23–55.
King, R.G., Levine, R., 1993. Finance and growth: Schumpeter might be right. Q. J. Econ. 108 (3), 717–737.
Kling, G., Volz, U., Murinde, V., Sibel, A., 2021. The impact of climate vulnerability on firms' cost of capital and access to finance. World Dev. 137, 105131.
Kose, M. A., Prasad, E., Rogoff, S. K., & Wei, S.-J. (2006). *Financial globalization: A reappraisal* (IMF Working Paper No. 06/189). Washington, DC: International Monetary Fund.
Krueger, P., Sautner, Z., Starks, L.T., 2020. The importance of climate risks for institutional investors. Rev. Financ. Stud. 33 (3), 1067–1111.
La Porta, R., Lopez-de-Silanes, F., Shleifer, A., 2008. The economic consequences of legal origins. J. Econ. Lit. 46 (2), 285–332.
Lambrecht, B., Myers, S., 2012. A Lintner model of dividends and managerial rents. J. Financ. 67, 1761–1810.
Lane, P.R., Milesi-Ferretti, G.M., 2007. The external wealth of nations mark II: Revised and extended estimates of foreign assets and liabilities, 1970–2004. J. Int. Econ. 73 (2), 223–250.
Lee, T., Markowitz, E., Howe, P., et al., 2015. Predictors of public climate change awareness and risk perception around the world. Nat. Clim. Chang. 5, 1014–1020.
Levine, R., 1997. Financial development and economic growth: views and agenda. J. Econ. Lit. 35 (2), 688–726.
Levine, R., Zervos, S., 1996. Stock market development and long-run growth. World Bank Econ. Rev. 10 (2), 323–339.
Levine, R., Loayza, N., Beck, T., 2000. Financial intermediation and growth: causality and causes. J. Monet. Econ. 46 (1), 31–77.
Levine, R., (2005). Finance and growth: theory and evidence. In: Aghion, P., Durlauf, S. (Eds.). Handbook of Economic Growth, 1, 865–934.
Lewbel, A., 2012. Using heteroscedasticity to identify and estimate mismeasured and endogenous regressor models. J. Bus. Econ. Stat. 30 (1), 67–80.
Lombardo, D., Pagano, M., 2002. Law and equity markets: A simple model. In: McCahery, J.A., Moerland, P., Raaijmakers, T., Renneboog, L. (Eds.), Corporate Governance Regimes: Convergence and Diversity. Oxford University Press, Oxford, UK, pp. 343–362.
Matsumura, E.M., Prakash, R., Vera-Munoz, S.C., 2014. Firm-value effects of carbon emissions and carbon disclosures. Account. Rev. 89, 695–724.

Murfin, J., Spiegel, M., 2020. Is the risk of sea level rise capitalized in residential real estate? Rev. Financ. Stud. 33, 1217–1255.
Painter, M., 2020. An inconvenient cost: the effects of climate change on municipal bonds. J. Financ. Econ. 135, 468–482.
Pankratz, N., Bauer, R., & Derwall, J. (2023). Climate change, firm performance, and investor surprises. *Management Science*. Forthcoming.
Richardson, S., 2006. Over-investment of free cash flow. Rev. Acc. Stud. 11 (2), 159–189.
Ridley, K. (2023) Institutional investors back Shell board lawsuit over climate risk. Available at: https://www.reuters.com/business/sustainable-business/institutional-investors-back-shell-board-lawsuit-over-climate-risk-2023-02-09/ Accessed: February 10, 2023.
Ross, S.A., Westerfield, R.W., Jordan, B.D., Roberts, G.S., 2016. Fundamentals of corporate finance. McGraw-Hill Education.
Sautner, Z., van Lent, L., Vilkov, G., Zhang, R., 2022. Firm- level climate change exposure. J. Financ. 78 (3), 1449–1498.
Wachtel, P., 2001. Growth and finance: what do we know and how do we know it? Int. Financ. 4 (3), 335–362.
Woo, J., 2009. Productivity growth and technological diffusion through foreign direct investment. Econ. Inq. 47 (2), 226–248.
Wu, N., Xiao, W., Liu, W., Zhang, Z., 2022. Corporate climate risk and stock market reaction to performance briefings in China. Environ. Sci. Pollut. Res. 29, 53801–53820.
Younas, J., 2009. Does institutional quality affect capital mobility? Evidence from developing countries. J. Inst. Econ. 5 (2), 207–223.
Zagorchev, A., Vasconcellos, G., Bae, Y., 2011. Financial development, technology, growth and performance: evidence from the accession to the EU. J. Int. Finan. Markets. Inst. Money 21 (5), 743–759.

Annex 561

“Members”, *The Vulnerable Twenty*

MEMBERS

Home » Members

Number of nations

68 Nations

Total of Population

1.7 Billion

Share of Global Emissions

5%

GDP Value

USD 3.8 Trillion

Membership Year

- 2009
- 2011
- 2015
- 2016
- 2021
- 2022
- Incoming member

Africa and the Middle East - 32

Burkina Faso

Benin

Chad

Comoros

Côte d'Ivoire

Democratic Republic of Congo

Ethiopia

eSwatini

The Gambia

Ghana

Kenya

Lebanon

Liberia

Madagascar

Malawi

Morocco

Niger

Palestine

Rwanda

Senegal

South Sudan

Sudan

Tanzania

Tunisia

Yemen

Uganda

Guinea

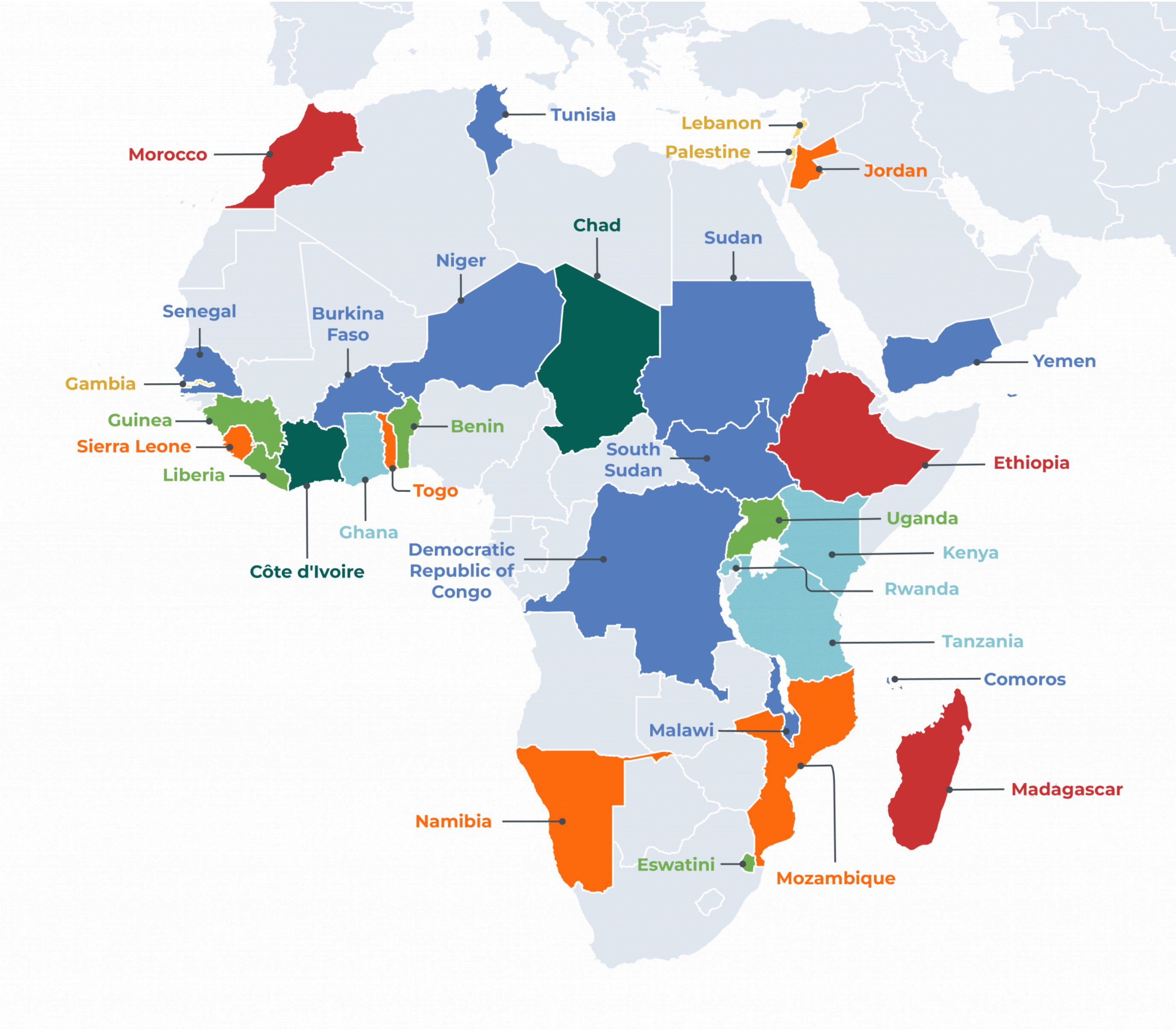
Jordan

Sierra Leone

Togo

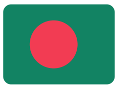
 **Namibia**

 **Mozambique**



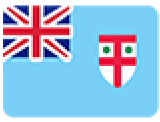
Asia - Pacific - 22

 Afghanistan

 Bangladesh

 Bhutan

 Cambodia

 Fiji

 Kiribati

Kyrgyzstan

Maldives

Marshall Islands

Mongolia

Nepal

Palau

Papua New Guinea

Philippines

Samoa

Sri Lanka

Timor-Leste

Tuvalu

Vanuatu

Vietnam

Pakistan

Tonga

Latin America and the Caribbean - 14

Barbados

Colombia

Costa Rica

Dominican Republic

Grenada

Guyana

Guatemala

Haiti

Honduras

Nicaragua

Saint Lucia

Dominica

Trinidad & Tobago

Paraguay


Haiti
Dominican Republic
Honduras
Guatemala
Dominica
Saint Lucia
Barbados
Nicaragua
Trinidad & Tobago
Costa Rica
Guyana
Colombia
Paraguay

Annex 562

"Barbados launches 'emergency plan' to tackle massive debt", *Financial Times*, 1 June 2018 fastFT Global Economy

Barbados launches ‘emergency plan’ to tackle massive debt

Robin Wigglesworth JUNE 1 2018

Barbados has announced an “emergency plan” to tackle its mounting economic crisis, including restructuring its public debt, after the Caribbean country’s new government discovered that its liabilities were much worse than thought, reaching 175 per cent of gross domestic product.

The Barbados Labour Party, led by Mia Mottley, came to power in an election in late May, propelled by the failure of a tough austerity programme implemented by her predecessor to turnround the island’s economic and fiscal crisis.

In a statement released on Friday, the country’s finance ministry said that after a review of the government’s finances it had discovered “substantial arrears that were not previously included in headline public debt figures”, which lifted Barbados’ debt-to-GDP ratio to over 175 per cent.

The International Monetary Fund estimated that the ratio was 137 per cent at the end of 2017, or 101 per cent excluding securities held by the National Insurance Scheme — already an exceptionally high debt burden for a small island country.

The finance ministry also said that conversations with the Central Bank of Barbados revealed that international reserves had shrunk to just $220m at the end of May, equivalent to seven weeks of imports. The IMF last put the reserves at about $275m at the end of September.

The government announced that “in light of what it has found” it would be seeking to restructure its domestic and external public debt.

“This exercise will address the severe challenges presented by current debt service commitments and, in conjunction with corrective economic and fiscal measures to be shortly introduced by the Government, will place the public debt on a sustainable footing,” the finance ministry said in a statement.

The government announced that in addition to a “comprehensive economic reform programme . . . to stabilise the public finances after years of mismanagement” it would also seek help from the IMF.

In a statement, Christine Lagarde, the IMF managing director, said that it was sending a delegation to the capital, Bridgetown, to help the government formulate the programme.

“The Barbados economy has been going through significant challenges for some years,” Ms Lagarde said. “The authorities are developing an economic reform plan designed to address these challenges, and they have asked the international community and the International Monetary Fund to assist them as they put the economy back on a path to recovery.”

Annex 563

“PG & E Is Just The First of Many Climate Change Bankruptcies”, *Forbes*, 24 January 2019

EDITORS' PICK

PG&E Is Just The First Of Many Climate Change Bankruptcies

Chunka Mui Former Contributor

I focus on innovations aimed at making the world a much better place.

Jan 24, 2019, 10:14am EST

Updated Jan 24, 2019, 11:37am EST

This article is more than 5 years old.

Flames burn near power lines in Sycamore Canyon near West Mountain Drive in Montecito, Calif. (Mike... [+]

Some argue that it is too expensive to do anything about the long-term effects of climate change—even if climate change is real. In a smart post at his Insurance Thought Leadership blog, Paul Carroll offers a stark reminder that there are significant short-term costs as well. And, those short-term costs will mount.

PG&E is preparing to file for bankruptcy. MUI

The post points out that the bankruptcy of PG&E will be, in fact, the first "climate change bankruptcy." PG&E is preparing to file for bankruptcy in the face potential liabilities of $30 billion or more resulting from wildfires that swept its service area in 2017 and 2018. The extensive damage was due in large part to extremely hot, dry conditions that spawned more frequent and intense fires. Those conditions, PG&E's (recently departed)

CEO argued, were the result of global warming and climate change. Many experts agree.

Rather than a hypothetical scenario or debatable model of long term effects, PG&E's imminent bankruptcy shows how climate change inflicts very specific, near-term pain:

1. Shareholders lost more than $20 billion as PG&E's stock plunge 85%.

2. Insurers will sustain huge costs due to losses triggered in life, health, property, disability and every other possible form of insurance.

3. Customers, who already pay the second-highest rates in the country, are facing annual increases of 12 – 24% over the next three years. The rate increases will likely go on for decades.

4. Creditors will suffer since PG&E will not be able to make good on many of its obligations.

5. Taxpayers nationally will pay, due to FEMA and other federal agencies' disaster relief costs.

Carroll argues that PG&E was in an especially poor position to deal with the wildfires because it did not take advantage of technology that could have sensed problems in its power grid. He calls for a greater focus on innovation. On that, he makes a solid point.

He risks, however, placing too much confidence on prevention and too much blame on PG&E. I understand the desire to hold the massive and once-mighty PG&E accountable. But, that assumes it could have avoided this disaster.

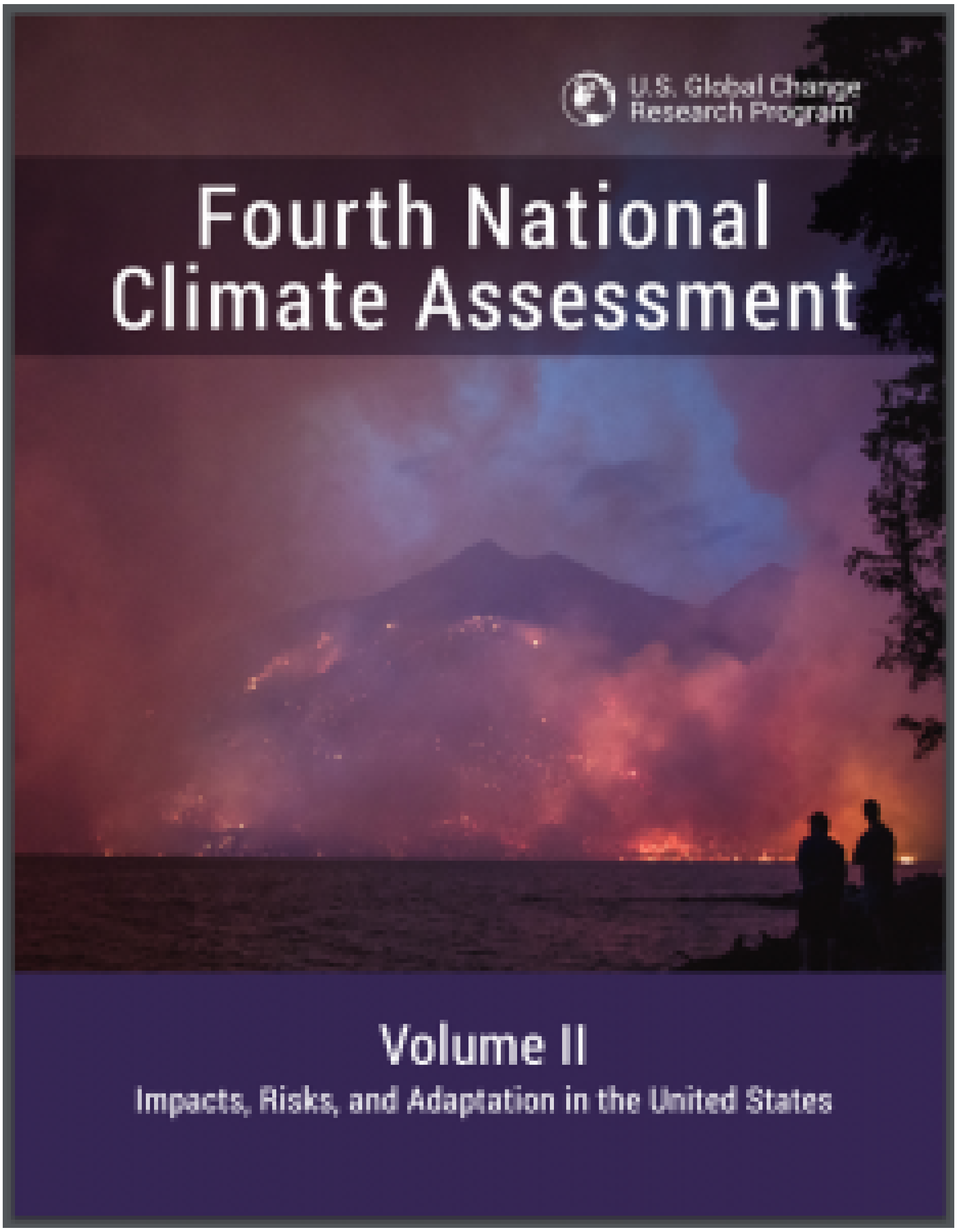
While PG&E could clearly have done better, as a class-action lawsuit and many reports have noted, the utility was dealt a very poor hand from a climate change standpoint.

Consider the trees, for example. Falling trees can topple power lines and start fires. Record droughts and a bark beetle infestation have killed tens of millions of trees, according to the California State Association of Counties. Some large number of these trees were, no doubt, among the 120 million trees that PG&E estimated could come in contact with its 125,000 miles of power lines. In 2016, in response to an emergency declared by California's governor, PG&E spent $435 million to clear dead and dying trees. Between 2015 and 2017, it removed about 400,000 such trees--in addition to a routine maintenance program that removes or prunes 1.4 million trees annually. That's a lot of trees, but nowhere near the 120 million total number. Is there any way that PG&E could dealt with 120 million trees?

PG&E could have done better on other measures as well, such as burying lines underground, replacing wooden poles with taller, metal ones, insulating wires, installing networks of sensors and cameras and being more aggressive in shutting off power to at-risk areas. But, it would have been economically impossible for any utility to have hardened its entire grid in such a narrow timeframe and, as you'd suspect, customers don't like getting their electricity cut off merely as a preventative measure.

To my mind, PG&E was a victim—actually it was a repeated victim of random acts of climate violence. If we hold companies liable in this way, expect other giants to fall, too.

Yes, every company needs to prepare for environmental changes and, as in the case of PG&E, labor to manage the increased risk due to the escalating number and magnitude acute climate events.



National Climate Assessment US FEDERAL GOVT

This doesn't just apply to the energy industry—many industries need to face up to the risks. Consider, for example, the U.S. federal government's gloomy National Climate Assessment outlining "growing challenges to human health and safety, quality of life and the rate of economic growth." (Spoiler Alert: President Donald Trump does not believe this report.) There's also the US Department of Defense's report on the national security Implications of climate-related risks and a changing climate. The New England Journal of Medicine recently argued that climate change is a health emergency. The International Association of

Insurance Supervisors offered a sobering analysis of the climate change risks to the insurance sector.

Pushing for prevention and mitigation where possible makes eminent sense. But, leaving it up to individual companies to defend us against random, acute climate events and other consequences of climate change will only lead to disappointment —and many more climate change bankruptcies.

Follow me on Twitter or LinkedIn. Check out my website or some of my other work here.

Chunka Mui

I'm a futurist and advisor on strategy and... **Read More**

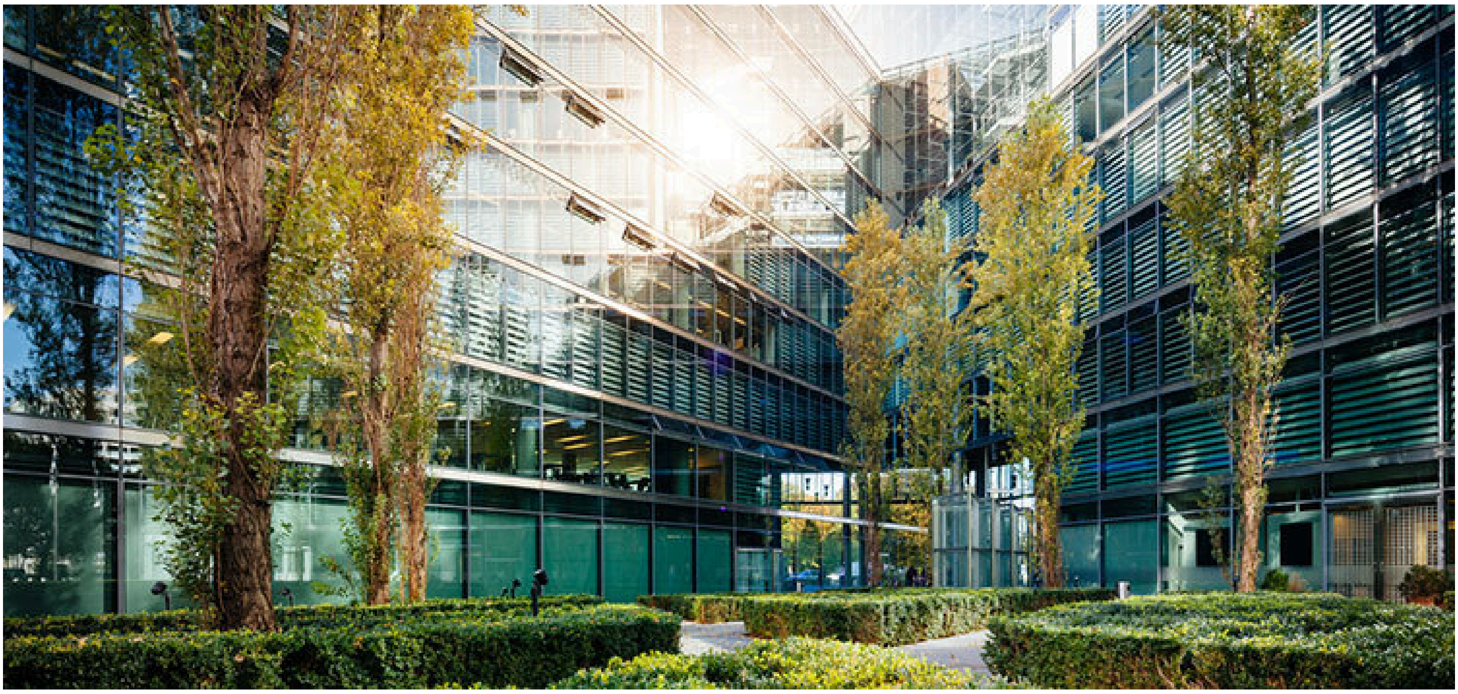
Annex 564

"World's first dedicated climate resilience bond, for US$ 700m, is issued by EBRD", *European Bank for Reconstruction and Development*, 20 September 2019

World's first dedicated climate resilience bond, for US$ 700m, is issued by EBRD

By Vanora Bennett (mailto:bennettv@ebrd.com)

20 Sep 2019



- **EBRD launches first ever dedicated climate resilience bond, raising US$ 700 million**
- **Proceeds to finance investments in climate resilience projects**
- **Launch follows adoption of Climate Resilience Principles by the Climate Bonds Initiative (CBI)**

The EBRD has successfully launched the first ever dedicated climate resilience bond, raising US$ 700 million with the issuance.

BNP Paribas, Goldman Sachs, and Skandinaviska Enskilda Banken AB acted as joint bookrunners, which saw demand from approximately 40 investors in 15 countries.

The proceeds from the five-year bond will be used to finance the Bank's existing and new climate resilience projects. These will typically fall under one of three categories:

- Climate resilient infrastructure (e.g. water, energy, transport, communications and urban infrastructure)
- Climate-resilient business and commercial operations; or
- Climate-resilient agriculture and ecological systems.

Currently, the EBRD has a portfolio of some €7 billion in climate resilient projects. Examples include the Qairokkum hydropower upgrade (https://www.ebrd.com/news/2019/ceremony-marks-start-of-work-on-major-climate-adaptation-project-in-tajikistan-.html) in Tajikistan and the Saiss water conservation project (https://www.ebrd.com/news/2017/ebrd-provides-a-120-million-loan-to-the-morocco-sass-water-conservation-project.html) in Morocco.

The EBRD's Climate Resilience Bond will be issued in conformity with the four core principles of the Green Bond Principles, while the projects earmarked for the Use of Proceeds are selected and managed in alignment with the Climate Resilience Principles (https://www.climatebonds.net/adaptation-and-resilience), published on 17 September 2019 by the Climate Bonds Initiative (CBI).

The principles provide clarity on the broad range and scope of potential resilience investments, incorporating climate resilience in the Climate Bonds Standard.

This weekend in New York, the United Nations Climate Action Summit (https://www.un.org/en/climatechange/un-climate-summit-2019.shtml) will see renewed calls for financial innovation to build climate resilience, as recently outlined by the United Nations Environment Programme Finance Initiative and the Global Centre on Adaptation (https://www.unepfi.org/wordpress/wp-content/uploads/2019/07/GCA-Adaptation-Finance.pdf).

"This is a major step forward in the development of capital market instruments that can crowd in private finance at scale for climate resilience," said Craig Davies, Head of Climate Resilience Investments at the EBRD.

Anna Creed, Head of Standards at the Climate Bonds Initiative, added: "We congratulate the EBRD on the launch of their dedicated Climate Resilience Bond and taking the lead in the initial implementation of the Climate Resilience Principles within their green bond programme. The alignment of their Resilience Bond with our newly launched Climate Resilience Principles (CRP) is a powerful example for green bond issuers, investors and the market of the practical application of the CRP. It reflects the increasing importance of directly addressing adaptation and resilience factors in climate finance and investment."

The EBRD is a pioneer in financing projects promoting renewable energy and combatting climate change. Since 2010, the triple-A-rated Bank has issued over €4.5 billion of green bonds denominated in 14 currencies with the proceeds earmarked to support key environmental projects.

(/f61217a453d065015090cd27fd6fb2c2)

Annex 565

“Growing global debt crisis to worsen with interest rate rises”, *Debt Justice*, 23 January 2022

New figures released today by Jubilee Debt Campaign show that developing country debt payments have increased 120% between 2010 and 2021 and are higher than at any point since 2001. Average government external debt payments were 14.3% of government revenue in 2021, up from 6.8% in 2010. Payments shot up in 2020 and have remained high in 2021.

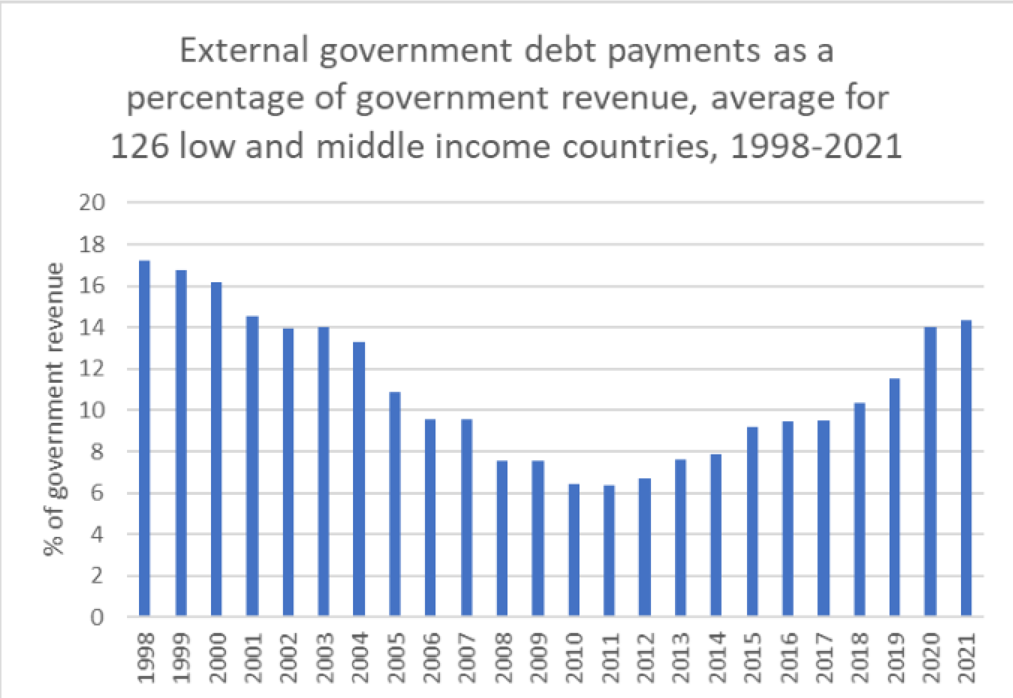
High debt payments are preventing many countries from tackling and recovering from the Covid pandemic. Rising US and global interest rates in 2022 could further intensify the debt crisis many lower income countries are facing. The US Federal Reserve meets on 25-26 January to discuss options for raising interest rates through 2022.

Heidi Chow, Executive Director of Jubilee Debt Campaign, said:

"The debt crisis continues to engulf lower income countries, with no end in sight unless there is urgent action on debt relief. The debt crisis has already stripped countries of the resources needed to tackle the climate emergency and the continued disruption from Covid, while rising interest rates threaten to sink countries in even more debt. G20 leaders cannot keep burying their heads in the sand and wish the debt crisis away. We urgently need a comprehensive debt cancellation scheme which compels private lenders to take part in debt relief."

In 2022, of external debt payments due to be paid by low and lower middle-income governments, 47% are to private lenders, 27% multilateral institutions, 12% China and 14% governments other than China.

The figures are released through Jubilee Debt Campaign's 'Debt Data Portal', which compiles key statistics and analysis on the debts of countries and governments. The latest analysis finds that 54 countries globally are in debt crisis, meaning that debt payments are undermining the ability of governments to protect the basic economic and social rights of their citizens. Kenya and Malawi are among the countries which have entered debt crisis this year. The updated analysis finds a further 14 countries are at risk of both a public and private debt crisis, 22 at risk of solely a private sector debt crisis, and 21 at risk of a public sector debt crisis.



Jason Braganza, Executive Director of the African Forum and Network on Debt and Development (AFRODAD) said:

"Since before the pandemic, AFRODAD had cautioned on the debt precipice facing many African countries. Covid-19 accelerated an already deteriorating situation and will reverse the socio-economic gains of the past decade. We have consistently said the current debt relief measures aren't good enough and have called for a truly inclusive debt relief programme with all creditors; and a comprehensive debt cancellation programme. This is what will save African citizens from difficult times ahead."

Faced with the prospect of an intensifying debt crisis in 2022, the World Bank has called for faster action on debt relief. On 18 January President of the World Bank David Malpass tweeted: *"With too many developing countries facing record levels of external and domestic debt, we cannot afford to wait any longer. The world's poorest urgently need deep debt relief, enhanced debt transparency and a rebalancing of creditor/debtor powers."*

The G20 created a new debt relief scheme at the end of 2020, called the Common Framework, but none of the countries which have applied for it have yet had any debt cancelled.

Notes

Jubilee Debt Campaign calculates the external government debt payments as a proportion of revenue for 126 low- and middle-income countries for which there is data. The data is from IMF Debt Sustainability Analyses, IMF programme documents and the World Bank International Debt Statistics database.

The average is the mean unweighted average for these 126 countries. This therefore shows the pattern across developing countries, rather than being dominated by larger countries, as using aggregate figures would.

The countries in crisis or at risk in each category are below. Methodology, data and sources are at the Debt Data Portal https://data.debtjustice.org.uk/

Countries in debt crisis	At risk of public and private debt crisis	At risk of private debt crisis	At risk of public debt crisis
Albania	Colombia	Australia	Barbados
Angola	Congo, Democratic Republic	Botswana	Benin

Argentina	Cyprus	Brazil	Central African Republic
Armenia	Dominica	Burkina Faso	Comoros
The Bahamas	Madagascar	Croatia	Côte d’Ivoire
Belarus	Niger	France	Ecuador
Belize	North Macedonia	Guinea-Bissau	Guinea
Bhutan	Papua New Guinea	Guyana	Haiti
Cabo Verde	Portugal	Hungary	Liberia
Cameroon	Seychelles	Ireland	Mali
Chad	Spain	Kazakhstan	Mexico
Congo, Republic	St Vincent and the Grenadines	Kyrgyz Republic	Nepal
Costa Rica	Turkey	Latvia	Nicaragua
Djibouti	United States	Lesotho	Samoa
Dominican Republic		Mauritius	São Tomé and Príncipe
Egypt		Moldova	Tajikistan
El Salvador		New Zealand	Tanzania
Ethiopia		Poland	Togo
Gabon		Slovakia	Tonga
Gambia		St Lucia	Uganda
Georgia		UK	Vanuatu
Ghana			
Greece			

Grenada

Indonesia

Jamaica

Jordan

Kenya

Laos

Lebanon

Malawi

Maldives

Mauritania

Mongolia

Montenegro

Morocco

Mozambique

Namibia

Pakistan

Panama

Rwanda

Senegal

Sierra Leone

Somalia

South Sudan

Sri Lanka

Sudan

Suriname

Tunisia

Turkmenistan

Venezuela

Yemen

Zambia

Zimbabwe

Annex 566

"Florida homeowners battle for insurance after Hurricane Ian", *Context*, 15 June 2023

Florida homeowners battle for insurance after Hurricane Ian

David Sherfinski, Diana Baptista
Published: June 15, 2023

Share

Remains of Fort Myers Beach Town Hall are pictured in Fort Myers Beach, Florida, USA, May 24, 2023. Thomson Reuters Foundation/Amie Santavicca

What’s the context?

With hurricane season underway again, residents of the US state are struggling to nd cover as insurers declare insolvency

This story is part of a series on weakening access to insurance protection in the United States in the face of growing losses from climate related disasters: End of insurance?

CAPE CORAL, Florida - When Hurricane Ian slammed into his home in Cape Coral, causing about $90,000 in damage, Tom Paulits faced significant rebuilding work - but at least he was insured.

Nine months after the devastating storm, however, his claim still has not been paid - and his provider, who had assured him of continuing coverage until at least the end of May this year, dropped his policy in March after becoming insolvent.

"The fact that they could just pick up and leave when you need it the most – that's just mind-boggling to me," Paulits said from his home in southwest Florida.

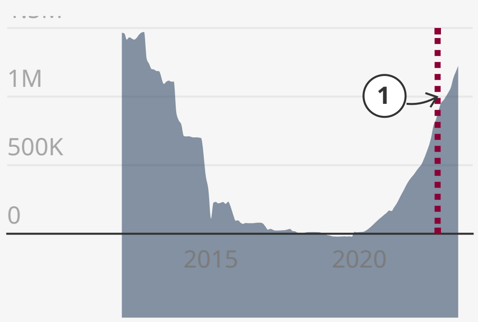
New insurance coverage, arranged through his mortgage provider, now has an effective annual premium of about $5,500 - well above his old rate of about $1,400.

He has looked into taking out a policy with Citizens Property Insurance Corporation, the fast-growing state-backed insurer of last resort, as an alternative.

But other private insurance providers will not take him on because his claim with his previous insurer remains unresolved, a situation he described as "just kind of in limbo".

With a new hurricane season underway, Paulits is one of thousands of Floridians scrambling to find affordable home insurance as a string of providers have been declared insolvent and others have become increasingly unwilling to write policies in higher risk areas.

Policies in force through Citizens Property Insurance Corporation



1 Hurricane Ian hits Florida

Data as of May 2023

Chart: Diana Baptista • Source: Citizens Property Insurance Corporation

Context

Climate change is fueling fiercer hurricanes, including along Florida's Gulf Coast.

Ian, which slammed into the area last September, was the costliest hurricane in state history, according to the National Hurricane Center, causing $112 billion-plus in damages and sending shockwaves through the insurance industry.

Such losses have exacerbated a growing insurance crisis in the state that threatens to leave homeowners - and taxpayers - out of pocket for worsening losses.

Just one more big storm, especially in the heavily populated Miami region, could tip the system, some insurance experts say.

"If south Florida was hit with a catastrophic storm and had major losses, it could deplete the reserves of Citizens," said Mark Friedlander with the Insurance Information Institute, an industry research group.

"When that happens, every Florida consumer is on the hook."

Insolvency, higher premiums

Heavy losses from Hurricane Ian have accelerated some of the state's insurance woes, but many of the industry's issues predate Ian.

Six insurers became insolvent in 2022, and more than a dozen others either left the state or placed moratoriums on writing new business, according to Friedlander's group.

Average homeowners insurance premiums have risen to nearly $6,000 in Florida this year, about four times the national average, the group estimated.

Sara Warnecke, a resident of Cape Coral, close to storm-decimated Fort Myers Beach, has been going without homeowners insurance after she was dropped by her insurer earlier this year.

She is still weighing her options after seeing some quotes many times higher than the roughly $1,700 a year she was paying when she first moved to the state several years ago.

"Right now I'm thinking about just risking it," rather than pay a higher premium plus a deductible if damage happens, she said at her home, swiping through photos of Ian's aftermath on her phone.

"You bet on the chances, like you're gambling. (You think) 'if I don't have a storm for five years, well look how much I could bank.'"

Tom Paulits

Warnecke, like Paulits, was a customer of United Property & Casualty (UPC) Insurance Company, which was declared insolvent and ordered into receivership in February.

At the time, it had about 146,000 active policies in force, according to the state's Department of Financial Services.

UPC did not respond to several requests for comment.

Nine months after Ian, even neighborhoods in Cape Coral that escaped relatively lightly compared to hard-hit Fort Myers Beach are still dotted with blue tarps covering roofs.

Rita Montano of Lee County, which includes Fort Myers and Cape Coral, has seen her homeowners premium more than double, from about $2,900 to about $6,600 since Ian, which caused more than $200,000 in damages to her home and its contents.

She has searched for other quotes. But like Paulits, her claim history - including for damage from Ian - is limiting her options.

"I'm having a heck of a time because companies won't write down here anymore," Montano said. "At this point, I'm hoping (our current insurer) doesn't un-renew us because, right now, we're not able to get any quotes."

"At least we have insurance ... there are a lot of people who do not," she added.

Last-resort cover

As private insurers pull back, more people are enrolling in Citizens, set up in 2002 as a not-for-profit government entity to provide insurance to residents unable to find it on the private market.

As of the end of May, it had more than 1.3 million policies in force. Citizens has a statewide market share of about 16%.

Citizens policies have roughly tripled since 2019 and are projected to top 1.5 million by year-end as more people are either dropped by their carriers or left unable to afford the higher rates on their policies.

Unlike private insurance firms, Citizens can impose surcharges on its policyholders and, if necessary, other Florida insurance policyholders, to pay the costs if a strong storm depletes its reserves.

That ability could drive up prices for all insurance in the state - even automobile policies - if a particularly bad storm hits.

"We'd all be paying to bail out Citizens," said Friedlander, a Florida resident.

Citizens currently has a surplus of about $4.6 billion, according to spokesman Michael Peltier.

"The risk is not that Citizens will not be able to pay claims," he said. "The risk is that we will have to levy assessments if we get hit by a big storm."

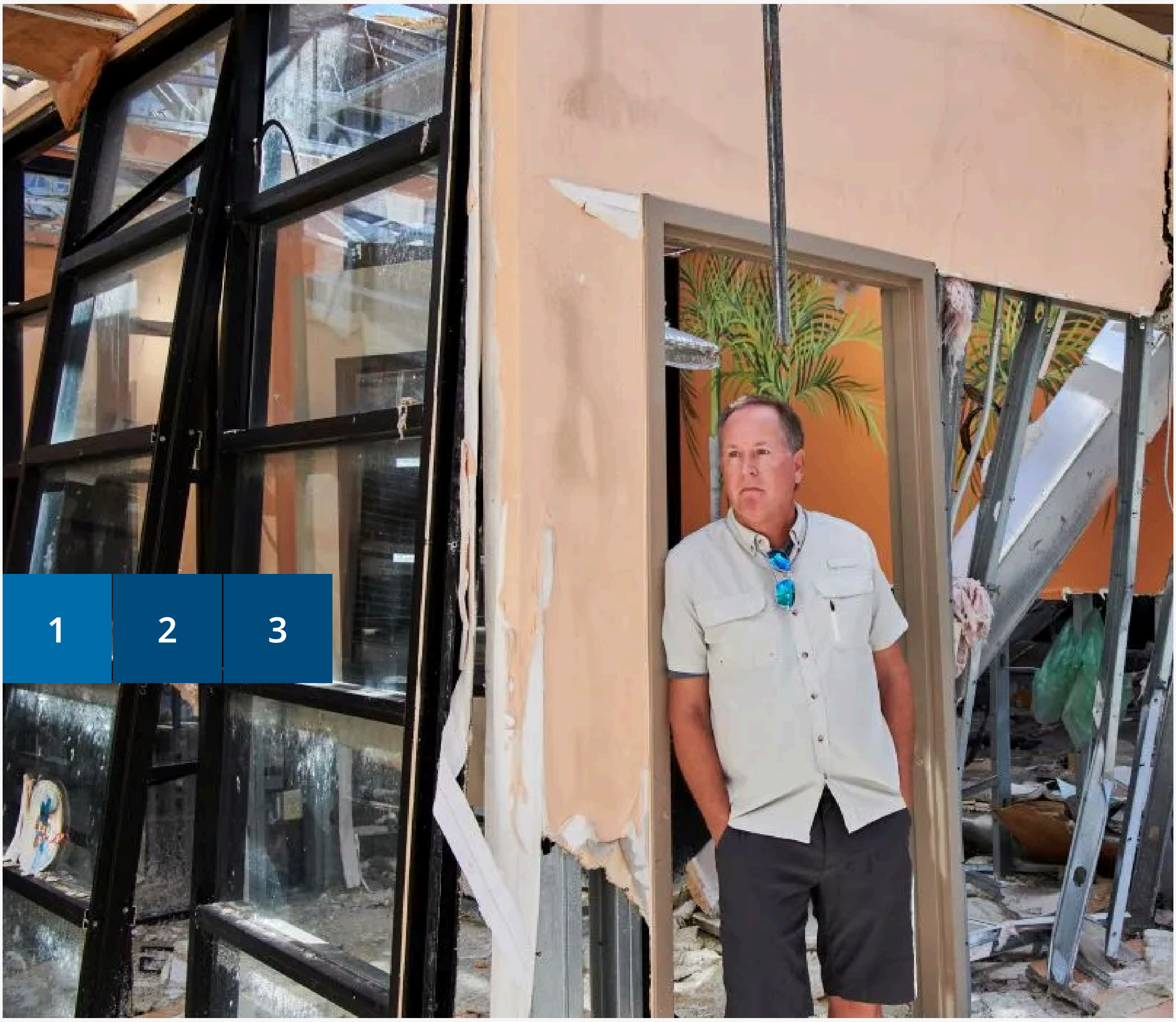
Still waiting for payments

As loss-hit private insurers struggle in Florida, residents like Paulits remain waiting for their Ian-related claims to be paid, a barrier to efforts to find cheaper insurance options.

"It's worrisome. We have mold growing in homes, we have people that are sick, we have kids that are sick, and insurance companies that are non-responsive," said lawyer Donna DeVaney Stockham.

"I understand the overall goal of 'let's save these companies so everything doesn't go into Citizens,'" said Stockham, whose firm works on property insurance issues.

"Nobody wants the insurance industry to go bankrupt. But it has to be balanced against these other interests."



Fort Myers Beach Vice Mayor Jim Atterholt is pictured in what remains of Fort Myers Beach Tow Florida, USA, May 24, 2023. Thomson Reuters Foundation/Amie Santavicca

Jim Atterholt, vice mayor of Fort Myers Beach, said insurance companies need to do a better job of paying claims in a timely manner or people who can will start canceling their policies and doing without cover - potentially upending the market even more.

"No one's going to pay higher rates, because if (insurance companies are) not paying your claims then (customers) lose faith in the system of insurance. So it's a circular problem and it's a challenge," he added.

Old pressures on insurers

Some newer companies – like Slide Insurance, founded in 2021 - have swooped in to snap up business as consumers are left with fewer options.

Besides facing storm losses, many older home insurance firms in Florida are saddled with a heavy burden of claims-related lawsuits filed by policyholders, under state rules that have made such claims relatively attractive to file.

Florida accounts for 79% of these lawsuits nationwide, even though it represents just 9% of homeowners insurance claims, Governor Ron DeSantis' office estimated last year.

The lawsuits - alongside rising reinsurance costs, insurance fraud and inflation - are helping push rates up, said Angel Conlin, chief insurance officer at Kin, a Chicago-based insurer that operates in Florida.

"The situation has decreased the number of insurers willing to write policies in Florida and made it difficult for customers to find coverage," Conlin said.

In December, Florida lawmakers passed legislation that makes it harder for plaintiffs in property insurance lawsuits to collect attorney's fees from insurers - one of several changes industry officials think will cut down on litigation and help shore up the market.

Bruce Lucas, CEO of Slide, said his company's lack of a backlog of open claims is one reason it can afford to write policies in Florida when others are wary.

But across the state, many homeowners are still struggling to figure out the way forward as more insurance firms buckle in the face of growing losses.

Paulits considers himself lucky compared to others whose homes were destroyed. He lost a boat dock and is dealing with ceiling damage, among other things.

But, he said, "it's stressful when finances come into play and you start worrying: Are we going to be able to repair our house?"

He questioned whether insurance firms still doing business in the state will hold up their end of the bargain moving forward.

"Who knows what they're going to do with the next hurricane?" he said.

"(Are they) going to go hopefully five to six years without a hurricane, collect all the premiums and then when another hurricane hits say 'we're out too'?"

(Reporting by David Sherfinski in Florida and Diana Baptista in Mexico City; Editing by Laurie Goering and Helen Popper)

Annex 567

“House repairs after Hurricane Elsa 80 per cent done”, *Barbados Today*, 9 October 2023

BUSINESS • LOCAL NEWS

House repairs after Hurricane Elsa 80 per cent done

written by Marlon Madden • Updated by Stefon Jordan • 09/10/2023 • 3 min read • • A+A-

Almost two and a half years after more than 1 700 houses were damaged or destroyed by Hurricane Elsa, repairs are now more than 80 per cent complete, Minister of Housing, Lands and Maintenance Dwight Sutherland has reported.

He gave this update on Sunday night as he reiterated the government's commitment to providing homes for as many Barbadians as possible.

Sutherland, who was addressing a special joint meeting of the St James South, St James Central and St James North branches of the Barbados Labour Party at Queen's College, said he was satisfied with the progress being made.

“We were struck by Hurricane Elsa and the freak storm in 2021. Some 1 709 homes [were] damaged,” he noted while indicating that close to 250 families received materials to carry out their own repairs and the government took responsibility for rebuilding and repairing the remainder.

Sutherland, who in December last year reported that the number for repairs and rebuild was about 1 796, told the gathering on Sunday that the cost to the government was now around $120 million.

In March this year, during the Budget debate, he had indicated that all homes which needed to be repaired or rebuilt after the passage of Hurricane Elsa would be completed before the start of the 2023 hurricane season.

However, he said on Sunday: “I stand here this afternoon to tell you that countries that have suffered, Puerto Rico and other countries across the globe, go and check them and see that the minimum amount of time it took them to rebuild from a hurricane is four years. Two years gone and we are more than 80 per cent completed with this housing project.”

Following the damage caused by the hurricane, which impacted the island on July 2, 2021, several homeowners also faced challenges with some contractors along the way.

Pointing to some of the housing projects taking place across the island, Sutherland told the gathering that it was the government’s plan to ensure that every Barbadian desirous of owning a piece of the rock was able to do so.

However, he admitted that the government’s plan to build 10 000 homes over the next five years would not be enough to plug the deficit for affordable housing.

The housing minister said a part of the difficulty will be finding suitable land, and he called on Barbadians “with a good piece of land, come and have a joint venture partnership with National Housing where we can build out a partnership where we can provide housing”.

Sutherland also said he was “on the hunt” for land to give to the Barbados Alzheimer’s Association “so that persons can indeed live a life in this country and get the necessary support”. **(MM)**

Annex 568

"Effects of climate change in Latin America and the Caribbean", *Development Bank of Latin America and the Caribbean*, 21 November 2023

Effects of climate change in Latin America and the Caribbean

November 21, 2023

The increase in temperatures, the greater number and frequency of extreme weather events, long droughts, more recurrent landslides and floods, increasing coastal erosion, and ocean acidification are increasingly everyday realities for Latin American and Caribbean populations.

Although Latin America and the Caribbean only generate 10% of greenhouse gas emissions, it already suffers the worst effects of global warming. Cyclones, hurricanes, floods, droughts, rising sea levels, or loss of glaciers will generate more and more migratory movements and put the lives of millions of people in the region at risk, both in cities and in the countryside. Climate change also affects basic infrastructure, the supply of clean water, food production, and electricity generation. It puts the population's livelihoods and basic services at risk with losses and damages whose economic value can exceed 2% of annual GDP.

The data are alarming: 70% of species worldwide are in danger of extinction due to habitat loss and biological invasions; between 1990 and 2014, natural capital shrank per inhabitant by 40%; In Latin America and the Caribbean, between 1998 and 2020, climate-related events and their impacts claimed more than 312,000 lives and affected more than 277 million people.

Furthermore, according to the World Meteorological Organization (WMO), in 2022 there was an almost total loss of snow cover in the glaciers of the central Andes, which accelerated the melting; Flooding and landslides caused by heavy rains caused hundreds of deaths and billions of dollars in economic losses across the region; and during January, November and December 2022, South America suffered long, intense heat waves that, combined with soil drying, sparked unprecedented wildfires.
These phenomena occur with the current increase of 1.3 degrees in the planet's temperature with respect to pre-industrial levels. According to WMO projections, there is a 66% probability that between 2023 and 2027 it will exceed 1.5%. This scenario is considered by some scientists as a turning point in the fight against climate change since it shows the inability to arrive in time to have productive systems that are carbon neutral, something that will accelerate both the warming of the earth and the intensity of the effects of climate change.

The region has six of the most biodiverse countries in the world that contain 70% of the species of mammals, birds, reptiles, amphibians, plants, and insects. Additionally, it has 40% of the biodiversity and more than 25% of the world's forests, while 50% of the Caribbean's plant life is found nowhere else on the planet. Likewise, the region's coastal and marine ecosystems cover an area of 16 million km2 and more than 70,000 km of coastline.

Natural ecosystems are an important source of protection and adaptation to climate change, since they contribute, among others, to moderating extreme weather events, regulating the climate, and absorbing carbon emissions. In fact, it is estimated that around a third of the reduction in greenhouse gas emissions needed over the next decade could be achieved by improving nature's ability to absorb emissions, a fact that benefits Latin America and the Caribbean.

Annex 569

"It's time to cancel debt for climate-stricken nations, Barbados leader says", *Politico*, February 2024

NEWS ENERGY AND CLIMATE

It’s time to cancel debt for climate-stricken nations, Barbados leader says

Mia Mottley has been leading a years-long push to transform how the global financial system handles climate funding.

Tackling debt distress is a matter of climate justice, Mia Mottley argued | Sean Gallup/Getty Images

FEBRUARY 20, 2024 6:48 PM CET
BY ZIA WEISE

AMSTERDAM — Countries on the front lines of climate change should have their debt forgiven, the prime minister of Barbados told POLITICO as she pushes to mainstream an issue long considered taboo.

“We need to have a different deal for island countries and the poor countries of the world,” Mia Mottley told POLITICO and Dutch newspaper De Volkskrant in a recent interview at Amsterdam’s Schiphol airport.

“Quite frankly, I think that we’re at a stage where we need another Jubilee moment — a debt cancellation policy,” she added, referring to a 1990s debt forgiveness campaign.

Mottley's appeal carries weight. The Barbados leader has spent the last few years leading a global push to transform the way global financial institutions help developing countries — and particularly vulnerable nations like hers — access the money needed to combat climate change.

Her reform drive, embraced by French President Emmanuel Macron, calls for measures such as boosting World Bank lending or adding disaster clauses so countries devastated by climate disasters can prioritize reconstruction over debt repayments.

But in the face of worsening climate impacts — Barbados struggles with water scarcity and increasingly ferocious storms — making more money available isn’t enough, she says.

High debt levels are already forcing many vulnerable countries to spend more on servicing their debts than on preparing for climate impacts or even basic social services. If a climate disaster hits, the reconstruction bill sends debt levels soaring even higher.

Until now, Mottley’s reform campaign, known as the Bridgetown Initiative, has often raised the issue of high debt but focused largely on improving lending and liquidity instead of outright debt cancelation.

“She understands that a plethora of solutions will be needed,” said Dileimy Orozco, a senior adviser on sustainable finance at think tank E3G. “I think what she's doing is us[ing] her position to try to elevate the voices of other countries ... because the debt issues are becoming more and more difficult for many economies, and there's no other way out.”

Small island countries have long called for debt relief, noted Michai Robertson, a research fellow at ODI who has served as a climate finance advisor to island nations.

“I always envisioned the Bridgetown Initiative as a first step,” he said, helping "ease people into the discussion."

Tackling debt distress is a matter of climate justice, Mottley argued, given that wealthy countries are disproportionately responsible for global warming while poorer countries are disproportionally affected by climate change.

These climate-damaged countries, she said, are being told that to rebuild they must borrow at a "high premium, and that I must now, in borrowing, crowd out myself from being able to borrow to build schools, and to build hospitals."

The practice, she added, "really is *the* injustice of the post-independence world."

It's not just global financial practices Mottley wants to change — it's also how often officials get together to talk about these issues.

Over the weekend at the Munich Security Conference, Mottley told the audience that she wants heads of state and government to convene climate summits not once a year, but two to three times. Not necessarily more COPs — the annual U.N. climate summit — but certainly more high-level gatherings.

“I think 12 months is too long a period for us to wait now to determine whether we've failed or succeeded in decision making and in execution,” she said, “because the window for effective action is narrowing.”

She added: "You don't need the theatrics of the COP. You do need countries coming to the table."

One idea is to delegate decision-making authority to regional bodies, Mottley suggested, “because 193 states sitting at a table will always be difficult.”

Dutch Climate Minister Rob Jetten, who met Mottley at the airport to discuss water management and finance issues, concurred: “If you want to make sure that we have new forms of insurance, financing, debt relief programs, etc., then you will have to meet each other a lot in the upcoming years because otherwise, we will be too late.”

Mottley also warned that preparing countries to handle climate shocks should get more attention than “sexy” issues like climate disaster funding, which is the focus of an ongoing global effort to erect a fund for communities to rebuild after extreme weather events.

Work on the climate disaster fund has become mired in delays as wealthy countries squabble over seats on the board, POLITICO reported last week.

“I won't say that it will collapse confidence overnight,” Mottley said of the delay. “But all of these things eat away at trust. And trust is the only currency that we have.”

Jetten agreed, adding: “I think it's up to the Europeans now to fix this.”

Annex 570

“‘Bridgetown Initiative 3.0’ unveiled to tackle debt, climate crises”, *Barbados Today*, 29 May 2024

LOCAL NEWS

'Bridgetown Initiative 3.0' unveiled to tackle debt, climate crises

written by Shanna Moore • Updated by Barbados Today • 29/05/2024 • 4 min read • • A+A-

From left, UN Secretary-General António Guterres, Prime Minister Mia Mottley, host Prime Minister Gaston Browne and Secretary General of UN Trade and Development Rebecca Grynspan.

ST JOHN'S – Prime Minister Mia Mottley has launched the Bridgetown Initiative 3.0 for consultation at the 4th International Conference on Small Island Developing States in the Antiguan capital. The new version marks a key moment in an international drive to address unsustainable borrowing, debt sustainability and climate-related shocks affecting small island nations.

Unveiled in 2022, the Bridgetown Initiative has sought a paradigm shift in the global discourse on scaling capital flows and reshaping the financing system to achieve the Sustainable Development Goals and spur climate action. Progress includes the creation of an International Monetary Fund Resilience and Sustainability Trust, a G-20 commitment to re-channel $100 billion in Special Drawing Rights, the launch of a $700 million Loss and Damage Fund, and the inclusion of natural disaster clauses by lenders like the Inter-American Development Bank.

However, Mottley said the current initiative "falls woefully short of what is required". The third version proposes changing "the rules of the game", better shock-proofing economies and ramping up financing.

"We have a date with destiny, and finance is not the destination. Finance is only the medium by which we achieve the resilience that we need to achieve," Mottley said as she provided more details on the Barbados Initiative 3.0 and its potential impact during a sit-down with UN Secretary-General António Guterres, Secretary General of UN Trade and Development Rebecca Grynspan, and host Prime Minister Gaston Browne.

Mottley underscored the urgency of addressing fundamental rules issues: "We are spending so much time and energy trying to get the financial reforms up to scale that we've forgotten that when we get that, we still have a marathon to run with respect to procurement, feasibility studies, execution."

Bridgetown 3.0 seeks to change rules around representation at international financial institutions and the use of per capita gross national income as a criterion for access. It also aims to shock-proof economies by scaling adaptation funding and addressing interconnected issues like climate, health and crime.

"There are a number of countries that, if they were given a shot of adrenaline, a bit of liquidity, would not find themselves needing to go into full IMF programmes or full structural transformation. And if we give them that, it will ease the pressure on all of us," Mottley said.

“We're not one-issue people. We can save the planet and die from the pandemic. We can save ourselves from the pandemic and die from the planet or die from crime.”

The initiative further seeks to increase overall financing volumes “not because we want to go on a spending spree but if I don't do coastal infrastructure at the same time that I'm doing resilient housing all while making access to do your labs so you can do the public health monitoring... If you don't do these things all at once, you're going to be in trouble”.

An 18-month consultation will focus on securing significant funding for small islands and extending the length of IMF extended fund facilities.

A draft notes: “If this agenda is not showing real progress on the ground at country level by the end of 2025, then the world will have failed to address the most critical issues of our time, putting the SDGs in jeopardy. This will result in unthinkable costs to lives, livelihoods and our planet. We can and must do better.”

The government has set a June 30 deadline for email comments on the draft upgrade to bridgetown.initiative@barbados.gov.bb, after which it will finalise and formally launch version 3.0 in July.

Annex 571

"Hurricane Beryl: 35,000 Without Power in Barbados", *Nationwide News*, 1 July 2024

Hurricane Beryl: 35,000 Without Power in Barbados

Posted by Tauna Thomas | 1 Jul, 2024

Hurricane Beryl floods a street in Hastings, Barbados, Monday. Ricardo Mazalan/AP

In Barbados, about a quarter of customers served by the Barbados Light and Power company are without electricity.

Director of Operations, Johann Greaves reported that around 10:40 am, service to 25 per cent or 35,000 customers was disrupted.

He said teams have been prepped to be on the road within an hour or two after the operational all clear is given, to restore power to affected customers. However, he noted that the speed of the restoration process might be affected by the weather.

The Caribbean Broadcasting Corporation is reporting that several roads are now flooded and inundated on the island. Some members of the fishing community have also lost their boats.

Minister of Home Affairs and Information, Wilfred Abrahams says they've had no reports so far of injuries.

Operations Officer at the National Emergency Operations Centre in Barbados, Superintendent Steven Herbert says there's been damage to property and downed power lines.

Superintendent Steven Herbert, Operations Officer at the National Emergency Operations Centre in Barbados.

He was speaking with the Caribbean Broadcasting Corporation.

Meanwhile, the Caribbean Examinations Council, CXC, says its headquarters in Barbados will be closed on Monday due to the passage of Hurricane Beryl.

But its office in Jamaica will remain open during normal business hours.

In a statement Monday morning, CXC says its committed to the safety of its employees and stakeholders and will advise of the agency's re-opening in accordance with the guidance provided by the Department of Emergency Management.

Annex 572

“Hurricane Beryl grows to Category 5 strength as it razes southeast Caribbean islands”, *The Associated Press*, 2 July 2024

Hurricane Beryl Grows to Category 5 Strength as It Razes Southeast Caribbean Islands

Hurricane Beryl has strengthened to Category 5 status as it crosses islands in the southeastern Caribbean

By Associated Press | July 1, 2024 |

Save

RICARDO MAZALAN

Fishing vessels lie damaged after Hurricane Beryl passed through the Bridgetown Fisheries in Barbados, Monday, July 1, 2024. (AP Photo/Ricardo Mazalan)

BRIDGETOWN, Barbados (AP) — Hurricane Beryl strengthened to Category 5 status late Monday after it ripped doors, windows and roofs off homes across the southeastern Caribbean with devastating winds and storm surge fueled by the Atlantic's record warmth.

Beryl made landfall on the island of Carriacou in Grenada as the earliest Category 4 storm in the Atlantic, then late in the day the National Hurricane Center in Miami said its winds had increased to Category 5 strength. Fluctuations in strength, and later a significant weakening, were forecast as the storm pushes further into the Caribbean in the coming days.

Grenada's Prime Minister Dickon Mitchell said one person had died and he could not yet say if there were other fatalities because authorities had not been able to assess the situation on the islands of Carriacou and Petite Martinique, where there were initial reports of major damage but communications were largely down.

"We do hope there aren't any other fatalities or any injuries," he said. "But bear in mind the challenge we have in Carriacou and Petite Martinique." Mitchel added that the government will send people first thing Tuesday morning to evaluate the situation on the islands.

Streets from St. Lucia island south to Grenada were strewn with shoes, trees, downed power lines and other debris. Banana trees were snapped in half and cows lay dead in green pastures with homes made of tin and plywood tilting precariously nearby.

"Right now, I'm real heartbroken," said Vichelle Clark King as she surveyed her damaged shop in the Barbadian capital of Bridgetown that was filled with sand and water.

Beryl was still swiping the southeast Caribbean early Tuesday on a track heading just south of Jamaica and toward Mexico's Yucatan Peninsula by late Thursday as a Category 1 storm.

It reached Category 5 strength late Monday and intensi ed further early Tuesday morning to 165 mph (270 kph) winds.

Beryl was about 445 miles (715 kilometers) east-southeast of Isla Beata in the Dominican Republic and was moving west-northwest at 22 mph (35 kph). A hurricane warning was in effect for Jamaica, and a tropical storm warning for the southern coast of Hispaniola, the island shared by Haiti and the Dominican Republic.

Fluctuations were likely but Beryl was expected to stay near major hurricane intensity as it moved into the central Caribbean and passed near Jamaica on Wednesday, the National Hurricane Center said. After that, signi cant weakening was expected.

The last strong hurricane to hit the southeast Caribbean was Hurricane Ivan 20 years ago, which killed dozens of people in Grenada.

On Monday afternoon, officials received “reports of devastation” from Carriacou and surrounding islands, said Terence Walters, Grenada’s national disaster coordinator. itchell said he would travel to Carriacou as soon as it’s safe, noting there’s been an “extensive” storm surge.

Grenada officials had to evacuate patients to a lower floor after hospital roof was damaged, he said.

“There is the likelihood of even greater damage,” he told reporters. “We have no choice but to continue to pray.”

In Barbados, Wilfred Abrahams, minister of home affairs and information, said drones — which are faster than crews fanning across the island — would assess damage once Beryl passed.

Jaswinderpal Parmar of Fresno, California, who was among the thousands who traveled to Barbados for Saturday’s Twenty20 World Cup cricket final, said he and his family were now stuck there with scores of other fans, their flights canceled on Sunday.

He said by phone that it’s the first time he has experienced a hurricane — he and his family have been praying, as well as taking calls from concerned friends and family as far away as India.

“We couldn’t sleep last night,” Parmar said.

Historic hurricane

Beryl strengthened from a tropical depression to a major hurricane in just 42 hours, which only six other Atlantic hurricanes have done, with Sept. 1 as the previous earliest date, according to hurricane expert Sam Lillo.

It also was the earliest Category 4 Atlantic hurricane, besting Hurricane Dennis, which became a Category 4 storm on July 8, 2005. Beryl later became the earliest Category 5 observed in the Atlantic basin on record, and only the second Category 5 hurricane in July after Hurricane Emily in 2005. the National Hurricane Center said.

Beryl amassed its strength from record warm waters that are hotter now than they would be at the peak of hurricane season in September, said hurricane specialist and storm surge expert Michael Lowry.

Beryl also marked the farthest east that a hurricane has formed in the tropical Atlantic in June, breaking a record set in 1933, according to Philip Klotzbach, Colorado State University hurricane researcher.

Beryl is the second named storm in the Atlantic hurricane season, which runs from June 1 to Nov. 30. Earlier this month, Tropical Storm Alberto made landfall in northeast Mexico and killed four people.

Short-lived Tropical Storm Chris had formed Sunday night near eastern Mexico before weakening back to a depression Monday. A cluster of thunderstorms mimicking Beryl's path in the western Atlantic was less organized late Monday but had a small chance of becoming a named storm in the next few days.

The National Oceanic and Atmospheric Administration predicted the 2024 hurricane season was likely to be well above average, with between 17 and 25 named storms. The forecast called for as many as 13 hurricanes and four major hurricanes.

An average Atlantic hurricane season produces 14 named storms, seven of them hurricanes and three major hurricanes.

—

Coto reported from San Juan, Puerto Rico. Associated Press videographer Lucanus Ollivierre in Kingstown, St. Vincent contributed to this report.

Annex 573

"Hurricane Beryl kills five as it barrels towards Jamaica", *The Economic Times*, 3 July 2024

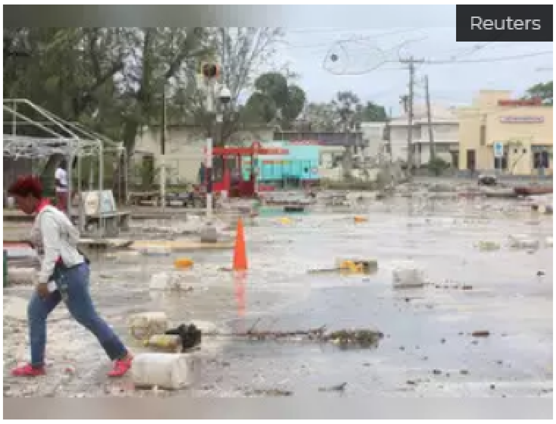
THE ECONOMIC TIMES | News

English Edition ▾ | Today's ePaper

Hurricane Beryl kills five as it barrels towards Jamaica

By AFP • Last Updated: Jul 03, 2024, 08:29:00 AM IST

Beryl is the first storm since US National Hurricane Center records began to reach the Category 4 level in June, and the earliest to reach Category 5 in July. A hurricane warning was in place for the island nation, according to the NHC, which said rain and flash flooding was to be expected in addition to the life-threatening wind and high water levels.


Reuters

Hurricane Beryl churned towards Jamaica Tuesday, with forecasters warning of potentially deadly winds and storm surge, after the storm killed at least five people and caused widespread destruction across the southeastern Caribbean.

The powerful hurricane, which is rare so early in the Atlantic season, weakened Tuesday but was still an "extremely dangerous" Category 4 storm, and is expected to pass "near or over" Jamaica on Wednesday, meteorologists said.

Beryl is the first storm since US National Hurricane Center records began to reach the Category 4 level in June, and the earliest to reach Category 5 in July.

A hurricane warning was in place for the island nation, according to the NHC, which said rain and flash flooding was to be expected in addition to the life-threatening wind and high water levels.

Across Jamaica, emergency response preparations were under way -- shelters stocked up on provisions, people safeguarded their homes and boats were pulled from the water.

"I urge all Jamaicans to stock up on food, batteries, candles, and water. Secure your critical documents and remove any trees or items that could endanger your property," Prime Minister Andrew Holness said on X.

Apart from Jamaica, hurricane warnings were also issued in the Cayman Islands, which Beryl is "expected to pass near or over" on Wednesday night or early Thursday, according to the NHC.

In the Dominican Republic, massive waves were seen crashing into the shore along Santo Domingo as the storm passed to the country's south, AFP photographers reported.

Beryl has already left a trail of death in its wake: At least three people were killed in **Grenada**, where Beryl made landfall Monday, as well as one in St Vincent and the Grenadines and one in Venezuela, officials said.

Grenada's Prime Minister Dickon Mitchell said the island of Carriacou, which was struck by the eye of the storm, has been all but cut off, with houses, telecommunications and fuel facilities there flattened.

"We've had virtually no communication with Carriacou in the last 12 hours except briefly this morning by satellite phone," Mitchell told a news conference.

The 13.5-square mile (35-square kilometer) island is home to around 9,000 people. At least two people there died, Mitchell said, with a third killed on the country's main island of Grenada when a tree fell on a house.

In St. Vincent and the Grenadines, one person on the island of Bequia was reported dead from the storm, and a man died in Venezuela's northeastern coastal state of Sucre when he was swept away by a flooded river, officials there said.

World Health Organization chief Tedros Adhanom Ghebreyesus expressed concern about the region, saying on X that his organization "stands ready to support the national authorities with any health needs."

'Alarming precedent'

Experts say it is extremely rare for such a powerful storm to form this early in the Atlantic **hurricane season**, which runs from early June to late November.

Warm ocean temperatures are key for hurricanes, and North Atlantic waters are currently between two and five degrees Fahrenheit (1-3 degrees Celsius) warmer than normal, according to the US National Oceanic and Atmospheric Administration.

The World Meteorological Organization (**WMO**) said Beryl "sets an alarming precedent for what is expected to be a very active hurricane season."

NOAA said in late May that it expects this year to be an "extraordinary" hurricane season, with up to seven storms of Category 3 or above.

Climate crisis 'chief culprit'

UN climate chief Simon Stiell, who has family on the island of Carriacou, said climate change was "pushing disasters to record-breaking new levels of destruction."

"Disasters on a scale that used to be the stuff of science fiction are becoming meteorological facts, and the climate crisis is the chief culprit," he said Monday, reporting that his parents' property was damaged.

As of 2200 GMT, Beryl had maximum sustained winds of 150 miles (240 kilometers) per hour as it headed towards Jamaica and the Cayman Islands on Tuesday, according to the NHC.

A hurricane watch and tropical storm warnings have also been issued for parts of Haiti.

Annex 574

“Beryl heads toward Jamaica as a major hurricane after ripping through southeast Caribbean”, *The Indian Express*, 3 July 2024

The Indian EXPRESS
JOURNALISM OF COURAGE

Beryl heads toward Jamaica as a major hurricane after ripping through southeast Caribbean

Several people evacuated Union Island via ferry and arrived at the Kingstown Ferry Terminal in Saint Vincent and the Grenadines on Tuesday.

By: AP
St. George's | July 3, 2024 09:43 IST

Boats damaged by Hurricane Beryl wade in the water at the Bridgetown Fisheries, Barbados, Tuesday, July 2, 2024. (AP Photo)

Hurricane Beryl roared through open waters Tuesday as a powerful Category 4 storm heading toward Jamaica after earlier crossing islands in the southeast Caribbean, killing at least six people.

A hurricane warning was in effect for Jamaica, Grand Cayman, Little Cayman, and Cayman Brac. Beryl was losing intensity but was forecast to still be near major-hurricane strength when it passes near or over Jamaica early Wednesday, near the Cayman Islands on Thursday and into Mexico's Yucatan Peninsula on Friday, according to the National Hurricane Centre.

A hurricane watch was in effect for Haiti's southern coast and the Yucatan's east coast. Belize issued a tropical storm watch stretching south from its border with Mexico to Belize City.

Late Monday, Beryl became the earliest storm to develop into a Category 5 hurricane in the Atlantic and peaked at winds of 165 mph (270 kph) Tuesday before weakening to a still-destructive Category 4.

On Tuesday night, the storm was about 300 miles (480 kilometres) east-southeast of Kingston, Jamaica. It had top winds of 150 mph (240 kph) and was moving west-northwest at 22 mph (35 kph), the centre said.

Beryl was expected to bring life-threatening winds and storm surge to Jamaica, where officials warned residents in flood-prone areas to prepare for evacuation.

“I am encouraging all Jamaicans to take the hurricane as a serious threat,” Prime Minister Andrew Holness said in a public address Tuesday. “It is, however, not a time to panic.” In Miami, National Hurricane Centre Director Michael Brennan said Jamaica appears to be in the direct path of Beryl.

“We are most concerned about Jamaica, where we are expecting the core of a major hurricane to pass near or over the island,” he said in an online briefing. “You want to be in a safe place where you can ride out the storm by nightfall (Tuesday). Be prepared to stay in that location through Wednesday.” Storm surge of 6-9 feet (1.8 to 2.7 metres) above typical tide levels are likely in Jamaica, as well as heavy rainfall.

“This is a big hazard in the Caribbean, especially with the mountainous islands,” Brennan said. “This could cause life threatening flash floods and mudslides in some of these areas.” A tropical storm warning was in place for the entire southern coast of Hispaniola, an island shared by Haiti and the Dominican Republic.

Trail of devastation

As the storm barrelled through the Caribbean Sea, rescue crews in southeastern islands fanned out to determine the extent of the damage Beryl inflicted on Carriacou, an island in Grenada.

Three people were reported killed in Grenada and Carriacou and another in St. Vincent and the Grenadines, officials said. Two other deaths were reported in northern Venezuela, where five people are missing, officials said. Some 25,000 people in that area also were affected by heavy rainfall from Beryl.

One fatality in Grenada occurred after a tree fell on a house, Kerryne James, the environment minister, told The Associated Press.

She said Carriacou and Petit Martinique sustained the greatest damage, with scores of homes and businesses flattened in Carriacou.

"The situation is grim," Grenadian Prime Minister Dickon Mitchell told a news conference Tuesday. “There is no power, and there is almost complete destruction of homes and buildings on the island. The roads are not passable, and in many instances they are cut off because of the large quantity of debris strewn all over the streets.” Mitchell added: "The possibility that there may be more fatalities remains a grim reality as movement is still highly restricted.” Meanwhile, Ralph Gonsalves, prime minister of St. Vincent and the Grenadines, promised to rebuild the archipelago in a statement early Tuesday. He noted that 90 per cent of homes on Union Island were destroyed, and that “similar levels of devastation” were expected on the islands of Myreau and Canouan.

Several people evacuated Union Island via ferry and arrived at the Kingstown Ferry Terminal in Saint Vincent and the Grenadines on Tuesday.

Sharon DeRoche, one of the evacuees, said Union Island is in a terrible state. She bore the hurricane in her bathroom before she fled. “It was a hard four hours battling with six of us in that little area,” she said.

The last strong hurricane to hit the southeast Caribbean was Hurricane Ivan 20 years ago, which killed dozens of people in Grenada.

Grenadian resident Roy O'Neale, 77, lost his home to Ivan and built back stronger. His current home sustained minimal damage from Beryl.

“I felt the wind whistling, and then for about two hours straight, it was really, really terrifying at times,” he said by phone.

“Branches of trees were flying all over the place.” Hundreds of people hunkered in shelters across the southeast Caribbean, including 50 adults and 20 children who huddled inside a school in Grenada.

“Maybe some of them thought they could have survived in their homes, but when they realised the severity of it … they came for cover,” said Urban Mason, a retired teacher who served as the shelter's manager. “People tend to be complacent.” One of the homes that Beryl damaged belongs to the parents of UN Climate Change Executive Secretary Simon Stiell, who is from Carriacou. The storm also destroyed the home of his late grandmother.

In a statement, Stiell said that the climate crisis is worsening, faster than expected.

“Whether in my homeland of Carriacou … hammered by Hurricane Beryl, or in the heatwaves and floods crippling communities in some of the world's largest economies, it's clear that the climate crisis is pushing disasters to record-breaking new levels of destruction,” he said.

Grenada, known as the “spice isle,” is one of the world's top exporters of nutmeg. Mitchell noted that the bulk of the spices are grown in the northern part of the island, which was hit hardest by Beryl.

Annex 575

"Fishing devastation prompts call for affordable boat insurance", *Barbados Today*, 3 July 2024

Fishing devastation prompts call for affordable boat insurance

written by Shamar Blunt • Updated by Barbados Today • 03/07/2024 • 2 min read • • A+A-

St Michael South MP and former maritime affairs and blue economy minister Kirk Humphrey. (SB)

Hurricane Beryl's destructive blow to the fishing industry has reignited a call for affordable insurance for fishing boats.

After some 20 fishing boats were sunk as high waves breached breakwater at the Bridgetown Fishing Complex, former maritime affairs and blue economy minister Kirk Humphrey told **Barbados TODAY** that the time has come for "a serious discussion regarding insurance for small to large sized fishing vessels with all parties involved in the fishing and insurance industries".

Humphrey, who spearheaded several initiatives to grow the sector during his tenure, described the loss as "inconceivable" and "painful to witness". He emphasised the critical role the industry plays in the island's food security.

"We've been having this conversation around insuring the fishing vessels, and I know it's a very costly thing to insure vessels, so I think we need to have conversations with the insurance companies around how we can make it affordable," Humphrey said.

He acknowledged that while insurance is available in some cases, fishermen find it prohibitively expensive.

"We have to work on doing better at that," he added.

The St Michael South MP visited the affected areas on Monday night to assess the damage firsthand. He noted that recently built jetties, designed to withstand serious surges, were overwhelmed by the unprecedented level of storm activity.

"I got to tell you that broke my heart, to be honest; we had a lot of plans in the industry, I worked very closely with the fisherfolk, I know the love that they have for the industry and the respect they have for the ocean," he said.

Speaking about the jetties which were built to "withstand a serious surge", Humphrey added: "Obviously we never anticipated that level of activity.... It tells me that we have to build out better when we rebuild that part of the fishing industry to withstand stronger surges from the ocean."

He also revealed that plans were already in motion to build a vessel haul-out facility in Bridgetown, which would help boat owners better protect their investments in the future.

Annex 576

"BAS head says urgent intervention needed for fishing sector", *Barbados Today*, 4 July 2024

BAS head says urgent intervention needed for fishing sector

written by Ryan Gilkes • Updated by Barbados Today • 04/07/2024 • 4 min read • • A+A-

Barbados Agricultural Society CEO James Paul. (FP)

The toll of Hurricane Beryl on the fishing industry appears to have doubled, with over 40 boats now reported lost or damaged, according to the head of the Barbados Agricultural Society (BAS) who has called for urgent government intervention to rebuild the fishing sector.

"As we look at the current situation with fisheries in Barbados, 40-plus boats, including ice boats, long liners, and day boats, are gone," said the BAS' Chief Executive Officer James Paul, emphasising the need for special funding to restore the fishing fleet's capacity.

"The challenge is that we need to identify special financing for those boats to get back in the water. What we need to do is ensure that we have the orders for those boats to fight again and to do the repairs if they are possible.... We need to come up with some level of financing for those boat owners to assist them in getting back in the water. That's the discussion we should have now."

Paul expressed hope that the government would extend the same level of support to fisheries as it had to the dairy and livestock sectors.

Turning to the broader agricultural situation, the BAS chief noted that the state of farming remained largely unchanged from what it was before the hurricane. However, he highlighted the impact of unpredictable weather on crop production.

"Right now, we're having some rain. I don't think people appreciate that the agricultural sector, in many instances, goes with the weather. If you have unfavourable weather, expect unfavourable circumstances – especially when it comes to crops and vegetables in general – because it has to do with the environment and changes in the environment, and sometimes those changes do not necessarily favour crop production," Paul said, warning that continued heavy rain could lead to significant crop losses, particularly for produce such as squash, watermelons, and tomatoes.

Dozens of boats were either destroyed or sank as a result of the violent waves whipped up by Hurricane Beryl. (KH)

The BAS CEO also raised concerns about potential shortages of agricultural products in the future, given the ongoing weather systems affecting the region. He cautioned against indiscriminate granting of import licences, which could harm local farmers.

Paul cited a recent example where poultry imports led to an oversupply, leaving local farmers unable to sell their stock.

He said: "We need to ensure that our information-gathering resources are heightened to make sure that when we do grant an import permit for certain commodities, that permit is based on solid evidence that we do not have the level of production necessary. For instance, before the World Cup, there was a rush to import poultry or pork because we were expecting thousands of people to come and visit. The World Cup is over, but we have a situation where many small farmers have chicken in storage at BICO and cannot get rid of it. Yet, we brought in chicken wings."

He stressed the need for better coordination and consultation between farmers and policymakers to avoid such issues in the future: "Do not listen to those who do not rely on the industry for a living and who would be too keen to import unnecessarily. We need to work with our farmers."

"We need to understand that our actions should not negatively impact the sector," Paul said, adding that there needed to be robust information systems and better coordination within the agriculture sector. "I don't want to hear about whether you are doing it correctly or not. Systems need to be working. We need a level of consultation, working with each other, and understanding what we need."

The BAS CEO also stressed the need for a better working relationship to prevent flooding the market with imported commodities while local farmers struggle.

Annex 577

"Boat tally at 204 and counting", *Nation News*, 4 July 2024

YOUR NEWS | YOUR TIME | YOUR WAY

DAILY **Nation**

1973-2023

The Newspaper of Barbados

[redacted]

THURSDAY, JULY 4, 2024 BARBADOS, WI www.nationnews.com BDS$1.50

Threat to insurance

Increasing major natural disasters 'may put coverage at risk'

by **SHAWN CUMBERBATCH**
shawncumberbatch@nationnews.com

BARBADOS' INSURANCE INDUSTRY, which now provides about $20 billion in coverage for properties in Barbados, is worried that if other major storms follow Hurricane Beryl the expansion of this protection could be threatened.

General Insurance Association of Barbados president Randy Graham says this is because the expectation is that reinsurance companies will either continue to reduce their appetite for covering disaster-related risks in the Caribbean, or ask regional insurers to pay substantially more for it.

He spoke yesterday shortly after AM Best, the largest credit rating agency in the world specialising in the insurance industry, warned that "a severe storm so early in the season may require protection from additional catastrophe events at what is likely to be premium prices" for Caribbean insurance companies.

Graham said that while **Hurricane Beryl** was a "bad" storm, "it probably won't be a major event in terms of dollar amounts for the reinsurance market".

A reminder

However, he said, "It will be a reminder that the region is exposed to these types of hurricanes and I think that's what may cause the market to continue to harden", which means reduced or costlier reinsurance for Barbados and the Caribbean.

"It is early days in this hurricane season but to be honest with you, I think for the last three or so years we have had a hardening of the reinsurance market, the amount of hurricanes increasing and reinsurers opting to use their capital in other markets away from the Caribbean because of the potential damage," said Graham, who is chief executive officer of CG United Insurance Limited.

He elaborated on what this meant

Continued on Page 4.

SOME OF THE BOATS that were removed yesterday were hauled off to a facility in the Fisheries Division while others will be trucked off to alternate, secure locations. (Picture by Reco Moore.)

Boat tally at 204 and counting

EFFORTS TO SALVAGE boats at the Bridgetown Fisheries Complex continued yesterday, with more than 200 now recorded as either damaged or submerged.

Yesterday staff of the Fisheries Division were once again on site, collecting information from boat owners and documenting the scope of damage dealt to boats via their vessel damage assessment forms.

Chief Fisheries Officer Shelly-Ann Cox refused to comment, but highly-placed sources confirmed the number of compromised boats in the marina to be 204 with many more still unaccounted.

Crews from Hinds Transport continue to man the cranes that cautiously pulled the wreckage from the area.

For the second day, boat owners congregated on the jetty waiting for the retrieval of their submerged vessels.

As some boats were brought up, owners looked for whatever supplies they could recover from the wreckage. **(JRN)**

Annex 578

"Plea against price rise amid fisheries losses", *Barbados Today*, 5 July 2024

LOCAL NEWS

Plea against price rise amid fisheries losses

written by Shamar Blunt • Updated by Barbados Today • 05/07/2024 • 3 min read • • A+A-

Senator Dr Shantal Munro-Knight. (SB)

Fish processors have been urged not to raise the wholesale price to vendors after a leading spokesman for the fishing community estimated that Hurricane Beryl has destroyed 90 per cent of the island's fleet.

“We are asking them, ‘don’t juck out we eye’,” said Kemar Harris, chairman of the Fisheries Advisory Committee, as he issued the plea during a media briefing at Oistins Bay Garden.

Urging processors not to exploit the crisis, he added: “I am hoping that the fish processors of this country do not put markups on their fish, because they don’t pay VAT for it, and understand that this is a seriously impacting moment at this time.”

The storm surge associated with Hurricane Beryl on Monday left fishing folk watching “in horror” as most of the country’s fishing fleet was destroyed or critically damaged.

Harris emphasised the need for discussions with processors to establish capped prices, considering the extraordinary circumstances.

“I want to meet with them so that we can have some conversations to see if we can come to some capped prices based on the circumstances that have now happened.... All of these small enterprises can have capped prices for these persons in this difficult period because we don’t have the boats going out,” he said.

Harris acknowledged that no accurate timeline could be provided for how long the local fish stock would last, given the lack of boats available to replenish supplies.

Chairman of the Fisheries Advisory Committee Kemar Harris. (SB)

“What we are going to miss is our local dolphin, our flying fish, the potfish, the snappers… those local fish that we get from here,” he explained, adding that traditional dishes like coucou and flying fish may be unavailable for some time.

The government has begun addressing the crisis, with Cabinet expected to devote its weekly meeting on Thursday to discuss recovery plans. Senator Dr Shantal Munro-Knight, BLP hopeful for the Christ Church South constituency, reported that over 156 workers from various agencies, including the National Conservation Commission, Ministry of Transport and Works and Coast Guard have been involved in cleaning up the Oistins area.

Senator Munro-Knight emphasised the need for a forward-looking approach: “The conversation is about how we build resilience in the future; it’s not just about rushing in and saying ‘okay, we are just going to replace’, but what are the lessons we learned from what has happened here, and how can we do it better.”

“Cabinet this morning was fully dedicated to having this discussion,” said the Minister of State in the Prime Minister’s Office with responsibility for Culture. “We got a full update from the prime minister who was fully on the ground for a number of days, and the discussion in Cabinet was about what is it that we need to be able to put in place to address what has happened, to make sure we are able to provide some level of assistance.”

Annex 579

"World Bank Carbon Credits to Boost International Carbon Markets", *The World Bank*, 1 December 2023

PRESS RELEASE | DECEMBER 1, 2023

World Bank Carbon Credits to Boost International Carbon Markets

World Bank Engagement Road map for High-Integrity Carbon Markets seeks to expand transparent and inclusive carbon markets that benefit developing countries first

DUBAI, December 1, 2023 — Today, the World Bank announced ambitious plans for the growth of high-integrity global carbon markets, with 15 countries set to earn income from the sale of carbon credits generated from preserving their forests. By next year, these countries will have produced over 24 million credits, and as many as 126 million by 2028. These credits could earn up to $2.5 billion in the right market conditions, with much of that going back to communities and countries. Thriving carbon markets have the potential to do the same for other countries in the long-term.

The 15 countries—**Chile, Costa Rica, Cote d'Ivoire, Democratic Republic of Congo, Dominican Republic, Fiji, Ghana, Guatemala, Indonesia, Lao PDR, Madagascar, Mozambique, Nepal, Republic of Congo, and Viet Nam**—are part of the World Bank's Forest Carbon Partnership Facility (FCPF), which has supported pilot programs since 2018 to establish efficient systems for carbon-crediting initiatives. Supporting five countries in 2024, the World Bank will work with governments and local communities to access carbon markets. By 2028, it is expected all 15 FCPF countries will be in a position to interact with carbon markets.

What makes World Bank carbon credits unique and of high-integrity are two things:

- Environmental integrity—ensuring credits are unique, real, additional, permanent, and measurable; and
- Social integrity—making sure that communities, especially Indigenous Peoples and Local Communities, benefit most from these programs.

Each carbon credit is monitored, reported, and verified by a third party against the World Bank-managed FCPF Standard and World Bank Environmental and Social Standards. The 15 programs use cutting edge technology to ensure that carbon credits are accurately measured and accounted. The programs cover entire jurisdictions, meaning that the reforestation and conservation efforts are not undermined by deforestation elsewhere.

The Bank supports countries in deciding how to use their carbon credits—either monetizing them through carbon markets, using them for their own Nationally Determined Contributions, or other transactions to raise additional finance.

"Blessed with natural resources, these countries are set to benefit from carbon markets by earning income from protecting forests and using their land more sustainably," **World Bank Group President Ajay Banga said**. *"With the World Bank Engagement Roadmap for High-Integrity Carbon Markets, we will collaborate with partners to scale effective global carbon markets. Our experience with the FCPF and other initiatives has resulted in a formula that can catalyze effective carbon markets and make good on their promise for people and planet."*

The Roadmap outlines the Bank's ambition to work with others to deliver solutions to expand liquid and transparent carbon markets. This includes working with private and public sector partners to implement integrity principles for buyers and sellers of credits and introducing common frameworks for organizations validating and verifying credits, such as independent credit rating agencies.

Today's announcement is the result of two decades of work to build sound, transparent carbon markets that pay developing countries for their climate efforts that benefit us all. The Bank's ambition is to go farther, so it is scaling its support to countries to reduce emissions in other sectors—including energy access and coal transition, soil organic carbon, and mangroves—to help generate carbon credits that can be paid for or purchased through Bank programs or sold through markets.

About the Forest Carbon Partnership Facility (FCPF)

The Forest Carbon Partnership Facility (FCPF) is a global partnership of governments, businesses, civil society, and Indigenous Peoples' organizations focused on reducing emissions from deforestation and forest degradation, forest carbon stock conservation, the sustainable management of forests, and the enhancement of forest carbon stocks in developing countries, activities commonly referred to as REDD+. Launched in 2008, the FCPF has worked with 47 developing countries across Africa, Asia, and Latin America and the Caribbean, along with 17 donors that have made contributions and commitments totaling $1.3 billion.

Last Updated: Dec 01, 2023

PRESS RELEASE NO: 2024/035/CCG

Annex 580

"Humanity Needs 'Exit Ramp off Road to Climate Hell', Secretary-General Insists, Urging Bolder, Faster Action to Save Planet", in Address at American Natural History Museum, *United Nations*, 5 June 2024

SG/SM/22255
5 June 2024

Humanity Needs 'Exit Ramp off Road to Climate Hell', Secretary-General Insists, Urging Bolder, Faster Action to Save Planet, in Address at American Natural History Museum

Following is UN Secretary-General António Guterres' special address on climate action, "A Moment of Truth", to the American Museum of Natural History, in New York today:

Today is World Environment Day. It is also the day that the European Commission's Copernicus Climate Change Service officially reports May 2024 as the hottest May in recorded history.

This marks 12 straight months of the hottest months ever. For the past year, every turn of the calendar has turned up the heat. Our planet is trying to tell us something. But we don't seem to be listening.

The American Museum of Natural History is the ideal place to make the point. This great Museum tells the amazing story of our natural world. Of the vast forces that have shaped life on Earth over billions of years. Humanity is just one small blip on the radar. But like the meteor that wiped out the dinosaurs, we're having an outsized impact. In the case of climate, we are not the dinosaurs. We are the meteor. We are not only in danger. We are the danger. But we are also the solution.

We are at a moment of truth. The truth is almost 10 years since the Paris Agreement was adopted, the target of limiting long-term global warming to 1.5 degrees Celsius is hanging by a thread. The truth is the world is spewing emissions so fast that by 2030, a far higher temperature rise would be all but guaranteed.

Brand new data from leading climate scientists released today show the remaining carbon budget to limit long-term warming to 1.5 degrees is now around 200 billion tons. That is the maximum amount of carbon dioxide that the Earth's atmosphere can take if we are to have a fighting chance of staying within the limit.

The truth is we are burning through the budget at reckless speed — spewing out around 40 billion tons of carbon dioxide a year. We can all do the math. At this rate, the entire carbon budget will be busted before 2030. The truth is global emissions need to fall 9 per cent every year until 2030 to keep the 1.5-degree limit alive. But they are heading in the wrong direction. Last year they rose by 1 per cent.

The truth is we already face incursions into 1.5-degree territory. The World Meteorological Organization reports today that there is an 80 per cent chance the global annual average temperature will exceed the 1.5-degree limit in at least one of the next five years. In 2015, the chance of such a breach was near zero. And there's a 50-50 chance that the average temperature for the entire next five-year period will be 1.5 degrees higher than pre-industrial times.

We are playing Russian roulette with our planet. We need an exit ramp off the highway to climate hell. And the truth is we have control of the wheel. The 1.5-degree limit is still just about possible. Let's remember — it's a limit for the long-term — measured over decades, not months or years. So, stepping over the threshold 1.5 for a short time does not mean the long-term goal is shot. It means we need to fight harder. Now.

The truth is the battle for 1.5 degrees will be won or lost in the 2020s — under the watch of leaders today. All depends on the decisions those leaders take — or fail to take — especially in the next 18 months.

It's climate crunch time. The need for action is unprecedented but so is the opportunity – not just to deliver on climate, but on economic prosperity and sustainable development. Climate action cannot be captive to geopolitical divisions.

So, as the world meets in Bonn for climate talks, and gears up for the Group of 7 (G7) and Group of 20 (G20) Summits, the United Nations General Assembly, and COP29 [Twenty-ninth Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change], we need maximum ambition, maximum acceleration, maximum cooperation — in a word, maximum action.

Why all this fuss about 1.5 degrees? Because our planet is a mass of complex, connected systems. And every fraction of a degree of global heating counts. The difference between 1.5 and 2 degrees could be the difference between extinction and survival for some small island States and coastal communities. The difference between minimizing climate chaos or crossing dangerous tipping points. 1.5 degrees is not a target. It is not a goal. It is a physical limit.

Scientists have alerted us that temperatures rising higher would likely mean: the collapse of the Greenland Ice Sheet and the West Antarctic Ice Sheet with catastrophic sea level rise; the destruction of tropical coral reef systems and the livelihoods of 300 million people; the collapse of the Labrador Sea Current that would further disrupt weather patterns in Europe; and widespread permafrost melt that would release devastating levels of methane, one of the most potent heat-trapping gasses.

Even today, we're pushing planetary boundaries to the brink — shattering global temperature records and reaping the whirlwind.

And it is a travesty of climate justice that those least responsible for the crisis are hardest hit: the poorest people; the most vulnerable countries; Indigenous Peoples; women and girls. The richest 1 per cent emit as much as two thirds of humanity.

And extreme events turbocharged by climate chaos are piling up: destroying lives, pummelling economies and hammering health; wrecking sustainable development; forcing people from their homes; and rocking the foundations of peace and security — as people are displaced and vital resources depleted.

Already this year, a brutal heatwave has baked Asia with record temperatures — shrivelling crops, closing schools and killing people. Cities from New Delhi to Bamako to Mexico City are scorching. Here in the United States, savage storms have destroyed communities and lives. We've seen drought disasters declared across Southern Africa; extreme rains flood the Arabian Peninsula, East Africa and Brazil; and a mass global coral bleaching caused by unprecedented ocean temperatures, soaring past the worst predictions of scientists.

The cost of all this chaos is hitting people where it hurts: from supply-chains severed to rising prices, mounting food insecurity and uninsurable homes and businesses. That bill will keep growing. Even if emissions hit zero tomorrow, a recent study found that climate chaos will still cost at least $38 trillion a year by 2050.

Climate change is the mother of all stealth taxes paid by everyday people and vulnerable countries and communities. Meanwhile, the godfathers of climate chaos — the fossil fuel industry — rake in record profits and feast off trillions in taxpayer-funded subsidies.

We have what we need to save ourselves. Our forests, our wetlands and our oceans absorb carbon from the atmosphere. They are vital to keeping 1.5 alive or pulling us back if we do overshoot that limit. We must protect them.

And we have the technologies we need to slash emissions. Renewables are booming as costs plummet and Governments realize the benefits of cleaner air, good jobs, energy security and increased access to power. Onshore wind and solar are the cheapest source of new electricity in most of the world — and have been for years.

Renewables already make up 30 per cent of the world's electricity supply. And clean energy investments reached a record high last year — almost doubling in the last 10 [years]. Wind and solar are now growing faster than any electricity source in history.

Economic logic makes the end of the fossil fuel age inevitable. The only questions are: Will that end come in time? And will the transition be just? We must ensure the answer to both questions is: yes. And we must secure the safest possible future for people and planet.

That means taking urgent action, particularly over the next 18 months: to slash emissions; to protect people and nature from climate extremes; to boost climate finance; and to clamp down on the fossil fuel industry.

Let me take each element in turn.

First, huge cuts in emissions. Led by the huge emitters. The G20 countries produce 80 per cent of global emissions — they have the responsibility, and the capacity, to be out in front. Advanced G20 economies should go furthest, fastest, and show climate solidarity by providing technological and financial support to emerging G20 economies and other developing countries.

Next year, Governments must submit so-called nationally determined contributions — in other words, national climate action plans. And these will determine emissions for the coming years.

At COP28, countries agreed to align those plans with the 1.5-degree limit. These national plans must include absolute emission reduction targets for 2030 and 2035.

They must cover all sectors, all greenhouse gases and the whole economy. And they must show how countries will contribute to the global transitions essential to 1.5 degrees — putting us on a path to global net zero by 2050; to phase out fossil fuels; and to hit global milestones along the way, year after year, and decade after decade.

That includes, by 2030, contributing to cutting global production and consumption of all fossil fuels by at least 30 per cent; and making good on commitments made at COP28 — on ending deforestation, doubling energy efficiency and tripling renewables.

Every country must deliver and play their rightful part. That means that G20 leaders working in solidarity to accelerate a just global energy transition aligned with the 1.5-degree limit. They must assume their responsibilities. We need cooperation, not finger-pointing.

It means the G20 aligning their national climate action plans, their energy strategies and their plans for fossil fuel production and consumption, within a 1.5-degree future. It means the G20 pledging to reallocate subsidies from fossil fuels to renewables, storage and grid modernization, and support for vulnerable communities.

It means the G7 and other Organisation for Economic Cooperation and Development (OECD) countries committing to end coal by 2030 and to create fossil-fuel-free power systems and reduce oil and gas supply and demand by 60 per cent — by 2035. It means all countries ending new coal projects — now. Particularly in Asia, home to 95 per cent of planned new coal power capacity.

It means non-OECD countries creating climate action plans to put them on a path to ending coal power by 2040. And it means developing countries creating national climate action plans that double as investment plans, spurring sustainable development and meeting soaring energy demand with renewables.

The United Nations is mobilizing our entire system to help developing countries to achieve this through our Climate Promise initiative.

Every city, region, industry, financial institution and company must also be part of the solution. They must present robust transition plans by COP30 next year in Brazil — at the latest: plans aligned with 1.5 degrees and the recommendations of the UN High-Level Expert Group on Net Zero.

Plans that cover emissions across the entire value chain; that include interim targets and transparent verification processes; and that steer clear of the dubious carbon offsets that erode public trust while doing little or nothing to help the climate.

We can't fool nature. False solutions will backfire. We need high-integrity carbon markets that are credible and with rules consistent with limiting warming to 1.5 degrees.

I also encourage scientists and engineers to focus urgently on carbon dioxide removal and storage — to deal safely and sustainably with final emissions from the heavy industries hardest to clean. And I urge Governments to support them.

But let me be clear: These technologies are not a silver bullet; they cannot be a substitute for drastic emissions cuts or an excuse to delay fossil fuel phase-out. But we need to act on every front.

The second area for action is ramping up protection from the climate chaos of today and tomorrow. It is a disgrace that the most vulnerable are being left stranded, struggling desperately to deal with a climate crisis they did nothing to create. We cannot accept a future where the rich are protected in air-conditioned bubbles, while the rest of humanity is lashed by lethal weather in unliveable lands.

We must safeguard people and economies. Every person on Earth must be protected by an early warning system by 2027. I urge all partners to boost support for the United Nations Early Warnings for All action plan.

In April, the G7 launched the Adaptation Accelerator Hub. By COP29, this initiative must be translated into concrete action — to support developing countries in creating adaptation investment plans and putting them into practice. And I urge all countries to set out their adaptation and investment needs clearly in their new national climate plans.

But change on the ground depends on money on the table. For every dollar needed to adapt to extreme weather, only about five cents is available. As a first step, all developed countries must honour their commitment to double adaptation finance to at least $40 billion a year by 2025. And they must set out a clear plan to close the adaptation finance gap by COP29 in November.

But we also need more fundamental reform. That leads me onto my third point: finance.

If money makes the world go round, today's unequal financial flows are sending us spinning towards disaster. The global financial system must be part of the climate solution. Eye-watering debt repayments are drying up funds for climate action. Extortion-level capital costs are putting renewables virtually out of reach for most developing and emerging economies.

Astoundingly — and despite the renewables boom of recent years — clean energy investments in developing and emerging economies outside of China have been stuck at the same levels since 2015. Last year, just 15 per cent of new clean energy investment went to emerging markets and developing economies outside China — countries representing nearly two thirds of the world's population.

And Africa was home to less than 1 per cent of last year's renewables installations, despite its wealth of natural resources and vast renewables potential.

The International Energy Agency reports that clean energy investments in developing and emerging economies beyond China need to reach up to $1.7 trillion a year by the early 2030s. In short, we need a massive expansion of affordable public and private finance to fuel ambitious new climate plans and deliver clean, affordable energy for all.

This September's Summit of the Future is an opportunity to push reform of the international financial architecture and action on debt. I urge countries to take it. And I urge the G7 and G20 Summits to commit to using their influence within Multilateral Development Banks to make them better, bigger and bolder. And able to leverage far more private finance at reasonable cost.

Countries must make significant contributions to the new Loss and Damage Fund. And ensure that it is open for business by COP29. And they must come together to secure a strong finance outcome from COP this year — one that builds trust and confidence, catalyses the trillions needed and generates momentum for reform of the international financial architecture.

But none of this will be enough without new, innovative sources of funds. It is [high] time to put an effective price on carbon and tax the windfall profits of fossil fuel companies.

By COP29, we need early movers to go from exploring to implementing solidarity levies on sectors such as shipping, aviation and fossil fuel extraction — to help fund climate action. These should be scalable, fair and easy to collect and administer.

None of this is charity. It is enlightened self-interest. Climate finance is not a favour. It is fundamental element to a liveable future for all.

Fourth and finally, we must directly confront those in the fossil fuel industry who have shown relentless zeal for obstructing progress — over decades. Billions of dollars have been thrown at distorting the truth, deceiving the public and sowing doubt. I thank the academics and the activists, the journalists and the whistleblowers, who have exposed those tactics — often at great personal and professional risk.

I call on leaders in the fossil fuel industry to understand that if you are not in the fast lane to clean energy transformation, you are driving your business into a dead end — and taking us all with you. Last year, the oil and gas industry invested a measly 2.5 per cent of its total capital spending on clean energy.

Doubling down on fossil fuels in the twenty-first century, is like doubling down on horseshoes and carriage wheels in the nineteenth. So, to fossil fuel executives, I say: your massive profits give you the chance to lead the energy transition. Don't miss it.

Financial institutions are also critical because money talks. It must be a voice for change.

I urge financial institutions to stop bankrolling fossil fuel destruction and start investing in a global renewables revolution; to present public, credible and detailed plans to transition [funding] from fossil fuels to clean energy with clear targets for 2025 and 2030; and to disclose your climate risks — both physical and transitional — to your shareholders and regulators. Ultimately, such disclosure should be mandatory.

Many in the fossil fuel industry have shamelessly greenwashed, even as they have sought to delay climate action — with lobbying, legal threats and massive ad campaigns. They have been aided and abetted by advertising and PR companies – *Mad Men*, remember the TV series — fuelling the madness.

I call on these companies to stop acting as enablers to planetary destruction. Stop taking on new fossil fuel clients, from today, and set out plans to drop your existing ones. Fossil fuels are not only poisoning our planet — they're toxic for your brand. Your sector is full of creative minds who are already mobilizing around this cause. They are gravitating towards companies that are fighting for our planet — not trashing it.

I also call on countries to act. Many Governments restrict or prohibit advertising for products that harm human health — like tobacco. Some are now doing the same with fossil fuels. I urge every country to ban advertising from fossil fuel companies. And I urge news media and tech companies to stop taking fossil fuel advertising.

We must all deal also with the demand side. All of us can make a difference, by embracing clean technologies, phasing down fossil fuels in our own lives and using our power as citizens to push for systemic change.

In the fight for a liveable future, people everywhere are far ahead of politicians. Make your voices heard and your choices count.

We do have a choice. Creating tipping points for climate progress or careening to tipping points for climate disaster. No country can solve the climate crisis in isolation. This is an all-in moment. The United Nations is all-in — working to build trust, find solutions and inspire the cooperation our world so desperately needs.

And to young people, to civil society, to cities, regions, businesses and others who have been leading the charge towards a safer, cleaner world, I say: Thank you. You are on the right side of history. You speak for the majority. Keep it up. Don't lose courage. Don't lose hope.

It is We the Peoples versus the polluters and the profiteers. Together, we can win. But it's time for leaders to decide whose side they're on. Tomorrow it will be too late. Now is the time to mobilize, now is the time to act, now is the time to deliver. This is our moment of truth.

Environmental issues and sustainable development

For information media. Not an official record.

Annex 581

“About”, *Notre Dame Global Adaptation Initiative*

Notre Dame Global Adaptation Initiative

About

There's a growing, global movement to make human communities and ecosystems more resilient to climate extreme impacts. For the Notre Dame Global Adaptation Initiative (ND-GAIN), it's a movement rooted in the power of data, grounded in science-based evidence and driven by a mission of "Science Serving Society."

A program within the Notre Dame Environmental Change Initiative [link:http://eci.nd.edu] , ND-GAIN works to enhance the world's understanding of adaptation through knowledge, products and services that inform public and private actions, and investments in vulnerable communities.

> Adjustment to the changing climate that minimize negative impacts on humans and on built and natural systems is called **"adaptation"**

Corporations, governments and civil societies adapt by addressing resource constraints, inadequate infrastructure, droughts, superstorms, migration, fire, civil conflicts and other global challenges that are exacerbated by the changing climate.

Adaptation involves both mitigating risk and exploring opportunities. ND-GAIN's annual Country Index [link:/our-work/country-index/] and new Urban Adaptation Assessment [link:/our-work/urban-adaptation/] serve as novel platforms to enable leaders to make informed decisions across critical environmental, economic and social sectors.

Researchers at Notre Dame have calculated that people living in the least developed countries have 10 times more chance of being affected by a climate disaster than those in wealthy countries each year. ND-GAIN data show it will take over 100 years for lower income countries to reach the resiliency [link:/admin/news/80915] of richer countries.

Through various research [link:/our-work/] initiatives, the ND-GAIN team aims to motivate communities to build social, physical and natural systems that save lives and improve livelihoods, protect our environment, and strengthen market and policy positions.

The Notre Dame Global Adaptation Initiative is a part of Notre Dame Research [link:http://research.nd.edu] .

Notre Dame Global Adaptation Initiative
721 Flanner Hall, Notre Dame, IN 46556 USA

Annex 582

“Credit ratings”, The World Factbook, *Central Intelligence Agency*

Field Listing Credit ratings

This entry provides the current bond ratings for a country or territory from each of the three major credit bureaus (Fitch, Moody's, and Standard & Poors). Rating factors include the current account balance, debt payment history and timeliness, banking and financial operations, future economic outlook, and national economic strength. These three credit agencies constitute more than 95% of the credit evaluation market globally and are the primary sovereign debt ratings considered by international and regional finance institutions.

Albania

Moody's rating: B1 (2021)

Standard & Poors rating: B+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Algeria

note: The year refers to the year in which the current credit rating was first obtained.

Andorra

Fitch rating: A- (2022)

Moody's rating: Baa2 (2022)

Standard & Poors rating: BBB+ (2023)

note: The year refers to the year in which the current credit rating was first obtained.

Angola

Fitch rating: CCC (2020)

Moody's rating: Caa1 (2020)

Standard & Poors rating: CCC+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Argentina

Fitch rating: CCC (2020)

Moody's rating: Ca (2020)

Standard & Poors rating: CCC+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Armenia

Fitch rating: B+ (2020)

Moody's rating: Ba3 (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Aruba

Fitch rating: BB (2020)

Standard & Poors rating: BBB+ (2013)

note: The year refers to the year in which the current credit rating was first obtained.

Australia

Fitch rating: AAA (2011)

Moody's rating: Aaa (2002)

Standard & Poors rating: AAA (2003)

note: The year refers to the year in which the current credit rating was first obtained.

Austria

Fitch rating: AA+ (2015)

Moody's rating: Aa1 (2016)

Standard & Poors rating: AA+ (2012)

note: The year refers to the year in which the current credit rating was first obtained.

Azerbaijan

Fitch rating: BB+ (2016)

Moody's rating: Ba2 (2017)

Standard & Poors rating: BB+ (2016)

note: The year refers to the year in which the current credit rating was first obtained.

Bahamas, The

Moody's rating: Ba2 (2020)

Standard & Poors rating: BB- (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Bahrain

Fitch rating: B+ (2020)

Moody's rating: B2 (2018)

Standard & Poors rating: B+ (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Bangladesh

Fitch rating: BB- (2014)

Moody's rating: Ba3 (2012)

Standard & Poors rating: BB- (2010)

note: The year refers to the year in which the current credit rating was first obtained.

Barbados

Moody's rating: Caa1 (2019)

Standard & Poors rating: B- (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Belarus

Fitch rating: B (2018)

Moody's rating: B3 (2018)

Standard & Poors rating: B (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Belgium

Fitch rating: AA- (2016)

Moody's rating: Aa3 (2011)

Standard & Poors rating: AA (2011)

note: The year refers to the year in which the current credit rating was first obtained.

Belize

Moody's rating: Caa3 (2020)

Standard & Poors rating: CCC+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Benin

Fitch rating: B (2019)

Moody's rating: B2 (2019)

Standard & Poors rating: B+ (2018)

note: The year refers to the year in which the current credit rating was first obtained.

Bermuda

Fitch rating: N/A (2015)

Moody's rating: A2 (2016)

Standard & Poors rating: A+ (2015)

note: The year refers to the year in which the current credit rating was first obtained.

Bolivia

Fitch rating: B (2020)

Moody's rating: B2 (2020)

Standard & Poors rating: B+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Bosnia and Herzegovina

Moody's rating: B3 (2012)

Standard & Poors rating: B (2011)

note: The year refers to the year in which the current credit rating was first obtained.

Botswana

Moody's rating: A2 (2020)

Standard & Poors rating: BBB+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Brazil

Fitch rating: BB (2023)

Moody's rating: Ba2 (2016)

Standard & Poors rating: BB- (2018)

note: The year refers to the year in which the current credit rating was first obtained.

Bulgaria

Fitch rating: BBB (2017)

Moody's rating: Baa1 (2020)

Standard & Poors rating: BBB (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Burkina Faso

Standard & Poors rating: B (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Cabo Verde

Fitch rating: B- (2020)

Standard & Poors rating: B (2013)

note: The year refers to the year in which the current credit rating was first obtained.

Cambodia

Moody's rating: B2 (2007)

Standard & Poors rating: N/A (2014)

note: The year refers to the year in which the current credit rating was first obtained.

Cameroon

Fitch rating: B (2006)

Moody's rating: B2 (2016)

Standard & Poors rating: B- (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Canada

Fitch rating: AA+ (2020)

Moody's rating: Aaa (2002)

Standard & Poors rating: AAA (2002)

note: The year refers to the year in which the current credit rating was first obtained.

Cayman Islands

Moody's rating: Aa3 (1997)

note: The year refers to the year in which the current credit rating was first obtained.

Chile

Fitch rating: A- (2020)

Moody's rating: A1 (2018)

Standard & Poors rating: A+ (2017)

note: The year refers to the year in which the current credit rating was first obtained.

China

Fitch rating: A+ (2007)

Moody's rating: A1 (2017)

Standard & Poors rating: A+ (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Colombia

Fitch rating: BBB- (2020)

Moody's rating: Baa2 (2014)

Standard & Poors rating: BBB- (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Congo, Democratic Republic of the

Moody's rating: Caa1 (2019)

Standard & Poors rating: CCC+ (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Congo, Republic of the

Fitch rating: CCC (2019)

Moody's rating: Caa2 (2018)

Standard & Poors rating: CCC+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Costa Rica

Fitch rating: B (2020)

Moody's rating: B2 (2020)

Standard & Poors rating: B (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Cote d'Ivoire

Fitch rating: B+ (2015)

Moody's rating: Ba3 (2015)

note: The year refers to the year in which the current credit rating was first obtained.

Croatia

Fitch rating: BBB- (2019)

Moody's rating: Ba1 (2020)

Standard & Poors rating: BBB- (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Cuba

Moody's rating: Caa2 (2014)

note: The year refers to the year in which the current credit rating was first obtained.

Cyprus

Fitch rating: BBB- (2018)

Moody's rating: Ba2 (2018)

Standard & Poors rating: BBB- (2018)

note: The year refers to the year in which the current credit rating was first obtained.

Czechia

Fitch rating: AA- (2018)

Moody's rating: Aa3 (2019)

Standard & Poors rating: AA- (2011)

note: The year refers to the year in which the current credit rating was first obtained.

Denmark

Fitch rating: AAA (2003)

Moody's rating: Aaa (1999)

Standard & Poors rating: AAA (2001)

note: The year refers to the year in which the current credit rating was first obtained.

Dominican Republic

Fitch rating: BB- (2016)

Moody's rating: Ba3 (2017)

Standard & Poors rating: BB- (2015)

note: The year refers to the year in which the current credit rating was first obtained.

Ecuador

Fitch rating: B- (2020)

Moody's rating: Caa3 (2020)

Standard & Poors rating: B- (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Egypt

Fitch rating: B+ (2019)

Moody's rating: B2 (2019)

Standard & Poors rating: B (2018)

note: The year refers to the year in which the current credit rating was first obtained.

El Salvador

Fitch rating: B- (2017)

Moody's rating: B3 (2018)

Standard & Poors rating: B- (2018)

note: The year refers to the year in which the current credit rating was first obtained.

Estonia

Fitch rating: AA- (2018)

Moody's rating: A1 (2002)

Standard & Poors rating: AA- (2011)

note: The year refers to the year in which the current credit rating was first obtained.

Eswatini

Moody's rating: B3 (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Ethiopia

Fitch rating: B (2014)

Moody's rating: B2 (2020)

Standard & Poors rating: B (2014)

note: The year refers to the year in which the current credit rating was first obtained.

European Union

Fitch rating: AAA (2010)

Moody's rating: Aaa (2014)

Standard & Poors rating: AA (2016)

note: The year refers to the year in which the current credit rating was first obtained.

Fiji

Moody's rating: Ba3 (2017)

Standard & Poors rating: BB- (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Finland

Fitch rating: AA+ (2016)

Moody's rating: Aa1 (2016)

Standard & Poors rating: AA+ (2014)

note: The year refers to the year in which the current credit rating was first obtained.

France

Fitch rating: AA (2014)

Moody's rating: Aa2 (2015)

Standard & Poors rating: AA (2013)

note: The year refers to the year in which the current credit rating was first obtained.

Gabon

Fitch rating: CCC (2020)

Moody's rating: Caa1 (2018)

Standard & Poors rating: N/A (2016)

note: The year refers to the year in which the current credit rating was first obtained.

Georgia

Fitch rating: BB (2019)

Moody's rating: Ba2 (2017)

Standard & Poors rating: BB (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Germany

Fitch rating: AAA (1994)

Moody's rating: Aaa (1986)

Standard & Poors rating: AAA (1983)

note: The year refers to the year in which the current credit rating was first obtained. Credit ratings prior to 1989 refer to West Germany.

Ghana

Fitch rating: B (2013)

Moody's rating: B3 (2015)

Standard & Poors rating: B- (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Greece

Fitch rating: BB (2020)

Moody's rating: Ba3 (2020)

Standard & Poors rating: BB- (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Grenada

Standard & Poors rating: SD (2013)

note: The year refers to the year in which the current credit rating was first obtained.

Guatemala

Fitch rating: BB- (2020)

Moody's rating: Ba1 (2010)

Standard & Poors rating: BB- (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Honduras

Moody's rating: B1 (2017)

Standard & Poors rating: BB- (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Hong Kong

Fitch rating: AA- (2020)

Moody's rating: Aa3 (2020)

Standard & Poors rating: AA+ (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Hungary

Fitch rating: BBB (2019)

Moody's rating: Baa3 (2016)

Standard & Poors rating: BBB (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Iceland

Fitch rating: A (2017)

Moody's rating: A2 (2019)

Standard & Poors rating: A (2017)

note: The year refers to the year in which the current credit rating was first obtained.

India

Fitch rating: BBB- (2006)

Moody's rating: Baa3 (2020)

Standard & Poors rating: BBB- (2007)

note: The year refers to the year in which the current credit rating was first obtained.

Indonesia

Fitch rating: BBB (2017)

Moody's rating: Baa2 (2018)

Standard & Poors rating: BBB (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Iraq

Fitch rating: B- (2015)

Moody's rating: Caa1 (2017)

Standard & Poors rating: B- (2015)

note: The year refers to the year in which the current credit rating was first obtained.

Ireland

Fitch rating: A+ (2017)

Moody's rating: A2 (2017)

Standard & Poors rating: AA- (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Isle of Man

Moody's rating: Aa3 (2020)

Standard & Poors rating: N/A

note: The year refers to the year in which the current credit rating was first obtained.

Israel

Fitch rating: A+ (2016)

Moody's rating: A1 (2008)

Standard & Poors rating: AA- (2018)

note: the year refers to the year in which the current credit rating was first obtained.

Italy

Fitch rating: BBB- (2020)

Moody's rating: Baa3 (2018)

Standard & Poors rating: BBB (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Jamaica

Fitch rating: B+ (2019)

Moody's rating: B2 (2019)

Standard & Poors rating: B+ (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Japan

Fitch rating: A (2015)

Moody's rating: A1 (2014)

Standard & Poors rating: A+ (2015)

note: The year refers to the year in which the current credit rating was first obtained.

Jordan

Fitch rating: BB- (2019)

Moody's rating: B1 (2013)

Standard & Poors rating: B+ (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Kazakhstan

Fitch rating: BBB (2016)

Moody's rating: Baa3 (2016)

Standard & Poors rating: BBB- (2016)

note: The year refers to the year in which the current credit rating was first obtained.

Kenya

Fitch rating: B+ (2007)

Moody's rating: B2 (2018)

Standard & Poors rating: B+ (2010)

note: The year refers to the year in which the current credit rating was first obtained.

Korea, South

Fitch rating: AA- (2012)

Moody's rating: Aa2 (2015)

Standard & Poors rating: AA (2016)

note: The year refers to the year in which the current credit rating was first obtained.

Kuwait

Fitch rating: AA (2008)

Moody's rating: A1 (2020)

Standard & Poors rating: AA- (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Kyrgyzstan

Moody's rating: B2 (2015)

Standard & Poors rating: NR (2016)

note: The year refers to the year in which the current credit rating was first obtained.

Laos

Fitch rating: CCC (2020)

Moody's rating: Caa2 (2020)

note: the year refers to the year in which the current credit rating was first obtained.

Latvia

Fitch rating: A- (2014)

Moody's rating: A3 (2015)

Standard & Poors rating: A+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Lebanon

Fitch rating: RD (2020)

Moody's rating: C (2020)

Standard & Poors rating: D (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Lesotho

Fitch rating: B (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Liechtenstein

Standard & Poors rating: AAA (1996)

note: The year refers to the year in which the current credit rating was first obtained.

Lithuania

Fitch rating: A (2020)

Moody's rating: A3 (2015)

Standard & Poors rating: A+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Luxembourg

Fitch rating: AAA (1994)

Moody's rating: Aaa (1989)

Standard & Poors rating: AAA (1994)

note: The year refers to the year in which the current credit rating was first obtained.

Macau

Fitch rating: AA (2018)

Moody's rating: Aa3 (2016)

note: The year refers to the year in which the current credit rating was first obtained.

Malaysia

Fitch rating: BBB+ (2020)

Moody's rating: A3 (2004)

Standard & Poors rating: A- (2003)

note: The year refers to the year in which the current credit rating was first obtained.

Maldives

Fitch rating: CCC (2020)

Moody's rating: B3 (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Mali

Moody's rating: Caa1 (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Malta

Fitch rating: A+ (2017)

Moody's rating: A2 (2019)

Standard & Poors rating: A- (2016)

note: The year refers to the year in which the current credit rating was first obtained.

Mauritius

Moody's rating: Baa1 (2012)

note: The year refers to the year in which the current credit rating was first obtained.

Mexico

Fitch rating: BBB- (2020)

Moody's rating: Baa1 (2020)

Standard & Poors rating: BBB (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Moldova

Moody's rating: B3 (2010)

note: The year refers to the year in which the current credit rating was first obtained.

Mongolia

Fitch rating: B (2018)

Moody's rating: B3 (2018)

Standard & Poors rating: B (2018)

note: The year refers to the year in which the current credit rating was first obtained.

Montenegro

Moody's rating: B1 (2016)

Standard & Poors rating: B+ (2014)

note: The year refers to the year in which the current credit rating was first obtained.

Montserrat

Standard & Poors rating: BBB- (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Morocco

Fitch rating: BB+ (2020)

Moody's rating: Ba1 (1999)

Standard & Poors rating: BBB- (2010)

note: The year refers to the year in which the current credit rating was first obtained.

Mozambique

Fitch rating: CCC (2019)

Moody's rating: Caa2 (2019)

Standard & Poors rating: CCC+ (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Namibia

Fitch rating: BB (2019)

Moody's rating: Ba3 (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Netherlands

Fitch rating: AAA (1994)

Moody's rating: Aaa (1986)

Standard & Poors rating: AAA (2015)

note: The year refers to the year in which the current credit rating was first obtained.

New Zealand

Fitch rating: AA (2011)

Moody's rating: Aaa (2002)

Standard & Poors rating: AA (2011)

note: The year refers to the year in which the current credit rating was first obtained.

Nicaragua

Fitch rating: B- (2018)

Moody's rating: B3 (2020)

Standard & Poors rating: B- (2018)

note: The year refers to the year in which the current credit rating was first obtained.

Niger

Moody's rating: B3 (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Nigeria

Fitch rating: B (2020)

Moody's rating: B2 (2017)

Standard & Poors rating: B- (2020)

note: The year refers to the year in which the current credit rating was first obtained.

North Macedonia

Fitch rating: BB+ (2019)

Standard & Poors rating: BB- (2013)

note: The year refers to the year in which the current credit rating was first obtained.

Norway

Fitch rating: AAA (1995)

Moody's rating: Aaa (1997)

Standard & Poors rating: AAA (1975)

note: The year refers to the year in which the current credit rating was first obtained.

Oman

Fitch rating: BB- (2020)

Moody's rating: Ba3 (2020)

Standard & Poors rating: B+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Pakistan

Fitch rating: B- (2018)

Moody's rating: B3 (2015)

Standard & Poors rating: B- (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Panama

Fitch rating: BBB (2011)

Moody's rating: Baa1 (2019)

Standard & Poors rating: BBB (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Papua New Guinea

Moody's rating: B2 (2016)

Standard & Poors rating: B- (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Paraguay

Fitch rating: BB+ (2018)

Moody's rating: Ba1 (2015)

Standard & Poors rating: BB (2014)

note: The year refers to the year in which the current credit rating was first obtained.

Peru

Fitch rating: BBB+ (2013)

Moody's rating: A3 (2014)

Standard & Poors rating: BBB+ (2013)

note: The year refers to the year in which the current credit rating was first obtained.

Philippines

Fitch rating: BBB (2017)

Moody's rating: Baa2 (2014)

Standard & Poors rating: BBB+ (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Poland

Fitch rating: A- (2007)

Moody's rating: A2 (2002)

Standard & Poors rating: A- (2018)

note: The year refers to the year in which the current credit rating was first obtained.

Portugal

Fitch rating: BBB (2007)

Moody's rating: Baa3 (2018)

Standard & Poors rating: BBB (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Puerto Rico

Standard & Poors rating: D (2015)

note: The year refers to the year in which the current credit rating was first obtained.

Qatar

Fitch rating: AA- (2017)

Moody's rating: Aa3 (2017)

Standard & Poors rating: AA- (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Romania

Fitch rating: BBB- (2011)

Moody's rating: Baa3 (2006)

Standard & Poors rating: BBB- (2014)

note: The year refers to the year in which the current credit rating was first obtained.

Russia

Fitch rating: BBB (2019)

Moody's rating: Baa3 (2019)

Standard & Poors rating: BBB- (2018)

note: The year refers to the year in which the current credit rating was first obtained.

Rwanda

Fitch rating: B+ (2014)

Moody's rating: B2 (2016)

Standard & Poors rating: B+ (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Saint Vincent and the Grenadines

Moody's rating: B3 (2014)

note: The year refers to the year in which the current credit rating was first obtained.

San Marino

Fitch rating: BB+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Saudi Arabia

Fitch rating: A (2019)

Moody's rating: A1 (2016)

Standard & Poors rating: A- (2016)

note: The year refers to the year in which the current credit rating was first obtained.

Senegal

Moody's rating: Ba3 (2017)

Standard & Poors rating: B+ (2000)

note: The year refers to the year in which the current credit rating was first obtained.

Serbia

Fitch rating: BB+ (2019)

Moody's rating: Ba3 (2017)

Standard & Poors rating: BB+ (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Seychelles

Fitch rating: B+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Singapore

Fitch rating: AAA (2003)

Moody's rating: Aaa (2002)

Standard & Poors rating: AAA (1995)

note: The year refers to the year in which the current credit rating was first obtained.

Slovakia

Fitch rating: A (2020)

Moody's rating: A2 (2012)

Standard & Poors rating: A+ (2015)

note: The year refers to the year in which the current credit rating was first obtained.

Slovenia

Fitch rating: A (2019)

Moody's rating: A3 (2020)

Standard & Poors rating: AA- (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Solomon Islands

Moody's rating: B3 (2015)

note: The year refers to the year in which the current credit rating was first obtained.

South Africa

Fitch rating: BB- (2020)

Moody's rating: Ba2 (2020)

Standard & Poors rating: BB- (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Spain

Fitch rating: A- (2018)

Moody's rating: Baa1 (2018)

Standard & Poors rating: A (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Sri Lanka

Fitch rating: CCC (2020)

Moody's rating: Caa1 (2020)

Standard & Poors rating: CCC+ (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Suriname

Fitch rating: C (2020)

Moody's rating: Caa3 (2020)

Standard & Poors rating: SD (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Sweden

Fitch rating: AAA (2004)

Moody's rating: Aaa (2002)

Standard & Poors rating: AAA (2004)

note: The year refers to the year in which the current credit rating was first obtained.

Switzerland

Fitch rating: AAA (2000)

Moody's rating: Aaa (1982)

Standard & Poors rating: AAA (1988)

note: The year refers to the year in which the current credit rating was first obtained.

Taiwan

Fitch rating: AA- (2016)

Moody's rating: Aa3 (1994)

Standard & Poors rating: AA- (2002)

note: The year refers to the year in which the current credit rating was first obtained.

Tajikistan

Moody's rating: B3 (2017)

Standard & Poors rating: B- (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Tanzania

Moody's rating: B2 (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Thailand

Fitch rating: BBB+ (2013)

Moody's rating: Baa1 (2003)

Standard & Poors rating: BBB+ (2004)

note: The year refers to the year in which the current credit rating was first obtained.

Togo

Moody's rating: B3 (2019)

Standard & Poors rating: B (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Trinidad and Tobago

Moody's rating: Ba1 (2017)

Standard & Poors rating: BBB- (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Tunisia

Fitch rating: B (2020)

Moody's rating: B2 (2018)

Standard & Poors rating: N/A (2013)

note: The year refers to the year in which the current credit rating was first obtained.

Turkey (Turkiye)

Fitch rating: BB- (2019)

Moody's rating: B2 (2020)

Standard & Poors rating: B+ (2018)

note: The year refers to the year in which the current credit rating was first obtained.

Uganda

Fitch rating: B+ (2015)

Moody's rating: B2 (2016)

Standard & Poors rating: B (2014)

note: The year refers to the year in which the current credit rating was first obtained.

Ukraine

Fitch rating: CC (2022)

Moody's rating: Ca (2023)

Standard & Poors rating: CCC (2023)

note: The year refers to the year in which the current credit rating was first obtained.

United Arab Emirates

Fitch rating: AA- (2020)

Moody's rating: Aa2 (2007)

Standard & Poors rating: AA (2007)

note: The year refers to the year in which the current credit rating was first obtained.

United Kingdom

Fitch rating: AA- (2020)

Moody's rating: Aaa (2020)

Standard & Poors rating: AA (2016)

note: The year refers to the year in which the current credit rating was first obtained.

United States

Fitch rating: AAA (1994)

Moody's rating: Aaa (1949)

Standard & Poors rating: AA+ (2011)

note: The year refers to the year in which the current credit rating was first obtained.

Uruguay

Fitch rating: BBB- (2013)

Moody's rating: Baa2 (2014)

Standard & Poors rating: BBB (2015)

note: The year refers to the year in which the current credit rating was first obtained.

Uzbekistan

Fitch rating: BB- (2018)

Moody's rating: B1 (2019)

Standard & Poors rating: BB- (2018)

note: The year refers to the year in which the current credit rating was first obtained.

Venezuela

Fitch rating: RD (2017)

Moody's rating: WR (2019)

Standard & Poors rating: SD (2017)

note: The year refers to the year in which the current credit rating was first obtained.

Vietnam

Fitch rating: BB (2018)

Moody's rating: Ba3 (2018)

Standard & Poors rating: BB (2019)

note: The year refers to the year in which the current credit rating was first obtained.

Zambia

Fitch rating: RD (2020)

Moody's rating: Ca (2020)

Standard & Poors rating: SD (2020)

note: The year refers to the year in which the current credit rating was first obtained.

Annex 583

“Barbados Credit Rating”, *Trading Economics*

Barbados Credit Rating

Standard & Poor's credit rating for Barbados stands at B- with positive outlook. Moody's credit rating for Barbados was last set at B3 with stable outlook. Fitch's credit rating for Barbados was last reported at B with positive outlook. This page provides - Barbados Credit Rating- actual values, historical data, forecast, chart, statistics, economic calendar and news.

Agency	Rating	Outlook	Date
S&P	B-	positive	Oct 26 2023
Moody's	B3	stable	Aug 03 2023
S&P	B-	stable	Jan 13 2020
S&P	B-	stable	Dec 11 2019
Moody's	Caa1	stable	Jul 03 2019
S&P	SD	n/a	Jun 06 2018
Moody's	Caa3	stable	Mar 09 2017
S&P	CCC+	negative	Mar 03 2017
S&P	B-	negative	Sep 23 2016
Moody's	Caa1	stable	Apr 04 2016
S&P	B	negative	Dec 19 2014
Moody's	B3	negative	Jun 02 2014
Moody's	Ba3	negative	Dec 20 2013
S&P	BB-	negative	Nov 20 2013
S&P	BB+	negative	Jul 18 2013
Moody's	Ba1	negative	Dec 12 2012

Barbados Credit Rating

S&P	BBB-	stable	Oct 22 2010
S&P	BBB	negative	Nov 13 2009
Moody's	Baa3	stable	Oct 13 2009
S&P	BBB	stable	Jun 10 2009
Moody's	Baa2	negative watch	May 14 2009
S&P	BBB+	negative	Apr 08 2009
S&P	BBB+	stable	Jul 26 2006
S&P	BBB+	negative	Jul 29 2005
S&P	BBB+	stable	Aug 05 2004
S&P	A-	negative	Aug 20 2003
Moody's	Baa2	stable	Feb 08 2000
S&P	A-	stable	Dec 17 1999
Moody's	Ba1	positive	Nov 10 1998
Moody's	Ba1	stable	Apr 18 1997
Moody's	Ba2	positive watch	Feb 13 1997
Moody's	Ba2	stable	Oct 05 1994

View Credit Ratings by Country

Related

Barbados Prime Lending Rate at 4.00 percent
Barbados Credit Rating at 26.00
Barbados Average Precipitation at 1504.46 mm
Barbados Average Temperature at 26.45 celsius
Barbados Tourist Arrivals at 49682.00

+

Latest

Heating Oil Drops to 7-Week Lows
Week Ahead - July 29th
Canada Government Budget Surplus Narrows in May
Baltic Dry Index Falls to 8-Week Low
Oil Heads for 3rd Straight Week of Losses
European Shares Extend Gains in Afternoon Trading
Ibovespa Hovers Flat on Friday
US Consumer Sentiment Revised Higher
US Year-Ahead Inflation Expectations Confirmed at 2.9% in July
TSX Poised for Weekly Gains

+

Barbados

Calendar
Indicators

GDP

Labour

Prices

Money

Corruption Rank
Credit Rating
Government Budget
Holidays

Consumer

Taxes

Climate

More Indicators

National Statistics
World Bank

Annex 584

“Vulture Funds in the Sovereign Debt Context”, *African Development Bank Group*

Vulture Funds in the Sovereign Debt Context

ALSF
African Legal Support Facility
Facilité africaine de soutien juridique

A secondary market for debt is a fundamental feature of sovereign borrowing and lending. When creditors can freely sell the debt they hold on the secondary market, there is less risk involved in lending to sovereigns, and creditors are therefore more likely to provide the capital sovereigns need.

In recent decades, as the secondary market for debt has developed, new players have arisen, leading some to question whether the "tradable debt model" for sovereign debt is appropriate. One set of such players is called "vulture funds" - the term given to entities that purchase distressed debt on the secondary market, where it trades significantly below its face value, and then seek to recover the full amount, often through litigation. These intransigent creditors are able to litigate because most debt relief initiatives such as that for HIPCs do not alter the legal rights and obligations between HIPCs and their external creditors. Accordingly, until the HIPC debtors and their creditors reach bilateral legal agreements in line with the HIPC initiative, creditors are legally entitled to use available legal mechanisms to enforce their credit claims against HIPCs. In some instances, prior to decision point some HIPCs have paid commercial creditors in full either because of the litigation or the threat of litigation, a desire to avoid disrupting a commercial relationship, or the fear of losing productive assets in cases where commercial debt was secured by collateral.

Vulture funds buy debt often at deep discounts with the intent of suing the debtor for full recovery. Vulture funds have averaged recovery rates of about 3 to 20 times their investment, equivalent to returns of (net legal fees) 300%-2000%. The vulture fund modus operandi is simple: purchase distressed debt at deep discounts, refuse to participate in restructuring, and pursue full value of the debt often at face value plus interest, arrears and penalties through litigation, if necessary. The vulture funds grind down poor countries in cycles of litigation, a practice referred to as "champerty" and largely unknown in African legal systems. Litigation is typically protracted with many lawsuits taking three to ten years to "settle." Legal documents indicate six years as a conservative medium estimate for recovery, which suggests that annualized returns average 50 to 333 percent. Some of these claims were bought at roughly 10 percent of face value, implying very high gross recovery rates. Subtracting legal costs, often recouped from the sovereign, these recovery rates are probably the highest in the distressed debt market.

A willingness and ability to pursue litigation appears central to the strategy and success of the vulture funds. In one recent case against Zambia, a vulture fund, having bought a debt for US$3 million, sued Zambia for US$55 million and was awarded US$ 15.5 million. The vulture funds exert pressure on the sovereign debtor by attempting to obtain attachment of the government's assets abroad. Such proceedings are always burdensome to the debtors concerned, and can complicate financial and reserve management. By precluding debt relief and costing millions in legal expenses, these vulture funds undermine the development of the most vulnerable RMCs.

The IMF reports the amounts claimed by Vulture Funds represent a significant portion of the relevant national gross domestic product (GDP). The IMF reports that eleven HIPCs have been targeted so far in forty-six lawsuits and that the litigators (plaintiffs) are concentrated in three countries. The lawsuits are concentrated in only a few courts. Some lawsuits are reportedly also in HIPCs.

Generally, these vulture funds have won their lawsuits. Twenty-five judgments in favour of vulture funds so far have yielded nearly US$1 billion. Out of this amount 72% of the judgments have been against RMCs. Significantly, the reported number of outstanding cases against debtor countries has doubled since 2004. On average eight new cases are filed each year. This figure includes lawsuits filed in year 2006 and part of 2007. It is anticipated that the success rate of past litigation would generate even more lawsuits against HIPCs. At least three RMCs namely Liberia, Cote d'Ivoire, and Sudan have large commercial creditor claims that are likely to be raised against these countries, although it is not yet clear who holds the various claims.

Litigation is costly for these debtor countries and distracts financial and other authorities from important policy issues. These lawsuits threaten the core objectives of the HIPC initiative. The lawsuits effectively reduce the impact of the debt relief for the HIPCs and cause inequitable burden sharing among creditors. The IMF foresees a risk of taxpayer backlash in the affected creditor countries when taxpayers realize the amount of their taxes being used to pay claims from vulture funds. The vulture fund problem is encouraging opaque financial management, as HIPCs devise ways to shield or hide assets from aggressive creditors.

The central criticism of the vulture funds is that, by purchasing distressed debt at discounted rates, refusing to participate in voluntary restructurings, and seeking to recover the full value of the debt through litigation, vulture funds are preying on both other creditors and on the indebted countries themselves. Countries whose debt is trading at deep discounts are almost by definition in deep financial trouble and many of them are poor. Holdout behaviour by vulture funds makes restructuring slower, more difficult, and uncertain. Debtors are harmed by the substantial uncertainty faced and also by being forced to repay individual creditors far more than the agreements negotiated with other creditors.

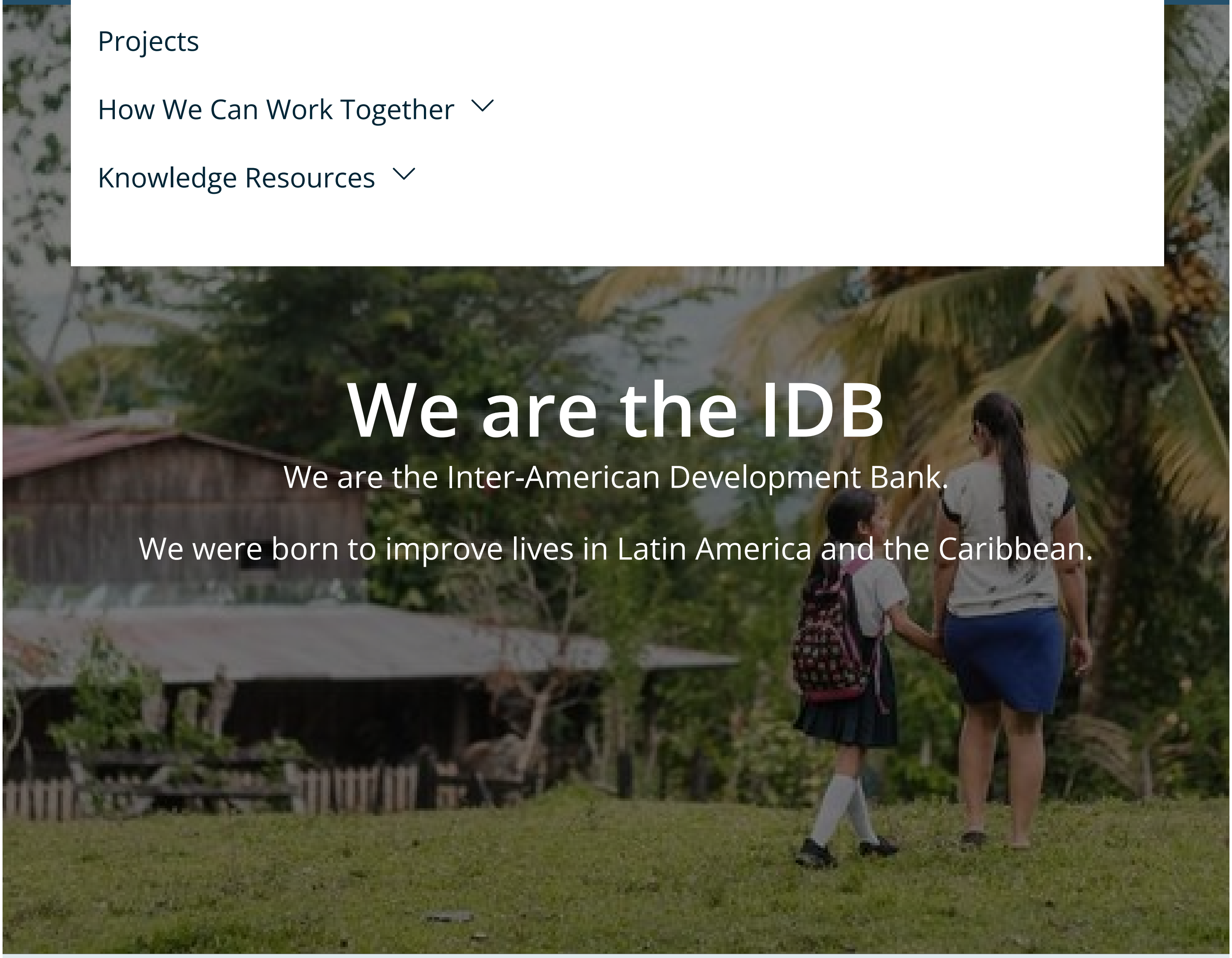
At least twenty heavily indebted poor countries have been threatened with or have been subjected to legal actions by commercial creditors and vulture funds since 1999 including Sierra Leone by Greganti Secondo and ARCADE, and by Industrie Biscoti against **Cote d'Ivoire** and **Burkina Faso**. Other RMCs that have been targeted include **Angola**, **Cameroon**, **Congo**, Democratic Republic of the Congo, Ethiopia, Liberia, Madagascar, Mozambique, Niger, Sao Tome and Principe, Tanzania, and Uganda.

A joint IMF and World Bank study has observed that although in many cases debtors have not made payments on court judgments obtained by creditors, in some cases debtors have made payments in excess of HIPC parameters. The study further observed that pending litigation and outstanding court judgments may also inhibit HIPCs from regularizing financial relationships with the international banking community. The World Bank estimates that more than one-third of the countries which have qualified for its debt relief have been targeted with lawsuits by at least 38 litigating creditors with judgments totalling $1 billion in 26 of these cases.

The Paris Club has expressed concern with vulture fund litigation. Taking stock of the harmful consequences of litigation for HIPC countries and consistent with the Paris Club principle of comparability of treatment, in May 2007 the Paris Club resolved to avoid the sale of their claims on HIPCs to other creditors who do not intend to provide debt relief under the HIPC initiative. The Paris Club urges other creditors to follow suit. In cooperation with relevant international institutions, the Paris Club creditors agreed to intensify their work on this issue with a view to identifying concrete measures to tackle this problem. In a Pre-summit statement issued in Essen, Germany on 19 May, 2007, the G-8 Finance Ministers expressed concern about actions of some litigating creditors against HIPCs and agreed to work together to identify measures to tackle this problem based on the work of the Paris Club. On 12 December 2007, the G-7 Debt Experts invited the IMF, the World Bank and the Bank to a meeting in Paris chaired by the Secretary General of the Paris Club to discuss the impact of vulture funds on debt relief and measures that could be employed to minimize the adverse affect on economic development of HIPCs.

Annex 585

"About the IDB", *Inter-American Development Bank*

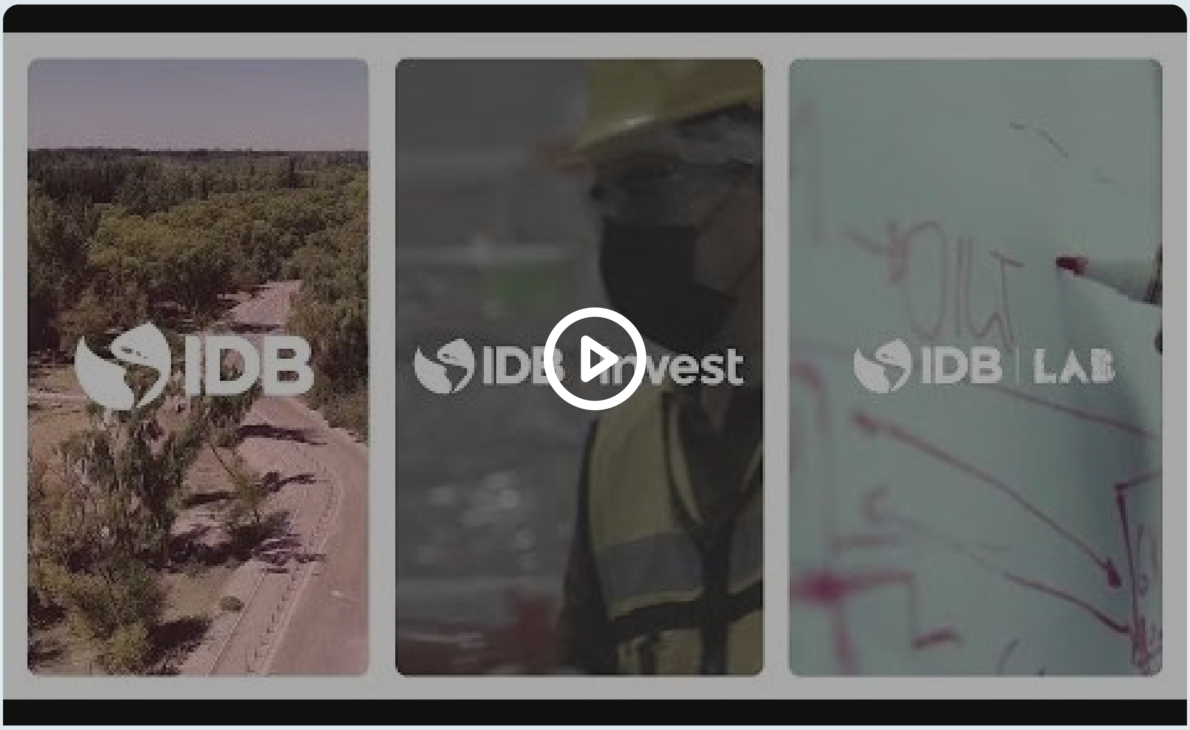


We are the IDB

We are the Inter-American Development Bank.

We were born to improve lives in Latin America and the Caribbean.

We are the main source of development financing for Latin America and the Caribbean.

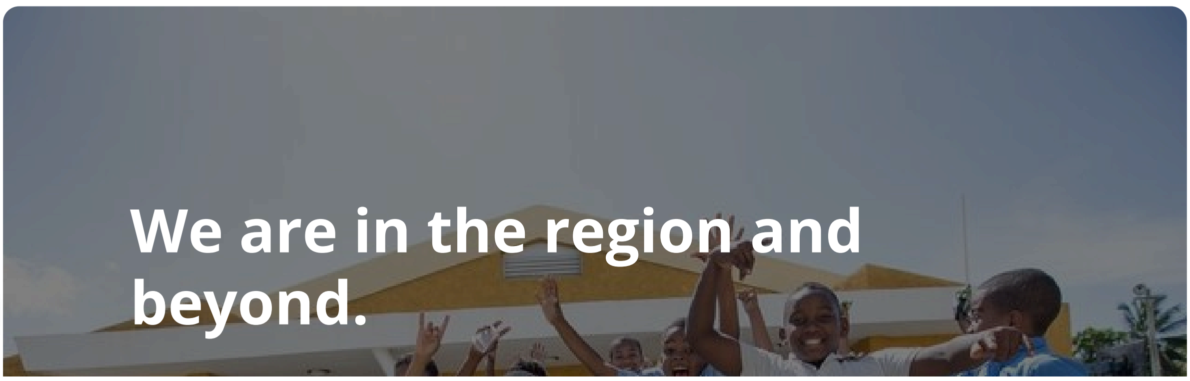


With a history of results dating to 1959, we work to improve the quality of life of millions of people in our 26 borrowing countries. We have 48 member countries.

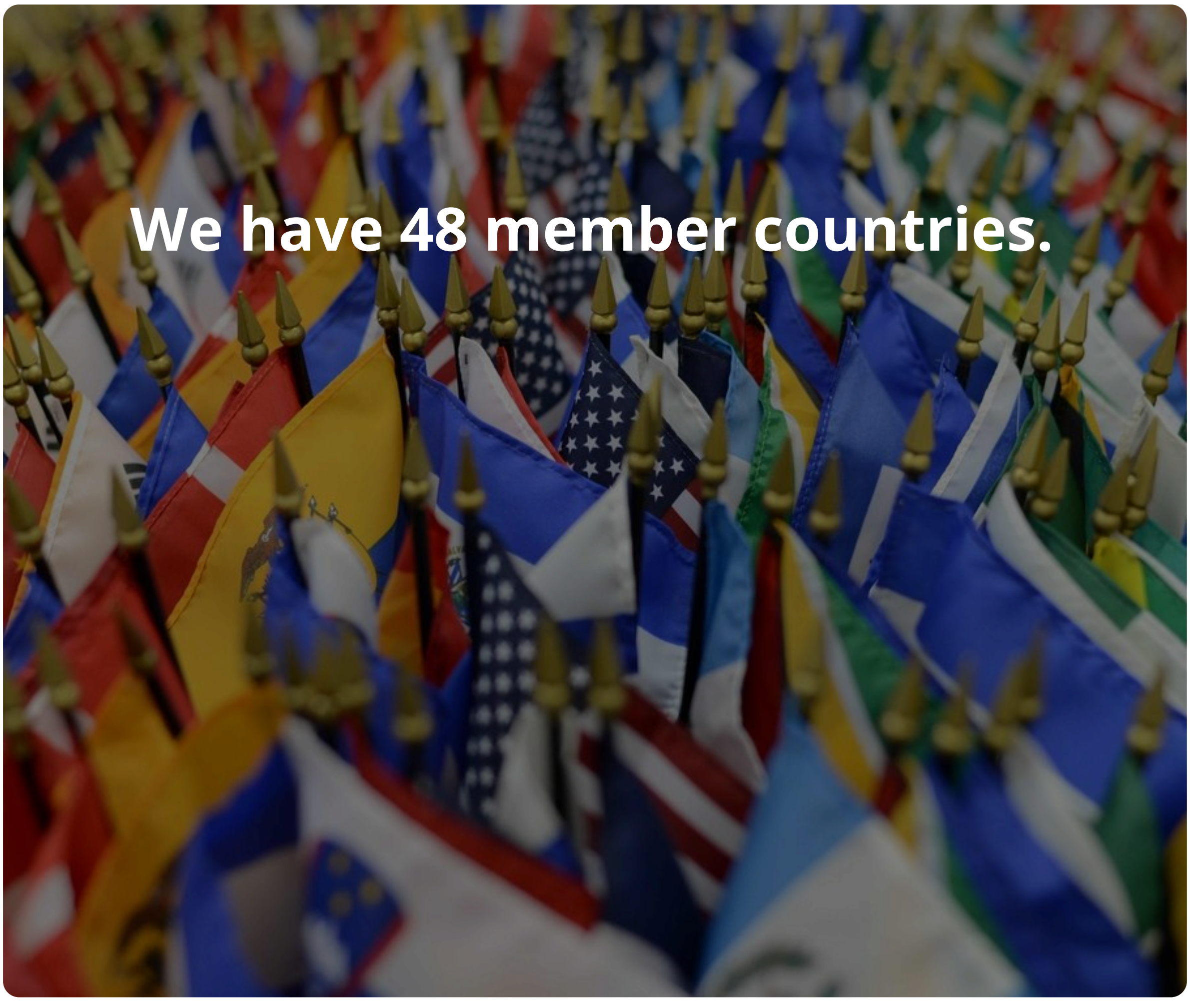
We provide financial and technical support to national and sub-national governments and other entities in the region and conduct cutting-edge research. That is how we drive progress in health, education, infrastructure, climate action and diversity, among other fundamental issues, to reduce poverty and improve lives in our region.

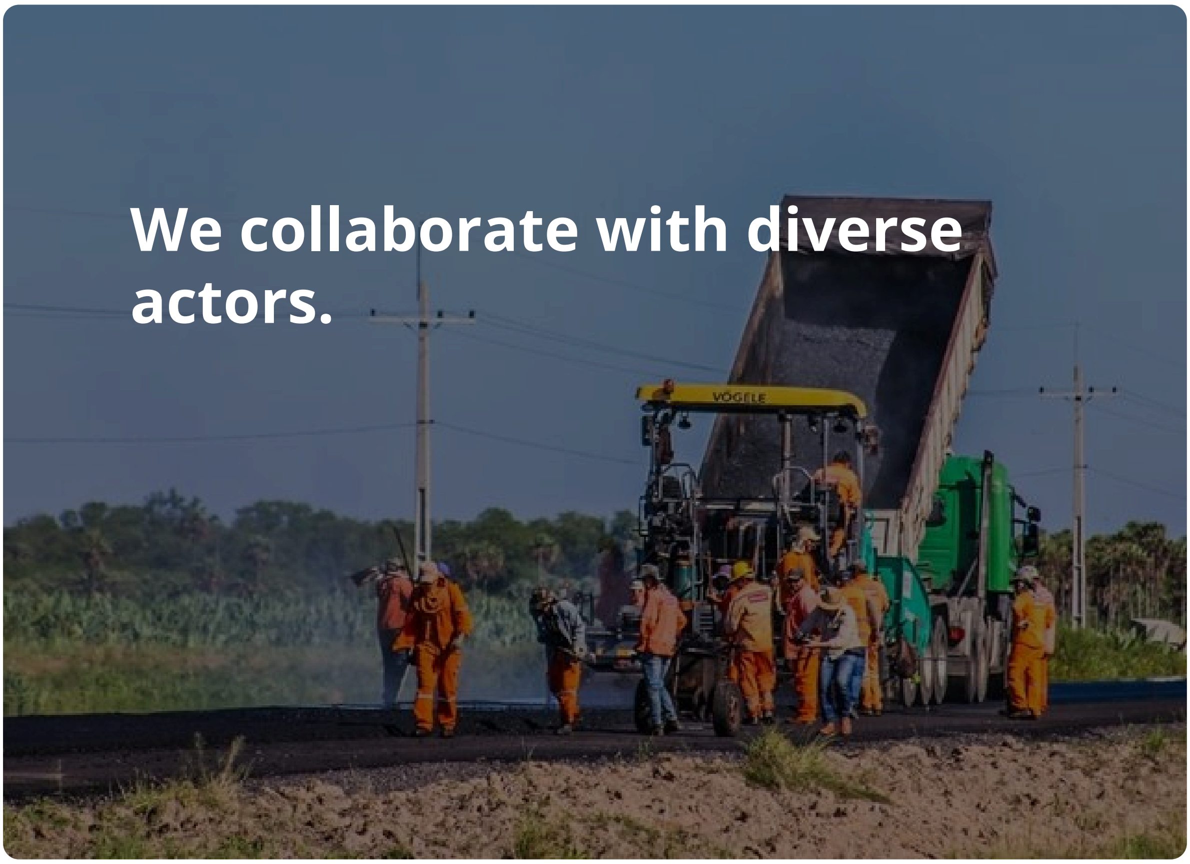
Working with our member countries, our goal is sustainable and inclusive development in the region.

The IDB in 4 Key Facts




We financed and mobilized $13.5 billion in 2023. The IDB Group total was nearly $24.3 billion.


We have 48 member countries.


We collaborate with diverse actors.
VÖGELE

Annex 586

“Risks and Opportunities From the Changing Climate – Playbook for the Truly Long-Term Investor”, *Cambridge Associates*, 2015

Risks and Opportunities From the Changing Climate

Playbook for the Truly Long-Term Investor

2015

CAMBRIDGE C|A ASSOCIATES

Risks and Opportunities From the Changing Climate

Playbook for the Truly Long-Term Investor

2015

Liqian Ma

CAMBRIDGE C|A ASSOCIATES

Other contributors to this report include Michael Brand, Christine Cheong, Brendan Cosgrove, Sara Kwasny, Noelle Laing, Kristine Leary, Jessica Matthews, Tom Mitchell, Alexandra Readey, TJ Scavone, David Sternlicht, David Thurston, and Philip Walton.

C | A

- **Considering climate factors is an economic risk management and opportunity capitalization issue core to prudent investing for the long term.** As a possible systemic driver of more frequent and/or severe weather events over the coming decades, climate change—defined as the long-term evolution of global and regional weather patterns driven by the rising level of greenhouse gas emissions—has the potential to materially impact businesses, economic assets, and communities. Potential impacts include direct effects on real property and supply chains, economic consequences from policy and regulatory responses to climate change, and/or indirect effects on financial markets at a global scale through the heightening of broader uncertainty and risk aversion.
- As part of incorporating climate risk into long-term investment decision-making, investors should consider whether and how to stay ahead of the climate risk curve to preserve value in their portfolios ("defense"), as well as whether and how to position themselves to capitalize on investment opportunities arising from technological advances, business model innovations, and policy evolution ("offense"). For many, the first step is not necessarily making immediate portfolio changes, but rather asking key questions to establish guideposts today to arrive at better decisions tomorrow.
- Given the interconnected and systemic nature of climate risks, investors will find it difficult to predict and precisely manage every potential impact on portfolios. However, we have identified four approaches investors can take to better understand and manage these risks: (1) engagement through delegation to managers, asking them to consider incorporating climate risks; (2) engagement through advocating for more transparency and reporting on climate risk metrics, while overlaying a climate risk lens to the due diligence and monitoring process; (3) proactive hedging via low-carbon index products, derivatives, or use of active managers that employ environmental, social, and governance (ESG) metrics; and (4) policy-level exclusion of fossil fuel and other sectors. Not all these themes are appropriate for all investors, and some will pursue none or only a few of them. But considering the options will enable long-term investors concerned about climate risks to craft their own strategy reflecting their views and objectives.
- Beyond defense, investors should consider proactive, solution-oriented strategies to capitalize on investment opportunities linked to climate change. Our basic thesis is that the more challenging the problem, the greater the opportunity set for innovations, solutions, and, ultimately, attractive investment returns. We identify five current themes: renewable infrastructure, clean transportation, smart energy, energy efficiency in buildings, and water and agricultural efficiency. Attractive

C|A

risk/return profiles exist in select areas within the broader "resource efficiency" arena. The themes discussed and the various approaches to access them are neither all-inclusive nor static, as new themes can emerge and existing themes can evolve over time. The objective for truly long-term investors is not only to identify and evaluate the available and accessible investment opportunities today, but also to uncover and capitalize on the opportunities that will present themselves in the future.

- Both strong defense and offense are important to manage risks and capitalize on opportunities associated with climate change. Long-term investors would benefit from properly integrating defense and offense into a cohesive investment strategy aligned with their own views and motivations.
- We continue to seek and refine effective approaches to understand and manage risks amplified by climate change, and search for positive returns from capturing the value created by businesses and assets that play a role in the world's gradual transition to a lower-carbon and more resource-efficient economy. These opportunities are and will continue to be driven by a combination of technological and business model innovations, policy and regulatory shifts, and, perhaps more fundamentally, the human entrepreneurial spirit that is drawn to creating real solutions to large problems. ■

Risks and Opportunities From the Changing Climate: Playbook for the Truly Long-Term Investor

The uncertain and changing climate poses serious challenges to investors making decisions for the very long term. As a possible systemic driver of more frequent and/or severe weather events over the coming decades, climate change—defined as the long-term evolution of global and regional weather patterns driven by the rising level of greenhouse gas emissions—has the potential to materially impact businesses, economic assets, and communities. Potential impacts include direct effects on real property and supply chains, economic consequences from policy and regulatory responses to climate change, and/or indirect effects on financial markets at a global scale through the heightening of broader uncertainty and risk aversion.

Yet precisely predicting every aspect of the *when*, the *where*, and the *how* of climate change impact is guaranteed to be inaccurate. While one might categorize climate change as a "tail risk," traditionally defined as a low probability event with large magnitude consequences, perhaps it is more appropriate to categorize climate change as an uncertain-probability event with uncertain timing and magnitude of consequences. This multi-dimensional uncertainty, coupled with the difficulty of empirically isolating and measuring climate-induced losses, creates a unique type of risk management challenge for investors. That said, long-term investors would benefit from recognizing and integrating climate change as a real economic factor in positioning portfolios for the future. *Fundamentally, considering climate factors is an economic risk management and opportunity capitalization issue core to prudent investing for the long term.*

C | A

For investors seeking to manage their assets in perpetuity, a long-term perspective is critical. Yet despite many investors' stated long-term time horizon, actual time horizons for investment risk/return evaluation and decision-making are largely skewed to the near term. For truly long-term investors, integrating a more comprehensive set of risk factors and opportunity sets into investment decision-making is a sensible and necessary approach. As part of incorporating climate risk into long-term investment decision-making, investors should consider whether and how to stay ahead of the climate risk curve to preserve value in their portfolios ("defense"), as well as whether and how to position themselves to capitalize on investment opportunities arising from technological advances, business model innovations, and policy evolution ("offense"). Effectively integrating both defense and offense into a cohesive investment strategy is important. For many, the first step is not necessarily making immediate portfolio changes, but rather asking key questions to establish guideposts today to arrive at better decisions tomorrow.

As with any other risk factor (central bank policy and interest rates, inflation, deflation, unemployment, corporate earnings, etc.), not all risks are created equal. Indeed, different investors will weigh climate risk differently as they assess the future investment landscape, depending on their view of the materiality and urgency of the risk. Some will likely assign climate risk a zero or near-zero weighting in their risk models today, discounting risks related to climate change as a non-issue for their investment portfolios. Others will likely assign a higher weighting if they view the economic impacts of climate change as more immediate and/or severe, and seek to establish the guideposts that will allow them to position their portfolios accordingly. Recognizing the wide range of perspectives, we aim to provide a working "playbook" for investors to customize their climate risk management approach.

In *Part I: Risks and the Playbook for Defense*, we discuss the potential risks that climate change can inflict upon certain sectors and asset classes and outline corresponding strategies to defend against those risks. In *Part II: Opportunities and the Playbook for Offense*, we review the thematic areas across public and private asset classes to proactively capitalize on the evolving opportunity set within the "resource efficiency" sector. While we are framing the discussion into these two broad categories for the sake of simplicity, we recognize that underlying investment approaches and themes lie along a continuum where lines of separation between "defense" and "offense" are blurred. The key for long-term investors is to develop a cohesive and customized strategy that fits their beliefs, motivations, and governance structures.

Part I: Risks and the Playbook for Defense

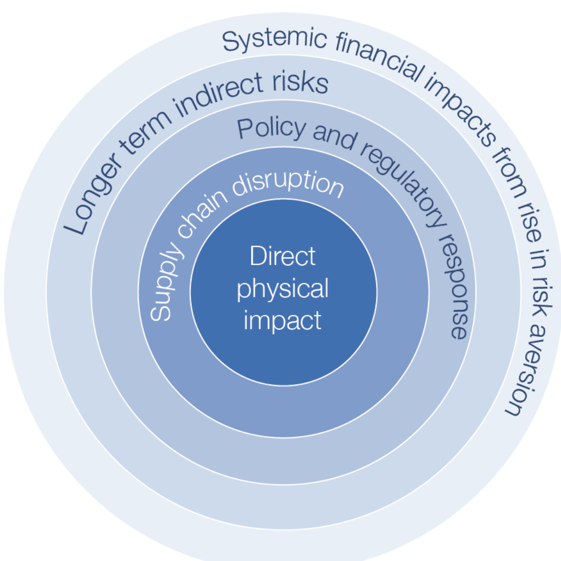
According to a recent report from the Economist Intelligence Unit, the economic consequences of climate change could be dire. The study attempts to model the climate-affected value at risk (VAR)[1] of the $143 trillion global stock of manageable assets.[2] According to the report, the *mean* expected loss through the year 2100, in discounted present value terms, amounts to $4.2 trillion, which is the approximate equivalent of Japan's entire GDP.[3] At more severe climate scenarios, for example a 5°C warming, mean expected loss rises to $7 trillion, while a 6°C warming scenario could result in $13.8 trillion of losses, which approximates *10% of the current global stock of assets*. The Stern Review, which accounts for governmental losses in addition to private investors, estimates the total costs of climate change to be anywhere in the range of 5%–20% of global GDP depending on the scenario.[4] As recently as September 2015, a *Nature* paper by Stanford and Berkeley researchers suggested that unmitigated warming is expected to reduce global incomes by roughly 23% by 2100, relative to scenarios without climate change.[5]

Naturally, economists have and will continue to debate the methodology of these imperfect forecasts. We cite these forecasts not to draw any conclusions on the certainty or magnitude of economic loss, but rather to paint a picture of one tail risk scenario. Directionally, the economic risks to the status quo introduced by climate-related uncertainties skew to the downside, not the upside. The various economic risk factors of climate change are complex and multi-dimensional. They will likely range in their method, timeframe, and severity of manifestation. Some impacts may be sudden, while others may be much more gradual. The many facets of climate risk[6] include: (1) the physical impairment or destruction of real estate property and infrastructure assets caused by more frequent or severe extreme weather events; (2) supply chain disruptions to businesses as a result of these events, particularly related to disruption of resource inputs, such as water; (3) increased costs for carbon-intensive sectors

[1] Value at risk measures the size of loss within a given time period at a particular probability.
[2] According to estimated data by the Financial Stability Board. Total manageable assets account for the total stock of assets held by non-bank financial institutions.
[3] The Economist Intelligence Unit, "The Cost of Inaction: Recognising the Value at Risk from Climate Change," July 2015.
[4] Nicholas Stern, "The Stern Review: Economics of Climate Change," HM Treasury, October 2006.
[5] Marshall Burke, Solomon Hsiang, and Edward Miguel, "Global Non-Linear Effect of Temperature on Economic Production," *Nature*, Accessed November 16, 2015. doi: 10.1038/nature15725.

[6] We recognize that "climate risk" is a broad term that relates not only to economic factors but also human communities and ecological habitats. For the purposes of this paper, the scope will be primarily focused on economic and financial impacts.

The Many Layers of Climate Risk



such as coal, oil sands, and many utilities as policymakers and regulators take action in responding to climate change and other environmental issues; (4) longer-term indirect effects on human health, productivity, geopolitical and fiscal stability; and (5) potential systemic re-pricing of broader risky assets driven by increased societal risk aversion to climate impacts. These risks are described in more detail in Figure 1.

One might view direct physical impact, supply chain disruption, and longer-term indirect risks as primarily driven by ecological factors. Policy, regulatory, and systemic financial risks, in contrast, are primarily *human responses* to climate risks that in turn become economic risks themselves. That is, policy and regulatory activity can create a "recoil" effect, where the attempt to defend against and mitigate climate impact can itself cause economic repercussions. These repercussions can occur even if the ecologically driven risks do not materialize. For investors, understanding policy and regulatory risks is critical, as those risks can affect the long-term competitiveness and cost structures of many existing industries that are intricately linked within the current high-carbon global economy. Moreover, unexpected policy or regulatory developments may also affect near-term pricing and sentiment. See Appendix A for examples of policy, regulatory, and legal developments relating to climate change.

Systemic financial risk, a second form of human response, is perhaps the most unpredictable and undiversifiable. This risk relates to the market's "endogenization" of the climate change externality and could lead to a rise in the equity risk premium.

As any experienced investor knows, *perceived risk may drive markets as much as materialized risk*, so any systemic change in the market's perception of how climate affects long-term economic output may create real volatility and impairment in asset values. While there is limited evidence that this systemic risk has materialized to date, investors should be on the lookout for broader market reactions to climate driven catalysts in the future.

Given the interconnected and systemic nature of these and other climate risks that could arise, investors will find it difficult to predict and precisely manage every potential impact on portfolios. However, we have identified gradations in defensive themes and suggest approaches investors can take to better understand and manage these risks.

Defense Theme #1

Engagement Through Delegation

In the simplest approach, investors can engage with managers by asking them to discuss and consider climate-related factors. This allows the investor to delegate the responsibility of incorporating climate risk with the agents most actively making buying and selling decisions on specific assets. In an August 2014 letter from Yale's Chief Investment Officer David Swensen, written to the endowment's external investment managers, he asks Yale's managers to "assess the greenhouse gas footprint of prospective investments, the direct costs of the consequences of climate change on the expected returns, and the costs of policies aimed at reducing greenhouse gas emissions on expected returns. Simply put, those investments with relatively small

Figure 1. The Many Layers of Climate Risk

Type of Risk	Description of Risk	Examples
Direct physical impact	Extreme or shifting weather events can cause destruction of real property, or interrupt economic activity	• According to data from Swiss Re Sigma Insurance Research, climate related losses have increased in each decade (both insured and total, including uncovered losses) from 1974 to 2013.[1] • According to projections by Rhodium Group in the Risky Business study in 2014, between $66 billion to $106 billion worth of existing coastal property in the United States will likely be below sea level nationwide by 2050, assuming the world stays on its current emissions path. That range increases to $238 billion to $507 billion by 2100.[2] • Over the last century, the global mean sea level has already risen 4–8 inches and could rise by another 2.5 to 6.5 feet by 2100,[3] directly impacting communities and economies along the coasts. The trend of growing coastal populations will likely amplify these effects. • The US winter tourism industry has seen an impact on business due to shifting snowmelt and abbreviated winter seasons in certain regions, such as the Sierra Nevada and the Colorado Rockies.[4,5]
Supply chain disruption	Changing weather patterns can affect water and other economic resource inputs Extreme weather events can impact supply chain assets	• 2011 flooding in Thailand, a supply chain manufacturing hub for many multinational corporations, caused $15 billion to $20 billion in losses and impacted profitability of these firms.[6] • Brazil, going through its worst drought in over 80 years, faces an energy crisis as it relies on hydropower for about 70% of its electricity supply. Moreover, Santander predicts that water rationing at the 5% or 10% level would detract from the country's real GDP growth by 1%–2%.[7] • Unilever estimated that the natural disasters linked to climate change, and in particular food price increases, water scarcity, and reduced productivity in parts of its agricultural supply chain, cost the company ~$400 million per year.[8] • An August 2015 study by the UC Davis Center for Watershed Sciences estimated that the 2015 drought in California could cause $2.7 billion in statewide economic costs and 21,000 job losses.[9] • A 2013 Oxford University study estimated that as much as $11.2 trillion in agricultural assets, including processing facilities, transportation networks, and distribution assets could be stranded annually because of environmental risk factors such as climate change and water scarcity.[10]
Policy and regulatory response	Policy and regulatory action in response to climate change can impose higher costs on resource-intensive sectors such as fossil fuels, utilities, transportation, and heavy industry	• 40 countries and more than 20 cities, states, and regions are putting a price on carbon according to a new World Bank report, representing almost a quarter of global greenhouse gas emissions.[11] • More global companies are putting a price on their carbon pollution in anticipation of more aggressive global climate policies. • US utilities are retiring coal power plants and shifting investments toward natural gas and renewable generation assets. Meanwhile, China has implemented restrictions on "dirty" coal (i.e., coal high in ash and sulfur content) and has committed to taper its national coal consumption. • Some resource reserves such as tar sands and coal, as well as high-cost oil & gas, may be unburnable due to a combination of higher carbon prices and technological displacement. This is known as "stranded asset risk."
Longer-term indirect risks	Other potential impacts on human health, productivity, geopolitics, fiscal stability	• Increase in frequency and/or magnitude of sector and water-borne diseases, primarily affecting health, labor, and economic activity in developing regions such as Africa and Latin America. • Decline in labor productivity in certain sectors (e.g., construction, agriculture) driven by less tolerable outdoor working conditions. According to a recent paper in *Nature Climate Change* by 2100, certain areas of the Persian Gulf are projected to experience temperatures intolerable to humans.[12] • Food and/or water scarcity worsened by the changing climate can catalyze or exacerbate geopolitical instability, in turn creating economic and financial implications. • Adaptation to climate change can potentially put pressure on governmental balance sheets and budgets, in turn affecting sovereign and municipal credits.
Systemic financial impacts	Repricing of risk premiums if market's expectations of climate's impact on economic output changes	• *Unknown*

1 Swiss Re Economic Research & Consulting, Sigma World Insurance Database, www.sigma-explorer.com, Accessed November 13, 2015.
2 Rhodium Group, LLC, "American Climate Prospectus: Economic Risks in the United States, Version 1.2," October 2014.
3 National Geographic, "Sea Levels Rise," Accessed November 13, 2015, www.ocean.nationalgeographic.com/ocean/critical-issues-sea-level-rise.
4 Elizabeth Burakowski and Matthew Magnusson, "Climate Impacts on the Winter Tourism Economy in the United States," Natural Resources Defense Council, 2012.
5 Katharine Q. Seelye, "Rising Temperatures Threaten Fundamental Change for Ski Slopes," *The New York Times*, December 12, 2012.
6 Joyce Coffee, "Supply Chains in the Face of a Changing Climate," The Environmental Leader, April 30, 2014.
7 Joe Leahy, "São Paulo Drought Raises Fears of Brazil Energy Crisis," *Financial Times*, February 11, 2015.
8 "Unilever CEO Calls for Decisive Action to Tackle Climate Change," Unilever, April 18, 2014. Accessed November 13, 2015, www.unilever.com/news/press-releases/2014/14-04-08-Unilever-CEO-calls-for-decisive-action-to-tackle-climate-change.html.
9 Richard E. Howitt et al., "Economic Analysis of the 2015 Drought for California Agriculture," Center for Watershed Sciences, University of California – Davis, August 17, 2015.
10 Ben Caldecott et al., "Stranded Assets in Agriculture: Protecting Value from Environmental-Related Risk," Smith School of Enterprise and the Environment, Oxford University, August 2013.
11 World Bank Organization and Ecofys, "State and Trends of Carbon Pricing," September 2015.
12 Jeremy S. Pal and Elfatih A. B. Eltahir, 2014, "Future Temperature in Southwest Asia Projected to Exceed a Threshold for Human Adaptability," *Nature Climate Change (Online)*, Accessed November 13, 2015. doi:10.1038/nclimate2833.

greenhouse gas footprints will be advantaged relative to those investments with relatively large greenhouse gas footprints." In making these assessments, investment managers are expected by Yale to discuss financial risks driven by climate change and by governmental polices intended to reduce emissions—policies that impose costs on investments with high emissions. Finally, Swensen opines that "consideration of the risks associated with climate change should produce higher-quality portfolios."[7]

In our observation, Yale's, and an increasing number of other institutions' approach to managing climate risk emphasizes basic *engagement* with underlying managers. Engagement via delegation is a relatively time- and resource-efficient approach for the asset allocator. It allows for increased climate risk integration without necessarily making changes to the roster of existing active managers, the highest quality of which may be difficult to re-access if terminated.

Defense Theme #2

Engagement Through Advocacy

Some investors may prefer to pursue a more hands-on form of defense, especially if they believe that the delegation model of engagement is insufficient. Asking managers to consider climate risk is one thing, advocating for managers to follow through with implementation and reporting is another. Some managers may not even have the appropriate motivation, frameworks, tools, and data to effectively monitor and manage climate risks. As such, investors can: (1) advocate for more transparency and reporting on climate risk metrics, and (2) actively overlay a climate risk lens to the due diligence and monitoring process.

Advocating for climate-related transparency/reporting. Some investors may choose to engage in advocacy primarily through their investment managers, while others may engage with companies through shareholder discussions and/or proxy voting. Regardless of the preferred channel, by advocating for more transparency and reporting from managers and companies on climate risk metrics, investors can enhance stakeholders' and their own ability to better understand and manage climate risk.

Climate risk metrics include portfolio companies' carbon emissions, sensitivity to climate policy and regulation, water resource security, fossil fuel resource reserves, energy intensity, and broader resource consumption. Managers and underlying portfolio companies often do not closely track or report this data. This lack of transparency makes it challenging for investors to understand their exposure to various climate risks. For example, only 7% of asset owners surveyed are currently able to calculate the carbon emissions embedded in their portfolios.[8] But the industry is recognizing this gap and is developing new frameworks and resources. To that end, the World Resources Institute and the UNEP Finance Initiative recently compiled a list of currently available commercial tools and resources for investors seeking to assess carbon risk in portfolios.[9]

[7] David Swenson to Yale External Investment Managers, August 27, 2014.

[8] *World's Largest Asset Owners Continue to Gamble on Climate Risk*, Asset Owner's Disclosure Project, April 27, 2015.

[9] World Resources Institute and UNEP Finance Initiative, "Carbon Asset Risk: Discussion Framework," Washington, DC, and Geneva, Switzerland, August 2015.

Overlaying a climate risk lens in manager diligence and monitoring. Applying a "climate overlay" in manager diligence and monitoring requires ongoing discussions around the many facets of climate risk (discussed above). Simply asking a question such as "how do you think about water security in your companies' supply chain?" could lead to productive conversations about those companies' sustainable competitive advantage and supply chain security. Similarly, asking a question such as "are your energy and industrial companies using an internal carbon price?" could prompt discussions about portfolio companies' preparedness for more stringent carbon regulation. Asking long-term oriented real estate managers about the geographic exposure and diversification of properties, as they relate to coastal risks, should shed light on their risk management and time horizon. By engaging in these discussions, investors can actually gain more insight into managers' thinking about all risks and not just climate risk. Figure 2 provides a few examples of overlaying a climate lens on the investment process for various asset classes. Of course, application of this overlay should fit within standard considerations such as valuations and near-term fundamentals to balance the longer-term dynamics with near-term catalysts. A possible outcome from this overlay exercise could be to take no immediate action upon assessing the risks, for example, if the investor feels comfortable that the underlying assets are expected to exit within the near term and/or are located away from high-risk coastal regions. The important takeaway is that the investor should integrate climate risk in the underwriting and ongoing monitoring process.

Defense Theme #3

Proactive Hedging

Beyond engagement, investors that want to take more aggressive action to defend against various climate risks may consider several other measures. We consider the risk management approaches we discuss below primarily as defensive tools for mitigating risks to existing portfolio assets, rather than vehicles to capitalize on solution-oriented opportunities. That said, some investors may justifiably view them as more proactive actions and therefore classify them as offensive tools. As noted, the lines between defense and offense are blurred and the ideas we discuss in this paper fall onto a continuum of options to navigate climate risk and opportunity.

Low-carbon index products. Investment products based on low-carbon indexes are becoming increasingly available. These include exchange-traded funds (ETFs) and mutual funds. The products are different from fossil-free index products in that they are *sector neutral* relative to a mainstream index (e.g., MSCI All Country World Index), but the positions within each sector have the lowest carbon emissions profile. As a result, the index weights the "cleanest" companies highest, while underweighting or excluding companies with the dirtiest carbon footprints. Some investors may pursue these strategies primarily to mitigate policy and regulation risks from climate change, but there also may be reputational, management quality, and governance benefits associated with these cleaner companies. Additionally, we are seeing the industry develop broader resource efficiency beta-oriented products that integrate factors

C | A

Figure 2. Illustration of Overlaying a Climate Risk Lens on Selected Assets

Asset Class/ Strategy	Potential Climate Risk Impact	Considerations in Due Diligence and Monitoring	What to Watch (and Watch Out) For
Real estate and infrastructure (public and private); equities and corporate credits with exposure to high-risk regions	Direct physical impact Supply chain disruption	• Inquire about insurance coverage related to extreme weather events, and the underlying credit quality of those insurers. • Inquire about geographic exposure and diversification of coastal assets. • Stress test future cash flow and exit value assumptions, especially in coastal regions with more sensitivity to extreme climate events. • For equity investments in businesses that have a strong real estate component to their values, stress test the cash flow and terminal value assumptions on the real estate, while evaluating the reliance of the business model on a particular set of climate conditions. For example, winter tourism and related businesses in warming regions may face headwinds. • A similar list applies for related co-investments. For direct, sponsor-less investments, apply long-term scenario analysis especially if there is no defined exit period for the assets.	• For strategies with real estate development components, favor managers and operators that embrace best-in-class practices to comply with, and stay ahead of, stricter building efficiency and disaster resiliency standards. • Exercise extra caution when evaluating region-specific mandates/strategies that do not have the flexibility to diversify geographically. • For long-term infrastructure assets in high-risk regions, look for strong contractual cash flows and/or diversified revenue sources to mitigate risk.
Equities and credits (particularly those in the consumer, food and beverage, and agriculture sectors)	Supply chain disruption	• Engage with active managers to increase disclosure from relevant portfolio companies on water disruption risks on production, manufacturing, and agricultural supply chains. • Request and review the managers' underwriting assumptions about downside risks from supply chain disruptions in high-sensitivity sectors (e.g., food and beverages, agriculture, data centers). In some cases, higher input costs are passed on to end consumers, but investors and investment managers should test the sensitivity and long-term viability of these pass-through effects. • Understand the policy and regulatory responses in jurisdictions affected by droughts—how are rules going to change for businesses operating in water-constrained regions, how will their cost structures change, and what are the potential actions needed for compliance?	• Favor businesses that have diversified their supply chain and have adopted more advanced technologies (such as wastewater recycling or water efficiency) to mitigate and manage water resource risks. • Look for managers that have developed strong risk-disclosure policies, monitoring and reporting of supply chain risk factors.
Natural resources (public and private); equities/ credits in utilities, industrials, energy	Policy and regulatory response	• Ask relevant managers about portfolio companies' internal carbon price assumptions. • Ask relevant managers about portfolio companies' emissions profiles. If profiles are not available, encourage managers to engage best-in-class data providers to measure emissions exposure. • Stress test portfolio using incrementally higher carbon price scenarios. • For utility positions, inquire about generation fuel mix and preparedness against carbon regulations. • For upstream energy managers and companies, seek clarity around reserves profile and underlying cost of development and production. The objective is to gauge stranded asset risk.	• Look for managers that have adopted and incorporated scenario analysis and stress testing around carbon pricing and regulations. • Favor managers that have strong and real-time understanding of policy and regulatory dynamics. • Favor upstream managers with the lowest-cost resource reserves.
Sovereign and municipal fixed income	Direct physical impact Longer-term indirect risks (on fiscal stability)	• For water and sewer municipal credits, better understand the impact of severe droughts on water revenues. • For municipal and sovereign credits with high exposure to coastal regions, inquire about longer-term budgetary risks from climate adaptation and extreme weather disaster costs.	• Apply caution when evaluating long-duration strategies that do not have the flexibility to diversify geographically. • Look for managers that are developing or integrating climate modeling and scenario analysis capabilities.

C | A

such as water consumption and waste creation. These emerging products may help investors mitigate supply chain risks in addition to policy and regulatory risks.

Traditional (non-exclusionary) ESG active managers. Investors that prefer active management can consider active managers that integrate ESG (environmental, social, governance) metrics into company selection and weighting. These investors should keep in mind that many of these managers may not exclusively focus on climate risk factors but rather a broader set of ESG factors, so the extent of defense against climate-specific risks will vary by manager.

Hedging with derivative instruments (e.g., options and total return swaps). Some investors might choose to use derivatives to more precisely hedge against climate-sensitive assets. One route is to employ put options to hedge against indexes or select baskets of securities. Alternatively, investors could implement a total return swap. This involves first identifying specific long positions the investor believes will face headwinds from climate impacts (e.g., coal, tar sands, and coal-heavy utilities as they relate to climate policy/regulation, coastal businesses and municipal credits as they relate to physical impact risk). The investor can then enter into a total return swap with a counterparty to short that basket of positions. The timing and duration of the hedge relative to the duration of the risks need to be considered. Depending on the tenor of the derivative instrument, the hedging position may not be a sufficiently long-term hedge against climate risks if the risks materialize gradually. The credit risk of the counterparty providing the total return swap is another consideration. Finally, while using derivatives may optimize for precision in fulfilling specific risk management objectives, it will nonetheless carry some opportunity and transaction costs.

Defense Theme #4

Policy-Level Exclusion

Investors worried about the long-term risk of stranded assets could avoid investing in them altogether. Stranded asset risk refers to the notion that certain resources (like fossil fuels) could become unusable due to climate policies, regulations, legal rulings, and technological displacement. In turn, unusable resources would limit the investment returns of investors in those

A Note on Green Bonds

An emerging and growing asset class, green bonds are fixed income instruments whose proceeds are earmarked for environmental, climate mitigation, or climate adaptation projects. Supranational entities (e.g., World Bank and European Investment Bank), municipalities, and corporations typically issue these bonds to support investment in areas such as renewable energy infrastructure, energy efficiency, sustainable waste management, sustainable land use, biodiversity conservation, clean water, and clean transportation. That said, guidelines and definitions around what exactly constitutes “green” activities and projects are still developing. Moreover, not all green bonds are backed by the cash flows of the green projects they are meant to fund; in fact most corporate green bonds are backed by the issuers’ balance sheet, similar to their plain vanilla bonds. Regardless, the issuers are generally held to higher transparency and reporting scrutiny. As such, green bonds can serve as both defense and offense for investors, depending on the precise use of proceeds.

See our 2014 research note “The Growing Market for Green Bonds” for a more thorough discussion of this evolving area.

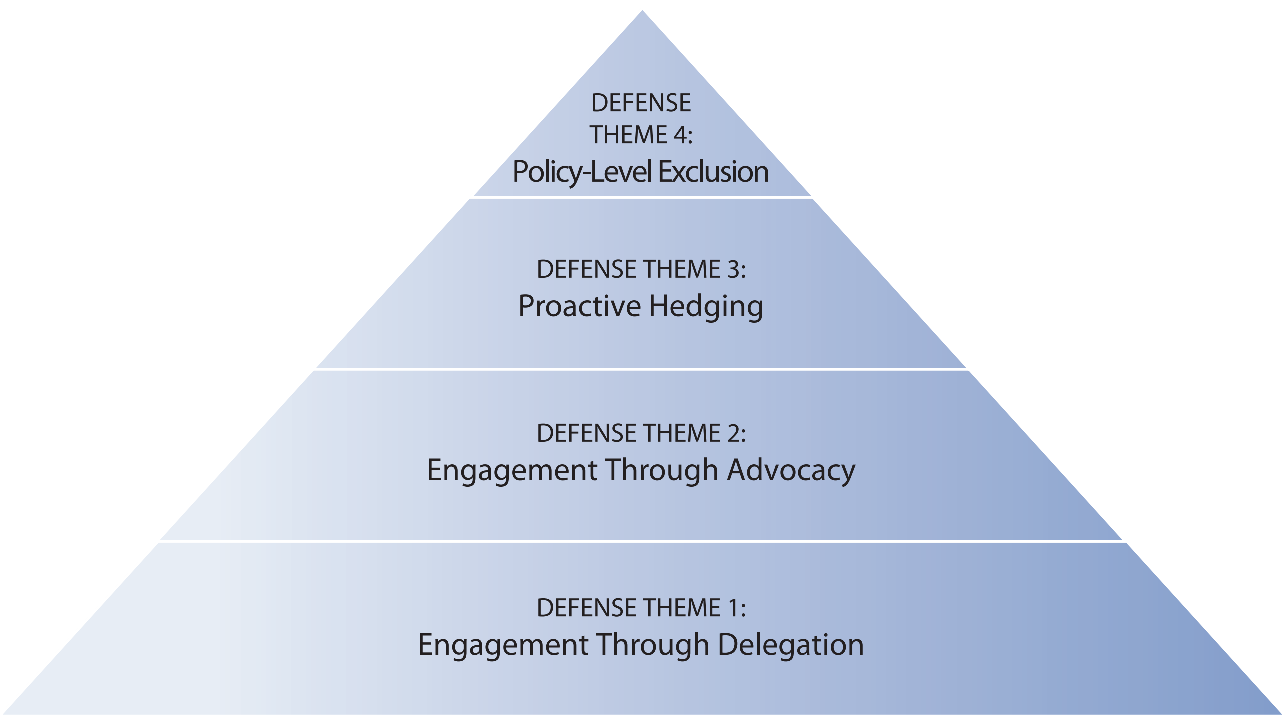
companies that hold the reserves. Excluding investments in strategies tied to assets at risk from stranding can be a long-term economic decision to defend against climate risk. That said, permanent exclusion or divestment of broad fossil fuel sectors at the policy level, without any consideration for price, can pose a handicap to the investor. Policy constraints may preclude investors from capitalizing on the broadest universe of opportunities at any given time. As we elaborated in our 2014 research note "The Fossil Fuel Divestment Discussion," policy-level divestment is a decision specific to each institution and should incorporate that institution's specific objectives, including its mission and values.

The Playbook for Defense: Summary

Long-term investors concerned about economic risks from climate change should be aware of the set of available risk management options, which are summarized in Figure 3. We recognize that some investors will pursue none or only a few of these defensive measures. For long-term investors concerned about incorporating climate risks into their decision-making process, considering the options will enable them to craft their own defensive strategy reflecting their views and objectives.

Be mindful of opportunity costs. The latter two themes carry opportunity costs. Investors shifting assets into low-carbon index strategies, for example, should think carefully about the source of funds and

Figure 3. The Playbook for Defense Against Climate Risk



remain sensitive to relative value. With natural resources equities at relatively cheap valuations today, the opportunity cost for funding out of this asset class will be relatively high. While carbon regulation and technological advances in alternative energy may be long-term headwinds for traditional fossil fuels, markets are likely to see many more cycles in which investors can capture returns. Investors should benefit from the flexibility to take advantage of near- to medium-term valuation opportunities, no matter the sector in which these opportunities may arise.

Beyond defense. Along those lines, long-term investors should consider looking beyond defense as a risk management approach and seek proactive, solution-oriented strategies to capitalize on investment opportunities linked to climate change.

Part II: Opportunities and the Playbook for Offense

Our basic thesis is that *the more challenging the problem, the greater the opportunity set for innovation, solutions, and, ultimately, attractive investment returns.* Thus, investors seeking to incorporate climate risk in their long-term decision-making should focus not just on defending against climate risk, but also on planning a strategy to invest (and/or be prepared to invest) in related solutions. In this section, we discuss the many *themes* associated with climate change that should lead to actionable investment opportunities, some in the near term and others in the long term. Investors can access these themes through a variety of vehicles and strategies. For each theme, we identify various *drivers of opportunity*, *available strategies* to pursue these themes in a portfolio, *manager characteristics and skillsets*, and market *signposts* that investors should look for along the way as they seek to gain conviction in, and exposure to, these opportunities.

Some of these opportunities are more sensitive to policy and regulatory actions guiding the economy toward a lower-carbon future, but many are more market-driven solutions, with their success reliant on factors such as unit economics, technological differentiation, business model innovation, and sheer execution. Some investors, burned by their experience investing in clean tech in the 2000s, may justifiably find it hard to stomach investment opportunities that feel similar to arguments from that time. Yet, the clean tech experience is more nuanced than often presented, as discussed in the sidebar on page 14. For investors today, attractive risk/return profiles do exist in select areas within the broader "resource efficiency" arena, regardless of an investor's stance on incorporating climate risks into investment decision making.

Economic opportunities appear when a resource can be used more efficiently at lower or comparable cost—hence the "resource efficiency" opportunity. Given the demands on all types of resources that climate change will impose, innovations that create more with less, and businesses that implement these innovations with unit economics that make sense, will generate value. *Resources* can mean energy sources for electricity generation and transportation; water, food, and agricultural inputs; industrial production inputs such as metals and other materials; and even waste products that can in turn be repurposed into useful economic assets. *Efficiency* can be created by a combination of superior technology, business model innovations and value-added services, strong execution, and/or economies of scale.

We recognize the universe of institutional-quality managers in this area is still evolving, and some of the highest quality and ultimately successful teams are not yet formed. Similarly, trends such as rapid technological advancements, declining cost structures, business and financing model innovations, policy and regulatory evolution, and improving management quality will open up new areas of investment opportunity in the future. Managers and teams that have the multi-dimensional expertise and networks to navigate these trends will have the highest likelihood of success. For investors, there is a need for continued monitoring and coverage of resource efficiency themes, strategies, and managers. The objective for truly long-term investors is not only to identify and evaluate the available and accessible investment opportunities today, but also to uncover and capitalize on the opportunities that will present themselves in the future.

Opportunity Theme #1

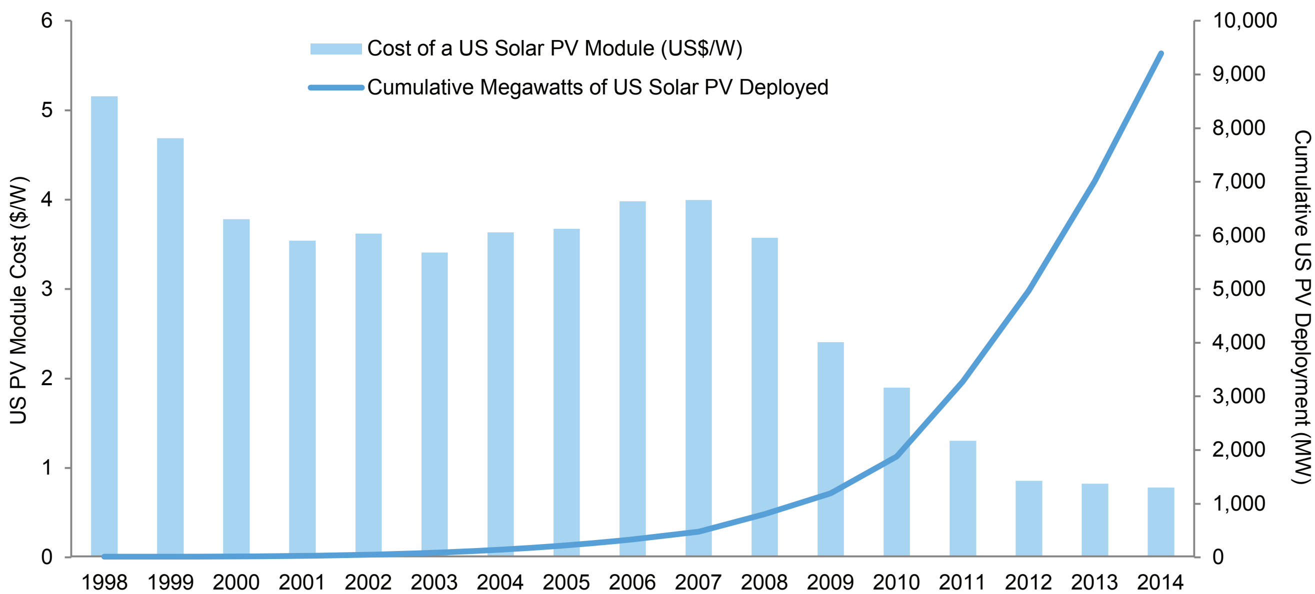
Renewable Infrastructure

Drivers of opportunity. Renewable infrastructure is one theme for investors who want to hedge the risk of aggressive policy and regulatory response against climate change. If policies and regulations continue to evolve and favor investment in lower-carbon energy sources, then renewables should gain competitiveness and market share over time against traditional high-carbon sources. In many ways, this trend is already occurring. Through 2014, the cost to install solar photovoltaic arrays had declined by 73% since 2006,[10] due primarily to manufacturing scale-up and technological advancements. Booming Chinese production has been a significant contributor to cost reductions. As an example, Figure 4 shows how solar deployment has increased as module costs have declined.

The decline in prices and costs upstream typically leads to greater adoption and opportunities downstream in the value chain. Some companies have taken advantage of cheaper capital costs driven by rapidly declining solar module prices. This has been a tailwind for renewable project developers, financing companies, and other downstream service providers. With increased adoption, standardization of processes such as power purchase agree-

[10] Solar Energy Industries Association®, "Solar Energy Facts: 2014 Year in Review," December 17, 2014.

Figure 4. US Deployment and Cost for Solar Photovoltaic Modules
1998–2014



Source: Lawrence Berkeley National Laboratory.
Note: All deployment-related numbers are direct current-standard test conditions, and dollar values are real 2014 US$ terms.

The Clean Tech Experience

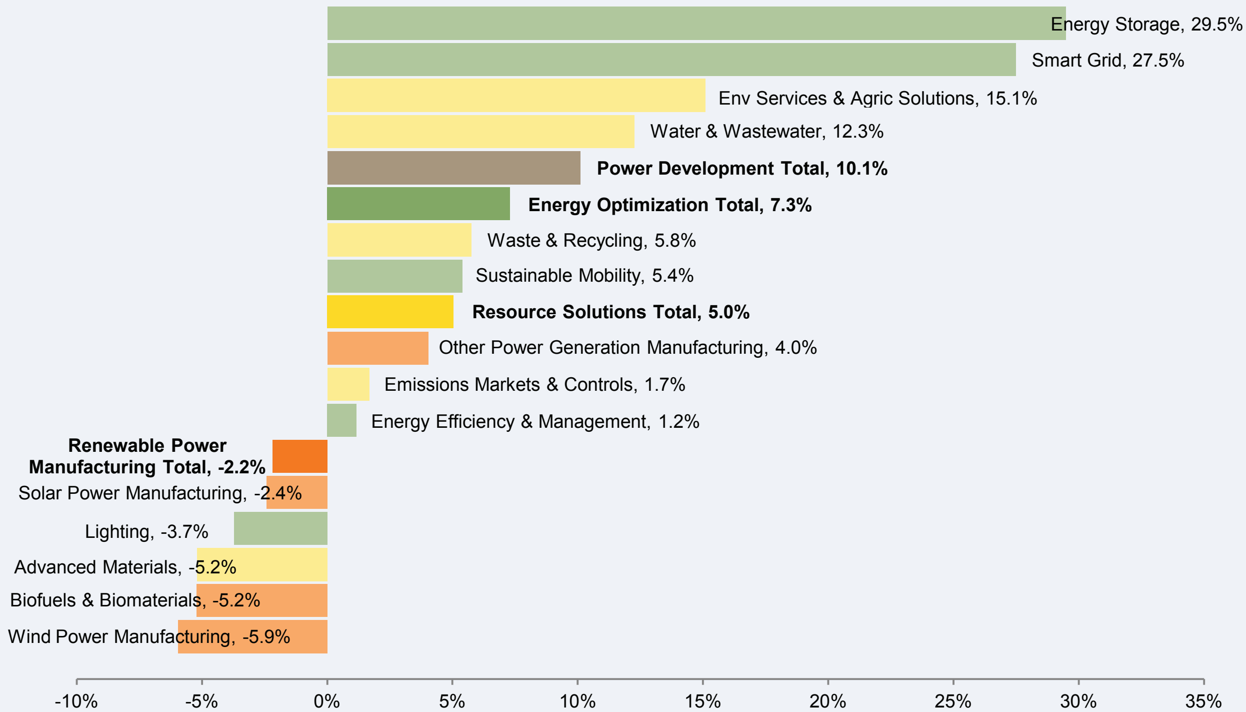
We are fully aware that the "clean tech" sector comes with a tarnished track record, as the area is littered with failed companies and projects from the last boom and bust cycle leading up to and through the great recession. According to our Clean Tech Company Performance Benchmark as of March 31, 2015,[1] the pooled return for all companies in our benchmark has been lackluster: gross 5.1% internal rate of return (IRR) and 1.2x gross multiple on invested capital (MOIC).

Many investors with exposure to clean tech investments have scar tissue that they will likely not forget. As a result of the sector's broad challenges, many clean tech managers have been unsuccessful at raising subsequent funds, and even more have moved out of the sector completely, terminated their clean tech practices and investment professionals, or revised their strategies significantly.

Closer observation, however, shows that sub-sectors within clean tech have performed quite differently, and reasonable returns have been generated in several pockets of the universe, as shown below.

[1] The CA Clean Tech Company Performance Benchmark was launched in 2013. We track more than 1,400 distinct investments made between 2000 and 2013, representing $28.0 billion of invested capital. These investments are in over 800 distinct companies backed by 480 different private investment funds (including 345 venture capital funds, 129 private equity, and 6 infrastructure funds). We publish this benchmark on our public website (www.cambridgeassociates.com) on a quarterly basis, and add new companies to the benchmark every quarter as we expand coverage of the relevant universe. See our quarterly report, "Clean Tech Company Performance Statistics," for detailed definitions of each sub-sector and group within the benchmark.

CA Clean Tech Company Performance Benchmark Sub-Sectors by Gross IRR
As of March 31, 2015



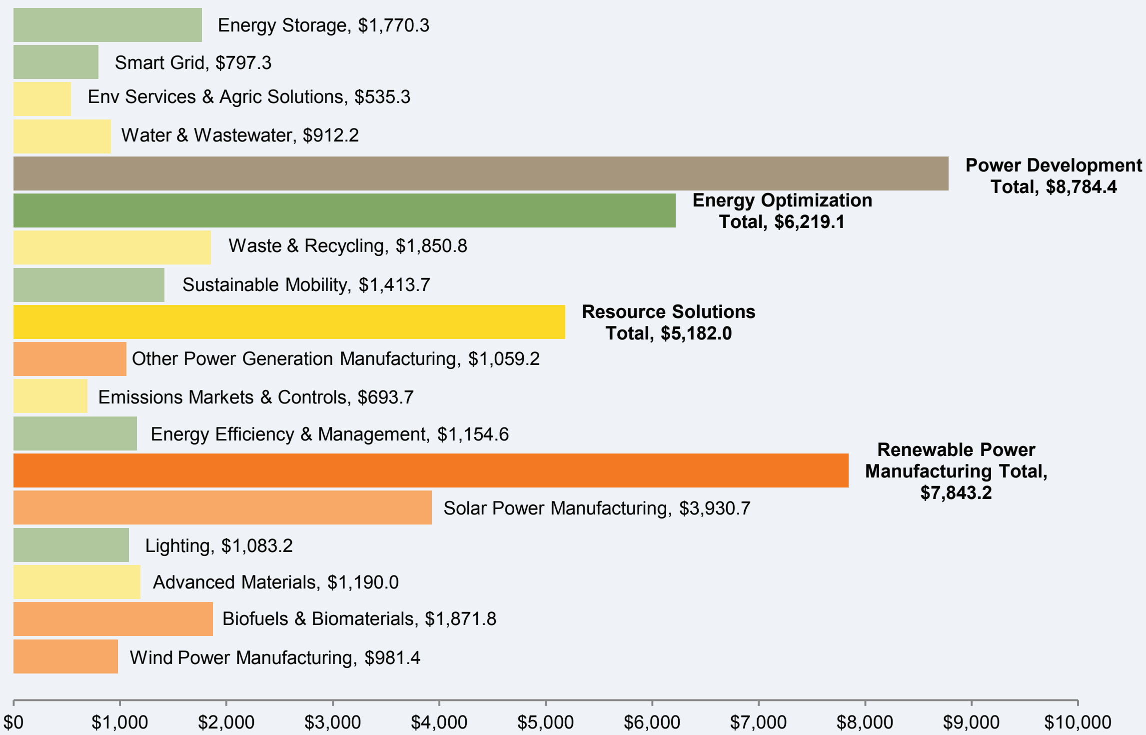
Source: Cambridge Associates LLC Private Investments Database.
Notes: All returns included in the clean tech performance statistics are gross company-level returns and are not net of any fund management or incentive fees that may be incurred by limited partners. Clean tech investments were identified from various venture capital and private equity partnerships and do not represent entire investment portfolios, therefore a direct gross-to-net IRR comparison is not available. However, to approximate the difference between net-to-limited partner fund–level IRRs and gross company-level IRRs, Cambridge Associates compared the gross and net returns of 258 US venture capital funds with a gross company-level return range of 0 to 10% and found the median return spread for these funds to be approximately 4.4% (440 bps).

Sub-sectors like smart grid, energy storage, power development, environmental services and agricultural solutions, and water-related companies have generated reasonable to strong rates of returns in aggregate.

Most of the negative performing sub-sectors have been in upstream renewable manufacturing—areas like biofuels and solar panels. The upstream segment of the industry experienced rapid inflows of capital, leading to overinvestment and overcapacity, especially driven by a ramp-up in Chinese production in the case of solar panels. Incremental improvements to existing technologies quickly commoditized a race to the bottom of the cost curve. Some technologies could not scale with commercialized production and in the process burned excessive amounts of capital. In our benchmark, a total of $7.8 billion of invested capital went to this renewable manufacturing sub-sector group (shown below), making it the second largest group by invested capital and a meaningful drag on overall benchmark returns.

We note that venture capital and private equity represents only a portion of total investment in the clean tech sector, as seen in Appendix Figure B-1. Additionally, Appendix Figure B-3 provides a selection of marketable indexes relating to resource efficiency against traditional indexes.

CA Clean Tech Company Performance Benchmark Sub-Sectors by Invested Capital
As of March 31, 2015 • US$ millions



Source: Cambridge Associates LLC Private Investments Database.

ments (PPAs), net metering, and financing mechanisms have led to greater efficiency and scale. As seen in Figure 5, solar's share of new investments in clean energy has grown significantly over recent years.

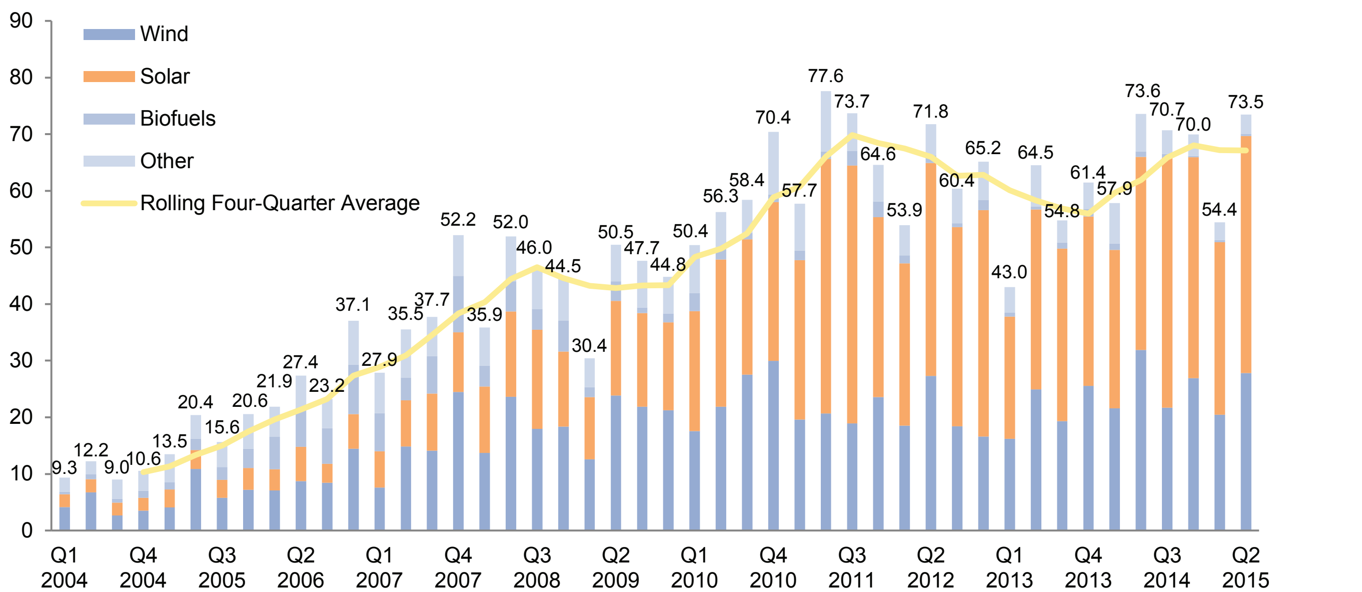
The combination of policy and regulatory pressure toward cleaner power generation, net metering incentives, and consumer behavioral changes is further driving demand growth. A few other datapoints to highlight:

- Worldwide installed capacity of distributed generation (including small-scale wind and solar) is expected to grow from 87,300 megawatts annually in 2014 to more than 165,000 megawatts in 2023, according to Navigant Research.[11]
- China has made a commitment to deriving 20% of its primary energy consumption sourced by non-fossil fuels by 2030. This additional renewable generation capacity (composed of 800–1,000 gigawatts of nuclear, wind, solar, etc.) equates to more than all the coal power plants in China today and is similar to the current electricity generation capacity in the United States.[12]
- In Texas, a state that does not offer state-level incentives to utilities to buy or build solar power generation, demand for solar is increasing rapidly as prices decline. The Electric Reliability Council of Texas (ERCOT) expects between 10,000 and 12,500 MW of solar generation capacity to be installed by 2029, up

[11] Navigant Consulting, Inc., "Global Distributed Generation Deployment Forecast," Third Quarter 2015.

[12] The White House Office of the Press Secretary, "Fact Sheet: US-China Joint Announcement on Climate Change and Clean Energy Cooperation," The White House, November 16, 2015.

Figure 5. New Investment in Clean Energy by Sector
First Quarter 2004 – Second Quarter 2015 • US Dollar (billions)



Source: Bloomberg New Energy Finance.
Notes: Total values include estimates for undisclosed deals. Excludes corporate and government R&D and spending for digital energy and energy storage projects (reported in annual statistics).

from the 193 MW currently. ERCOT's director of system planning recently noted that "solar is going to become one of the most cost-effective sources of electricity on the grid."[13]

Available strategies. Investors with interest in accessing this theme can take many potential approaches depending on their risk and illiquidity tolerance. Some strategies focus on developed markets (primarily North America and Western Europe) while others pursue opportunities in emerging markets. Some target utility-scale projects while others focus on distributed generation assets. And finally, some strategies target mature, cash flow generating assets, while others seek earlier-stage development opportunities.

- Marketable equity strategies in resource efficiency that have exposure to downstream renewable infrastructure development, financing, and service businesses.
- Marketable yieldco (a dividend-paying public company that owns operating cash flow power generation assets, analogous to master limited partnerships [MLPs] and real estate investment trusts [REITs]) strategies that have exposure to renewable infrastructure projects. Note that these vehicles can be volatile and sensitive to interest rate movements and investor flows.
- In fixed income, green bonds, whose proceeds are specifically tied to renewable energy infrastructure projects.
- Private infrastructure managers focused on renewable development, construction, and/or asset management. The search for yield in a low-rate environment has led to investor interest in private infrastructure funds more broadly. Some generalist infrastructure teams invest in renewables as part of a diversified mandate. Meanwhile, we have seen an increasing number of specialist managers exclusively pursuing renewable infrastructure opportunities.
- Venture capital or private equity managers that invest in companies providing services or technologies to downstream renewable developers.
- For larger investors, direct or co-investments in renewable infrastructure assets.

Manager characteristics and skillsets

- ✓ Strong relationships and/or differentiated access to strong asset developers and operators.
- ✓ Strong credit underwriting capabilities to evaluate counterparties for power purchase agreements (typically regulated utilities, independent power producers).
- ✓ Access to regulatory and policy expertise at the regional/state level.
- ✓ Ability to stage capital appropriately upon asset performance milestones.
- ✓ Modest use of leverage at the asset and/or portfolio level.
- ✓ Thoughtfulness about monetization/exit strategy. Smaller-sized strategies that can scale-up assets and sell to larger strategic buyers should be well positioned.

[13] Russell Gold, "Texas Takes a Shine to Solar Power," *The Wall Street Journal*, August 23, 2015.

Signposts

- ✓ Further signs of grid parity, where renewables are cost-competitive with traditional fuels, without subsidies. This may be particularly the case in regions that have relatively high energy costs, and/or regions with abundant renewable resources (e.g., sun, wind).
- ✓ Developments in technology or costs of energy storage, which would further increase competitiveness of renewables and increase adoption.

Opportunity Theme #2

Clean Transportation

Drivers of opportunity. Similar to power generation, the transportation industry is subject to policy, regulatory, and technological factors that can create opportunities for investors while also serving as a hedge against risks from policy and regulatory response. In the longer term, the clean transportation theme can also be an avenue to reduce sensitivity to geopolitical risks in oil-producing regions, many of which are also sensitive to climate factors.

Cost and adoption trends seen in solar and wind (and in other industries, as discussed in the sidebar on page 21) are also occurring in the transportation industry, albeit still in earlier stages. The cost of lithium battery storage technology continues to decline as the electric vehicle industry scales, with one research study estimating that the cost has declined from $1,000 per kWh in 2007 to about $450 per kWh or lower in 2014.[14] Meanwhile, stricter vehicle emission and fuel efficiency standards will continue to drive increased scale and further cost declines. The United States has set its sights on a nationwide auto fleet average of nearly 55 miles per gallon by 2025 (Figure 6). Brazil, Canada, China, the European Union, India, Japan, Mexico, and South Korea have also established or proposed fuel economy or greenhouse-gas emissions standards. These markets combined cover 80% of global passenger car sales in 2013.[15]

To achieve these fuel economy goals, the clean transportation industry will need to make up a larger share of vehicle sales. Of the 16.5 million total vehicles sold in the United States in 2014, only ~120,000 were electric. But that represents a 23% growth rate from 2013 and over 120% growth from 2012.[16] Although charging stations and refueling infrastructure will be a bottleneck for industry growth, the number of plug-in electric vehicle charging ports has grown meaningfully in recent years (Figure 7).

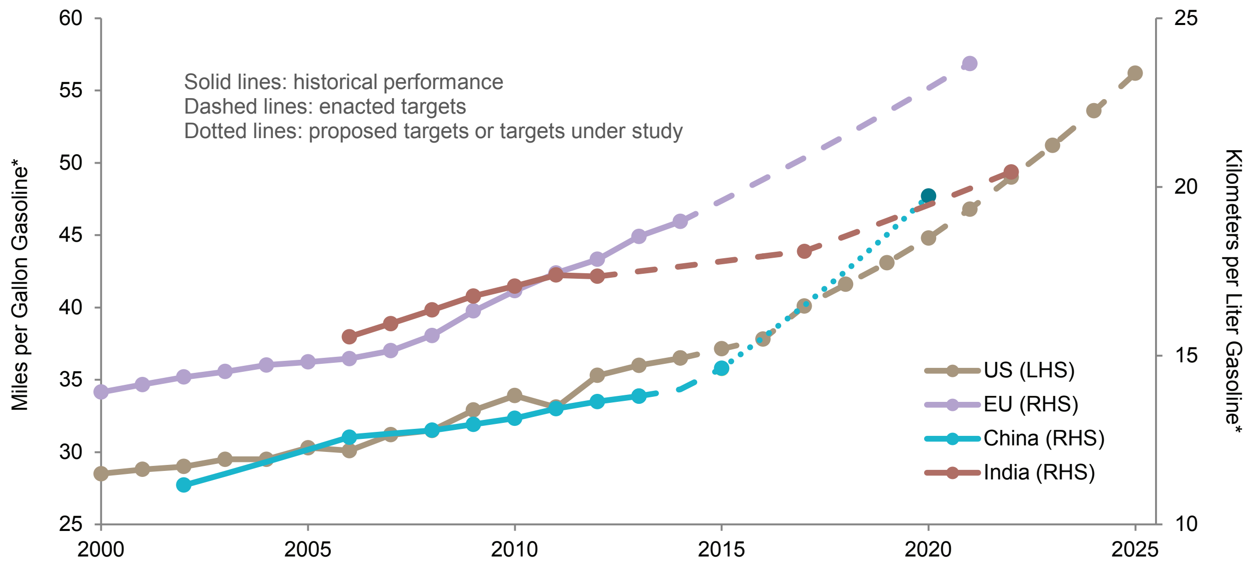
Available strategies. Unlike the renewable infrastructure theme, clean transportation has few dedicated managers exclusively focused on it. Investors seeking exposure to this area generally do so through growth-oriented generalists or multi-thematic resource efficiency managers (both marketable and private) that are actively tracking or investing in clean transportation companies as part of their strategy. Some green bond issuances may also link proceeds to clean transportation investments such as low-emission vehicle fleets and electric

[14] Megan Geuss, "Electric Vehicle Batteries Are Getting Cheaper Much Faster Than We Expected," *ARS Technica (Online)*, July 16, 2015.

[15] The International Council on Clean Transportation, "Info & Tools: Global Passenger Vehicle Standards," Accessed November 16, 2015, www.theicct.org/info-tools/global-passenger-vehicle-standards.

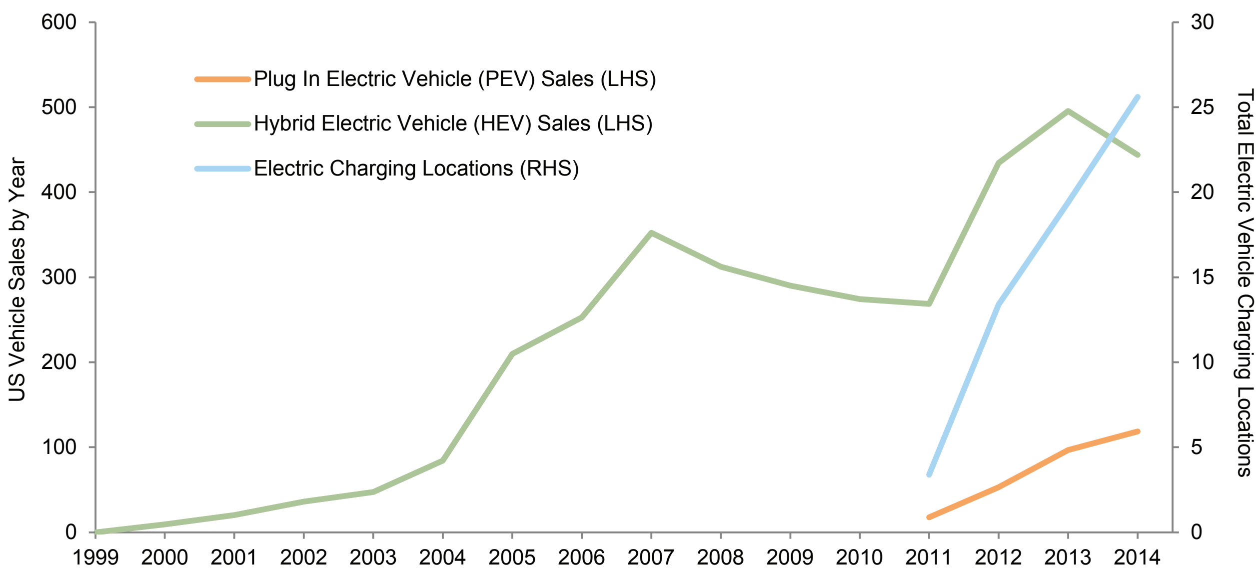
[16] Ben Geier, "Electric Vehicle Sales Charged Up in 2014," *Fortune*, January 8, 2015.

Figure 6. Selected Global Passenger Vehicle Greenhouse Gas Emission Standards
2000–25



Source: The International Council on Clean Transportation (ICCT).
Notes: Data are as of August 2015. Supporting data can be found at the ICCT Global PV Standards Chart Library.
* Gallons and liters are normalized to corporate average fuel economy (CAFE) test cycle.

Figure 7. US Alternative Fuel Vehicle Sales and Charging Locations
1999–2014 • Thousands



Source: US Department of Energy - Alternative Fuels Data Center (AFDC).
Notes: Total electric vehicle charging locations reflect electric charge equipment by the plug rather than by the geographic location, beginning in 2011. Data for PEV sales also begin in 2011.

vehicle infrastructure. Given the long-term transition toward cleaner transportation, more opportunities are likely to be found in the private markets, where managers are looking for emerging technology and service solutions catering to the evolving transportation industry.

Manager characteristics and skill sets

- ✓ Transportation industry expertise, including relevant areas such as manufacturing operations, supply chain, and distribution channels.
- ✓ Access to strategic players such as large auto manufacturers and/or large technology companies such as Google, Apple, and Uber for partnership, follow-on financing, and exits.
- ✓ Access to expertise on regulatory and policy developments for the transportation industry.
- ✓ Ability to recruit and attract best-in-class engineering and management talent.

Signposts

- ✓ Continued storage technology advancement and cost declines (monitor effects of manufacturers' scale up of battery production, for example).
- ✓ Further build-out of vehicle charging infrastructure networks.
- ✓ Unabated push by regulators for higher fuel economy standards.
- ✓ Rise in prices of traditional transportation fuels from market forces or policy action.

Opportunity Theme #3

"Smart Energy"

As policy, technology, and market forces push consumers and companies toward more efficient usage and management of energy resources, two key areas for investors to consider under the "smart energy" theme are the smart grid and the so-called Internet of Things. Both of these areas are where software, hardware, and energy management can intersect to form opportunities for investment.

Drivers of opportunity: smart grid. As the power grid becomes more connected, advanced software and hardware tools that facilitate improved control, integration, and interoperability across a more diverse mix of power generation inputs (storage, renewables, demand reduction assets, microgrids, etc.) will likely see growth and opportunity. Navigant Research forecasts that the global smart grid technology market will grow from $44 billion in revenues in 2014 to over $70 billion in 2023.[17] An example includes a venture-backed startup company that provides grid infrastructure solutions, combining both hardware and software to help utilities solve for distributed energy challenges.

Drivers of opportunity: Internet of Things. Energy-saving and return-generating opportunities will be found in the "Internet of Things" as more devices and appliances become connected to the internet. Recent examples include smart home products such as energy-saving thermostats and controllers for these smart home devices.

[17] Navigant Consulting, Inc., "Smart Grid Techologies," Chicago, Third Quarter 2014.

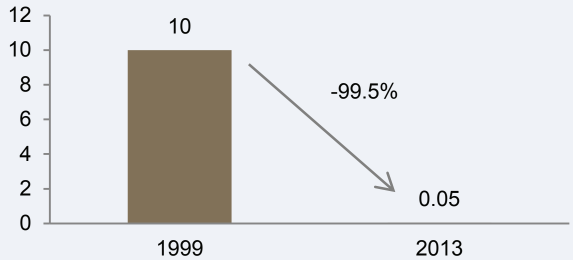
Parallels With Other Industries

The rapid cost declines in renewables and battery storage invoke memories of powerful trends in other industries. In information technology, cheaper processing, storage, bandwidth, and hardware have led to rapid adoption of personal computers and mobile devices. That has in turn spawned innovation and value creation in applications. In life sciences, exponential declines in human genome sequencing, the rise of virtual labs and computational biology, and more variable cost structures in the use of outsourced clinical research organizations have led to a boom in biotechnology companies addressing cancer, genetic diseases, and other human health challenges.

Cost Declines in Information Technology . . .

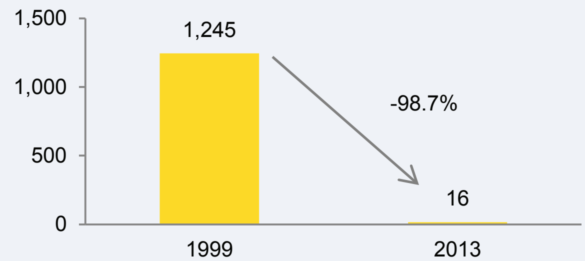
Moore's Law

US$/1 Million Transistors



Metcalfe's Law

US$/MB Bandwidth

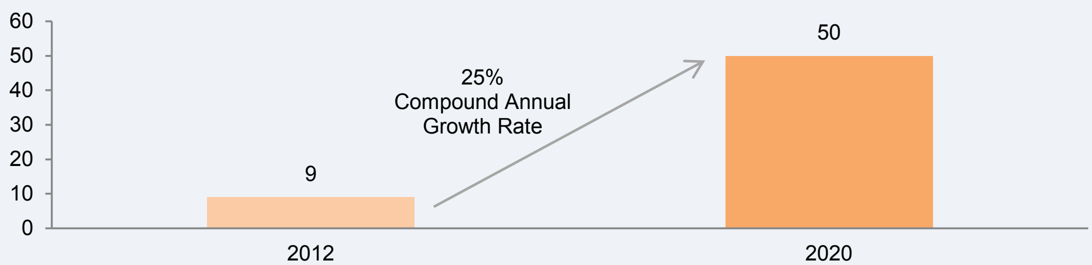


Sources: Deloitte, KPCB, and Silver Lake Partners.

. . . Enable More Connected Technological Devices (Globally)

Connected Technological Devices

Billions

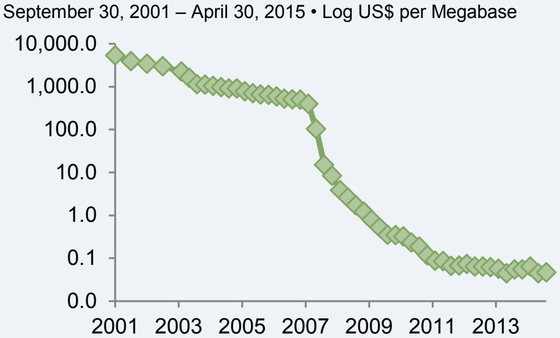


Sources: Cisco, Deloitte, Mooreland, and Silver Lake Partners.

Areas of Biotechology Also Seeing Cost Declines

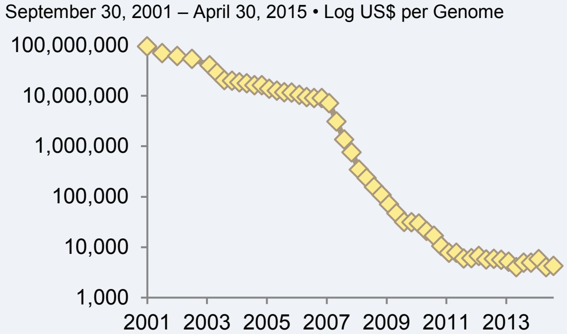
Cost per Raw Megabase of DNA Sequence

September 30, 2001 – April 30, 2015 • Log US$ per Megabase



Cost per Genome of DNA Sequence

September 30, 2001 – April 30, 2015 • Log US$ per Genome



Source: National Human Genome Research Institute.

Available strategies. Both marketable and private managers are pursuing smart grid and "Internet of Things" opportunities. Marketable managers generally pursue larger or more diversified companies, while private managers tend to focus more on emerging technologies and solutions. Given the software component of this theme, managers with a focus on information technology are well suited to pursue these areas. It is no surprise that many venture capital managers have focused more on this area.

Manager characteristics and skillsets

- ✓ Expertise and experience in software, hardware, *and* energy. All three are important for managers and their company management teams to navigate a complex regulatory and technical sub-sector.
- ✓ Nuanced understanding of local and regional power utility markets and regulations (particularly relevant for smart grid investments).
- ✓ Access to key industry players (power utilities, power equipment manufacturers like General Electric, and large technology companies like Samsung, Cisco, and Google) for partnerships, follow-on financing, and exits.

Signposts

- ✓ Increased visibility on interoperability standards (i.e., smart devices from different manufacturers need to be able to "talk to each other").
- ✓ Continued adoption of distributed generation, which will cause utilities to have to manage a more complex grid, thereby increasing demand for smart grid technologies and services.

Opportunity Theme #4

Energy Efficiency in Buildings

Drivers of opportunity. Businesses and technologies that contribute to energy efficiency measures in residential, commercial, and industrial buildings make up an emerging and growing opportunity for investors. According to the International Energy Agency, the global energy efficiency market is worth at least $310 billion a year and growing.[18]

An important driver of opportunity in this market is the rising cost of electricity transmission, which is one of the largest components of electricity bills. For example, in the United States, the cost of transmission has already increased five-fold between 1997 and 2012 to improve reliability and accommodate the growing fleet of renewables.[19] As the adoption of distributed generation rises further, utilities' fixed costs (transmission and distribution costs) will be split among fewer customers, putting further upward pressure on prices. Moreover, regulatory measures to curtail power plant CO_2 emissions, including the recently proposed Clean Power Plan of 2014, may add more upward pressure to electricity prices in the United States. With electricity prices rising irrespective of fuel prices, demand for energy efficiency improvements should remain strong.

Commercial and industrial building owners have taken to common energy efficiency measures such as lighting and HVAC (heat, ventilation, and air conditioning) upgrades in light of rising electricity prices, and an increasing number of third-party

[18] International Energy Agency, "Global Energy Efficiency Market 'An Invisible Powerhouse' Worth at Least USD 310 Billion Per Year," October 8, 2014.
[19] Lori Aniti, "Investment in Electricity Transmission Infrastructure Shows Steady Increase," US Energy Information Administration, August 26, 2014.

financing options have emerged to alleviate up-front project costs for customers. Today these trends are picking up in the United States, and we are beginning to see them internationally as well via entities such as the European Commission and the International Finance Corporation.[20,21]

Keep in mind that some of the next-generation energy efficiency opportunities will overlap with those in the "smart energy" theme we discussed earlier. For example, we have seen companies that provide both intelligent lighting technology solutions and professional services to deploy the solutions in residential, commercial, and industrial settings.

Available strategies. Marketable energy managers can pursue the energy efficiency theme by investing in energy service companies (ESCOs) or in listed value chain companies selling into the energy efficiency market. In fixed income, municipalities and corporations can issue green bonds tied to energy efficiency projects.

Private managers can invest in energy efficiency technologies, project contractors, and other value chain businesses. On the asset-oriented side, we have also recently seen the formation of private strategies directly targeting diversified portfolios of energy efficiency projects via equity or debt financing.

[20] European Commission, "Financing Energy Efficiency," Accessed November 16, 2015, www.ec.europa.eu/energy/en/topics/energy-efficiency/financing-energy-efficiency.
[21] The Independent Evaluation Group and The World Bank Group, "Energy Efficiency Finance: Assessing the Impact of IFC's China Utility-Based Energy Efficiency Finance Program," The International Bank for Reconstruction and Development/The World Bank, 2010.

Manager characteristics and skill sets

For resource-efficiency managers pursuing value chain opportunities:

- ✓ Nuanced understanding of technological trends, competitive dynamics, and end customer pain points in each major energy efficiency market (residential, commercial, industrial).
- ✓ Knowledge of local and regional regulatory context and third-party financing availability.

For project-oriented managers:

- ✓ In-house engineering and contracting capabilities, or access to high-quality contractors that can execute energy efficiency projects on time and on budget.
- ✓ Strong sourcing and marketing capabilities; energy efficiency projects can have a long sales cycle if the manager cannot properly communicate value proposition.
- ✓ Adoption of institutionalized processes for documentation, financing, and measurement and verification of energy savings to maximize scale.
- ✓ Disciplined harvesting and recycling of project cash flows.

Signposts

- ✓ Institutionalization of scalable processes in project documentation, and measurement and verification.
- ✓ Accelerated sales cycles and scalability of energy efficiency projects through business model innovation.

- ✓ Continued innovation and evolution in energy efficiency financing models in addition to existing programs such as PACE (Property Assessed Clean Energy) in the United States.

Opportunity Theme #5

Water and Agricultural Efficiency

Drivers of opportunity. As discussed earlier in *Part I*, supply chain disruptions are a risk from a changing climate, particularly related to negative impacts on water and food supply. Companies that provide technologies or services that increase data visibility on resource utilization, and/or provide the solutions to actually increase water efficiency and crop productivity should benefit. Agricultural and water assets that are operated in a resource-efficient manner should also benefit from long-term competitive advantages.

In water, as an example, some companies are providing water-management solutions to US water utilities, decreasing water demand and saving on costs in the meantime. Other examples of opportunities for better technologies and services are in wastewater treatment and recycling.

In agriculture, California farmers affected by the drought are increasingly investing in data-driven technologies that save water and increase crop productivity.[22] Venture-backed companies are already providing data-driven tools for farmers to monitor and manage their farm businesses. Other thematic areas such as seeds, labor automation, controlled-environment agri/aquaculture, specialty fertilizers and nutrient enhancements, and precision agriculture (e.g., drip irrigation) are additional examples of value chain opportunities in the agricultural sector.

Drones make up yet another opportunity set in the context of precision agriculture. In fact, agriculture drones are expected to make up 80% of the future global commercial market, according to the Association for Unmanned Vehicles Systems International.[23] Drones benefit from declining costs partially as a result of leveraging ever-cheaper smartphone components such as gyroscopes, altimeters, and compasses. High-resolution imaging technology via drones enables farmers to precisely and efficiently deploy fertilizer, water, and labor, thereby increasing crop yields and saving on often costly inputs.

Available strategies. An increasing number of marketable and private managers are focusing on water and agriculture value chain companies. Some are specialists on this theme while others are generalists who have some exposure within a broader portfolio. In fixed income, green bond issuances focused on clean water and sustainable agriculture are options to consider. Within private markets, investors can also choose among venture, growth equity, and buyout managers depending on their risk tolerance for stage of underlying companies' development. Furthermore, there are private strategies that focus on sustainable water and agricultural assets with an operational value-add component.

Manager characteristics and skill sets

- ✓ Sector specialists that bring industry experience, networks, and expertise in water and agriculture should be

[22] Ilan Brat, "California Drought Plants Seeds for Tech," *The Wall Street Journal*, July 17, 2015.

[23] John Wihbey, "Drones Are Revolutionizing Farming. Is America Being Left in the Dirt?," *Boston Globe*, August 23, 2015.

favored. Access to relevant operationally oriented resources provides further differentiation.

- ✓ For generalist firms with some exposure to this theme, those with investment professionals who have built specific domain expertise over time are preferable.
- ✓ Access to potential customers and acquirers.
- ✓ Nuanced understanding of regulatory dynamics at the local and regional level.

Signposts

- ✓ Increasing number and quality of technologically savvy entrepreneurs and management teams that also understand water, food & agriculture sectors. Also look for signs that current and next-generation executives in water and agribusiness companies are focusing on developing capabilities and talent that position their companies to be on the technological cutting edge.
- ✓ Continued appetite by larger industry strategic players (e.g., Veolia, GE, Ecolab, Danaher in water; Monsanto and Syngenta in agriculture) to acquire smaller firms backed by venture or private equity.

Other Emerging Themes

The themes just discussed make up only a selection of available opportunity areas. Resource efficiency managers are also pursuing many other themes including biomass, waste-to-value, water rights, sustainable community development, and wetland mitigation banking strategies, just to name a few. In the future, more investment products may become available in the insurance space as more businesses and asset owners desire to transfer components of climate risk. Climate resilience and adaptation themes (such as sea wall and elevated real estate, flood control and pumping solutions, and geo-engineering) could also emerge. Because we expect climate-related opportunities to continue to evolve and emerge, we are watching markets and managers carefully to identify and evaluate these opportunities.

Other Strategies for Offense

Investors that desire a more precise and concentrated way to access resource efficiency opportunities can also do so through direct investments in companies or projects, or through co-investments with fund managers. Some investors have the domain knowledge, networks, and governance structure to properly source, diligence, execute, and monitor direct investments themselves. But most do not and will have to primarily rely on resource efficiency managers to do most of the heavy lifting on co-investment opportunities. As we discussed in our recent paper on co-investments, "Making Waves: The Cresting Co-investment Opportunity," investors should focus on opportunities that are within a sponsor's "strike zone" in terms of the investment's size, sector, and geography.[24] Investors considering direct or co-investments should view these within the context of a diversified private portfolio and should size these investments appropriately relative to fund commitments.

Foundations with a mission-related mandate to combat environmental or climate issues

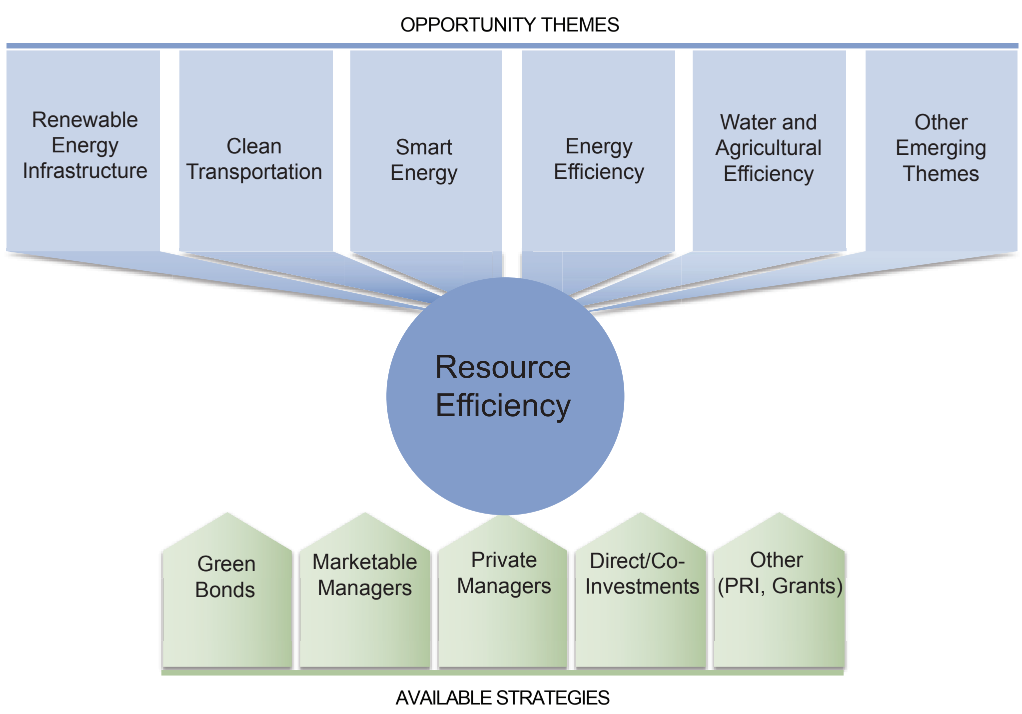
[24] Andrea Auerbach et al., "Making Waves: The Cresting Co-investment Opportunity," Cambridge Associates Research Report, 2015.

also have their grant-making strategy in their arsenal to support projects. They can also make program-related investments (PRIs), which come out of the program budget rather than the endowment. Through PRIs in particular, these investors may be able to support and access early-stage projects with a high degree of technology risk and that venture capital managers may not be pursuing. While these strategies are outside the scope of this paper, we note them for these relevant institutions to consider as part of their comprehensive menu of options for offense.

The Playbook for Offense: Summary

The select opportunity themes discussed and the various approaches to access those themes are neither all-inclusive nor static, as new themes can emerge and existing themes can evolve over time. Various vehicles are available to access underlying resource efficiency themes, with some opportunities lending themselves more to certain structures than others. The mandate of the strategies can differ, with the scope of some more narrowly focused on a single theme (e.g., renewables, water, or agriculture), while others focus on multiple themes, and generalists deploy capital not only to resource efficiency themes but a broader range of sectors. Direct and co-investments, grants, and PRIs are other offense options that some investors can pursue as part of a broader playbook of offense strategies. Figure 8 summarizes the themes that make up the resource efficiency opportunity, and Appendix Figure B-2 provides a pictorial representation of managers pursuing resource efficiency themes in both marketable and private formats.

Figure 8. The Playbook for Offense: Investment Themes and Strategies

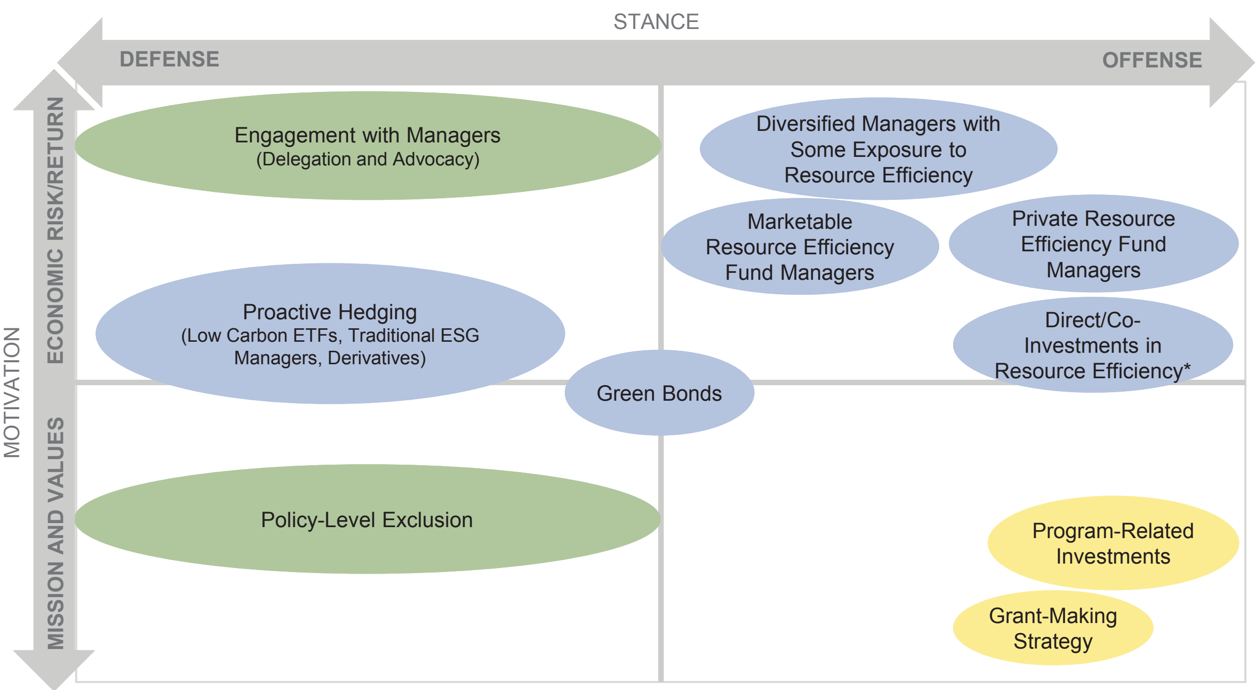


Integrating Defense and Offense

Both strong defense and offense are important to manage risks and capitalize on opportunities associated with climate change. Long-term investors would benefit from not only developing playbooks for effective defense and offense within their portfolios, but also properly integrating them into a cohesive investment strategy that is aligned with their own views and motivations. Every investor should think about when to dial up and down defense and offense measures appropriately as circumstances evolve. Deciding when to use certain plays is just as important as executing well on those plays. And finally, setting an appropriate time horizon and benchmark (on an *absolute basis*, on a *relative basis versus a relevant index*, and *relative to the sources of funds and opportunity costs*) for any defense or offense measures taken, are important considerations. Aside from the clean tech company performance benchmark mentioned in the sidebar, we include in Appendix Figure B-3 a select sample of public market indexes that investors could consider in benchmarking both defense and offense strategies, with the caveat that these indexes are end-point sensitive and many are still quite young.

Figure 9 provides a high-level schematic of the full array of strategies for defense and offense, solving for both stance and motivation. We acknowledge that investors may hold different views on the positioning of each of these strategies. Our intention is not to stamp these labels into permanence, but rather to lay out an initial framework for investors to evaluate and contextualize their options.

Figure 9. Framework for Integrating Climate Defense and Offense



* Direct/co-investments should be viewed within the context of a well-diversified VC/PE portfolio and sized appropriately relative to fund commitments.
Note: Blue indicates investment vehicles from long-term investment pool. Green indicates investment-related actions that do not necessarily involve deploying capital. Yellow indicates strategies that can be pursued on the program side of a foundation, outside the endowment or long-term investment pool.

Stay Tuned . . .

Rather than ending with a summary conclusion, we prefer to pause here and say "stay tuned for more." As we strive to be truly long-term investors ourselves, we recognize that there will be continued evolution in both risk factors and opportunity sets involving climate change. Given the many uncertainties around this long-term issue, we will be committed to collaborating with our clients and the broader industry to constructively iterate on both theoretical framework and practical implementation. In the meantime, we continue to seek and refine effective approaches to 1) understand and manage risks amplified by climate change, and 2) search for positive returns that capture the value created by businesses and assets that play a role in the world's gradual transition to a lower-carbon and more resource-efficient economy. These opportunities are and will continue to be driven by a combination of technological and business model innovations, policy and regulatory shifts, and, perhaps more fundamentally, the human entrepreneurial spirit that is drawn to creating real solutions to large problems. ■

Examples of Policy, Regulatory, and Legal Action on Climate Change

- The **European Union** enacted a cap-and-trade system in 2005 known as the EU Emission Trading Scheme (ETS) to place a limit on greenhouse gas emissions. In addition, the EU has committed to reducing its overall emissions at least 40% below 1990 levels by 2030. Several European countries, including Denmark, Finland, Ireland, the Netherlands, Norway, Slovenia, Sweden, Switzerland, and the United Kingdom, have enacted a carbon tax.
- In 2014, **Chile** enacted the first climate pollution tax in South America, targeting large factories and the electricity sector.
- **Brazil** pledged in 2010 to reduce its emissions by 36.1%–38.9% in 2020 compared to business-as-usual emissions.
- **South Africa** is considering a carbon tax in 2016.
- **New Zealand** set up an emission trading scheme in 2008, covering forestry initially, but then expanded in 2010 to cover energy, transport, liquid fossil fuels, and industrial processes.
- **South Korea**'s emissions trading scheme, legislated in 2012, officially entered into force on January 1, 2015, and is now the second largest carbon market worldwide after the EU's ETS.
- **Japan** introduced a carbon tax in 2012 to reduce emissions; it also recently announced its Intended Nationally Determined Contribution (INDC) of targeting an emission reduction of 26% below 2013 emission levels by 2030.
- **China**, the world's largest emitter, committed to target peak emissions by 2030 and lower the carbon intensity of GDP by 60%–65% below 2005 levels by 2030. The country currently has seven city and provincial level pilot carbon emissions trading schemes. In September 2015, China announced that it will launch a national "cap and trade" system in 2017. Once initiated, it will become the world's largest carbon trading market.
- In **India**, the government in 2010 introduced a nationwide carbon tax of 50 rupees per tonne of coal both produced and imported to the country; this tax has since been doubled twice and is now 200 rupees per tonne. Moreover, India has pledged to reduce its GDP emis-

Information contained in this section was compiled from sources including:
- Carbon Tax Center, "Where Carbon Is Taxed," Accessed November 16, 2015, www.carbontax.org/where-carbon-is-taxed.
- Climate Action Tracker, "Climate Action Tracker: Countries," Accessed November 16, 2015, www.climateactiontracker.org/countries/.
- International Carbon Action Partnership, "Korea's Emissions Trading System Started on 1 January 2015," Accessed November 16, 2015, www.icapcarbonaction.com/news/news-archive/263-korea-s-emissions-trading-system-started-on-1-january-carbon-trading-opens-on-12-january.
- Japan for Stability, "Japan Introduces New Tax on Carbon Emissions," Accessed November 16, 2015, www.japanfs.org/en/news/archives/news_id032490.html.
- Ryan Koronowski, "Half of California's Electricity Will Come From Renewables Within 15 Years," Climate Progress, September 12, 2015.
- Quirin Schiermeier, "Landmark Court Ruling Tells Dutch Government to do More on Climate Change," *Nature*, June 24, 2015.
- Special Broadcasting Service Corporation, "Factbox: Carbon Taxes Around the World," Accessed November 16, 2015, www.sbs.com.au/news/article/2013/10/29/factbox-carbon-taxes-around-world.
- James Wood, "Alberta Boosts Carbon Tax to $20 a Tonne Starting in 2016 as Part of Climate Change Plan," *Financial Post*, June 25, 2015.

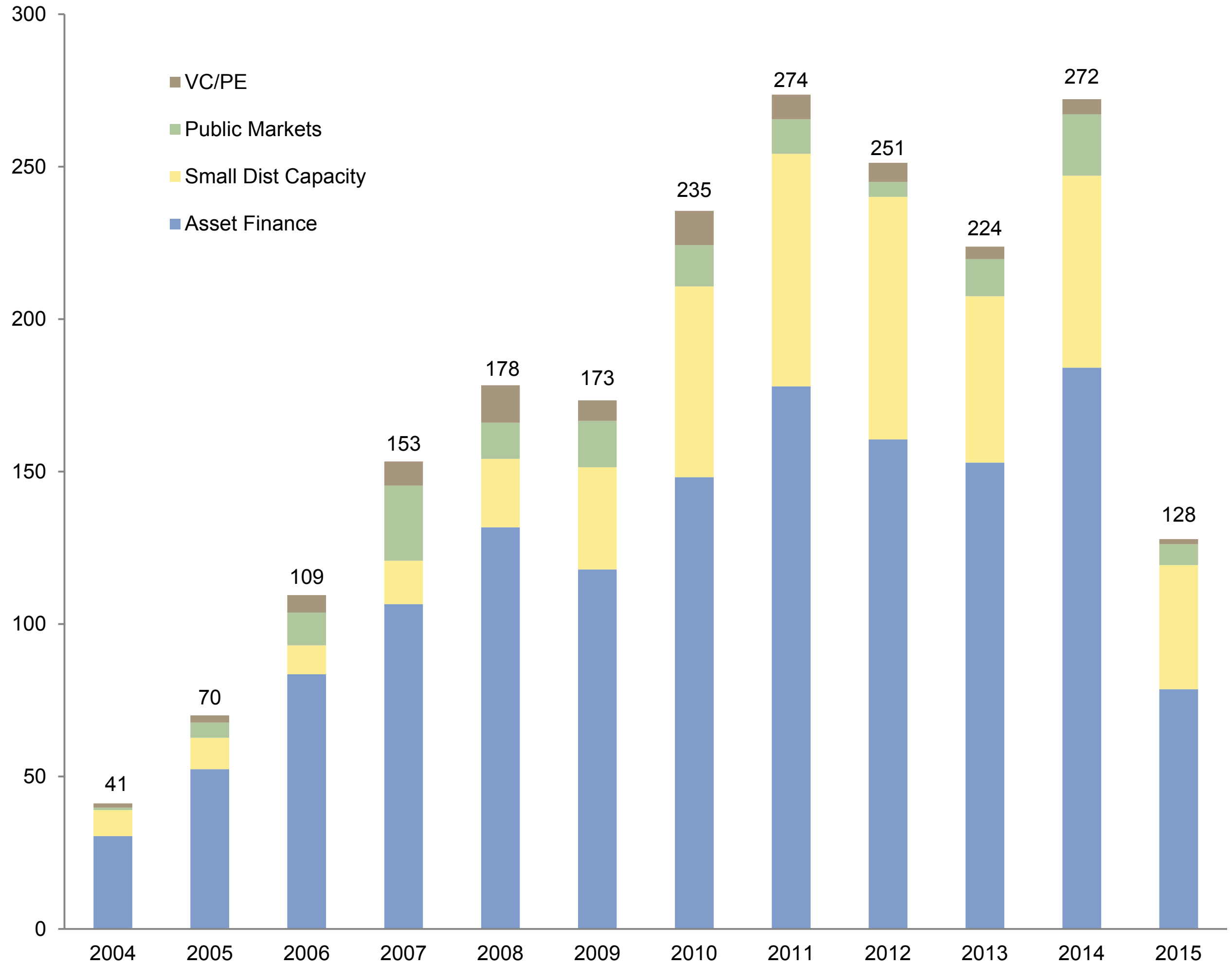
sions intensity by 20%–25% by 2020 compared to 2005 levels.

- In **Canada**, the province of British Columbia implemented a carbon tax in 2008 and has increased it four times; similarly, in June 2015, Alberta announced that it will increase its existing provincial carbon levy on larger emitters from the current C$15 per tonne to C$20 per tonne in 2016, and $30 per tonne in 2017.
- In the **United States**, the proposed federal Clean Power Plan would require a 32% cut in power-plant carbon dioxide emissions by 2030 from 2005 levels. It also calls for the United States to generate 28% of its electricity from renewable sources by 2030 (versus 13% as of 2014). At the state and regional levels, there are currently two cap-and-trade markets: (1) Regional Greenhouse Gas Initiative (RGGI), which covers nine Northeastern and Mid-Atlantic States; and (2) California. The latter, the largest US state and also the world's eighth largest economy, passed a bill in early September that sets a target of 50% electricity generation coming from renewable sources and a requirement of 50% increase in buildings' energy efficiency by 2030.
- A recent Hague court ruling concluded that the government in **the Netherlands** must take action to cut greenhouse gas emissions by 25% by 2020. This ruling is significant in that it can be a precedent-setting case for other jurisdictions, especially in Europe, that make these policies more legally enforceable. ■

Additional Exhibits

The figures in this section provide additional information and context for consideration. Figure B-1 displays total investment in renewable energy, showing that the venture capital and private equity strategies discussed in the report's clean tech sidebar are only a portion of total investment in the sector. Figure B-2 is a pictorial representation of managers pursuing resource efficiency themes in both marketable and private formats. Finally, Figure B-3 compares a selection of marketable indexes relating to resource efficiency with traditional indexes on a risk/return basis over different periods.

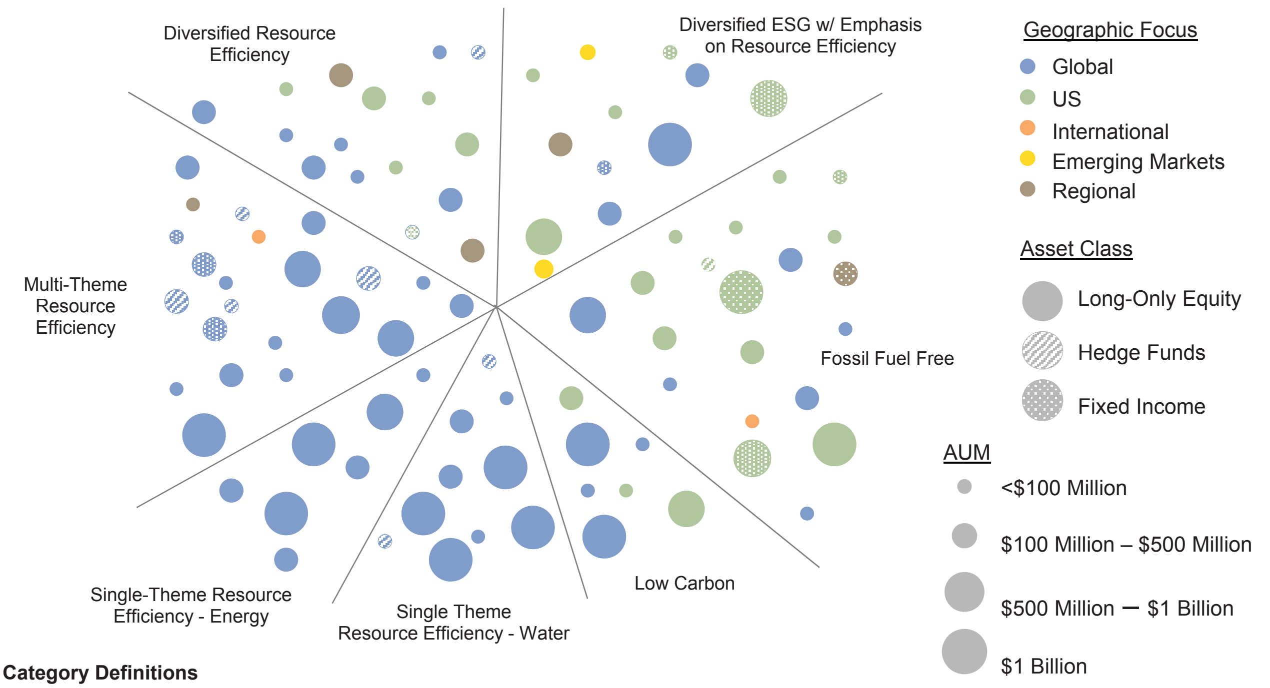
Appendix Figure B-1. Global Investment in Renewable Energy
2004–15 • US Dollar (billions)



Source: Bloomberg New Energy Finance.
Notes: Data for 2015 are through June 30, 2015. Total values include estimates for undisclosed deals. Excludes corporate and government R&D and spending for digital energy and energy storage projects.

Appendix Figure B-2. Manager Universe Addressing Climate Risk/Opportunity

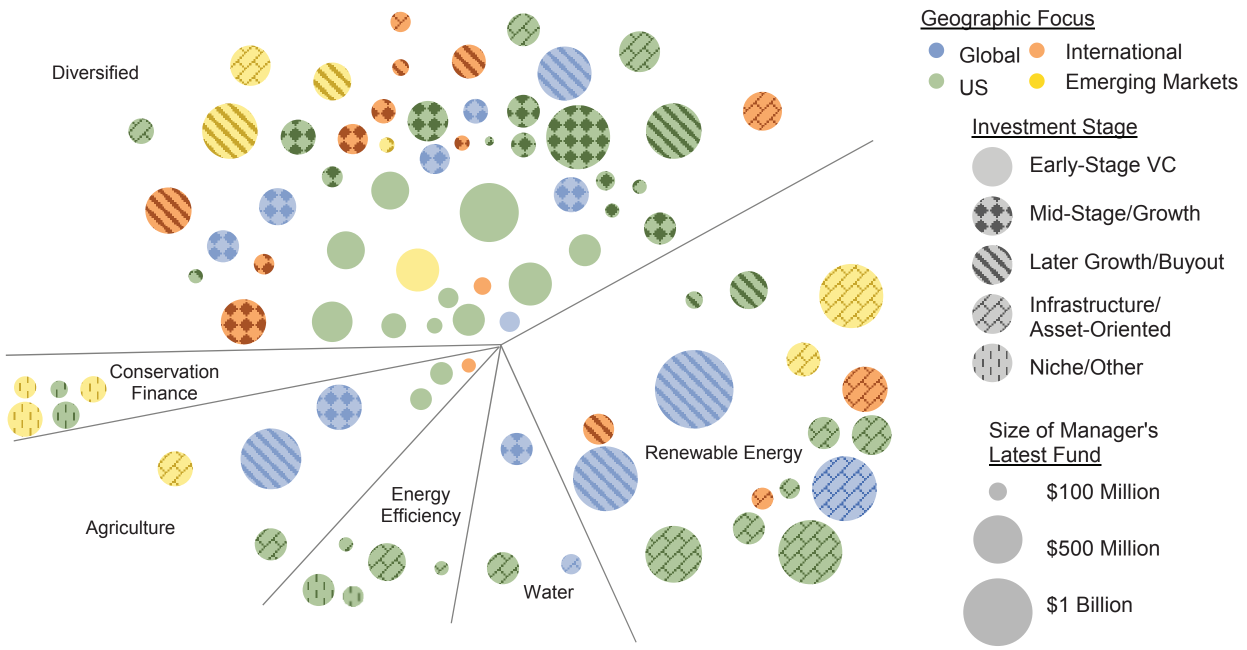
Marketable Managers



Category Definitions

Single Theme Resource Efficiency: Focused on a single sector/industry within the resource efficiency space, e.g., water, alternative energy, etc.
Multi-Theme Resource Efficiency: Invested around multiple, distinct themes with the resource space, e.g., water and alternative energy
Diversified Resource Efficiency: Invested across all sectors but with explicit focus on environmental/resource efficiency factors as investment thesis
Diversified ESG With Emphasis on Resource Efficiency: Core-like strategies integrating ESG criteria into the investment process with a strong focus on environmental/resource efficiency factors
Fossil Fuel Free: Excludes fossil fuel companies, as defined by the manager
Low Carbon: Designed to reduce the overall carbon emissions profile of a base index or strategy, typically by overweighting resource efficient companies and underweighting heavy emitters

Private Investment Managers

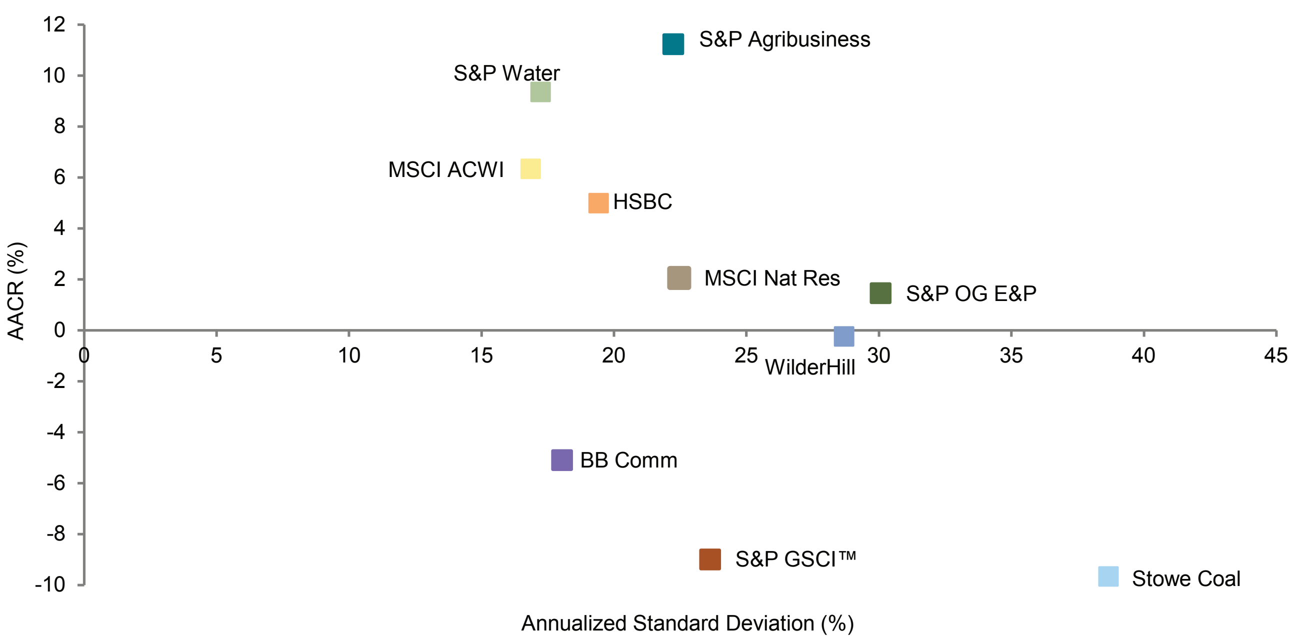


Appendix Figure B-3. Historical Performance and Risk/Return of Various Public Equity Market Indexes

Public Market Index Performance
As of October 31, 2015 • US Dollar

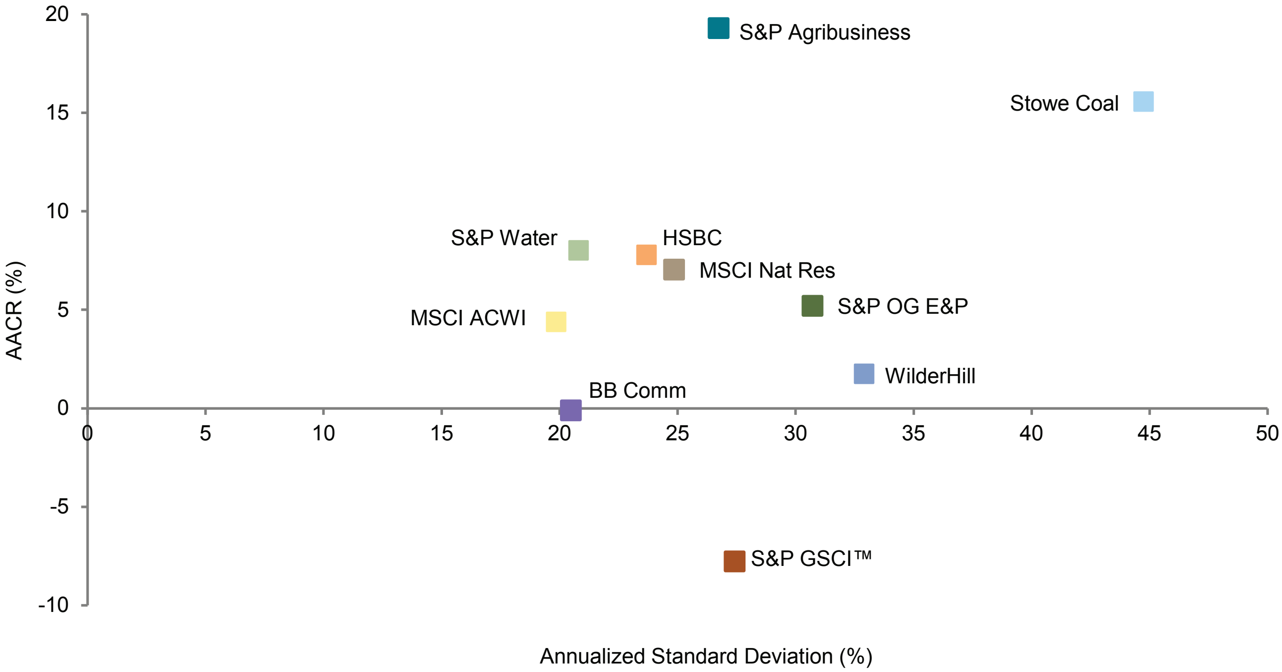
	Average Annual Compound Return (%)				
Index (start date)	One Yr	Three Yrs	Five Yrs (2010–2015)	Five Yrs (2005–2010)	Ten Yrs
S&P Global Water (11/30/01)	3.09	12.91	10.70	8.01	9.35
MSCI AC World Low Carbon Target (11/30/10)	1.11	8.91	6.93	—	—
HSBC Global Climate Change (12/31/03)	-3.65	9.74	2.26	7.77	4.98
Nasdaq OMX Clean Edge Smart Grid Infr (11/30/06)	-5.45	7.99	3.12	—	—
WilderHill New Energy Global Innovation (12/31/00)	-6.48	17.69	-2.20	1.74	-0.25
S&P Global Agribusiness (11/30/03)	-7.08	5.76	3.70	19.29	11.22
Nasdaq Clean Edge Green Energy (11/30/06)	-17.51	20.67	-0.24	—	—
MSCI World Natural Resources (12/31/98)	-23.13	-6.13	-2.68	7.03	2.06
Bloomberg Commodity (12/31/91)	-25.72	-15.04	-9.85	-0.10	-5.10
S&P GSCI™ (12/31/59)	-37.89	-18.66	-10.21	-7.78	-9.00
S&P Oil & Gas Exploration & Production (12/31/99)	-38.20	-10.48	-2.16	5.19	1.45
Stowe Global Coal (12/31/04)	-56.03	-36.00	-29.40	15.56	-9.67
MSCI AC World (12/31/87)	0.57	10.57	8.32	4.38	6.33

Risk/Return Analysis for Various Public Market Indexes: Ten Years
October 31, 2005 – October 31, 2015 • US Dollar

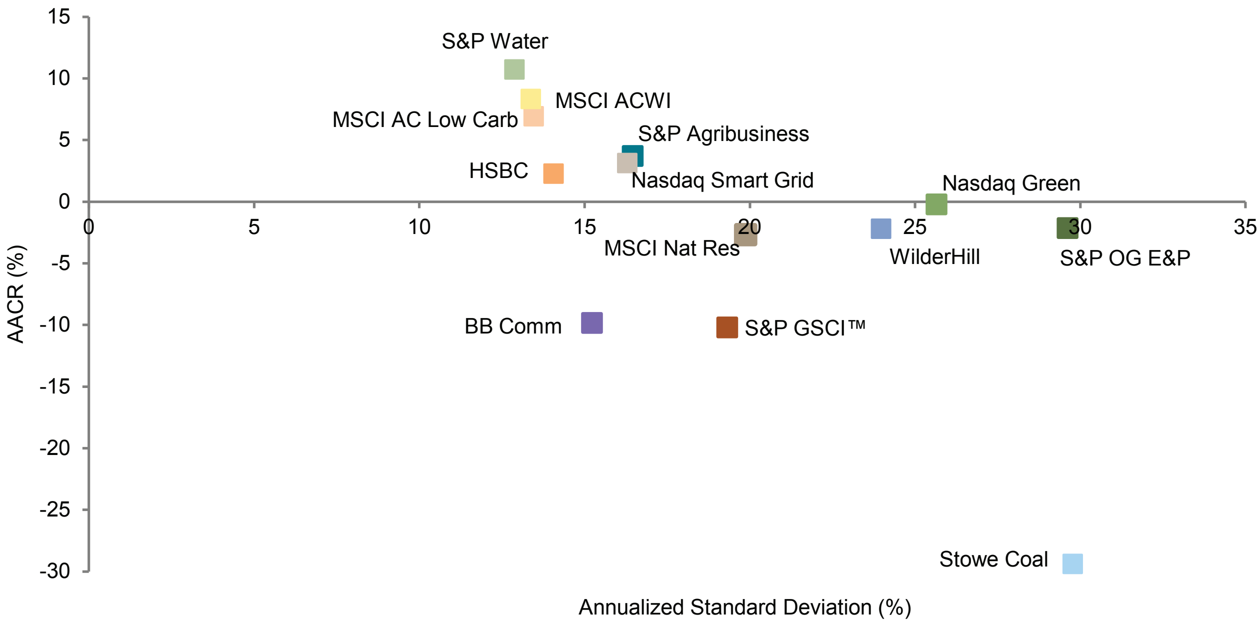


Appendix Figure B-3 (cont). Historical Performance and Risk/Return of Various Public Market Indexes

Risk/Return Analysis for Various Public Equity Market Indexes: Five Years (2005–2010)
October 31, 2005 – October 31, 2010 • US Dollar



Risk/Return Analysis for Various Public Market Indexes: Five Years (2010–2015)
October 31, 2010 – October 31, 2015 • US Dollar



Sources: Bloomberg L.P., HSBC Inc., MSCI Inc., NASDAQ Inc., Standard & Poor's, Stowe Partners LLC, Thomson Reuters Datastream, and WHNEF LLC. MSCI data provided "as is" without any express or implied warranties.
Notes: Data are monthly. Performance data are total returns gross of dividend taxes except for HSBC, which are price returns.

Select Reading List for Climate Change Risk and Opportunities

Numerous articles and reports discuss the risks and opportunities related to climate change. We have highlighted a few that we believe provide helpful information and context for investors that seek further understanding of this issue. This list is certainly not exhaustive and is not meant to endorse one particular view over another, but rather should serve as further reference for those wishing to explore some of the points made in this report.

Investor Frameworks on Climate-Related Risks

Christopher Weber and Mark Fulton, "Carbon Asset Risk: Discussion Framework," World Resources Institute, August 2015

- Discusses the non-physical risks (e.g., policy, market, and technology risks) that climate change may pose for investors and lays out a framework for investors to think about carbon asset risk in their portfolios.

"Climate Change Investment Solutions: A Guide for Asset Owners," Institutional Investors Group on Climate Change, April 24, 2015

- Seeks to provide investors with tools for, and guidance on, integrating climate change into investment processes. The paper notes that corporate and policy engagement is an important complementary strategy to both address risks and identify opportunities.

Studies on Broader Economic Risks of Climate Change

"Unhedgeable Risk: How Climate Change Sentiment Impacts Investment," Cambridge Institute for Sustainability Leadership, November 2015

- A guide to approaching an "unhedgeable risk"—climate change—for institutions, investors, and regulators. The authors argue that certain asset allocation moves within a portfolio may help minimize exposure to climate sentiment risk.

Marshall Burke, Solomon M. Hsiang, and Edward Miguel, "Global Non-linear Effect of Temperature on Economic Production," *Nature*, October 21, 2015

- An empirical analysis of temperature and productivity. The authors of this article analyzed historical temperatures and productivity of 166 countries and observed that climate change may have a more severe impact on the global economy than previously suggested.

"The Cost of Inaction," *The Economist*, September 26, 2015

- Analyzes the economic costs of inaction on climate change, on both a global- and investor-level scale. The report posits that climate change, both minor and severe, may lead to weaker economic growth and asset class returns.

C | A

"Risky Business: The Economic Risks of Climate Change in the United States," Risky Business Project, 2014

- Analyzes the potential economic consequences associated with climate change in the United States. Specifically, the report looks at property and infrastructure damage caused by rising sea levels and storms, shifting agricultural patterns and crop yields, and impacts on labor productivity and public health.

Research on Select Opportunity Themes

"Crossing the Chasm," Deutsche Bank, February 27, 2015

- Analyzes the future of solar electricity. Due to declining prices of solar panels and improving financing and customer acquisition costs, the report asserts that solar electricity is expected to become a more viable option versus traditional retail electricity despite low oil & gas prices. Going forward, the report argues that solar costs may continue to decline due to improved economics in the industry.

Beijia Ma, Barnaby Martin, Sarbjit Nahal, and Emmanuel Owusu-Darkwa, "Fixing the Future: Green Bonds Primer," Bank of America Merrill Lynch, September 8, 2014

- Explores the financial consequences of climate change and potential investment opportunities, specifically the opportunity to invest in Green Bonds.

"Energy Efficiency: A Compelling Global Resource," McKinsey & Company, 2010

- A compilation of articles on energy-efficiency opportunities and how to potentially capture them in companies and countries.

Review of Climate Change Policy and Regulation Trends

"State and Trends of Carbon Pricing 2015," World Bank Group, September 2015

- An overview of existing and emerging carbon pricing instruments around the world, including national and state initiatives, updated annually. This report covers instruments that put an explicit price on greenhouse gas emissions, such as emissions trading systems, carbon taxes, offset mechanisms, and results-based finance, but also internal carbon prices. It also provides a forward-looking assessment of the advantages of international cooperation in reaching global targets.

Perspectives From Asset Managers

"The Price of Climate Change: Global Warming's Impact on Portfolios," BlackRock Investment Institute, October 2015

- Examines the potential implications of climate policy and other factors on investors and investment outcomes, outlining potential winners and losers from efforts to mitigate climate change. The paper considers ways for asset owners to promote sustainability, including a focus on environmental, social, and governance (ESG) factors.

Ian Simm, "Climate Change: Now Risk Not Uncertainty," Impax Asset Management, May 26, 2015

- Outlines ways investors can measure and respond to climate change risk to position their portfolios for long-term outperformance.

Rick Stathers and Alexia Zavos, "Responding to Climate Change Risk in Portfolio Management," Schroders, February 2015

- Explores the various strategies investors can employ to better understand and manage their exposure to climate change risk.

Related Research From Cambridge Associates

Seth Hurwitz and Noelle Laing, "The Growing Market for Green Bonds," Cambridge Associates, August 13, 2014

- Reviews the growth of the green bonds market, investigates the issuers and buyers of green bonds, and discusses key considerations and what to watch going forward as this market matures.

Jessica Matthews et al., "The Fossil Fuel Divestment Discussion," Cambridge Associates, June 2014

- Offers a framework to help navigate the important discussion of fossil fuel divestment within institutions and some practical considerations that investors should keep in mind when exploring the investment decision.

Kyle Johnson et al., "Impact Investing: A Framework for Decision Making," Cambridge Associates, 2013

- Defines impact investing, explores its allure and challenges, and offers a decision-making framework to help investors successfully build impact investing portfolios within the context of their long-term investment pools. ■

Cambridge Associates does not provide stock selection recommendations, and any reference to specific companies is not to be interpreted as a recommendation of that company as an investment option.

Index Disclosures

Bloomberg Commodity Index
The Dow Jones-UBS Commodity Index (DJ-UBSCI) is a broadly diversified index that allows investors to track commodity futures through a single, simple measure. The DJ-UBSCI is composed of futures contracts on physical commodities. It is published on Bloomberg and Reuters. The index is designed to minimize concentration in any one commodity or sector. It currently includes 19 commodity futures in five groups. No one commodity can compose less than 2% or more than 15% of the index, and no group can represent more than 33% of the index (as of the annual re-weightings of the components).

CA Clean Tech Company Performance Benchmark
The CA Clean Tech Company Performance Benchmark was launched in 2013. We track more than 1,400 distinct investments made between 2000 and 2013, representing $28.0 billion of invested capital. These investments are in over 800 distinct companies backed by 480 different private investment funds (including 345 venture capital funds, 129 private equity, and 6 infrastructure funds). It is published on a quarterly basis, and new companies are added to the benchmark every quarter as coverage of the relevant universe is expanded.

HSBC Global Climate Change Index
The HSBC Global Climate Change Benchmark Index covers roughly 300 stocks from 34 countries and 19 themes, including solar, wind, energy-efficient solutions, power storage, biofuels, carbon trading, diversified renewable, investment companies, and building insulation. Companies must derive more than 10% of their annual revenues from climate change–related business activities. The minimum market capitalization is currently set at $500 million, and components must have a minimum average daily trading turnover of 0.02% of full market capitalization. Components are weighted based on a combination of full-float market capitalization and their exposure to the relevant fields.

MSCI All Country World Low Carbon Target Index
The MSCI ACWI Low Carbon Target is based on the MSCI ACWI, its parent index, and includes large- and mid-cap stocks across 23 developed markets and 23 emerging markets countries. The index aims for a tracking error target of 0.3% (30 bps) while minimizing the carbon exposure. By overweighting companies with low carbon emissions (relative to sales) and those with low potential carbon emissions (per dollar of market capitalization), the index reflects a lower carbon exposure than that of the broad market. It uses MSCI ESG CarbonMetrics data from MSCI ESG Research Inc.

MSCI All Country World Index
MSCI ACWI captures large- and mid-cap representation across 23 developed markets and 23 emerging markets countries. With 2,476 constituents, the index covers approximately 85% of the global investable equity opportunity set.

MSCI World Natural Resources Index
The MSCI World Natural Resources is based on the MSCI ACWI, its parent index, and includes energy sector stocks plus metals & mining, paper & forest products sub-industries. The MSCI data are composed of a custom index calculated by MSCI.

NASDAQ Clean Edge Green Energy Index
The NASDAQ® Clean Edge® Green Energy Index (CELS) is a modified market capitalization–weighted index designed to track the performance of companies that are primarily manufacturers, developers, distributors, or installers of clean energy technologies. To be eligible for inclusion in the Index, the security must be listed on NASDAQ, NYSE, or AMEX.

NASDAQ OMX Clean Edge Smart Grid Infrastructure Index
The NASDAQ OMX® Clean Edge® Smart Grid Infrastructure Index (QGRD) includes companies that are primarily engaged and involved in electric grid; electric meters, devices, and networks; energy storage and management; and enabling software used by the smart grid and electric infrastructure sector. The security must be listed on an index-eligible global stock exchange approved by the Index Administrator. The component securities are classified as pure play or diversified. Pure play securities are given a collective weight of 80% and the diversified securities are given a collective weight of 20% in the Index.

S&P Global Agribusiness Index
The S&P Global Agribusiness Index is a modified market cap–weighted index that includes 24 of the largest publicly traded agribusiness companies from around the world. The index is composed of a diversified mix of producers, distributors & processors, and equipment & materials suppliers companies.

S&P Global Water Index
The S&P Global Water Index provides liquid and tradable exposure to 50 companies from around the world that are involved in water-related businesses. To create diversified exposure across the global water market, the 50 constituents are distributed equally between two distinct clusters of water related businesses: water utilities & infrastructure and water equipment & materials.

S&P GSCI™ Index
The S&P GSCI™ is designed as a benchmark for investment in the commodity markets and as a measure of commodity market performance over time. The S&P GSCI™ is calculated primarily on a world production-weighted basis and comprises the principal physical commodities that are the subject of active, liquid futures markets. There is no limit on the number of contracts that may be included in the S&P GSCI™; any contract that satisfies the eligibility criteria and the other conditions specified in this methodology are included.

S&P Oil & Gas Exploration & Production Index
S&P Select Industry indexes are designed to measure the performance of narrow GICS® sub-industries. The index comprises stocks in the S&P Total Market Index that are classified in the GICS oil & gas exploration & production sub-industry.

Stowe Global Coal Index
The Stowe Global Coal Index includes globally traded stocks principally engaged in two segments of the coal industry: (1) coal mining and production, and (2) coal mining equipment, coal transportation, and coal technology. To be included constituents must be principally engaged in the coal industry, listed on recognized exchange, have a minimum capitalization adjusted for free float greater than US$200 million, and a minimum average daily trading volume greater than US$1 million. The index is modified capitalization weighted and adjusted for free float.

WilderHill New Energy Global Innovation Index
The NEX is a global index of 106 companies listed on 31 exchanges in 26 countries (excluding Hong Kong and Taiwan), with a primary focus on companies that advance the generation and use of cleaner energy, conservation, efficiency, and renewables. NEX is a rule-based index and uses equal-weighting methodology modified by sector and market capitalization bands to provide diversification across the clean energy industry. The index is rebalanced quarterly on the last business day of March, June, September, and December. At rebalancing no single component can exceed 5% weight.

Annex 587

"How Moody's Assesses the Physical Effects of Climate Change on Sovereign Issuers", *Moody's Investors Service*, 7 November 2016

MOODY'S
INVESTORS SERVICE

SECTOR IN-DEPTH
7 November 2016

Rate this Research

Contacts

Anne Van Praagh 212-553-3744
MD-Gbl Strategy & Research
anne.vanpraagh@moodys.com

Alastair Wilson 44-20-7772-1372
MD-Sovereign Risk
alastair.wilson@moodys.com

Atsi Sheth 65-6398-3727
MD-Sovereign Risk
atsi.sheth@moodys.com

Yves Lemay 44-20-7772-5512
MD-EMEA Sovereign
yves.lemay@moodys.com

Rahul Ghosh 44-20-7772-1059
VP-Sr Credit Officer
rahul.ghosh@moodys.com

Stanislas Rouyer 212-553-3684
Associate Managing Director
stanislas.rouyer@moodys.com

Ariane Ortiz-Bollin 212-553-4872
Analyst
ariane.ortiz-bollin@moodys.com

Youngjoo Kang 212-553-1124
Associate Analyst
youngjoo.kang@moodys.com

Carlos Morales-Villarreal 212-553-0554
Associate Analyst
carlos.morales@moodys.com

Environmental Risks - Sovereigns

How Moody's Assesses the Physical Effects of Climate Change on Sovereign Issuers

Summary Points

» **The credit implications of physical climate change are captured in a broad set of rating factors that influence a sovereign's ability and willingness to repay its debt.**[1] Economic and social systems are exposed to climate change, with governments typically the first line of defense in dealing with the mitigation and response to such challenges. While our sovereign bond rating methodology does not account separately or explicitly for the credit risks posed by climate change, climate risks are already broadly captured in the four key risk factors we use in our analysis – economic strength, fiscal strength, institutional strength and susceptibility to event risk – either directly or indirectly through a variety of indicators.

» **The physical effects of climate change will vary depending on time frame and magnitude of impact.** *Climate trends*, such as global warming, are typically gradual, multi-decade (or multi-century) phenomena, with little visible change from one year to the next. *Climate shocks*, such as major cyclones or droughts, can have significant and one-off credit implications given their potential to disrupt economic and social activity.

» **We identify four primary channels by which the effects of physical climate change are transmitted to sovereigns' credit profiles.** These are: 1) the potential economic impact (for example, weaker activity due to a loss of agricultural production); 2) damage to infrastructure assets as a direct result of the physical destruction incurred from climate shocks; 3) rising social costs brought about, for example, by a health crisis or food security concerns; and 4) population shifts due to forced displacements resulting from climate change. We plan to address additional credit challenges facing sovereigns from the transition to a low carbon economy in a separate publication.

» **Sovereign susceptibility will depend on an issuer's exposure and resilience to climate change.** Exposure to climate change is a function of a sovereign's economic diversification and geographic location. To assess resilience, we focus on a sovereign's adaptive capacity and fiscal flexibility, as well as the country's income levels. Furthermore, the presence of government policies to mitigate climate change risks (for example, natural disaster insurance or a savings funds) can also help bolster a sovereign's resilience. In general, sovereign issuers with smaller, less diversified economies and geographies, lower incomes and quality of infrastructure, and lower fiscal flexibility are more susceptible to the credit implications of climate change.

Governments are typically the first line of defense in dealing with the mitigation and response to climate change

Historically, stable and predictable climatic conditions have been important factors in the development of agriculture and in the location and growth of economic and population centers. Material climate change (see Appendix A) could therefore threaten the economic and social systems whose growth and success continue to depend on such stable climatic conditions.

For example, rising sea levels due to increasing global temperatures threaten countries with large coastal populations; while persistent drought and flooding are likely to disrupt economies still heavily dependent on agriculture.

Economic and social adaptation can minimize the adverse effects of climate change, but may not always be a viable option. Political leadership in many countries may lack the foresight, political will, or resources to adapt to changing conditions.

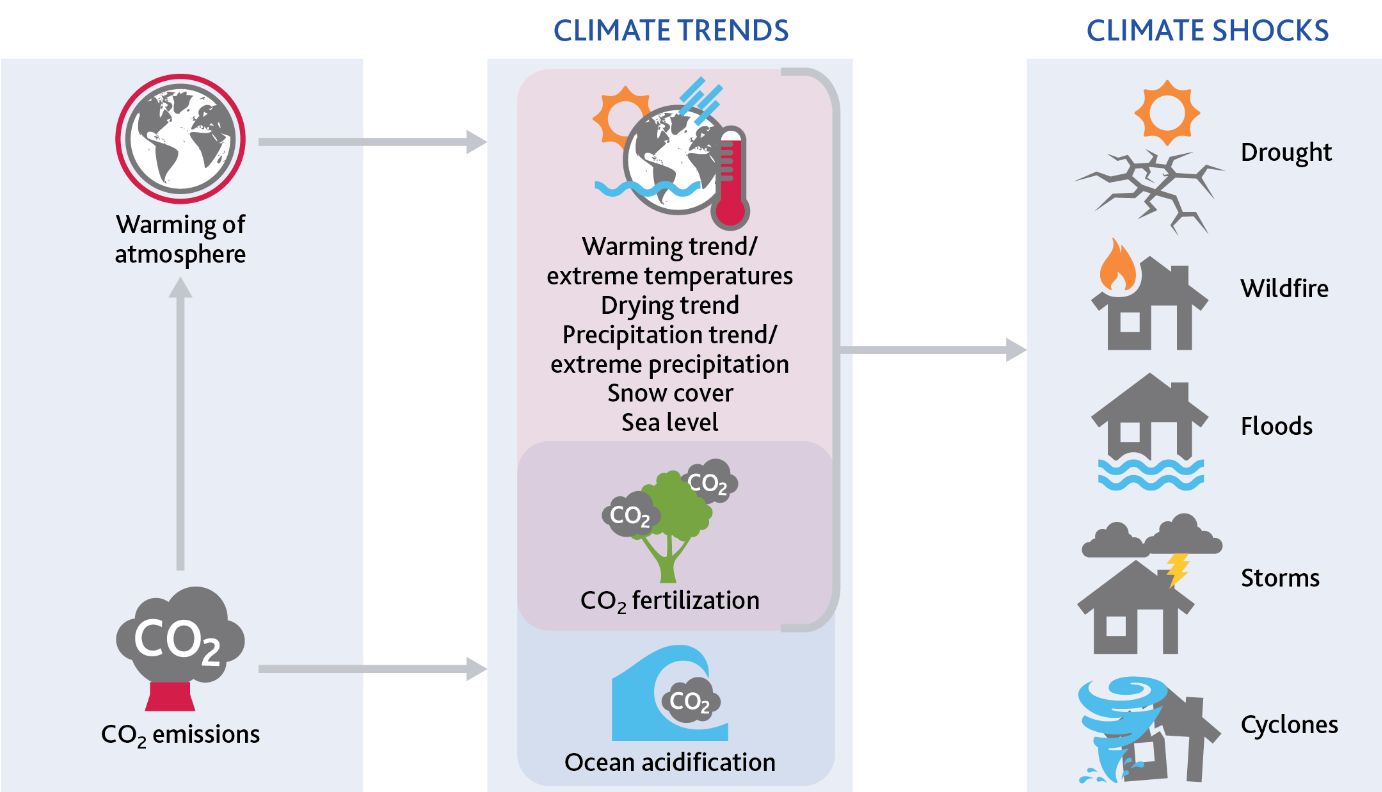
In the absence of private insurance, governments are ultimately responsible for providing support to sectors of the economy and populations affected by climate change, and often bear the cost of mitigating its effects. Such costs add to the rising burden on the government, and can represent a material credit consideration for a sovereign's credit profile.

This paper sets out an illustrative, but not comprehensive, set of indicators which offer insights into the potential impact of physical climate change on sovereign credit risk and the relative susceptibility of sovereign issuers to the physical effects of climate change.

The physical effects of climate change will vary depending on time frame and magnitude of impact

While not mutually exclusive, we categorize the physical effects of climate change into two broad, related groups: climate *trends* and climate *shocks* (Exhibit 1).

Exhibit 1
We Categorize Physical Effects into Climate Trends and Climate Shocks



Sources: Moody's Investors Service, Intergovernmental Panel on Climate Change

Climate trends are gradual, multi-decade (or multi-century) phenomena, with little visible change from one year to the next. These are typically chronic in nature, and include the trend of warming, as illustrated by rising mean temperatures globally, and other changes such as a decrease in cold temperature extremes and an increase in warm temperature extremes.

Climate shocks refer to the physical events that are a direct consequence of climate change. Such shocks are typically acute and include droughts, floods, and cyclones. While the occurrence of a singular, isolated climate shock may not be the direct result of climate change, the Intergovernmental Panel on Climate Change (IPCC) notes that the probability and frequency of such shocks (e.g. damaging cyclones) will increase at higher temperatures and/or greater extremes in temperatures and precipitation.[2]

In general, climate *trends* are unlikely to have a clearly discernible credit impact given long time frames, and the ability to mitigate or adapt. However, such trends will increase the probability and frequency of irreversible change and climate shocks, meaning that they can bring about substantive changes to economic and social systems over the long term. We will reflect climate trends in our credit analysis as they materialize or to the extent they can be foreseen.

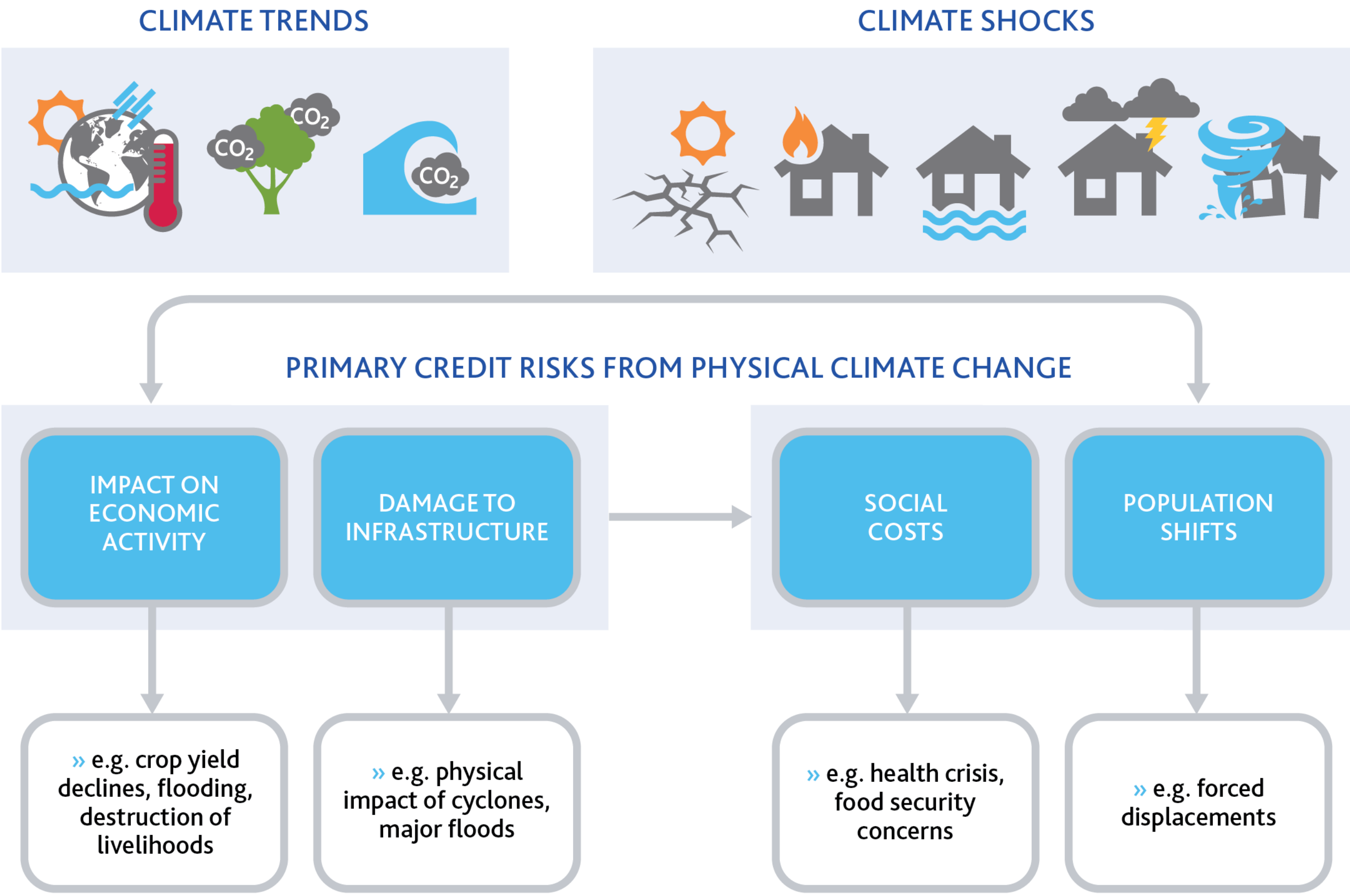
By contrast, climate *shocks* can have significant and one-off credit implications given their potential to disrupt economic activity. While the overall trend of climate *shocks* is increasing, the timing and magnitude of an individual physical event is unpredictable.

We identify four primary channels by which the effects of physical climate change are transmitted to sovereigns' credit profiles

We identify four primary transmission channels by which physical climate change can influence sovereign credit profiles (Exhibit 2). These four categories demonstrate a considerable degree of reflexivity: for instance, weaker economic activity and damage to infrastructure caused by climate trends or shocks is likely to lead to a crystallization of rising social costs and population shifts. We will aim to capture the impact of climate change transmitted through these channels in our analysis of economic, institutional and fiscal strength as they materialize over time and through our assessment of susceptibility to event risk.

Some sovereigns, in particular oil-exporting ones, will face an additional set of economic, fiscal and institutional credit challenges over the longer term related to a transition to a low carbon economy. We plan to address the credit challenges facing sovereigns from carbon transition in a separate publication.

Exhibit 2
We Identify Four Primary Transmission Channels From Physical Climate Change



Source: Moody's Investors Service

Impact on Economic Activity: Whether on a temporary or enduring basis, climate change can negatively influence the productive capacity of an economy. From a sovereign perspective, a material weakening of economic activity due to climate change will weigh on fiscal revenues and may lead to an increase in transfer payments and welfare expenditure.

Studies on the economic impact of climate change over the past 20 years vary significantly. They rely on a large number of assumptions, show considerable variations across countries and tend to focus on the economic impact of climate trends. The effects of climate shocks are idiosyncratic and generally studied on a case by case basis. These limitations notwithstanding, the IPCC finds that global temperature rises of approximately 2°C can, on average, lead to economic losses of between 0.2% and 2.0% of income.[3]

Extreme temperatures, drying and persistent droughts can significantly reduce crop yields. For instance, low rainfall and repeated droughts in recent years have stunted growth in India's (Baa3 positive) rural demand.[4] Major losses in crop production can also trigger other negative economic effects such as a spike in food price inflation.

In terms of climate trends, the gradual desertification of Israel (A1 stable), Lebanon (B2 negative), and Jordan (B1 stable) is leading to land degradation and soil infertility. According to the Lebanese authorities, economic damage from climate change could reach more than $80 billion (156% of 2015 GDP) by 2040.[5]

Climate change may generate some positive effects on economic activity in a limited group of countries. According to the Stern Review 2006 paper commissioned by the UK government, temperature increases of between 2°C and 3°C may produce net economic benefits in higher latitude countries or regions, such as Canada (Aaa stable), Russia (Ba1 negative), and Scandinavia, via higher agricultural yields, lower winter mortality, lower heating requirements, and a possible boost to tourism.[6]

Damage to Infrastructure: Climate shocks can inflict significant damage to the infrastructure assets of an economy. They may lead to the breakdown of supply chain networks and damage critical services such as electricity or water supply. Reconstruction costs can be large and impose a significant burden on public finances. Persistent climate shocks may also increase expenses related to adaptation and prevention.

The impact of a single event can be severe. The estimated value of disaster effects on Fiji's (B1 positive) economy from Tropical Cyclone Winston in early 2016 was approximately FJD1.99 billion ($0.9 billion), or 21% of 2015 nominal GDP, including FJD1.29 billion ($0.6 billion) in damage to physical assets and FJD0.71 billion ($0.3 billion) in losses.[7]

Floods in Mozambique (Caa3 negative) in 2015 resulted in critical damage to roads and bridges, cutting land access to almost 70% of the Zambézia province. Downed power cables and electricity towers also left several parts of northern Mozambique without power.[8]

Rising Social Costs: Climate trends and climate shocks may also raise social costs. Extreme flooding across highly populated low-lying areas often results in the spread of water-borne diseases and a deterioration in sanitary conditions. At the other end of the spectrum, sustained droughts can threaten food security and sufficient access to drinking water and irrigation, particularly in regions where agriculture makes up a large share of the local economy. Again, sovereigns are potentially exposed to such risks via the fiscal impact of higher spending requirements or, in extreme cases, the potential political, fiscal and economic implications of social unrest.

The severe El Nino-driven drought in Papua New Guinea (B2 stable) in 2015 affected more than 2 million people, or around one third of the population. The impact on food supply and the wider economy prompted the government to step in to buy rice, and provide drought assistance and disaster relief worth around PGK230 million, or 0.3% of GDP.[9]

Population Shifts: Finally, populations shifts can occur due to the forced displacement of human settlements resulting from climate change. Climate shocks may result in short-term internal displacements of populations. Sustained migration, meanwhile, may pose a long-term threat to countries where deteriorating climate trends are undermining local economies and livelihoods. The sovereign credit impact of significant population shifts will be felt through a tightening of labor markets, or outright shortages of labor. Migration can also have a negative impact on productivity to the extent that the more mobile part of the population is often more highly qualified and focused on higher value-added activities. On the other hand, long-term migration may also pose both opportunities and challenges for recipient countries.

The potential for population shifts as a result of climate change is elevated when combined with other socio-economic or political factors, such as social discontent. According to some studies, the prolonged drought in Syria (unrated) between 2006 and 2011 led to a large population displacement from rural to urban areas, a trend which contributed to the ongoing civil war.[10]

The credit implications of physical climate change are captured in a broad set of rating factors that influence a sovereign's ability and willingness to repay their debt

Our sovereign bond rating methodology does not separately account for physical risks posed by climate change.[11] Instead, we capture the potential impact from climate risks in the broad set of key rating factors – Economic Strength, Institutional Strength, Fiscal Strength and Susceptibility to Event Risk - which, collectively, influence sovereigns' ability and willingness to repay debt (Exhibit 3). [12]

Exhibit 3
Credit Impact of Physical Climate Change Captured in Key Rating Factors

Broad Rating Factor	Rating Sub-Factor	Factor Weighting	Impact of Climate Change Risks
Factor 1: Economic Strength	Growth Dynamics	50%	Weaker economic activity or damage to infrastructure due to climate trend/shock may impact GDP and/or potential GDP growth. High GDP concentration in sectors exposed to climate change risk (e.g. agriculture, tourism), and a geographic location in low lying densely populated coastal areas, increases susceptibility to climate change risks. Smaller, less diversified countries are particularly vulnerable.
	Scale of the Economy	25%	
	National Income	25%	
	Adjustment Factors	1 - 6 Scores	
Factor 2: Institutional Strength	Institutional Framework and Effectiveness	75%	Major climate shock may test institutional capacity to organize and deal with reconstruction costs. Proactive government policies to anticipate and prepare for climate-related shocks such as insurance against natural disasters or a savings fund would support the institutional capacity to deal with climate trends/shocks.
	Policy Credibility and Effectiveness	25%	
	Adjustment Factors	1 - 6 Scores	
Factor 3: Fiscal Strength	Debt Burden	50%	Fiscal strength may be challenged due to rise in social programs/current expenditures, reconstruction/mitigation costs, cost of displacement. Climate change risks could also represent a loss of government revenues due to lower economic activity and/or demographic shifts.
	Debt Affordability	50%	
	Adjustment Factors	1 - 6 Scores	
Factor 4: Susceptibility to Event Risk	Political Risk	Max. Function	Climate shock may be sufficiently disruptive to productive capacity or to government's balance sheet that it results in a sizable impact on economic and/or fiscal strength.
	Government Liquidity Risk	Max. Function	In extreme instances, political risk may manifest itself through social tensions due to food shortages, health crises, destruction of livelihood or forced displacements.
	Banking Sector Risk	Max. Function	Countries exposed to elevated external vulnerability and climate change risks are doubly vulnerable, as the manifestation of a climate shock could trigger a loss of confidence amongst foreign investors.
	External Vulnerability Risk	Max. Function	

Source: Moody's Investors Service

» **Economic Strength**, our methodology's first factor, captures a country's intrinsic economic or shock-absorption capacity to cope with adverse events, including climate-related disruptions. This factor implicitly captures the economic impact exposure by incorporating economic scale, diversity and wealth levels as indicators of the relative ability of a sovereign to generate revenue and ultimately service debt. As a rule, countries with high economic strength will be less exposed to climate-related shocks crystallizing, and less vulnerable to their impact when they do. Conversely, countries with low economic development levels, and often in consequence an important agricultural sector, tend to score low on economic strength and are more exposed to the lower, more volatile growth associated with exposure to climate trends and climate shocks. Sovereigns with greater economic concentration can also be more highly exposed to shocks which can result in lower nominal GDP over time, which may impact other sub-factors scored in our methodology.

» **Institutional Strength**, the second factor in our methodology, takes into account the government's economic and fiscal policy credibility, including its ability to develop the policies and institutional arrangements needed to foster stable economic growth and resilience to shocks. Unexpected, large-scale climate shocks may test a government's institutional capacity to deal with reconstruction costs. High institutional strength will tend to be associated with lower exposure and/or greater resilience to climate trends and climate shocks. The stronger rule of law and more effective policymaking and administrative institutions often found in countries with high institutional strength support the containment of exposure to climate change (for example, by developing greater economic diversity), and the enhancement of resilience through effective response to shocks when they occur. For countries most susceptible to climate change, our assessment of institutional strength will take into account, at least indirectly, the robustness of government policies aimed at anticipation, preparation and mitigation of climate change (for example, the existence of insurance or savings funds to compensate for natural disasters).

» **Fiscal Strength** captures the overall health of government finances and the capacity to absorb financial costs arising from economic and social disruptive events. Countries with higher fiscal strength tend to have greater access to larger and diversified funding sources and are better able to manage the financial consequences of one-off events, including climate shocks, without damaging their fiscal positions. In contrast, countries with lower fiscal strength tend to have less fiscal flexibility to deal with such shocks, given lower debt affordability, higher debt levels and/or limited funding sources. As such, countries with lower fiscal strength are in a weaker position to provide financial help to alleviate the impact of climate change, proving less resilient.

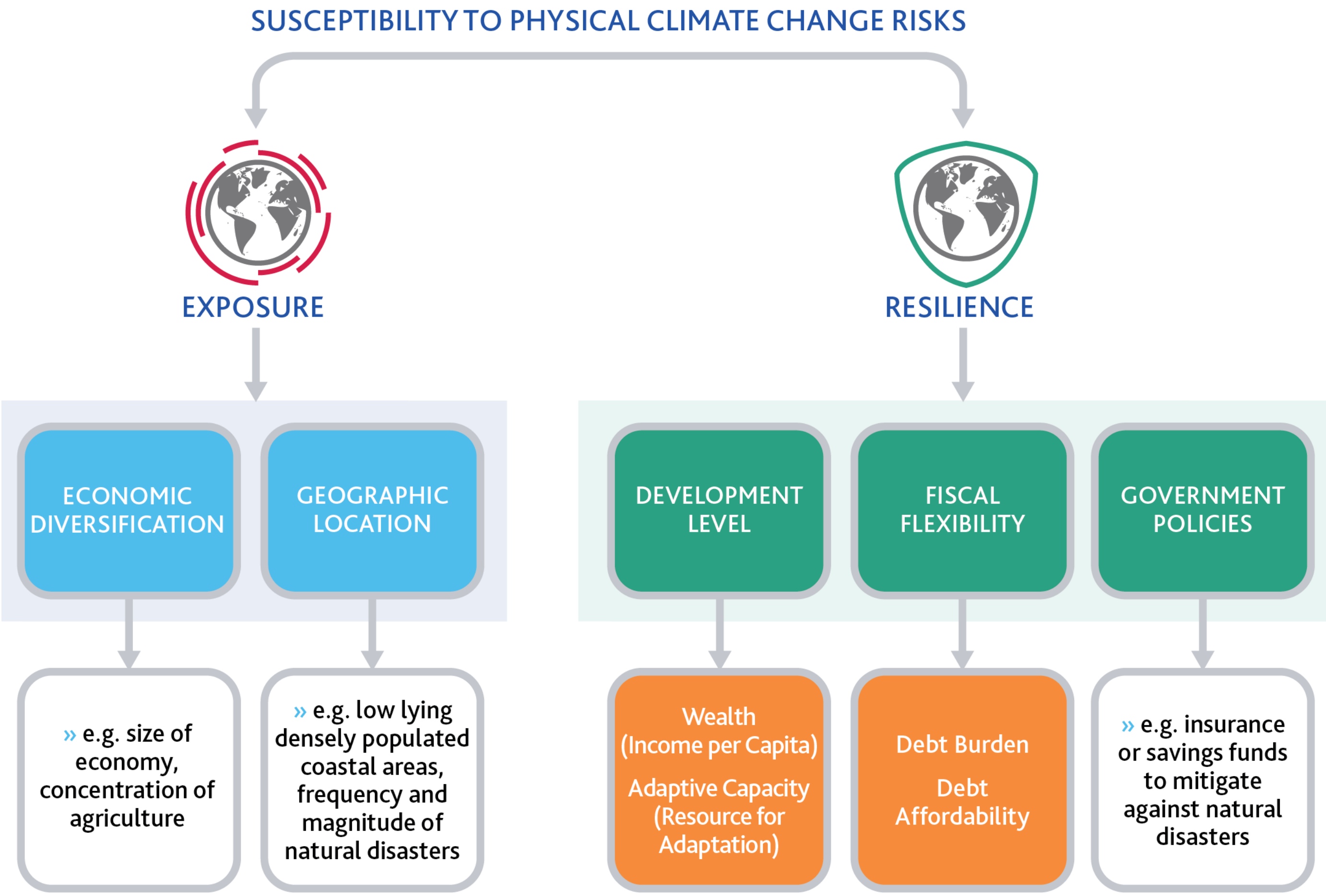
» **Susceptibility to Event Risk**, our final factor, evaluates a government's ability to withstand shocks from a medium-term perspective. It looks at features or trends which could potentially undermine a government's credit profile as some point in the future, but which have yet to crystallize with sufficient clarity to be reflected in the other factors. Climate change would be one such feature, particularly as its effects become more pronounced over time. In this context we look at four specific areas of event risk: Political Risk, Government Liquidity Risk, Banking Sector Risk and External Vulnerability Risk. While the threat posed by climate change falls less neatly into those categories, the economic, fiscal and social pressures that it can create may lead to outcomes which we would pick up here. For example, in smaller, open economies, the emerging prospect of a climate shock may undermine the near-term health of the government's finances (its liquidity), pose a threat to the resilience of the banking system or (in a country heavily dependent on external financing) undermine the confidence of external investors in the economy. In more extreme scenarios, climate change may exacerbate underlying political or geopolitical stability issues, leading to a material increase in political risk.

Sovereign susceptibility will depend on an issuer's exposure and resilience to climate change

A sovereign issuer's susceptibility to physical climate change risks is a function of its exposure and resilience (Exhibit 4).

Exhibit 4

Susceptibility to Climate Change is a Function of Exposure and Resilience



Source: Moody's Investors Service

We break down exposure into two sub-groups: economic diversification and geographic location. Economic diversification captures the extent to which an economy would be affected by climate trends or climate shocks. We look at the absolute size of the economy as a broad measure of economic diversification, and the concentration of agriculture as a share of total output and employment given that it is this sector which is typically most exposed to climate change.

A sovereign's geographic location can be closely linked to the probability of climate trends or climate shocks occurring. As such, we also gauge the magnitude and frequency of economic disruptive climate events occurring in a given country, as well as other key variables such as population density in low-lying areas.

To assess resilience, we focus on three sub-groups: development level, fiscal flexibility and government policies. Development level looks broadly at the resources available for adaption to climate change, which includes the quality of infrastructure and the country's income levels. Fiscal flexibility reflects a sovereign's capacity to carry extra debt to cope with any material physical damage.

Finally, the presence of government policies targeted to tackle climate change risks can enhance a sovereign's resilience to physical climate change risks significantly. In the Box below, we focus on natural disaster insurance or savings funds.

Box: Presence of natural disaster insurance or savings funds can enhance sovereign resilience to physical climate change risks significantly

The presence of natural disaster insurance or savings funds can enhance a sovereign's resilience to physical climate change risks significantly. Such contingencies can mitigate potential losses of income, and/or expedite the reconstruction of physical assets, following a climate shock. In addition, many countries have received large multilateral and bilateral aid and funding in the aftermath of a climate shock, which in turn has provided strong support to fiscal metrics.

Globally-orchestrated government policies include the Green Climate Fund, a mechanism established in 2010 to assist developing countries to counter climate change. The fund will help roll out pledges delivered at the Paris Agreement to provide at least $100 billion of annual financing by 2020 to help developing countries mitigate and adapt to climate change.[13]

Many countries operate government policies or initiatives on a standalone basis. By way of example, the National Flood Insurance Program in the US (Aaa stable) is a federal program which provides insurance against flooding of private and public structures. Mexico (A3 negative), meanwhile, established the Fund for Natural Disasters (FONDEN) in 1996 to provide adequate financial resources for reconstruction and relief efforts in the event of natural disasters. FONDEN issued Mexico's first catastrophe bond in 2006.

Regional insurance pools are typically employed in cases where a natural disaster may overwhelm the capacity of the public and private sectors in an individual country to provide sufficient coverage. Two such examples are the African Risk Capacity (ARC) and the Caribbean Catastrophe Risk Insurance Facility (CCRIF). The ARC is a specialized arm of the African Union, which helps member states improve their ability to prepare and respond to climate change. Using participating countries' premiums and partner contributions, the ARC aims to reach $1.5 billion in coverage for as many as 30 countries by 2020. The CCRIF operates along similar lines, providing financing to mitigate the impact of hurricanes, floods and earthquakes in the Caribbean. Between 2007 and 2015, it paid out $37.9 million to eight member countries.[14] So far, governments in Asia have relied on post-disaster funding, in the absence of broad national or regional insurance funds.

While all countries will experience the physical effects of climate change to some degree, sovereigns with larger, more diversified economies and geographies are less susceptible. These economies generally have better infrastructure quality that can withstand disruptive events and an ability to carry a higher debt burden at more affordable interest rates. In contrast, those with a greater reliance on agriculture, lower incomes, weaker infrastructure quality, and smaller fiscal capacity exhibit greater susceptibility.

The importance of a country's size and diversification, both economically and geographically, in terms of reducing climate change susceptibility is borne out in past data. As Exhibit 5 illustrates, while countries with large economies and landmasses have experienced a greater frequency of climate-related natural disasters on average over the past decade, the relative impact of such disasters on GDP is also much less pronounced.

Exhibit 5

Countries with High Frequency of Natural Disasters Tend to be Large Economies, but Average Damage Largest in Smaller Ones

Moody's Rated Countries with Highest Frequency of Disasters			Moody's Rated Countries with Largest Damage from Disasters		
Country	# of Climate Related Disasters (Avg. 10 yr)	Damage Amount (% of GDP, Avg. 10 yr)	Country	# of Climate Related Disasters (Avg. 10 yr)	Damage Amount (% of GDP, Avg. 10 yr)
China	25.0	0.21	Maldives	1.0	6.20
United States	22.7	0.19	Saint Vincent & the Grenadines	1.3	1.80
Philippines	17.8	0.68	Thailand	3.6	0.99
India	15.1	0.20	Oman	1.0	0.97
Indonesia	9.8	0.08	Pakistan	5.0	0.91
Vietnam	6.6	0.53	El Salvador	2.0	0.87
Mexico	6.0	0.18	Moldova, Republic of	1.2	0.80
Japan	5.7	0.04	Fiji	2.0	0.69
Brazil	5.3	0.06	Philippines	17.8	0.68
Bangladesh	5.2	0.27	Cambodia	1.3	0.67

Note: We categorize disasters related to climate change as including drought, extreme temperature, flood, landslide, storm and wildfire.
Source: Natural Disaster Database

Macroeconomic variables and independent indices illustrate sovereigns' relative susceptibility to climate change effects

We have compiled a list of macroeconomic variables and independent indices to illustrate the relative susceptibility of rated sovereigns to the effects of physical climate change. See Appendix B for full details of the metrics used.

We use the Notre Dame Global Adaptation Index (ND-GAIN) Vulnerability country indices, which assess a country's exposure, sensitivity, and capacity to adapt to climate change. The exposure sub-index includes projected changes in populations, climate change and biodiversity. The sensitivity sub-index focusses on specific vulnerabilities within a country, such as dependency on food imports or the share of population living in areas more than 5 meters below sea level. Finally, the adaptive capacity index comprises of indicators that evaluate the quality of infrastructure (e.g. access to electricity) and government policies (disaster preparedness).

We also include a number of indicators used in our sovereign bond methodology that are specifically linked to climate change susceptibility. These include the scale of the economy (as measured by nominal GDP), national income (GDP per capita), and our assessment of Fiscal Strength.

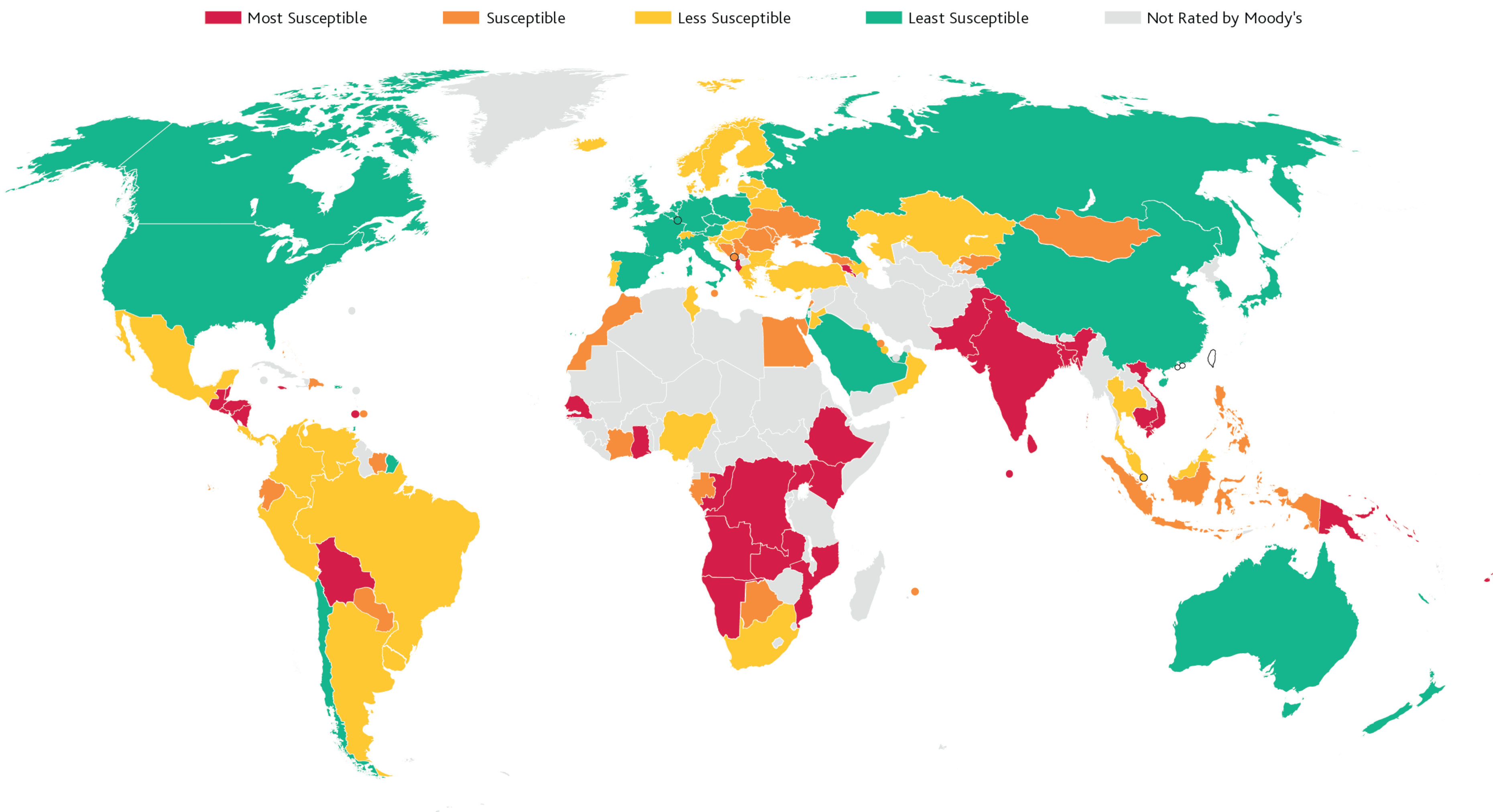
Our illustrated approach is not intended to be exhaustive. For instance, it does not capture the exposure of a specific climate hazard, or regional deviations within a country.

We also do not include the existence of insurance or savings funds to mitigate natural disasters due to the lack of consistent benchmark and, as mentioned earlier, such policies can enhance a country's resilience to the credit impact of climate change significantly.

However, the data we have used are widely available for the vast majority of sovereigns we cover, which allows for a cross-comparison. Exhibit 6 illustrates the relative susceptibility of sovereigns globally to the credit risks arising from physical climate change, while Exhibit 7 focusses on those sovereigns that these data would suggest are the most susceptible.

Exhibit 6

Susceptibility to Physical Climate Change of Moody's-Rated Sovereigns Based on Illustrative Data



Note: We apply a 70% weighting for "Exposure" and 30% for "Resilience" to all Moody's rated sovereigns. In each sub-category, the indicators are equal weighted. When data for one indicator (e.g. agricultural employment) is missing, we only consider other indicators in that sub-category. Data as of October 27.

Source: Moody's Investors Service; see Appendix B for details on indicators and sources

Exhibit 7

Rated Sovereigns Most Susceptible to Physical Climate Change Based on Illustrative Data

		'Exposure' to Climate Change Risk							'Resilience' to Climate Change Risk					
		Economic Diversification			Geographic Location				Development Level		Fiscal Flexibility			
												Selected F3 Sub-Indicators		
Country	LT Issuer Rating	Nominal GDP	Agricultural Employment	Agricultural Total Value Added	ND-GAIN Exposure	ND-GAIN Sensitivity	# Annual Disaster*	Annual Damage*	GDP per capita	ND-GAIN Capacity	F3 Fiscal Strength	Gen. Gov. Debt	Gov. Interest Payments	Fiscal Deficit
		(US$ Bn) 2015	(% Labor Force) 2011-14 (avg)	(% GDP) 2011-14 (avg)	Score 2014	Score 2014	(avg. 10yr) 2006-15	(% GDP) 2006-15	(PPP 2015	Score 2014	Score 2015	(% GDP) 2015	(% Revenue) 2015	(% GDP) 2015
Albania	B1	11	--	22.00	0.48	0.38	1.60	-	11,358	0.50	L-	72	10.09	-3.95
Angola	B1	122	--	11.00	0.57	0.38	2.11	-	7,344	0.75	M-	44	9.55	-1.63
Armenia	B1	11	37.50	21.11	0.45	0.35	2.00	0.06	8,468	0.41	M-	49	6.27	-4.61
Bangladesh	Ba3	195	--	16.80	0.53	0.43	5.20	0.27	3,398	0.64	M	27	18.32	-4.66
Belize	Caa2	2	--	14.78	0.50	0.44	1.25	0.18	8,373	0.44	VL	78	9.56	-10.41
Bolivia	Ba3	33	--	12.93	0.52	0.32	2.50	0.46	6,465	0.55	H-	40	3.00	-6.61
Cambodia	B2	18	--	34.06	0.38	0.50	1.25	0.67	3,488	0.64	M-	35	2.24	-1.99
Congo	B3	9	--	4.13	0.52	0.50	1.33	-	6,722	0.79	L+	46	1.92	-11.08
Congo, the Democratic Republic of	B3	40	--	22.62	0.51	0.56	2.44	0.00	770	0.88	H-	13	2.24	0.16
El Salvador	B1	26	20.73	11.68	0.49	0.36	2.00	0.87	8,303	0.49	M	61	12.41	-3.29
Ethiopia	B1	61	30.13	44.87	0.53	0.44	2.44	0.00	1,801	0.75	M-	49	3.87	-2.90
Fiji	B1	4	--	11.42	0.53	0.55	2.00	0.69	9,044	0.52	M	47	11.12	-4.13
Ghana	B3	37	44.70	23.79	0.53	0.38	1.43	0.00	4,266	0.55	VL-	71	29.19	-6.74
Guatemala	Ba1	64	34.20	11.43	0.54	0.37	3.11	0.26	7,738	0.48	M+	24	12.92	-1.44
Honduras	B2	20	36.87	14.21	0.50	0.40	2.00	0.06	4,869	0.51	L-	46	13.74	-3.09
India	Baa3	2,074	48.40	18.12	0.54	0.32	15.10	0.20	6,187	0.55	L	67	21.22	-6.45
Jamaica	Caa2	14	17.97	6.85	0.53	0.44	1.33	0.41	8,759	0.43	VL-	126	28.28	-0.52
Kenya	B1	61	--	29.52	0.47	0.47	3.50	0.02	3,208	0.73	L-	50	15.54	-8.85
Maldives	B2	3	--	3.83	0.74	0.50	1.00	6.20	14,923	0.35	L+	64	7.43	-6.93
Mozambique	Caa3	15	--	27.07	0.49	0.51	2.67	0.20	1,186	0.69	VL-	85	4.79	-5.98
Namibia	Baa3	12	29.53	7.90	0.56	0.50	1.22	0.07	10,556	0.62	M+	36	4.22	-5.23
Nicaragua	B2	13	--	19.23	0.50	0.36	2.00	-	4,997	0.45	M+	30	3.77	-1.78
Pakistan	B3	267	44.10	25.11	0.49	0.45	5.00	0.91	4,971	0.47	VL-	63	32.77	-5.13
Papua New Guinea	B2	23	--	--	0.53	0.66	1.89	0.04	3,495	0.89	M+	28	9.80	-3.95
Saint Vincent and the Grenadines	B3	1	--	7.51	0.54	0.48	1.33	1.80	10,937	0.48	VL+	69	8.05	-2.84
Senegal	B1	14	46.10	15.96	0.51	0.54	1.25	0.01	2,451	0.62	L-	57	7.53	-4.82
Solomon Islands	B3	1	--	--	0.57	0.79	1.43	0.25	1,950	0.69	H	9	0.48	-0.31
Sri Lanka	B1	82	31.47	8.59	0.45	0.45	3.20	0.09	10,566	0.51	VL-	76	34.89	-7.42
Uganda	B1	26	71.90	25.79	0.51	0.58	1.86	0.00	1,740	0.71	L+	35	11.75	-4.46
Vietnam	B1	195	47.10	18.61	0.50	0.39	6.60	0.53	6,037	0.45	L+	49	8.37	-5.88
Zambia	B3	22	52.20	9.83	0.61	0.43	1.43	-	3,868	0.60	VL	50	15.48	-8.13

Note: We apply a 70% weighting for "Exposure" and 30% for "Resilience" to all Moody's rated sovereigns. In each sub-category, the indicators are equal weighted. When data for one indicator (e.g. agricultural employment) is missing, we only consider other indicators in that sub-category. Data as of October 27. *We categorize disasters related to climate change as including drought, extreme temperature, flood, landslide, storm and wildfire.

Source: Moody's Investors Service; see Appendix B for details on indicators and sources

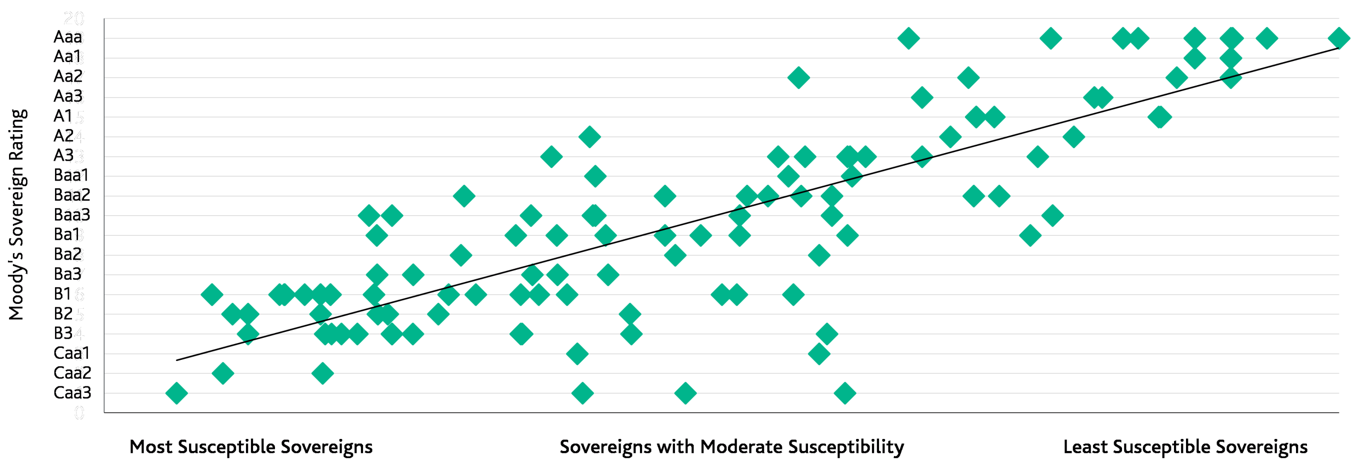
Countries susceptible to climate change risks are generally lower rated

As would be expected, given the overlap illustrated earlier between the factors we take into account in assessing sovereign credit profiles and those driving exposure and resilience to climate change, sovereigns' ratings are quite strongly correlated with their susceptibility to climate change as defined in this Comment (Exhibit 8).

Exhibit 8

Strong Correlation between Climate Change Susceptibility and Sovereign Creditworthiness

Moody's Sovereign Ratings vs. Climate Change Susceptibility

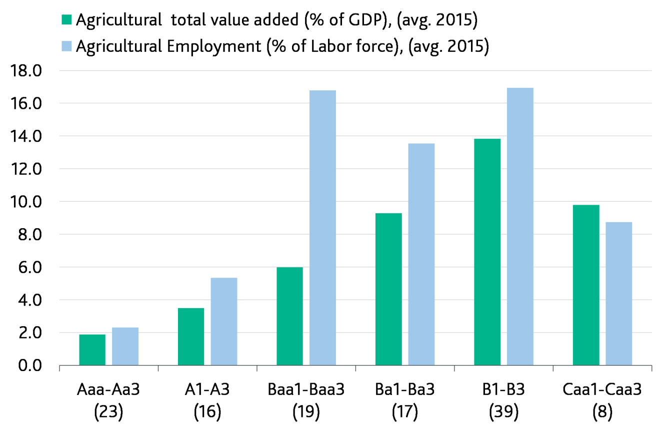


Note: Data as of October 27.
Source: Moody's Investors Service

However, as Exhibits 9 and 10 illustrate, it also reflects the fact that countries with an overarching reliance on agriculture and where the quality of infrastructure is typically weaker – two important aspects of susceptibility to physical climate change – tend to be lower rated.

Exhibit 9

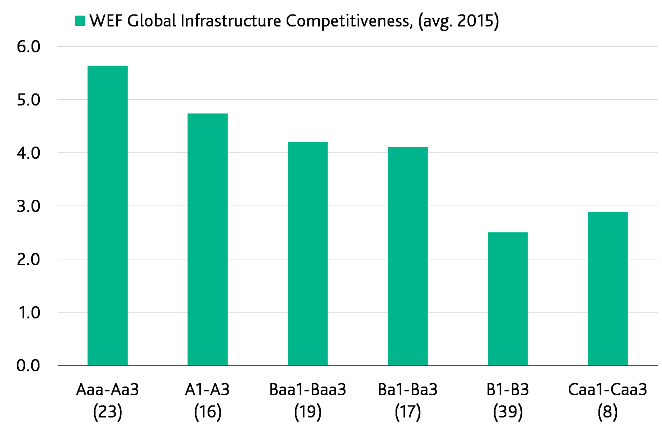
Economies More Reliant on Agriculture Tend to be Lower Rated…



Note: Numbers in parentheses indicate the number of sovereigns included within each rating range as of October 27.
Sources: World Bank, Moody's Investors Service

Exhibit 10

…as do Those With Weaker Infrastructure Quality



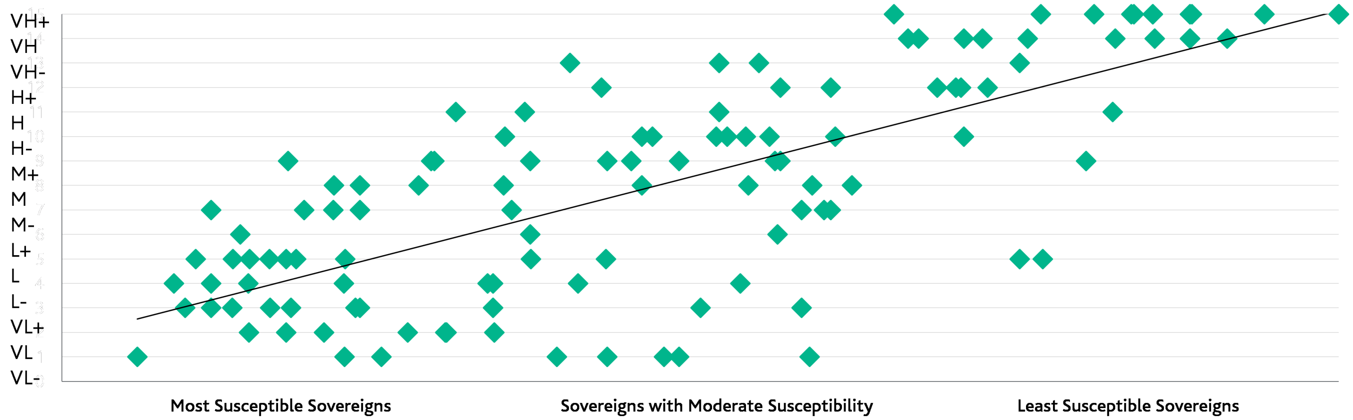
Note: Numbers in parentheses indicate the number of sovereigns included within each rating range as of October 27.
Sources: World Economic Forum, Moody's Investors Service

Another important observation is that institutional strength is generally higher amongst sovereigns with a lower susceptibility to physical climate change (Exhibit 11). While our assessment of institutional strength is from a much broader perspective, the strong correlation reinforces our view that a stronger rule of law and more effective policymaking and administrative institutions often support the containment of climate change risks.

Exhibit 11

Institutional Strength Is Higher in Countries with Low Susceptibility to Climate Change

Moody's Institutional Strength Factor Score vs. Climate Change Susceptibility



Source: Moody's Investors Service

Sovereign credit implications will build over time

As we have shown, therefore, climate change already exerts some influence on the credit profiles, and hence ratings, of those sovereigns that are the most susceptible to its effects. Accordingly, as a slowly-evolving influence, climate change does not have near-term implications for sovereign ratings.

However, the effect of climate change, and hence its impact on sovereign credit profiles, is projected to grow over time. We will monitor closely the evolving impact and will update and amend our credit assessment of sovereign exposure and resilience to climate change as needed. How quickly, and how severely, the impact of climate change grows will depend on the speed and effectiveness of the global response to climate change.

In that respect, the future is uncertain. The Paris Agreement entered into force on November 4. The agreement represents a landmark global pact on climate change with 192 signatories, even as the combined effects of submitted Nationally Determined Contributions (NDCs) country commitments are acknowledged to fall short of achieving the agreement's goals of holding the increase in the global average temperature to well below 2°C above pre-industrial levels. As Exhibit 12 illustrates, country commitments outlined in the Paris Agreement – which form the basis of our central scenario for the future trajectory of carbon emissions – are currently forecast to be insufficient to limit temperatures from rising more than 2°C above pre-industrial levels.

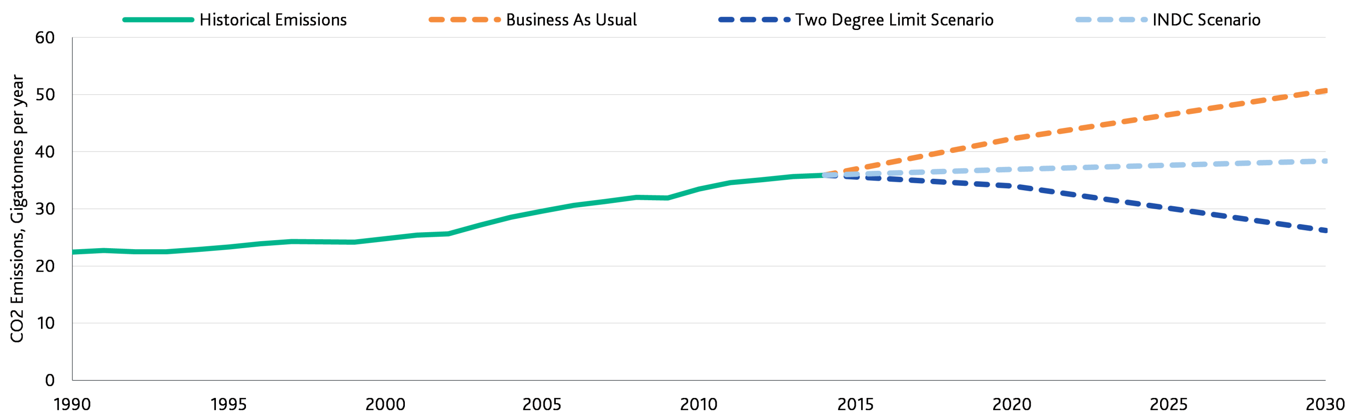
The Paris Agreement includes a ratcheting mechanism which could create momentum for further commitments in the future. And more recently, the announcement of a global agreement to implement a Carbon Offset and Reduction Scheme for International Aviation and, more importantly, a global deal to limit the use of hydrofluorocarbons serve to bolster the Paris Agreement.

Still, significant uncertainty exists over the magnitude and pace of carbon emission policies and their effects during the term of the agreement and beyond. In the meantime climate change is expected to become an increasingly dominant factor in our analysis of the credit profiles of those sovereigns that are most susceptible to its effects over the coming decades.

Exhibit 12

Paris Agreement Commitments Are Currently Insufficient to Limit Temperatures from Rising More than 2°C Above Pre-Industrial Levels

CO_2 Emissions, Gigatonnes per year



Note: “Business as usual” and “Two degree limit” scenarios are sourced from the Carbon Dioxide Information Analysis Centre. The INDC Scenario is based on data from the International Energy Agency.

Sources: Moody's Investors Service, Carbon Dioxide Information Analysis Centre, International Energy Agency

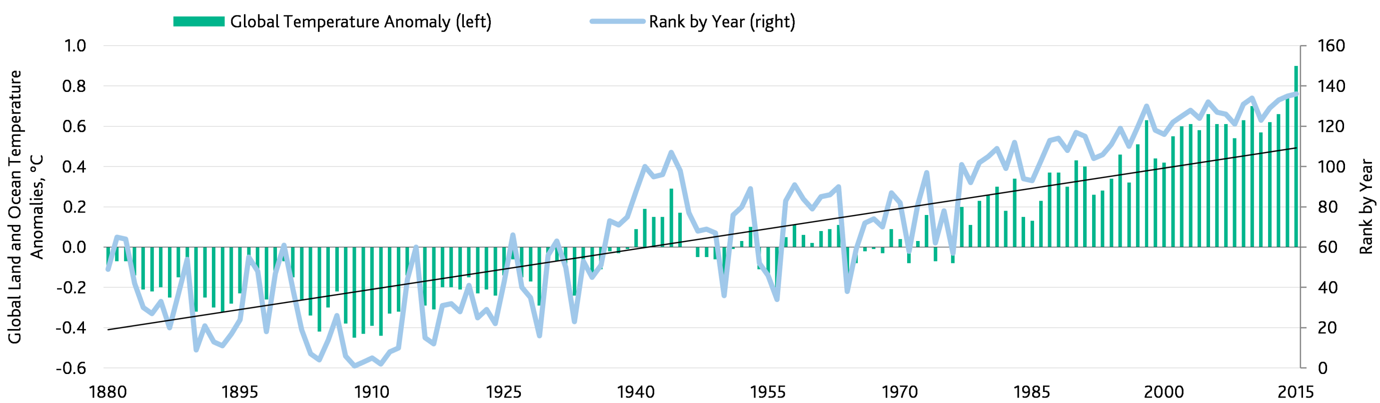
Appendix A – Background on Climate Change

According to the US government, the globally averaged temperature in 2015 was the highest since record keeping began in 1880 (Exhibit 13).[15] The average temperature across global land and ocean surfaces was 1.62°F (0.90°C) above the 20th century average, and was the highest among all years in the 1880-2015 record, surpassing the previous record set last year by 0.29°F (0.16°C).

Exhibit 13

Global Temperatures in 2015 Were the Highest on Record

Global Land and Ocean Temperature Anomalies, 1880-2015



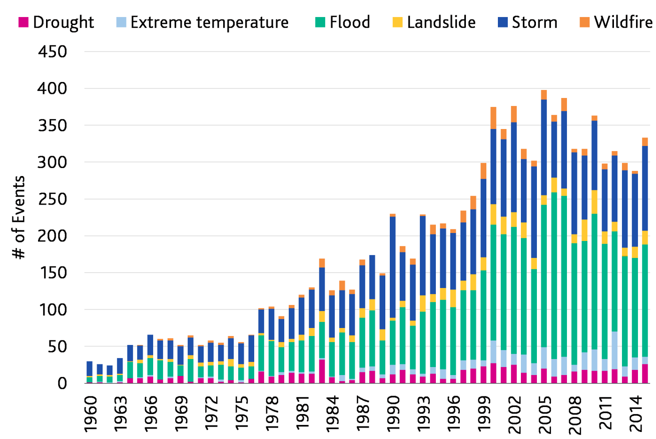
Note: Global and hemispheric anomalies are with respect to the 20th century average. Continental anomalies are with respect to the 1910 to 2000 average.
Sources: Moody's Investors Service, NOAA National Centers for Environmental information

Meanwhile, natural disasters occurring globally are increasing in terms of frequency and total damage incurred (Exhibits 14 and 15).

Exhibit 14

Natural Disasters Are Rising in Frequency...

Numbers of Natural Disasters Globally

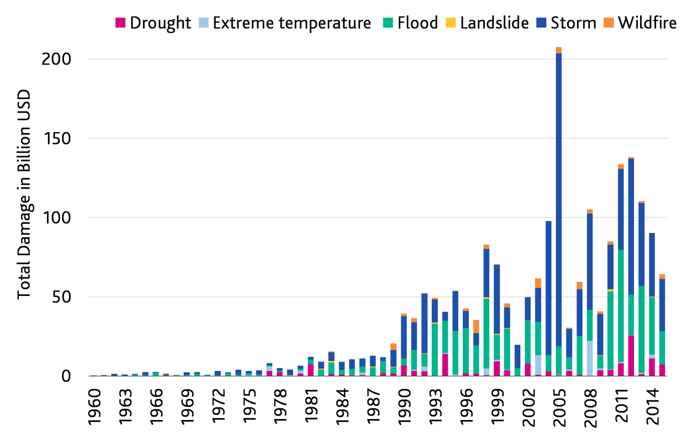


Sources: EM-DAT International Disaster Database 2016, Moody's Investors Service

Exhibit 15

...And Total Damage Is Rising in Magnitude

Total Damage from Natural Disasters, $ Billion



Sources: EM-DAT International Disaster Database 2016, Moody's Investors Service

These trends are expected to continue given the broad scientific agreement about the link between the level of greenhouse gas (GHG) in the atmosphere and the ongoing increase in surface air temperature, sea levels, and ocean acidification.[16]

As reported by the Intergovernmental Panel on Climate Change (IPCC), "It is extremely likely that more than half of the observed increase in global average surface temperatures from 1951 to 2010 was caused by the anthropogenic increase in GHG concentration and other anthropogenic forcing together."[17]

The IPCC noted that “Multiple lines of evidence indicate a strong, consistent, almost linear relationship between cumulative CO_2 emissions and projected global temperature change to the year 2100…”.[18]. It further reports that the risks of climate change are considerable at 1°C- 2°C degrees above pre-industrial levels and increase substantially as temperature rise beyond this level.

Scientific studies show that there is still some uncertainty about the specific implications of further GHG emission for atmospheric temperatures. This is reflected in the wide range of likely impacts around the mean estimated warming for a given GHG emission scenario. This means that any estimate of the risk of climate change under a given GHG emission pathway should also contemplate the possibility of a more (or less) severe adverse outcome. It is also worth noting that a recent study, using revised modeling of Antarctica's ice sheet, projects global sea level rise that could be almost twice as large as those reported by the IPCC.[19]

Appendix B – Details on Indicators Used to Illustrate Climate Change Susceptibility of Rated Sovereigns

Sub-factor Indicator (Unit)	Note
Nominal Gross Domestic Product (US$)	Source: IMF, Eurostat, AMECO, Official National Sources, Moody's
Employment in Agriculture (% of Total Employment)	Source: International Labor Organization, World Bank
Agriculture, Value Added (% of GDP)	Source: OECD, World Bank. Note: For Angola, data from source was missing; therefore, we use US Department of Agriculture.
ND-GAIN Vulnerability Index: Exposure Component (Index) 1	Source: Notre Dame Global Adaptation Index (ND-GAIN): Vulnerability Index The nature and degree to which a system is exposed to significant climate change. A component of vulnerability independent of socio economic context.
ND-GAIN Vulnerability Index: Sensitivity Component (Index) 1	Source: Notre Dame Global Adaptation Index (ND-GAIN): Vulnerability Index The extent to which a country is dependent upon a sector negatively affected by climate hazard, or the proportion of the population particularly susceptible to a climate change hazard.
Numbers of climate change related disasters (10 year average, Frequency)	Source: Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EM-DAT), Moody's Number of disasters related to climate change events. These include drought, extreme temperature, flood, landslide, storm and wildfire.
Damage Amount of climate change related disasters (10 year average, % of GDP)	Source: Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EM-DAT), Moody's For each climate change related disaster (drought, extreme temperature, flood, landslide, storm and wildfire.), the registered figure corresponds to the damage value at the moment of the climate change related event as a percentage of GDP. Note: For Maldives, EM-DAT data was missing; therefore, we use the government source.
GDP per capita (PPP, US$)	Source: IMF, Moody's
ND-GAIN Vulnerability Index: Adaptive Capacity Component (Index) 1	Source: Notre Dame Global Adaptation Index (ND-GAIN): Vulnerability Index The availability of social resources for sector-specific adaptation. In some cases, these capacities reflect sustainable adaptation solutions. In other cases, they reflect capacities to put newer, more sustainable adaptations into place.
Government Fiscal Strength (Score)	Source: Moody's Sovereign Scorecards
General Government Debt (% of GDP)	Source: IMF, OECD, Eurostat, AMECO, National Sources, Moody's
Gen. Govt. Interest Payments/General Government Revenues (%)	Source: IMF, OECD, Eurostat, AMECO, National Sources, Moody's
Government Fiscal Deficit (% of GDP)	Source: IMF, OECD, Eurostat, AMECO, National Sources, Moody's

1 The ND-GAIN vulnerability index defines vulnerability as (A) exposure and (B) sensitivity to climate, population, infrastructure and resource stress, as well as the country's (C) adaptive capacity to those stresses. Each sub-indicator measures overall score by considering 6 impacted areas from rising environmental risk: (1) food; (2) water; (3) health; (4) ecosystem service; (5) human habitat; and (6) infrastructure.

Moody's Related Research

- Rating Methodology: Sovereign Bond Ratings, December 2015 (186644)
- Environmental Risks: Paris Agreement to Take Effect, Adoption of Carbon Reduction Policies to Accelerate, October 2016 (1044876)
- Global Unregulated Utilities and Power Companies: Carbon Transition Brings Risks and Opportunities, October 2016 (1030584)
- Environmental Risks: Automotive Sector Faces Rising Credit Risks from Carbon Transition, September 2016 (1038590)
- Environmental Risks: Risks and Opportunities: What the Paris Agreement Means for Capital Markets, July 2016 (1033890)
- Environmental Risks and Developments – Moody's To Analyse Carbon Transition Risk Based On Emissions Reduction Scenario Consistent with Paris Agreement, June 2016 (1029574)
- Environmental Risks and Developments – Global: Paris Agreement Advances Adoption of Carbon Regulations; Credit Impact to Rise, April 2016 (1024553)
- Moody's Approach to Assessing the Credit Impacts of Environmental Risks, November 2015 (1010009)
- Environmental Risks: Heat Map Shows Wide Variations in Credit Impact Across Sectors, September 2015 (1009845)
- Environmental, Social and Governance (ESG) Risks - Global: Moody's Approach to Assessing ESG Risks in Ratings and Research, September 2015 (1007087)

To access any of these reports, click on the entry above. Note that these references are current as of the date of publication of this report and that more recent reports may be available. All research may not be available to all clients.

Endnotes

1 While not the subject of this report, Moody's also considers the credit implications of carbon transition risks; that is, the credit impact of increased costs and business model adjustments associated with the trend towards materially reducing global greenhouse gas (GHG) emissions, including for carbon. Please see Environmental Risks: Moody's To Analyse Carbon Transition Risk Based On Emissions Reduction Scenario Consistent with Paris Agreement, June 2016.

2 The Intergovernmental Panel on Climate Change (IPCC) was created by the United Nations Environmental Panel and the World Meteorological Organization in 1988. It does not conduct independent research, but produces a consensus of research published in the world.

3 See Climate Change 2014 Synthesis Report (IPCC), 2015.

4 See India, Government of Vulnerability to Drought Poses Credit Challenges, August 2015.

5 See Economic Costs to Lebanon from Climate Change: A First Look, Ministry of Environment – United Nations Development Programme, 2015.

6 See Stern Review: The Economics of Climate Change, 2006.

7 See Fiji: Post-Disaster Needs Assessment, May 2016 - Tropical Cyclone Winston, February 20, 2016.

8 See http://www.unicef.org/appeals/files/UNICEF_Update_Mozambique_Flooding_Emergency_in_Zambezia_Jan2015.pdf, January 2015.

9 The government directly allocated PGK50 million for disaster relief in the 2016 budget, see http://www.treasury.gov.pg/html/national_budget/files/2016/2016%20Budget%20Speech.pdf. Furthermore, according to reports, the government is also channelling an additional PGK176 million into district authorities for drought-related assistance, see http://devpolicy.org/politicising-drought-relief-in-papua-new-guinea-20160118/.

10 See Kelley, et al. (2015) 'Climate change in the Fertile Crescent and implications of the recent Syrian drought'.

11 For greater detail on our methodology, see Rating Methodology: Sovereign Bond Ratings, December 2015.

12 Rating outcomes may consider additional factors that are difficult to measure or that have a meaningful effect in differentiating credit quality only in some, but not all cases. While these are important considerations, it is not possible to express them precisely in the rating methodology scorecard without making it excessively complex and significantly less transparent.

13 See http://unfccc.int/bodies/green_climate_fund_board/body/6974.php.

14 See CCRIF Annual Report 2014-2015, November 2015.

15 See State of Climate Report, December 2015, National Centers for Environmental Information, US Department of Commerce.

16 See John Cook et al, Consensus on consensus: a synthesis of consensus estimates on human-caused global warming, Environmental Research Letters, April 13, 2016.

17 The IPCC defines "extremely likely" as having an assessed 95% to 100% likelihood.

18 See Climate Change 2014: Synthesis Report, 2015 IPCC

19 See Robert M. DeConto and & David Pollard, Contribution of Antarctica to past and future sea-level rise, Nature 531, 591–597, published online 30 March 2016, corrected online 05 April 2016.

This publication does not announce a credit rating action. For any credit ratings referenced in this publication, please see the ratings tab on the issuer/entity page on www.moodys.com for the most updated credit rating action information and rating history.

REPORT NUMBER 1039339

MOODY'S INVESTORS SERVICE

Annex 588

"Climate Risk Insurance: New Approaches and Schemes", Working Paper, *Allianz*, September 2016

ECONOMIC RESEARCH

Working Paper

September 2016

} MACROECONMICS | } FINANCIAL MARKETS | } ECONOMIC POLICY | } SECTORS

Alexandra Hermann, Dr. Peter Köferl, Jan Philip Mairhöfer

Climate Risk Insurance: New Approaches and Schemes

Allianz

Working Paper

Climate Risk Insurance:
New Approaches and Schemes

AUTHORS:

ALEXANDRA HERMANN
Phone +49.89.3800-62147

DR. PETER KÖFERL
Phone +49.89.3800-15562
peter.koeferl@allianz.com

JAN PHILIP MAIRHÖFER
Phone +49.89.3800-68391
janphilip.mairhoefer@allianz.com

EXECUTIVE SUMMARY

Finding solutions for how to deal with the impacts of climate change is one of the most pressing issues of our time. It is the least and less developed countries which are the most affected by increasing frequency and severity of extreme weather events such as droughts or floods, while being the least capable of coping with them. Relying on ad hoc donor support creates uncertainties concerning the timing, size, and frequency of the payout which is desperately needed for mitigating the negative repercussions of weather extremes. Consequently, new viable and sustainable pre-disaster arrangements for transferring financial risks need to be found and implemented. Various general problems arise when setting up formal disaster risk transfer schemes in developing countries, which are mainly related to the concentration of risk, lack of data, low resilience of infrastructure, and potential for moral hazard.

On the one hand, classic insurance schemes on the micro, meso, and macro level, covering individuals, intermediaries, and countries, respectively, serve as a way to sharing weather-related risks and losses. Microinsurance is designed to directly meet policyholders' specific needs. Microinsurance schemes hedging against losses caused by extreme weather events have already been implemented in numerous African, Asian, and Middle-American countries. Meso-level insurance enhances investment potential by reducing losses caused by credit default and currently exists in regions in Central- and South America as well as South East Asian island states. Insurance on the macro-level allows both insured and uninsured individuals to be compensated for damage caused by extreme weather events. Two macro-level pooling facilities cover Caribbean island states and Sub-Saharan African countries.

On the other hand, alternative formal approaches to transferring weather-related risks may be pursued. Catastrophe bonds transfer risks to the capital market, thereby spreading them widely. They have mainly been issued by macro-level risk pooling facilities for reinsurance, but are increasingly being taken into consideration by public entities as a risk-sharing mechanism. Weather derivatives are another way of transferring risks to the capital market. A limited amount of projects have been piloting them in developing countries, mainly in Africa. Sovereign insurance enables highly exposed governments with a low tax base and a vulnerable infrastructure to hedge their liabilities against weather-related risks. Macro-level risk pooling facilities may be regarded as providers of sovereign insurance.

The mentioned mechanisms are vastly index-based, such that payments are disbursed if an index crosses a predetermined strike value, contrary to traditional schemes, where payouts are determined by actual losses. The index-based approach reduces administration costs and moral hazard, but creates substantial basis risk.

Climate risk insurance fosters sustainable economic growth and development of poor countries by compensating for instantaneous losses following an extreme weather event, providing resources for reconstruction and hence future production, reducing income inequality, motivating people to rebuild, and enhancing investment potential.

1. INTRODUCTION

The United Nations Framework Convention on Climate Change's (UNFCCC) key objective is to stabilize "greenhouse gas concentrations in the atmosphere in order to prevent dangerous anthropogenic interference with the climate system" (Article 2, UNFCCC 1992). In addition to such mitigation concerns, many developing countries have called for international assistance in adapting to the consequences of climate change (Dröge 2016). Market insurance and other financial risk-transfer mechanisms can be part of an adaption plan to reduce vulnerability to the direct impacts of climate change, namely more frequent and more severe extreme weather events with longer-lasting repercussions. However, many developing countries have underdeveloped weather-related insurance markets, which threatens development and poverty reduction (UNFCCC 2008). Hence, new viable and sustainable risk-transfer solutions need to be found and implemented. The Intergovernmental Panel on Climate Change's (IPCC) latest special report published in 2012 emphasizes the urgency of doing so. In preparation of the Conference of Parties (COP) in December 2015 in Paris, where both mitigation and adaption challenges were included in the final agreement's three main purposes (Dröge 2016, p. 30), the G7 launched an initiative on climate risk insurance. It aims to provide up to 400 million poor people with climate risk insurance by 2020 in addition to the 100 million people already covered (German Federal Ministry for Economic Cooperation and Development (BMZ) 2015).

In this paper, we use the terms climate and weather interchangeably , despite the fact that climate is usually referred to as "the average weather over time and space" (NASA 2005). We assume climate change to mainly manifest itself in a change in the frequency, severity, and long-term nature of extreme weather events such as floods, droughts, or storms, and we disregard other impacts such as rising sea levels.

This paper firstly presents different risk transfer mechanisms, followed by an overview of if, where, and how such schemes have already been established. The paper elaborates on the economic virtue of providing insurance for protecting against the adverse effects of extreme weather events. Finally, the paper will present a short conclusion with regards to the future outlook.

2. RISK TRANSFER MECHANISMS: DEFINITIONS, BENEFITS AND LIMITATIONS

There are numerous risk sharing and risk transfer strategies, which provide "pre-disaster financing arrangements that shift economic risk from one party to another" (IPCC 2012, p. 321). Aside from more informal coping strategies such as relying on international financial aid or kinship ties, individuals, communities, and countries can rely on insurance as a formal risk transfer mechanism (IPCC 2012, p. 322). Additionally, other formal approaches to transferring risks may be pursued. Many classic insurance products are difficult to implement or not viable at all in developing countries, mainly due to "the nature of disaster risks, lack of data, restrictive regulations, small scale of operations, and potential for moral hazard" (UNFCCC 2008, p. 6). This section firstly explains the underlying potential determinants of payouts, followed by a presentation of classic insurance schemes and other risk transfer approaches including their benefits and limitations.

DETERMINANTS OF PAYOUTS: ACTUAL LOSS VS. INDEX

Traditionally, financial compensation of a disaster is directly related to actual losses. A comparatively new type of insurance – index insurance – "is linked to an index, such as rainfall, temperature, humidity or crop yields, rather than actual loss" (Hellmuth et al. 2009, p. 3). For example, policy holders are automatically compensated for a potential loss of crops in case a rainfall index falls below a certain level.

Due to the fact that no resources are required to be spent on thoroughly assessing and quantifying losses, contrary to the traditional mechanism, transaction costs are lower, implying potential for lower risk premiums. Moreover, payouts can be made more quickly, which does not only avoid distress sale of assets, but also contributes to averting severe poverty following a disaster, thereby alleviating migration and conflict. Index insurance is also subject to less adverse selection and moral hazard, since it does not matter whether one policyholder is more prone to risk than another and the payout is not linked to the crop's survival or failure, such that it cannot be influenced by the policyholder and preserves the incentive to make the best decisions. Moreover, index insurance requires less complex contracts. A substantial disadvantage of index-based payouts is basis risk, which occurs when actual losses do not equal financial compensation, making the insurance non-viable, or damaging livelihoods in the long run (UNFCCC 2008, p. 7; Hellmuth et al. 2009). Similar to traditional insurance, index insurance can be applied at the micro, meso, and macro level. Alternative risk transfer approaches are also frequently based on a weather index.

2.1 Classic insurance schemes

MICRO-LEVEL INSURANCE

Microinsurance is specifically designed to protect low-income individuals and households directly against diverse risks in exchange for a regular small premium payment, where the sums insured are relatively small (IPCC 2012, p. 322; UNFCCC 2008, p. 52). During the early stages of implementation, schemes are often supported with technical and financial assistance in the form of lower risk premiums, for instance, in order to reduce market barriers (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) 2015).

Mechler et al. (2006) provide further insights on the characteristics, advantages, and limitations of microinsurance. Not only is it possible to protect against death or health problems, but also against loss of small-scale assets, livestock, and crops in case of a weather-related disaster. Group contracts are reported to be very common as they reduce the costs of issuing contracts and of processing premiums and claims. Microinsurance may be offered as a 'stand-alone' product, or it may be linked to a microloan, for instance, protecting the microfinance institution against loan default. Such a bundled scheme may additionally provide an incentive for strengthening resilience if the loan is used for financing resilience-enhancing measures (UNFCCC 2008, p. 53 f.), which may also be achieved by offering reduced premiums.

One major advantage is that microinsurance addresses individual policyholders directly, and ideally meets their specific needs, as opposed to indirect insurance schemes on the macro level, where losses are not assessed and quantified individually. It is reasonable to assume that policy holders, especially in case of an index-based scheme, can be compensated more quickly than through indirect insurance solutions on the macro level, where bureaucratic obstacles might delay payouts. Mechler et al. (2006) furthermore point out that an insurance contract is regarded as a "more dignified means of coping with disaster than relying on the ad hoc generosity of donors" (p. 6).

A considerable problem when offering microinsurance against weather-related disasters is that such disasters usually affect whole communities or regions at a time, causing a large number of claims at the same time (IPCC 2012, p. 323). As a consequence, schemes must be sold on a very large and diversified scale, which has been rarely achieved so far (International Labor Organization (ILO) 2012). In such cases insurers face insolvency risks or must rely on donor support (Mechler et al. 2006). Furthermore, since large parts of the population in developing countries are unfamiliar with the institution of insurance , investments in consumer education are needed (UNFCCC 2008, p. 53).

MESO-LEVEL INSURANCE

At the meso level, insurance is sold to intermediaries providing goods and services to rural markets (UNFCCC 2008, p. 59). This insurance protects intermediaries, such as credit unions or microfinance institutions (GIZ 2015), or non-governmental organizations (NGOs), from losses which may occur if their clients or members experience losses from extreme weather events (Skees et al. 2007a, p. 9), for example loan defaults by farmers as a consequence of a severe drought (GIZ 2015). Insurance on the meso level may therefore be regarded as a direct insurance to intermediaries, or as an indirect insurance to the members or clients of the respective entity, who for example benefit through potential loan programs.

Providing insurance to meso-level intermediaries results in lower administration costs and achieves greater reach (Hazell and Rahman 2014, p. 234) “since they are generally smaller in size and larger individually in terms of assets” (UNFCCC 2008, p. 59). Moreover, intermediaries are more familiar with financial products (UNFCCC 2008), which reduces the need for resources to be spent on consumer education. Additionally, using an intermediary provides the possibility of bundling insurance with credit (as in the example above), and hence incentivizes smallholders sceptical or reluctant to take up microinsurance (Hazell and Rahman 2014, p. 234).

On the contrary, offering insurance on the meso level poses the problem that portions of the payout to the intermediary may be captured before being distributed to clients or members (Hazell and Rahman 2014). Furthermore, it is reasonable to believe that claims of members and clients are difficult to be met in a timely manner, as the payout to the aggregator needs to be determined and then processed first. Cascading payments further to individual clients increases the overall delay.

MACRO-LEVEL / SOVEREIGN INSURANCE

At the macro level, entire regions or countries, or international charity organizations buy insurance in order to be able to fund recovery measures in case of an extreme weather event. As losses are most likely to be substantial at the aggregate level, the coverage is often provided directly by a reinsurer (Skees et al. 2007a). Regions, countries, or organizations may be insured individually, or they may be part of a risk-pooling facility.

By pooling risks at a supranational level, coverage may be provided “at a significantly lower cost than what governments [...] could obtain individually from the insurance market” (ILO 2012) as it allows broader risk diversification. This makes obtaining insurance coverage possible for countries, which would have otherwise not been able to afford it (GIZ 2015, p. 10).

Insurance on the macro level offers further advantages, especially if compared to meso-level and micro-level insurance. Firstly, in case of an extreme weather event, both insured and uninsured individuals benefit from direct payments or the provision of public goods (repaired roads and other infrastructure assets, for instance) by an insured government. Secondly, as indicated above, a natural disaster can wipe out entire portfolios of microinsurance risks since large claims have to be met all at once. Higher level schemes can fill this potential gap (ILO 2012). The GIZ (2015) claims that such an indirect insurance solution makes it possible to reach a large number of the poor and vulnerable within a short time, which limits the negative repercussions of extreme weather events that would otherwise be "heightened if provision of disaster relief is delayed" (p. 9). Following argument mentioned above, this claim may be doubted. One drawback of macro-level insurance is that it is impossible to target the specific needs of individuals. Especially if a large part of the population has to be compensated within only a short time frame after the disaster, individuals and households are likely to receive a lump-sum, which implies significant basis risk.

Sovereign insurance: Definition and product overview

Sovereign insurance constitutes "all efforts taken by country governments or a private insurer to pool risks on a sovereign level" (UNFCCC [no date]). Sovereign insurance comprises both the coverage of micro entities on a sovereign level as a way to indirectly reduce the government's fiscal exposure to natural disasters, and direct coverage of the public entity itself.

National governments hold a large portfolio of public infrastructure and other assets which are exposed to climate risks. Governments also provide post-disaster financial relief and assistance to individuals, households and businesses, and they "may insure these liabilities through sovereign insurance" (IPCC 2012, p. 372). Sovereign insurance is defined as a risk financing strategy for governments and may include reserve funds, insurance, or contingent debt (Ghesquiere 2007, p. 4). It is hardly found in developed countries, where governments are capable of covering for their public assets. However, small, low-income and highly exposed countries can make use of sovereign insurance in order to transfer risks of public sector assets and relief expenditure (IPCC 2012, p. 343, 372) as they are otherwise "unable to raise sufficient and timely capital to replace or repair damaged assets and restore livelihoods following major disasters" (IPCC 2012, p. 360).

If covered by sovereign insurance, national governments do not need to rely on donor support. Hence, they are more independent in decision-making, and there are less insecurities concerning the size, time, and frequency of the payout. On the downside, in contrast to direct insurance schemes such as microinsurance, with this arrangement individuals remain to be at the government's mercy in case they are only covered indirectly.

2.2 Other approaches to transferring risk

CATASTROPHE BONDS AND RESILIENCE BONDS

Over the past decade, catastrophe bonds (otherwise known as cat bonds) have emerged as an alternative risk-transfer product, especially to handle catastrophic risks like earthquake and hurricane, which the insurance industry had partly avoided before (UNFCCC 2008, p. 44). These kinds of bonds bring natural disaster risks into the capital market: issuers of cat bonds use them to fund payments if a specific catastrophic event occurs, in which case buyers can lose the entire principal (Skees et al. 2007a). In return, investors receive regular interest payments (the coupon), reflecting the probability of loss of the capital invested (UNFCCC 2008, p. 44), i.e. the probability for the catastrophic event to occur. Cat bonds, which are typically in place for three to five years, are index-based products as they are triggered "when a disaster reaches a predetermined threshold" (Refocus Partners 2015, p. 2). Originally, they provided an alternative to traditional reinsurance for insurance companies, but they have increasingly been used not only by public or quasi-public entities but also by large asset holding entities (Scism 2015; Refocus Partners 2015, p. 31).

One major advantage of cat bonds is that they spread the risks of a major catastrophic event, which would result in substantial financial losses. According to John Soe, a hedge fund manager specialized in cat bonds, "they [are] the ideal mechanism for dissipating the potential losses to [...] insurers [and other bond issuers] by extending them to the broader markets" (Lewis 2007) and hence a large group of investors. Moreover, the UNFCCC (2008) describes cat bonds to be an attractive investment due to the fact that the likelihood of the occurrence of a triggering event and thus the default of the bond is uncorrelated with any other default risk, providing "diversification of the investment portfolio whilst attracting good rates of return" (p. 44).

On the downside, the possibility of basis risk remains as the default is triggered by an index reaching a pre-specified level instead of an evaluation of actual losses (Elabed, G. et al. 2013). Basis risk also exists due to the fact that total payouts are limited by the size of the issued bond (Refocus Partners 2015, p. 40). However, it should be noted, that recent studies have shown the that the level of basis risk is comparable with the residual risk that is associated with individual insurance (Castillo, M. et al. 2012) Furthermore, if physical damage are caused by a source other than the specified catastrophic event, no compensation will be paid (UNFCCC 2008, p. 85).

In order to additionally reduce the physical risks of disasters, the RE: bound program has recently put forward the idea of converting cat bonds into resilience bonds, which are designed rather identically. The main distinguishing feature is that resilience bonds incentivize making investments in physical risk reduction projects by offering lower coupon pricings reflecting the reduction in expected losses in case risk reduction measures are implemented (Refocus Partners 2015, p. 33). Consequently, resilience bonds help to reduce vulnerability before a disaster strikes by stimulating prevention.

WEATHER DERIVATIVES

Weather derivatives have emerged in the late 1990s as another risk transfer mechanism (UNFCCC 2008, p. 44; Gandel 2012). A weather derivative is a financial contract which can be used by individuals or organizations. It typically takes the form of forward contracts or options ("call" and "put"), and its value is determined by a weather index, for example temperature, rainfall, or snowfall (Skees et al. 2007a, p. 12). For instance, a ski area could pay a certain premium to collect a specified amount for every inch of snow below a strike amount ("put" option), or the ski area could collect a certain premium and pay a specified amount for every inch of snow above a strike amount ("call" option) (Jones 2001). The major difference between insurance and derivatives is that derivatives are usually tradable (Skees et al. 2007a, p. 12).

Advantages of weather derivatives (as an index-based insurance instrument) include low moral hazard and adverse selection, less complex contracts and timely payout (UNFCCC 2008, p. 102). Similar to cat bonds, drawbacks of weather derivatives are the existence of basis risk and the fact that no compensation will be paid in case of damage caused by a source other than precisely the one previously specified (UNFCCC 2008, p. 85). Weather derivatives are not regarded as insurance or reinsurance instruments by insurance regulations in many countries. Hence, such that insurance companies wishing to use weather derivatives will be required to keep in reserves the full amount of the outstanding insured risks (UNFCCC 2008, p. 64). Skees et al. (2007a) claim that weather derivatives are generally "not well suited for developing countries [as they are] standardized products which require sophisticated markets and regulation, all of which are constraints to their use for agriculture in developing countries" (p. 19).

3. IMPLEMENTATION OF RISK TRANSFER MECHANISMS SO FAR

This section presents an overview of whether, where, and how well established the various disaster risk transfer mechanisms are in the less and least developed world. The GIZ (2015) reports a total of 100 million people currently being protected by different kinds of climate risk insurance. The following overview is not considered to be a review of all existing schemes but aims to provide conclusive and fact-based information and examples.

3.1 Classic insurance schemes

MICRO-LEVEL INSURANCE

According to the IPCC (2012), microinsurance schemes hedging against risks such as death or illness are widespread, "but applications for catastrophic risks to crops and property are [only] in the beginning phases" (p. 524). The vast majority of microinsurance schemes is index-based as traditional insurance "has failed in many countries, mainly because of the high costs associated with settling claims on a case-by-case basis" (Mechler et al. 2006, p. 9).

The *Agriculture and Climate Risk Enterprise (ACRE)* is described to be the largest index insurance program in the developing world, working with local insurers to mainly offer crop insurance to smallholders in Kenya, Tanzania and Rwanda. For its core product, the ACRE makes use of rainfall data to assess and compensate crop losses, but it also offers insurance against death of livestock (GIZ 2015, ACRE 2015).

The *R4 Rural Resilience Initiative* (former Horn of Africa Risk Transfer for Adaptation, HARITA) is another program targeted at Africa. It is currently active in Senegal and Ethiopia, where 26,000 smallholders have been reached by now, and aims to extend to Malawi and Zambia. The initiative provides insurance, among others, to poor farmers and other food insecure households, who are given access to insurance by paying into Insurance-for-Assets (IfA) schemes with their own labour. When a drought hits, as indicated by a specified weather index, policyholders receive compensation (World Food Program 2015, 2016).

In order to protect individuals in the Caribbean, more specifically St. Lucia, the *Livelihood Protection Policy (LPP)* does not only pay out when threshold values for rainfall or wind are exceeded, but also warns policy holders about approaching weather events via text message in order to enable them to employ risk reduction strategies (Munich Climate Insurance Initiative (MCII [no date a]).

In India, several different disaster microinsurance schemes are in place, covering the loss of life or property, among others, caused by natural disasters. The *All India Disaster Mitigation Institute (AIDMI)* offers the disaster insurance program *Afat Vimo*, which protects households and microbusiness owners from several major types of disasters such as earthquake or flood in return for small annual premiums (Mechler et al. 2006, p. 18). Another insurance product is offered by *BASIX*, a microfinance institution, to address high loan default rates and protect smallholder farmers from damages caused by excessive rainfall (Skees et al. 2007a, p. 24). As reported by the UNFCCC (2008), this was the “first micro-level rainfall insurance in the world” (p. 66). Allianz SE’s Group Economic Research presents a number of other insurance schemes in Asia, which are specifically targeted at agricultural firms and households (2016b).

In Pakistan, a pilot project creating a *National Disaster Insurance Fund* for protecting poor people at risk of extreme weather is still in design (MCII [no date b]). In Bangladesh, the NGO *Proshika*, a microfinance institution, offers an insurance which is bundled with savings. In case of damage due to flooding, clients receive indemnity payments twice the amount in their savings account (Mechler et al. 2006, p. 11; UNFCCC 2008, p. 92). In Malawi, an insurance product protecting farmers against drought is offered bundled with a loan to foster investment in improved seeds. In case the associated drought index exceeds a specified level, the lender receives an insurance indemnity (Skees and Collier 2008, p. 17).

MESO-LEVEL INSURANCE

In Peru, microfinance institutions are covered by an index-based insurance scheme, protecting from loan defaults in response to crop losses due to heavy rainfall and massive flooding caused by El Niño. Payouts are triggered if a sea surface temperature index exceeds a predetermined strike value, and they are commensurate with by how much the strike value is exceeded (Skees et al. 2007b).

Similarly, in Vietnam, creditors are protected from costs resulting from default risk and restructuring the loan portfolio due to excess water levels as indicated by measurements at a hydrological station. Intermediaries who purchase an index insurance contract receive a one percent payment for every centimetre above a strike value (Skees et al. 2007b).

The *Loan Portfolio Cover (LPC)* offers policies to financial institutions in the Caribbean, more specifically Jamaica, St. Lucia and Grenada, to protect their loan portfolios from extreme climate events and subsequent loan default. Payouts are made if previously specified values for wind speed and/or rainfall are exceeded (MCII [no date c]).

Another form of meso-level insurance is to be found in Uruguay, where it is not a microfinance institution, but an electricity company that is covered by weather insurance. Uruguay strongly dependent on its hydroelectric plants to supply the country with electricity, making it vulnerable to droughts. Therefore, the state-owned electric company entered into a weather insurance contract with the World Bank treasury, where payments are triggered when water levels fall below a critical value. The compensation payments are used for purchasing oil as another source of energy to provide the county’s inhabitants with electricity (Swiss RE 2015).

In Bangladesh, it is the local NGO Manab Mukti Sangstha working with community-based organizations and individual households which is covered by a flood insurance scheme. Payouts are determined by an index combining information on the water level and the number of flood days and are then distributed to households (Swiss RE 2015).

MACRO-LEVEL INSURANCE

In Mexico, the government has set up the natural disaster relief fund *Fondo de Desastres Naturales (FONDEN)*, which “provides rapid insurance payouts to help the public sector manage disaster situations” (GIZ 2015). This includes the repair of uninsured infrastructure, such as roads, bridges, and schools, and relief for low-income individuals

(GIZ 2015; UNFCCC 2008, p. 67). According to a recent report published by Swiss RE (2015), in addition to reconstruction, FONDEN now increasingly focuses on prevention. Resources are allocated to the fund through the Federal Budget. It has to be borne in mind that despite the fund functions like an insurance and is regarded as one by the GIZ.

For protecting other Central-American countries highly exposed to hurricanes and earthquakes, the *Caribbean Catastrophe Risk Insurance Facility (CCRIF SPC)* was set up in 2007 as the world's first catastrophe risk insurance pool, providing coverage to 16 Caribbean island states (IPCC 2012, p. 420, p. 524). Participating countries, such as the Bahamas, Barbados, Haiti, Jamaica, and Nicaragua[1], pay membership fees and receive immediate payouts to cover parts of the costs incurred by a natural disaster in return (IPCC 2012, p. 524). Additional funding is provided by the European Union (EU) and the World Bank, among others (GIZ 2015). Payouts are triggered by an index for hurricanes, as measured by wind speed, and an index for earthquakes, as measured by ground shaking (IPCC 2012, p. 420).

The *African Risk Capacity (ARC)* and its affiliate insurance company, the African Risk Capacity Insurance Company Limited is another disaster risk pool which was established as a Specialized Agency led by the African Union (AU) in 2012 (ARC 2016a; Swiss RE 2015). It aims at protecting African countries against droughts as indicated by a precipitation index (GIZ 2015). Initially, five African countries, namely Kenya, Mauritania, Niger, Senegal, and Mozambique were covered by drought insurance (ARC 2014). The second group of countries which joined in 2015 comprises Burkina Faso, The Gambia, Malawi, Mali and Zimbabwe (ARC 2016d). By 2020, the ARC aims to reach up to 30 of the 54 AU member countries (Swiss RE 2015). The capital mainly comes from participating countries' premiums, which are calculated based on the individual country's selection of the amount of financing it wishes to obtain from the ARC in case of droughts (ARC 2016b). Payouts are described to be made to national governments within two to four weeks of the end of the rainfall season if a predetermined critical threshold of the precipitation index is crossed (ARC 2016c).

Sovereign insurance: Pilot projects

In Mexico the government has insured its emergency relief expenditure through the natural disaster relief fund FONDEN (IPCC 2012, p. 372). Sovereign insurance is also provided through the CCRIF SPC to 16 Caribbean island states (IPCC 2012, p. 372). A similar product is provided by the ARC for numerous countries in Africa is also an application of sovereign insurance.

The Turkish Catastrophe Insurance Pool (TCIP) provides another important showcase as a form of "sovereign insurance provided at a national level" UNFCCC [no date]. The TCIP is claimed to be the second largest catastrophe pool in the world (the first being the CCRIP), as of 2008. It has been set up to provide compulsory earthquake insurance to Turkey's citizens, thereby reducing the Turkish government's "fiscal exposure to earthquakes by transferring excess catastrophe risk to the international reinsurance markets" (GFDRR 2011b; The Turkish Government 1999 [English translation]). Hence, the TCIP may be regarded to operate both on the micro and the macro level, as the Turkish government is covered indirectly through the fund's reinsurance, which protects from having to finance reconstruction in case the fund is unable to do so sufficiently. The TCIP serves as a role model to other

[1] For an overview of all participating countries of the CCRF see http://www.ccrif.org/content/member-countries.

countries highly exposed to disaster risk such as the Philippines, which are reported to be considering the establishment of an insurance pool similar in design to the Turkish one (Artemis 2014b). It is noteworthy that not only governments exposed to disaster risk through their post-disaster relief and assistance, but also donor organizations such as the World Food Program, which hedged against the risk of the occurrence of a drought in Ethiopia by purchasing index-based reinsurance (IPCC 2012, p. 372).

3.2 Other approaches to transferring risks

CATASTROPHE BONDS AND RESILIENCE BONDS

In 2008, cat bonds were still a relatively "novel instrument to transfer risks" (UNFCCC 2008, p. 41). In 2015, the cat bond market had an overall volume of US$ 25 billion and had grown by 25 percent over the preceding decade, as compared to 10 percent for the rest of the insurance sector, and it is predicted to grow further (Refocus Partners 2015, p. 3; Phillips 2014). As of 2014, it has mainly focused on developed countries, the United States in particular, accounting for 75 percent of the cat bond sector as described by a 2013 BNY Mellon report, where "cat bonds are regularly used by government-sponsored insurance programs" (e.g. the California Earthquake Authority or the Florida Citizens Property Insurance) (Refocus Partners 2015, p. 3). However, the market is predicted to grow drastically in developing countries in the future (Phillips 2014).

According to the IPCC (2012), Mexico was "the first transition country to transfer part of its public sector catastrophe risk to the international capital markets" (p. 362). As a reinsurance, the Mexican disaster relief fund *FONDEN* issued catastrophe bonds amounting to US$ 315 to cover earthquake and hurricane risks between 2012 and 2015. The bonds were designed to be triggered if a storm passed through a specific coastal zone and reached a predetermined pressure level, or if an earthquake reaching a certain magnitude and depth occurred (Swiss RE 2015).

In 2014, the World Bank issued its first cat bond ever. It had a value of US$ 30 million for providing reinsurance to 16 Caribbean island states through *the CCRIF SPC* (World Bank 2014). In the same year, the *ARC*, covering a number of African countries, announced the launch of the Extreme Climate Facility (XCF) as a second financial affiliate to access private capital through issuing a series of multi-year cat bonds. Payments are triggered by an index indicating a potential change in the frequency and severity of extreme weather events in the region, and they are to be used for financing adaption measures (ARC 2014; Artemis 2014a) instead of providing financial relief in response to specific disasters.

The first ever Asian cat bond was issued in 2015 by *China Re*, amounting to US$ 50 million to cover for earthquakes (Artemis 2015c). The World Bank is currently working on an approach to transfer disaster risk for the Philippines and is taking catastrophe bonds into consideration as a source of capital after an extreme weather event (Artemis 2015b).

A rise in cat bond issuance is expected in the future for the entire Asia Pacific region, according to a 2015 report by Fitch Ratings (Artemis 2015c). Most recently, the Start Network, an international network of non-governmental humanitarian organizations, has announced to investigate and develop cat bonds as a new method of making funding available for managing a disaster, in this case pandemics (Artemis 2015a). Other NGOs providing assistance and financial relief for extreme weather events may therefore also consider issuing cat bonds as a risk transfer mechanism.

The idea of resilience bonds as a new financial product providing post-disaster relief as well as incentivizing resilient infrastructure investment was first unveiled in April 2015 and formally announced at the COP in December 2015 in Paris (Jenkins 2015). The structure has not been implemented yet, but the Refocus Partners (2015) report provides project examples of where and how resilience bonds could be used, focusing on three US cities.

WEATHER DERIVATIVES

In developed countries, weather derivatives have been used since the 1990s, mainly by large energy companies in the US, and applications in the agricultural sector are only slowly increasing in number (Skees et al. 2007a, p. 17-19). In the past decade, international development organizations have been piloting weather derivatives in developing countries (Banerjee 2013).

Several case studies for weather derivatives in developing countries can be found in Africa. In 2002, the first weather derivative deal was settled in South Africa. *Genbel Securities*, a financial service provider, entered into a contract protecting ZZ2 Ceres, one of the country's largest fruit and vegetable producers, against early-spring frost. Payout is triggered if temperatures are zero or fall below zero degrees Celsius (Singh [no date]).

The *Climate Adaptation Development Program (CADP)* was launched in 2007 by Swiss Re in order to protect village clusters in Kenya, Mali, and Ethiopia against severe drought (UNFCCC 2008, p. 56 ff.). The program addresses the problem that financial institutions would not provide farmers with loan because of high default risk. Weather derivative contracts were developed for village clusters in the respective countries, where the payout is determined by an index correlated to crop production. It is to be used for the production and delivery of goods and services such as food aid or support for the local clinic. The project was to be extended to Ghana, Malawi, Nigeria, Rwanda, Senegal, Uganda, and the United Republic of Tanzania in 2008. At the current time, the potential of the project is not entirely clear.

Separately from the protection of village clusters in Malawi, between 2008 and 2011, the *Government of Malawi* purchased weather derivative contracts structured as put options on a rainfall index. Payouts were triggered if precipitation fell below a specified level, and were then used to lock maize prices before they increase due to poor harvest (Global Facility for Disaster Risk Reduction and Recovery (GFDRR) 2011a). Another showcase for weather derivatives can be found in Morocco. The contracts, which are sold in the form of an insurance contract by the agricultural mutual insurance company *MAMDA*, are designed as a European put option, and payouts are triggered when a rainfall index falls below a specified threshold (Stoppa and Hess 2003).

Outside of Africa, examples of weather derivatives in developing countries can for example be found in India, where the microfinance institution *BASIX* provides weather index insurance to smallholders, thereby protecting them from excessive rainfall (Banerjee 2013, p. 6; Skees et al. 2007a).

4. ECONOMIC VIRTUES OF CLIMATE RISK INSURANCE

Extreme weather events lead to a decline in agricultural output and disconnects in the agricultural production cycle among others, which is especially severe in developing countries, where the economy heavily relies on the agricultural sector for livelihoods, production and employment. Take Ethiopia for example, where agriculture accounts for roughly 40 percent of the nation's output and employs 80 to 85 percent of the population, according to the Food and Agriculture Organization of the United Nations (FAO) (Mengistu 2003). Here, droughts alone have been estimated to reduce total gross domestic product (GDP) by 1 to 4 percent (Group Economic Research / Allianz SE 2016a). A decline in agricultural output reduces employment and creates food scarcity, thereby increasing the incidence of poverty and reducing economic growth, which "jeopardize[s] sustainable development, and exacerbate[s] migration and conflict" (GIZ 2015, p.1).

Insurance is needed to compensate for the instantaneous loss in agricultural output and to averting long-lasting consequences for agricultural production caused by an interruption of the agricultural cycle. A cost-benefit analysis examining the economic advantages of establishing a risk pooling facility such as the *ARC* as a rapid response mechanism has found that "getting aid to households in the critical three months after harvest could result in economic gains of over USD 1,200 per household assisted" (ARC 2012, p. 4). Not only do extreme weather events reduce economic growth directly by disrupting agricultural production and threatening future production, but they can also have an indirect impact by raising the degree of income inequality (Mideksa 2010). Here, insurance contributes to mitigating the adverse effects of climate change by making sure that more heavily affected regions, do not fall behind further.

Economic growth and development is also impacted by underinvestment ensuing from the sheer risk of damage caused by extreme weather events. The risk of credit default in response to poor harvest caused by an extreme weather event raises the cost of providing financial services. Hence, credit is only supplied at unaffordable prices. For instance, this reduces the opportunity of investing in productivity enhancing fertilizers (Hellmuth et al. 2009, p. 5). Meso-level insurance schemes may serve as a way to reduce the negative consequences of default to creditors, thereby enhancing the investment and growth potential. There are also demand-side obstacles to investment. Uninsured individuals are likely to avoid taking risks through an investment or innovation which could potentially increase productivity, "since these innovations may increase their vulnerability" (Hellmuth et al. 2009, p. 2). In this case, both meso-level and microinsurance can provide security to farmers.

In order to incentives external businesses to invest and physically locate in areas prone to extreme weather events, special zones based on the model of Enterprise Zones or Charter Cities[2] could be created. In such zones, in addition to offering tax relief or financial grants, macro-level insurance could provide extra protection against climate risk, thereby giving businesses more planning security as compared to other regions, which is crucial for investment.

Developed countries may also benefit economically from supporting the implementation of insurance in developing countries. Without insurance, "climate impacts could lead to a downward socio-economic and humanitarian spiral" (UNFCCC 2008, p. 20), leading to not only economic dependence, but also geopolitical conflicts and migration, which is likely to incur even more lives lost and overall higher costs.

5. CONCLUSION

It is the less and least developed countries with low-level infrastructure and insufficient prevention policies – mostly African and Small Island States – which are greatly affected by climate change and its negative repercussions. Not only are these states the most

[2] For more information on Special Economic Zones, and Enterprise Zones and Charter Cities in particular see (Group Economic Research / Allianz SE 2015b).

exposed to the direct consequences, but they are also the least capable of reducing the risks and recovering from them (IPCC 2012, p.7; GIZ 2015, p.1).

Insurance may play a substantial role in protecting vulnerable countries from climate change. Various classic insurance schemes on the micro-, meso- and macro-level exist, and there are further alternative approaches to transferring climate risks. Such risk transfer mechanisms do not only contribute to reducing the adverse effects of extreme weather events caused by the disaster directly. Furthermore, they can provide incentives for strengthening resilience prior to the disaster and for faster local learning and competence building. Moreover, insurance fosters investment as it reduces uncertainties. Such investments can be utilized for resilience infrastructure or in order to create “greener cities” (Group Economic Research/Allianz SE 2014) and hence contributing to the reduction of greenhouse gas emissions, which mitigates the process of climate change, and hence the frequency and intensity of extreme weather events and their negative repercussions altogether. However, problems arise when setting up insurance schemes in developing countries, which are mainly related to the concentration of risk, the question of ownership, and difficulties in quantifying damages. Lack of data, restrictive regulations, small scale of operations, and potential for moral hazard may also impede the establishment of formal risk transfer schemes (UNFCCC 2008, p. 30, p. 6).

It has to be borne in mind that an increase in the frequency and severity of floods or droughts and the question how to cope with it does not only concern the developing world, but is rather sooner than later also going to be a highly relevant issue in developed regions such as Europe, requiring rethinking today’s insurance approaches and business models as well (Group Economic Research / Allianz SE 2014b, 2015a).

REFERENCES

Agriculture and Climate Risk Enterprise (ACRE) (2015). *Products.* http://acreafrica.com/

African Risk Capacity (ARC) (2012). *ARC Response to the Cost-Benefit Analysis of the African Risk Capacity.* http://www.africanriskcapacity.org/documents/350251/371565/ARC_CBA_and_Response.pdf (last accessed on 22 March 2016)

African Risk Capacity (ARC) (2014). *ARC Extreme Climate Facility (XCF).* Presentation by Dr. Richard Wolcox. 5th International Disaster & Risk Conference IDRC Davos 24-27 August 2014.

African Risk Capacity (ARC) (2016a). *Vision and Mission.* http://www.africanriskcapacity.org/about/vision-and-mission (last accessed on 22 March 2016)

African Risk Capacity (ARC) (2016b). *ARC Agency Treaty Signatories.* http://www.africanriskcapacity.org/countries/signatories (last accessed on 22 March 2016)

African Risk Capacity (ARC) (2016c). *How ARC works.* http://www.africanriskcapacity.org/about/how-arc-works (last accessed on 22 March 2016)

African Risk Capacity (ARC) (2016d). *Risk Pool II.* http://www.africanriskcapacity.org/de/risk-pool2 (last accessed on 22 March 2016)

Artemis (2014a). *Climate change catastrophe bonds for Africa to be launched by ARC.* 23 September 2014. http://www.artemis.bm/blog/2014/09/23/climate-change-catastrophe-bonds-for-africa-to-be-launched-by-arc/ (last accessed on 21 March 2016)

Artemis (2014b). *Philippines seeks TCIP type catastrophe pool: Could lead to cat bonds.* 29 July 2014. http://www.artemis.bm/blog/2014/07/29/philippines-seeks-tcip-type-catastrophe-pool-could-lead-to-cat-bonds/ (last accessed on 21 March 2016)

Artemis (2015a). *Start Network looks to parametrics & cat bonds for crisis response.* 2 October 2015. http://www.artemis.bm/blog/2015/10/02/start-network-looks-to-parametrics-cat-bonds-for-crisis-response/ (last accessed on 21 March 2016)

Artemis (2015b). *World Bank confirms Philippines catastrophe bond discussions.* 18 September 2015. http://www.artemis.bm/blog/2015/09/18/world-bank-confirms-philippines-catastrophe-bond-discussions/ (last accessed on 21 March 2016)

Artemis (2015c). *Catastrophe bond issuance in Asia Pacific to increase: Fitch.* 21 August 2015. http://www.artemis.bm/blog/2015/08/21/catastrophe-bond-issuance-in-asia-pacific-to-increase-fitch/ (last accessed on 21 March 2016)

Banerjee, C. (2013). *Weather Derivatives Revisited: A Disclosure on Scalability, Feasibility and Sustainability*. PhD Dissertation, Hohe Landwirtschaftliche Fakultät Rheinische Friedrich-Wilhelms-Universität zu Bonn. http://hss.ulb.uni-bonn.de/2014/3556/3556.pdf (last accessed on 21 March 2016)

Castillo, Maria Jose, Stephen Boucher, and Michael Carter. *Will I be paid after a loss? Evaluating conventional versus index insurance contracts in Ecuadorean Agriculture*. working paper. UC Davis Working paper. Accessed July 2016, available at http://arefiles.ucdavis.edu/uploads/filer_public/2014/06/19/castillobouchercarternov2012_1.pdf

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (2015). *Climate Risk Insurance: For Strengthening Climate Resilience of Poor People in Vulnerable Countries.*

Dröge, S. (2016). *The Paris Agreement: Turning Point for the International Climate Regime*. Stiftung Wissenschaft und Politik (SWP) Research Paper.

Elabed, Ghada, et al. (2013) *Managing basis risk with multiscale index insurance.* Agricultural Economics 44.4-5: 419-431.

Federal Ministry for Economic Cooperation and Development (BMZ) (2015*). Outcomes of the Elmau summit.* http://www.bmz.de/g7/en/Entwicklungspolitische_Schwerpunkte/ Klimawandel/index.html (last accessed on 21 March 2016)

Gandel, S. (2012). *No Snow, No Problem: How Wall street Profits from Weird Weather. Time* 24 January 2012 [online]. http://business.time.com/2012/01/24/no-snow-no-problem-how-wall-street-profits-from-weird-weather/ (last accessed on 21 March 2016)

Ghesquiere, F. (2007). *Sovereign natural disaster insurance for developing countries: A paradigm shift in catastrophe risk financing*. Vol. 4345. World Bank Publications.

Global Facility for Disaster Risk Reduction and Recovery (GFDRR) (2011a). Weather Derivative in Malawi. http://www.gfdrr.org/sites/gfdrr.org/files/documents/DRFI_Malawi Derivative_Jan11.pdf (last accessed on 23 March 2016)

Global Facility for Disaster Risk Reduction and Recovery (GFDRR) (2011b). *Turkish Catastrophe Insurance Pool.* http://www.gfdrr.org/sites/gfdrr.org/files/documents/DFI_TCIP__Jan11.pdf (last accessed on 21 March 2016)

Group Economic Research / Allianz SE (2014a). *Increasing Risk of Precipitation-induced Floods in Europe: Implications for Insurance*.

Group Economic Research/Allianz SE (2014b). *Investment in greener cities: Mind the gap.* Published in May 2014.

Group Economic Research / Allianz SE (2015a). *2015 Drought Report Europe*.

Group Economic Research / Allianz SE (2015b). *Special Economic Zones – Chances and Challenges.*

Group Economic Research / Allianz SE (2016a). *Extreme Weather Impacts in Africa.*

Group Economic Research / Allianz SE (2016b). *Climate Risk: Agricultural Insurance Schemes in Asia. In preparation.*

Hazell, P. and A. Rahman (eds.) (2014). *New Directions for Smallholder Agriculture. Oxford University Press.*

Hellmuth, M. E., D. E. Osgood, U. Hess, A. Moorhead and H. Bhojwani (eds.) (2009). *Index insurance and climate risk: Prospects for development and disaster management.* Climate and Society No. 2. International Research Institute for Climate and Society Climate and Society (IRI).

Intergovernmental Panel on Climate Change (IPCC) (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaption. Special Report.

International Labor Organization (ILO) (2012). Can climate be insured? http://www.ilo.org/global/about-the-ilo/press-and-media-centre/news/WCMS_186254/lang--en/index.htm (last accessed on 21 March 2016)

Jenkins, N. (2015). *The RE.bound Program Leverages Innovative Risk Transfer Solutions As a Mechanism for Resilient Infrastructure Project Finance. RE.bound press release* 2 April 2015. New York: Refocus Partners. http://www.refocuspartners.com/press-releases/refocus-partners_REbound-Program-Press-Release-20150402.pdf (last accessed on 24 March 2016)

Jones, D. (2001). *How weather derivatives work.* USA Today 11 December 2001 [online]. http://usatoday30.usatoday.com/weather/news/2001/2001-12-11-weatherderivativesqa.htm (last accessed on 21 March 2016)

Lewis, M. (2007). *In Nature's Casino.* New York Times Magazine 26 August 2007 [online]. http://www.nytimes.com/2007/08/26/magazine/26neworleans-t.html?pagewanted=all&_r=2 (last accessed on 21 March 2016)

Mechler, R., J. Linnerooth-Bayer and D. Peppiatt (2006). *Disaster Insurance for the Poor? A review of microinsurance for natural disaster risks in developing countries*. ProVention/International Institute of Applied Systems Analysis (IIASA) Study.

Mengistu, A. (2003). *Ethiopia.* Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/ag/AGP/AGPC/doc/Counprof/Ethiopia/Ethiopia.htm

Mideksa, T. K. (2010). Economic and distributional impacts of climate change: The case of Ethiopia. *Global Environmental Change 20(2)*, pp. 278-286. http://www.sciencedirect.com/science/article/pii/S0959378009001022

Munich Climate Insurance Initiative (MCII) [no date a]. *For Individuals: The Livelihood Protection Policy. LPP Factsheet.* http://www.climate-insurance.org/projects/climate-risk-adaptation-and-insurance-in-the-caribbean/latest-project-updates/latest-news/launch-of-the-livelihood-protection-policy-in-saint-lucia/ (last accessed on 21 March 2016)

Munich Climate Insurance Initiative (MCII) [no date b]. *Designing Disaster Risk Insurance Framework for Pakistan.* http://www.climate-insurance.org/projects/designing-a-disaster-risk-insurance-framework-for-pakistan/ (last accessed on 23 March 2016)

Munich Climate Insurance Initiative (MCII) [no date c]. *For Financial Institutions: The Loan Portfolio Cover.* http://www.climate-insurance.org/projects/climate-risk-adaptation-and-insurance-in-the-caribbean/the-loan-portfolio-cover/ (last accessed on 21 March 2016)

NASA (2005). *NASA – What's the Difference between Weather and Climate?* http://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html (last accessed on 22 March 2016)

Phillips, L. (2014). *Cat bonds: Cashing in on catastrophe.* Road to Paris. http://roadtoparis.info/2014/11/18/cat-bonds-cashing-catastrophe/

Refocus Partners (2015). *Leveraging Catastrophe Bonds: As a Mechanism for Resilient Infrastructure Project Finance.* http://www.refocuspartners.com/reports/RE.bound-Program-Report-December-2015.pdf (last accessed on 21 March 2016)

Scism, L. (2015). *From the Makers of Catastrophe Bonds, a New 'Resilience Bond'.* The Wall Street Journal 9 December 2015 [online]. http://blogs.wsj.com/moneybeat/2015/12/09/from-the-makers-of-catastrophe-bonds-a-new-resilience-bond/ (last accessed on 21 March 2016)

Singh, S. [no date]. *Weather Insurance and Derivatives in Developing Countries: an Alternative to Agriculture Insurance (2)*. Appleton, Wisconsin: MicroInsurance Centre. http://www.microinsurancecentre.org/resources/documents/weather-insurance-and-derivatives-in-developing-countries-an-alternative-to-crop-insurance/download.html (last accessed on 21 March 2016)

Skees, J. and B. Collier (2008). *The Potential of Weather Index Insurance for Spurring a Green Revolution.* Forum for Agricultural Risk Management in Development. http://agriskmanagementforum.org/doc/potential-weather-index-insurance-spurring-green-revolution-africa (last accessed on 21 March 2016)

Skees, J., A. Murphy, B. Collier, M. J. McCord and J. Roth (2007a). *Scaling up index insurance: What is needed for the next big step forward?* Paper prepared for Kreditanstalt für Wiederaufbau (KfW), Microfinance Centre, LLC and GlobalAgRisk, Inc.

Skees, J., J. Hartell and A. Goes (2007b). Using Index-based Risk Transfer Products to Facilitate Micro Lending in Peru and Vietnam. *American Journal of Agricultural Economics 89(5)*, Proceedings Issue, pp. 1255-1261.

Stoppa, A. and U. Hess (2003). *Design and Use of Weather Derivatives in Agricultural Policies: the Case of Rainfall Index Insurance in Morocco.* Contributed paper presented at the International Conference Agricultural policy reform and the WTO: Where are they heading? Capri, 23-26 June 2003. Appleton, Wisconsin: MicroInsurance Centre. http://www.microinsurancecentre.org/resources/documents/products/agriculture-incl-index/design-and-use-of-weather-derivatives-in-agricultural-policies-the-case-of-rainfall-index-insurance-in-morocco.html

Swiss RE (2015). *Closing the protection gap: Disaster risk financing: Smart solutions for the public sector.* http://media.swissre.com/documents/Closing_the_Gap_2015_FINAL.pdf (last accessed on 21 March 2016)

The Turkish Government. 1999. *Governmental Decree Law No. 587 on Compulsory Earthquake Insurance.* [English Translation] Official Gazette No. 23919. Accessed on 06.07.2016 As published under: https://www.gfdrr.org/sites/gfdrr/files/publication/Earthquake%20Insurance%20in%20Turkey%20History%20of%20the%20Turkish%20Catastrophe%20Insurance%20Pool.pdf

United Nations Framework Convention on Climate Change (UNFCCC) (1992). *United Nations Framework Convention on Climate Change.* https://unfccc.int/resource/docs/convkp/conveng.pdf (last accessed on 21 March 2016)

United Nations Framework Convention on Climate Change (UNFCCC) (2008). *Mechanisms to manage financial risks from direct impacts of climate change in developing countries.* Technical paper.

United Nations Framework Convention on Climate Change (UNFCCC) [no date]. *Risk management approaches to address adverse effects of climate change – Insurance.* https://unfccc.int/cooperation_support/response_measures/items/4971txt.php#SI (last accessed on 21 March 2016)

World Bank (2014). *World Bank Issues its First Ever Catastrophe Bond Linked to Natural Hazard Risks in Sixteen Caribbean Countries.* Press release 30 June 2014. http://treasury.worldbank.org/cmd/htm/FirstCatBondLinkedToNaturalHazards.html (last accessed on 21 March 2016)

World Food Program (2015) *R4 Rural Resilience Initiative: Building resilience to climate change for long-term food security and livelihoods improvement.* Accessed on: 06.07.2016 Available under: http://documents.wfp.org/stellent/groups/public/documents/communications/wfp278287.pdf

World Food Program (2016). *The R4 Rural Resilience Initiative: Building long-term resilience to climate change for food and income security.* http://www.wfp.org/climate-change/initiatives/r4-rural-resilience-initiative (last accessed on 21 March 2016

These assessments are, as always, subject to the disclaimer provided below.

ABOUT ALLIANZ

Together with its customers and sales partners, Allianz is one of the strongest financial communities. About 85 million private and corporate customers insured by Allianz rely on its knowledge, global reach, capital strength and solidity to help them make the most of financial opportunities and to avoid and safeguard themselves against risks. In 2015, around 142,000 employees in over 70 countries achieved total revenues of 125.2 billion euros and an operating profit of 10.7 billion euros. Benefits for our customers reached 107.4 billion euros.
This business success with insurance, asset management and assistance services is based increasingly on customer demand for crisis-proof financial solutions for an aging society and the challenges of climate change. Transparency and integrity are key components of sustainable corporate governance at Allianz SE.

CAUTIONARY NOTE REGARDING FORWARD-LOOKING STATEMENTS

The statements contained herein may include prospects, statements of future expectations and other forward-looking statements that are based on management's current views and assumptions and involve known and unknown risks and uncertainties. Actual results, performance or events may differ materially from those expressed or implied in such forward-looking statements.
Such deviations may arise due to, without limitation, (i) changes of the general economic conditions and competitive situation, particularly in the Allianz Group's core business and core markets, (ii) performance of financial markets (particularly market volatility, liquidity and credit events), (iii) frequency and severity of insured loss events, including from natural catastrophes, and the development of loss expenses, (iv) mortality and morbidity levels and trends, (v) persistency levels, (vi) particularly in the banking business, the extent of credit defaults, (vii) interest rate levels, (viii) currency exchange rates including the euro/US-dollar exchange rate, (ix) changes in laws and regulations, including tax regulations, (x) the impact of acquisitions, including related integration issues, and reorganization measures, and (xi) general competitive factors, in each case on a local, regional, national and/or global basis. Many of these factors may be more likely to occur, or more pronounced, as a result of terrorist activities and their consequences.

NO DUTY TO UPDATE

The company assumes no obligation to update any information or forward-looking statement contained herein, save for any information required to be disclosed by law.

ANNEX

Table 1: Summary of characteristics and examples of classic insurance schemes

Risk transfer mechanism	Micro-level insurance	Meso-level insurance	Macro-level insurance
Target Users (direct)	Low-income individuals and households	Intermediaries providing goods and services to rural markets, e.g. microfinance institutions, electricity providers, NGOs	Regional or national governments, international charity organizations
Premium and Payout	Low premium paid by individual policyholder, often subsidized at early stages Low payout to individual policyholder, vastly index-based	Intermediaries decide on the value to be insured and are charged premiums accordingly Payouts are index-based and mostly proportional to by how much a strike value is exceeded	Individual: contributions to funds from Government Budget, payout through direct access to fund Pooled: premiums are paid for by participating countries and donors; countries receive direct and timely payouts from the pooling facility in case an event strikes
Risks covered so far	Flooding and drought causing crop loss and food insecurities, diseases and accidents causing loss of livestock, wind and rainfall endangering livelihoods	Loan default and savings withdrawal due to extreme weather event, electricity shortages due to droughts	Large costs for repair of infrastructure and financial relief to individuals incurred by extreme weather events such as droughts, hurricanes, or earthquakes
Examples	Kenya, Tanzania and Rwanda (ACRE); Senegal and Ethiopia (R4 Rural Resilience Initiative, to be extended to Malawi and Zambia); St. Lucia (LPP); India (Afat Vimo and BASIX); Bangladesh (Proshika, bundled with savings); Malawi (bundled with loan)	Peru; Vietnam; Jamaica, St. Lucia and Grenada (LPC); Uruguay; Bangladesh	Individual: Mexico (FONDEN) Pooled: Kenya, Mauritania, Niger, Senegal, Mozambique, Burkina Faso, The Gambia, Malawi, Mali and Zimbabwe (ARC); Bahamas, Barbados, Haiti, Jamaica, Nicaragua and 11 other Caribbean island states (CCRIF)
Notes	The vast majority of classic insurance schemes on all levels is based on a weather index. Skees et al. (2007a, pp. 20-21) provide a conclusive table on index-based risk transfer products in developing countries.		

Table 2: Summary of characteristics and examples of other approaches to transferring risks

Risk transfer mechanism	Catastrophe bonds and resilience bonds	Weather derivatives	Sovereign insurance
Target Users (direct)	Insurance companies, governments, large asset holders, NGOs	Individuals, insurance companies, governments	Governments, donor organizations
Premium and Payout	Coupon payments may be regarded as the premium payments, rate depends on risk exposure, thus lower for resilience bonds Bond defaults such that seller receives payout (and investors lose the principal) in case a specific index crosses a predetermined value	Put: Cost of the option may be regarded as the premium, call: payouts to the other party in case of the triggering event may be regarded as the premium Put: payout is triggered if the underlying index crosses a predetermined value, call: payout is received as the cost of the option sold	Premiums paid by governments to a national fund, risk pooling facility, or reinsurer Timely payouts in case an event strikes
Risks covered so far	Earthquakes, hurricanes, long-term increases in the frequency and severity of extreme weather events	Excessive rainfall, drought, frost	Destruction of public infrastructure and other assets, provision of post-disaster financial relief and assistance
Examples	Mexico (reinsurance for FONDEN); Bahamas, Barbados, Haiti, Jamaica, Nicaragua and 11 other Caribbean island states (Reinsurance for CCRIF SPC, cat bond issued by World Bank); China (China Re) Resilience bonds have not been issued yet	India; Kenya, Mali, Ethiopia, Ghana, Malawi, Nigeria, Rwanda, Senegal, Uganda, United Republic of Tanzania (CADP); Malawi; Morocco; South Africa	Mexico (FONDEN); Bahamas, Barbados, Haiti, Jamaica, Nicaragua and 11 other Caribbean island states (CCRIF SPC); Kenya, Mauritania, Niger and Senegal, Mozambique, Burkina Faso, The Gambia, Malawi, Mali and Zimbabwe (ARC); Turkey (TCIP); Ethiopia (purchased by World Food Programme)
Notes		Banerjee (2013, p. 8) gives a comprehensive table of the forms of weather derivatives in different developing countries.	

Annex 589 bis

“How We Rate Sovereigns”, *S&P Global*, 15 February 2019

How We Rate Sovereigns

February 15, 2019

This article provides a summary of each key stage of S&P Global Ratings' "Sovereign Rating Methodology," published Dec. 18, 2017.

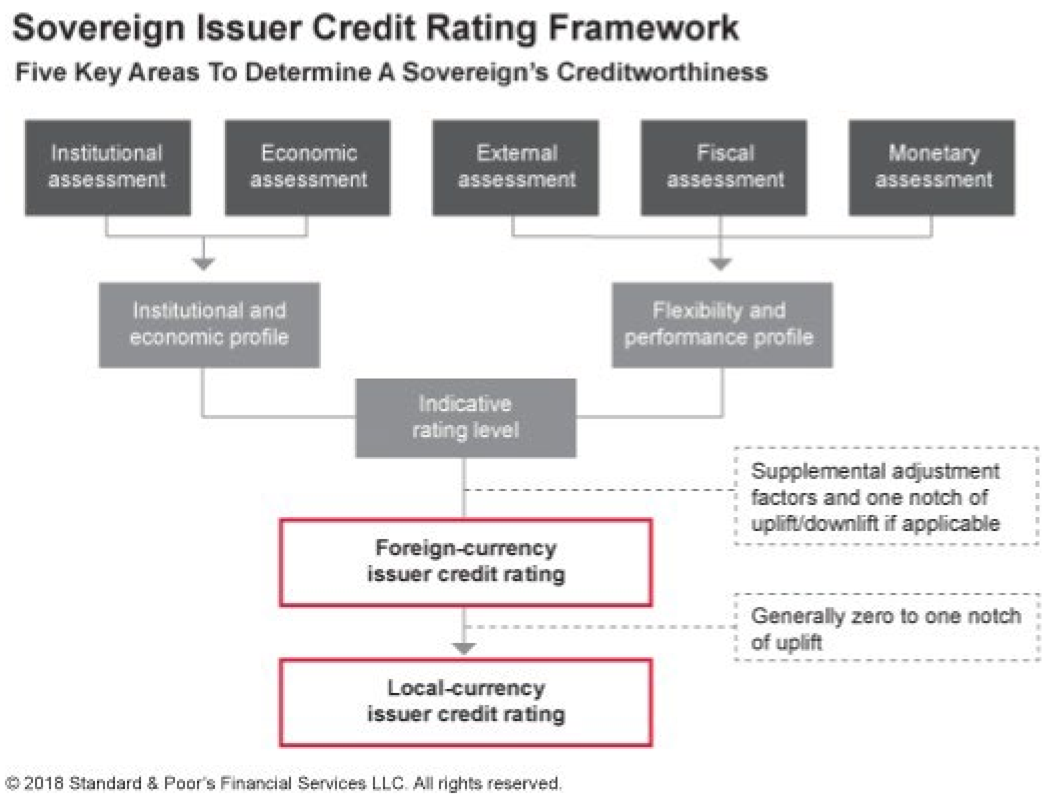
S&P Global Ratings' global methodology applies to sovereign governments and monetary authorities and aims to give market participants a clear picture of how we rate both types of entities. The criteria apply to issuer credit and issue ratings. For the purpose of the criteria, we define a sovereign as a state that administers its own government and is not subject to or dependent on another sovereign for all or most prerogatives. In particular, one of the most important prerogatives of a sovereign, in our view, is the right to determine the currency it uses, as well as the political and fiscal frameworks in which it operates.

All references to sovereign ratings in this article pertain to a sovereign's ability and willingness to service financial obligations to nonofficial (commercial) creditors. The issuer credit rating (ICR) on a sovereign does not reflect its ability and willingness to service other types of obligations, such as obligations:

- To other governments (Paris Club debt or intergovernmental debt);
- To supranationals, such as the International Monetary Fund (IMF) or the World Bank;
- To honor a guarantee not meeting our criteria for credit substitution (see "Guarantee Criteria," published Oct. 21, 2016); or
- To public-sector enterprises or local and regional governments.

The methodology does take into account these obligations' potential effect on a sovereign's ability to service its commercial financial obligations. In this article, "rating" refers to an ICR if not otherwise specified. For further information on what we consider a default for sovereigns, please refer to "What Does S&P Global Ratings Consider A Default For Sovereign And Non-U.S. Local And Regional Governments?," published April 13, 2017.

Our sovereign rating criteria incorporate the factors that we believe affect a sovereign government's willingness and ability to service its financial obligations to nonofficial creditors on time and in full. The foundation of our sovereign credit analysis rests on five pillars (see chart).



The institutional assessment reflects our view of how a government's institutions and policymaking affect a sovereign's credit fundamentals by delivering sustainable public finances, promoting balanced economic growth, and responding to economic or political shocks. It also reflects our view of the transparency and accountability of data, processes, and institutions; a sovereign's debt repayment culture; and potential external and domestic security risks.

The history of sovereign defaults suggests that a wealthy, diversified, resilient, and adaptable economy ultimately boosts its debt-bearing capacity. The economic assessment incorporates our view of:

- The country's income levels as measured by its GDP per capita, indicating broader potential tax and funding bases upon which to draw, which generally support creditworthiness;
- Growth prospects; and
- Its economic diversity and volatility.

A country's external assessment, which refers to the transactions and positions of all residents (public- and private-sector entities) vis-à-vis the rest of the world, is primarily driven by our view of:

- The status of a sovereign's currency in international transactions;
- The country's external liquidity, which provides an indication of the economy's ability to generate the foreign exchange necessary to meet its public- and private-sector obligations to nonresidents; and

- The country's external position, which shows residents' assets and liabilities (in both foreign and local currency) relative to the rest of the world.

The fiscal assessment reflects our view of the sustainability of a sovereign's deficits and its debt burden. This measure considers fiscal flexibility, long-term fiscal trends and vulnerabilities, debt structure and funding access, and potential risks arising from contingent liabilities. Given the many dimensions that this assessment captures, the analysis is divided into two segments, "fiscal performance and flexibility" and "debt burden."

The monetary assessment considers our view of the monetary authority's ability to fulfill its mandate while sustaining a balanced economy and attenuating any major economic or financial shocks. We derive the monetary assessment by analyzing:

- The exchange rate regime, which influences a sovereign's ability to coordinate monetary policy with fiscal and other economic policies to support sustainable economic growth; and
- The credibility of monetary policy as measured, among other factors, by inflation trends over an economic cycle and the effects of market-oriented monetary mechanisms on the real economy, which is largely a function of the depth and diversification of a country's financial system and capital markets.

Each of the above-mentioned five factors is assessed on a six-point numerical scale from '1' (strongest) to '6' (weakest). Both quantitative factors and qualitative considerations form the basis for these forward-looking assessments.

The sovereign's institutional and economic profile (the average of the institutional assessment and the economic assessment) reflects our view of the resilience of a country's economy, the strength and stability of its civil institutions, and the effectiveness of its policymaking. The sovereign's flexibility and performance profile (the average of the external assessment, the fiscal assessment, and the monetary assessment) reflects our view of the sustainability of a government's fiscal balance and debt burden, in light of the country's external position, as well as the government's fiscal and monetary flexibility.

We then use the flexibility and performance profile and institutional and economic profile to determine an "indicative rating level" (see table). We expect that our sovereign foreign-currency rating would, in most cases, fall within one notch of the indicative rating level. For example, for a sovereign we view as having a "moderately strong" institutional and economic profile and a "very strong" flexibility and performance profile, we would most likely assign a rating within one notch of 'AA-'.

Indicative Rating Levels

From The Combination Of The Institutional And Economic Profile With The Flexibility And Performance Profile

		INSTITUTIONAL AND ECONOMIC PROFILE										
	Category	Superior	Extremely strong	Very strong	Strong	Moderately strong	Intermediate	Moderately weak	Weak	Very weak	Extremely weak	Poor
FLEXIBILITY AND PERFORMANCE PROFILE — Category	Assess-ment	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6
Extremely strong	1 to 1.7	aaa	aaa	aaa	aa+	aa	a+	a	a-	bbb+	bb+	bb-
Very strong	1.8 to 2.2	aaa	aaa	aa+	aa	aa-	a	a-	bbb+	bbb	bb+	bb-
Strong	2.3 to 2.7	aaa	aa+	aa	aa-	a	a-	bbb+	bbb	bb+	bb	b+
Moderately strong	2.8 to 3.2	aa+	aa	aa-	a+	a-	bbb	bbb-	bb+	bb	bb-	b+
Intermediate	3.3 to 3.7	aa	aa-	a+	a	bbb+	bbb-	bb+	bb	bb-	b+	b
Moderately weak	3.8 to 4.2	aa-	a+	a	bbb+	bbb	bb+	bb	bb-	b+	b	b
Weak	4.3 to 4.7	a	a-	bbb+	bbb	bb+	bb	bb-	b+	b	b-	b-
Very weak	4.8 to 5.2	bbb	bbb	bbb-	bb+	bb	bb-	b+	b	b	b-	b-
Extremely weak	5.3 to 6	bb+	bb+	bb	bb-	b+	b	b	b-	b-	b-	b-

Assigning 'CCC+', 'CCC', 'CCC-', and 'CC' ratings is based on "Criteria For Assigning 'CCC+', 'CCC', 'CCC-', And 'CC' Ratings," Oct. 1, 2012.

In some cases, a sovereign foreign-currency rating might differ by more than one notch compared with the indicative rating level if it meets one or more of the supplemental adjustment factors. If a sovereign has several of these characteristics, the foreign-currency rating on the sovereign would be adjusted by the cumulative effect of those adjustments or the caps indicated by those adjustments. These factors could be negative (an extremely high fiscal debt burden, extremely weak external liquidity, event risk, or very high institutional risk and high debt burden) or positive (very large liquid financial government assets). When relevant, our sovereign ratings may also be informed by the methodologies described in "Criteria For Assigning 'CCC+', 'CCC', 'CCC-', And 'CC' Ratings," published Oct. 1, 2012.

Absent supplemental adjustment factors, our sovereign foreign-currency rating is within one notch of the indicative rating level. The main factors that can lead to an ICR that is one notch higher or lower than the indicative rating level are the following:

- At least one of the five rating factors is in a positive or negative transition that supports or detracts from creditworthiness and that is not already fully captured in the indicative rating level;
- The sovereign is a sustained and projected over- or underperformer among similarly rated sovereigns for at least one of the key rating factors, unless already captured elsewhere in the

methodology;

- We view the change in a particular assessment as temporary and expect it either to revert or to be offset (over the medium to long term) by an opposite dynamic in other assessments. An example is deterioration in the external assessment because of large investment projects that we expect, if successful, will improve economic growth potential over the medium term;
- A change in only one rating factor can sometimes lead to a multinotch change in the indicative rating in our indicative rating matrix (see table). In this case, the final rating may be set one notch apart from what's indicated in the table. For example, if a sovereign has an institutional and economic profile assessment of 2.0 and a flexibility and performance profile assessment of 4.8, the final rating might be set at 'BBB' (absent supplemental factors), instead of 'BBB-' as indicated in the matrix, if one assessment change would be sufficient to raise the indicative rating level to 'bbb+'; and
- Other factors that are not fully captured in the indicative rating and that have a positive or negative impact on our view on creditworthiness could also lead us to adjust the indicative rating level by one notch.

We determine a sovereign local-currency rating by applying up to usually no more than one notch of uplift over the foreign-currency rating. Sovereign local-currency ratings can be higher than sovereign foreign-currency ratings because local-currency creditworthiness may be supported by the unique powers that sovereigns possess within their own borders, including issuance of the local currency and regulatory control of the domestic financial system. When a sovereign is a member of a monetary union, and thus cedes monetary and exchange-rate policy to a common central bank, or when it uses the currency of another sovereign, the local-currency rating is, under our criteria, equal to the foreign-currency rating.

Related Criteria

- Sovereign Rating Methodology, Dec. 18, 2017

- Principles of Credit Ratings, Feb. 16, 2011

Annex 589

"Recommendations of the Task Force on Climate-related Financial Disclosures", *Task Force on Climate-Related Financial Disclosures*, 15 June 2017

Final Report

Recommendations of the Task Force on Climate-related Financial Disclosures

TCFD | TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES

June 2017

June 15, 2017

Mr. Mark Carney
Chairman
Financial Stability Board
Bank for International Settlements
Centralbahnplatz 2
CH-4002 Basel
Switzerland

Dear Chairman Carney,

On behalf of the Task Force on Climate-related Financial Disclosures, I am pleased to present this final report setting out our recommendations for helping businesses disclose climate-related financial information.

As you know, warming of the planet caused by greenhouse gas emissions poses serious risks to the global economy and will have an impact across many economic sectors. It is difficult for investors to know which companies are most at risk from climate change, which are best prepared, and which are taking action.

The Task Force's report establishes recommendations for disclosing clear, comparable and consistent information about the risks and opportunities presented by climate change. Their widespread adoption will ensure that the effects of climate change become routinely considered in business and investment decisions. Adoption of these recommendations will also help companies better demonstrate responsibility and foresight in their consideration of climate issues. That will lead to smarter, more efficient allocation of capital, and help smooth the transition to a more sustainable, low-carbon economy.

The industry Task Force spent 18 months consulting with a wide range of business and financial leaders to hone its recommendations and consider how to help companies better communicate key climate-related information. The feedback we received in response to the Task Force's draft report confirmed broad support from industry and others, and involved productive dialogue among companies and banks, insurers, and investors. This was and remains a collaborative process, and as these recommendations are implemented, we hope that this dialogue and feedback continues.

Since the Task Force began its work, we have also seen a significant increase in demand from investors for improved climate-related financial disclosures. This comes amid unprecedented support among companies for action to tackle climate change.

I want to thank the Financial Stability Board for its leadership in promoting better disclosure of climate-related financial risks, and for its support of the Task Force's work. I am also grateful to the Task Force members and Secretariat for their extensive contributions and dedication to this effort.

The risk climate change poses to businesses and financial markets is real and already present. It is more important than ever that businesses lead in understanding and responding to these risks—and seizing the opportunities—to build a stronger, more resilient, and sustainable global economy.

Sincerely,

Michael R. Bloomberg

Executive Summary

Financial Markets and Transparency

One of the essential functions of financial markets is to price risk to support informed, efficient capital-allocation decisions. Accurate and timely disclosure of current and past operating and financial results is fundamental to this function, but it is increasingly important to understand the governance and risk management context in which financial results are achieved. The financial crisis of 2007-2008 was an important reminder of the repercussions that weak corporate governance and risk management practices can have on asset values. This has resulted in increased demand for transparency from organizations on their governance structures, strategies, and risk management practices. Without the right information, investors and others may incorrectly price or value assets, leading to a misallocation of capital.

> Increasing transparency makes markets more efficient and economies more stable and resilient.
> —Michael R. Bloomberg

Financial Implications of Climate Change

One of the most significant, and perhaps most misunderstood, risks that organizations face today relates to climate change. While it is widely recognized that continued emission of greenhouse gases will cause further warming of the planet and this warming could lead to damaging economic and social consequences, the exact timing and severity of physical effects are difficult to estimate. The large-scale and long-term nature of the problem makes it uniquely challenging, especially in the context of economic decision making. Accordingly, many organizations incorrectly perceive the implications of climate change to be long term and, therefore, not necessarily relevant to decisions made today.

The potential impacts of climate change on organizations, however, are not only physical and do not manifest only in the long term. To stem the disastrous effects of climate change within this century, nearly 200 countries agreed in December 2015 to reduce greenhouse gas emissions and accelerate the transition to a lower-carbon economy. The reduction in greenhouse gas emissions implies movement away from fossil fuel energy and related physical assets. This coupled with rapidly declining costs and increased deployment of clean and energy-efficient technologies could have significant, near-term financial implications for organizations dependent on extracting, producing, and using coal, oil, and natural gas. While such organizations may face significant climate-related risks, they are not alone. In fact, climate-related risks and the expected transition to a lower-carbon economy affect most economic sectors and industries. While changes associated with a transition to a lower-carbon economy present significant risk, they also create significant opportunities for organizations focused on climate change mitigation and adaptation solutions.

For many investors, climate change poses significant financial challenges and opportunities, now and in the future. The expected transition to a lower-carbon economy is estimated to require around $1 trillion of investments a year for the foreseeable future, generating new investment opportunities.[1] At the same time, the risk-return profile of organizations exposed to climate-related risks may change significantly as such organizations may be more affected by physical impacts of climate change, climate policy, and new technologies. In fact, a 2015 study estimated the value at risk, as a result of climate change, to the total global stock of manageable assets as

[1] International Energy Agency, *World Energy Outlook Special Briefing for COP21*, 2015.

ranging from $4.2 trillion to $43 trillion between now and the end of the century.[2] The study highlights that "much of the impact on future assets will come through weaker growth and lower asset returns across the board." This suggests investors may not be able to avoid climate-related risks by moving out of certain asset classes as a wide range of asset types could be affected. Both investors and the organizations in which they invest, therefore, should consider their longer-term strategies and most efficient allocation of capital. Organizations that invest in activities that may not be viable in the longer term may be less resilient to the transition to a lower-carbon economy; and their investors will likely experience lower returns. Compounding the effect on longer-term returns is the risk that present valuations do not adequately factor in climate-related risks because of insufficient information. As such, long-term investors need adequate information on how organizations are preparing for a lower-carbon economy.

Furthermore, because the transition to a lower-carbon economy requires significant and, in some cases, disruptive changes across economic sectors and industries in the near term, financial policymakers are interested in the implications for the global financial system, especially in terms of avoiding financial dislocations and sudden losses in asset values. Given such concerns and the potential impact on financial intermediaries and investors, the G20 Finance Ministers and Central Bank Governors asked the Financial Stability Board to review how the financial sector can take account of climate-related issues. As part of its review, the Financial Stability Board identified the need for better information to support informed investment, lending, and insurance underwriting decisions and improve understanding and analysis of climate-related risks and opportunities. Better information will also help investors engage with companies on the resilience of their strategies and capital spending, which should help promote a smooth rather than an abrupt transition to a lower-carbon economy.

Task Force on Climate-related Financial Disclosures

To help identify the information needed by investors, lenders, and insurance underwriters to appropriately assess and price climate-related risks and opportunities, the Financial Stability Board established an industry-led task force: the Task Force on Climate-related Financial Disclosures (Task Force). The Task Force was asked to develop voluntary, consistent climate-related financial disclosures that would be useful to investors, lenders, and insurance underwriters in understanding material risks. The 32-member Task Force is global; its members were selected by the Financial Stability Board and come from various organizations, including large banks, insurance companies, asset managers, pension funds, large non-financial companies, accounting and consulting firms, and credit rating agencies. In its work, the Task Force drew on member expertise, stakeholder engagement, and existing climate-related disclosure regimes to develop a singular, accessible framework for climate-related financial disclosure.

The Task Force developed four widely adoptable recommendations on climate-related financial disclosures that are applicable to organizations across sectors and jurisdictions (Figure 1). Importantly, the Task Force's recommendations apply to financial-sector organizations, including banks, insurance companies, asset managers, and asset owners. Large asset owners and asset managers sit at the top of the investment chain and, therefore, have an

Figure 1

Key Features of Recommendations

- Adoptable by all organizations
- Included in financial filings
- Designed to solicit decision-useful, forward-looking information on financial impacts
- Strong focus on risks and opportunities related to transition to lower-carbon economy

[2] The Economist Intelligence Unit, "The Cost of Inaction: Recognising the Value at Risk from Climate Change," 2015. Value at risk measures the loss a portfolio may experience, within a given time horizon, at a particular probability, and the stock of manageable assets is defined as the total stock of assets held by non-bank financial institutions. Bank assets were excluded as they are largely managed by banks themselves.

important role to play in influencing the organizations in which they invest to provide better climate-related financial disclosures.

In developing and finalizing its recommendations, the Task Force solicited input throughout the process.[3] First, in April 2016, the Task Force sought public comment on the scope and high-level objectives of its work. As the Task Force developed its disclosure recommendations, it continued to solicit feedback through hundreds of industry interviews, meetings, and other touchpoints. Then, in December 2016, the Task Force issued its draft recommendations and sought public comment on the recommendations as well as certain key issues, receiving over 300 responses. This final report reflects the Task Force's consideration of industry and other public feedback received throughout 2016 and 2017. Section E contains a summary of key issues raised by the industry as well as substantive changes to the report since December.

Disclosure in Mainstream Financial Filings

The Task Force recommends that preparers of climate-related financial disclosures provide such disclosures in their mainstream (i.e., public) annual financial filings. In most G20 jurisdictions, companies with public debt or equity have a legal obligation to disclose material information in their financial filings—including material climate-related information. The Task Force believes climate-related issues are or could be material for many organizations, and its recommendations should be useful to organizations in complying more effectively with existing disclosure obligations.[4] In addition, disclosure in mainstream financial filings should foster shareholder engagement and broader use of climate-related financial disclosures, thus promoting a more informed understanding of climate-related risks and opportunities by investors and others. The Task Force also believes that publication of climate-related financial information in mainstream annual financial filings will help ensure that appropriate controls govern the production and disclosure of the required information. More specifically, the Task Force expects the governance processes for these disclosures would be similar to those used for existing public financial disclosures and would likely involve review by the chief financial officer and audit committee, as appropriate.

Importantly, organizations should make financial disclosures in accordance with their national disclosure requirements. If certain elements of the recommendations are incompatible with national disclosure requirements for financial filings, the Task Force encourages organizations to disclose those elements in other official company reports that are issued at least annually, widely distributed and available to investors and others, and subject to internal governance processes that are the same or substantially similar to those used for financial reporting.

Core Elements of Climate-Related Financial Disclosures

The Task Force structured its recommendations around four thematic areas that represent core elements of how organizations operate: governance, strategy, risk management, and metrics and targets (Figure 2, p. v). The four overarching recommendations are supported by recommended disclosures that build out the framework with information that will help investors and others understand how reporting organizations assess climate-related risks and opportunities.[5] In addition, there is guidance to support all organizations in developing climate-related financial disclosures consistent with the recommendations and recommended disclosures. The guidance assists preparers by providing context and suggestions for implementing the recommended disclosures. For the financial sector and certain non-financial sectors, *supplemental* guidance was developed to highlight important sector-specific considerations and provide a fuller picture of potential climate-related financial impacts in those sectors.

[3] See Appendix 2: Task Force Objectives and Approach for more information.

[4] The Task Force encourages organizations where climate-related issues could be material in the future to begin disclosing climate-related financial information outside financial filings to facilitate the incorporation of such information into financial filings once climate-related issues are determined to be material.

[5] See Figure 4 on p. 14 for the Task Force's recommendations and recommended disclosures.

Figure 2

Core Elements of Recommended Climate-Related Financial Disclosures

Governance
The organization's governance around climate-related risks and opportunities

Strategy
The actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning

Risk Management
The processes used by the organization to identify, assess, and manage climate-related risks

Metrics and Targets
The metrics and targets used to assess and manage relevant climate-related risks and opportunities

Climate-Related Scenarios

One of the Task Force's key recommended disclosures focuses on the resilience of an organization's strategy, taking into consideration different climate-related scenarios, including a 2° Celsius or lower scenario.[6] An organization's disclosure of how its strategies might change to address potential climate-related risks and opportunities is a key step to better understanding the potential implications of climate change on the organization. The Task Force recognizes the use of scenarios in assessing climate-related issues and their potential financial implications is relatively recent and practices will evolve over time, but believes such analysis is important for improving the disclosure of decision-useful, climate-related financial information.

Conclusion

Recognizing that climate-related financial reporting is still evolving, the Task Force's recommendations provide a foundation to improve investors' and others' ability to appropriately assess and price climate-related risk and opportunities. The Task Force's recommendations aim to be ambitious, but also practical for near-term adoption. The Task Force expects to advance the quality of mainstream financial disclosures related to the potential effects of climate change on organizations today and in the future and to increase investor engagement with boards and senior management on climate-related issues.

Improving the quality of climate-related financial disclosures begins with organizations' willingness to adopt the Task Force's recommendations. Organizations already reporting climate-related information under other frameworks may be able to disclose under this framework immediately and are strongly encouraged to do so. Those organizations in early stages of evaluating the impact of climate change on their businesses and strategies can begin by disclosing climate-related issues as they relate to governance, strategy, and risk management practices. The Task Force recognizes the challenges associated with measuring the impact of climate change, but believes that by moving climate-related issues into mainstream annual financial filings, practices and techniques will evolve more rapidly. Improved practices and techniques, including data analytics, should further improve the quality of climate-related financial disclosures and, ultimately, support more appropriate pricing of risks and allocation of capital in the global economy.

[6] A 2° Celsius (2°C) scenario lays out an energy system deployment pathway and an emissions trajectory consistent with limiting the global average temperature increase to 2°C above the pre-industrial average. The Task Force is not recommending organizations use a specific 2°C scenario.

Contents

A Introduction

A Introduction

1. Background

It is widely recognized that continued emission of greenhouse gases will cause further warming of the Earth and that warming above 2° Celsius (2°C), relative to the pre-industrial period, could lead to catastrophic economic and social consequences.[7] As evidence of the growing recognition of the risks posed by climate change, in December 2015, nearly 200 governments agreed to strengthen the global response to the threat of climate change by "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels," referred to as the Paris Agreement.[8] The large-scale and long-term nature of the problem makes it uniquely challenging, especially in the context of economic decision making. Moreover, the current understanding of the potential financial risks posed by climate change—to companies, investors, and the financial system as a whole—is still at an early stage.

There is a growing demand for decision-useful, climate-related information by a range of participants in the financial markets.[9] Creditors and investors are increasingly demanding access to risk information that is consistent, comparable, reliable, and clear. There has also been increased focus, especially since the financial crisis of 2007-2008, on the negative impact that weak corporate governance can have on shareholder value, resulting in increased demand for transparency from organizations on their risks and risk management practices, including those related to climate change.

The growing demand for decision-useful, climate-related information has resulted in the development of several climate-related disclosure standards. Many of the existing standards, however, focus on disclosure of climate-related information, such as greenhouse gas (GHG) emissions and other sustainability metrics. Users of such climate-related disclosures commonly cite the lack of information on the financial implications around the climate-related aspects of an organization's business as a key gap. Users also cite inconsistencies in disclosure practices, a lack of context for information, use of boilerplate, and non-comparable reporting as major obstacles to incorporating climate-related risks and opportunities (collectively referred to as climate-related issues) as considerations in their investment, lending, and insurance underwriting decisions over the medium and long term.[10] In addition, evidence suggests that the lack of consistent information hinders investors and others from considering climate-related issues in their asset valuation and allocation processes.[11]

In general, inadequate information about risks can lead to a mispricing of assets and misallocation of capital and can potentially give rise to concerns about financial stability since markets can be vulnerable to abrupt corrections.[12] Recognizing these concerns, the G20 (Group of 20) Finance Ministers and Central Bank Governors requested that the Financial Stability Board (FSB) "convene public- and private-sector participants to review how the financial sector can take account of climate-related issues."[13] In response to the G20's request, the FSB held a meeting of public- and private-sector representatives in September 2015 to consider the implications of climate-related issues for the financial sector. "Participants exchanged views on the existing work of the financial sector, authorities, and standard setters in this area and the challenges they face,

[7] Intergovernmental Panel on Climate Change, *Fifth Assessment Report,* Cambridge University Press, 2014.
[8] United Nations Framework Convention on Climate Change, "The Paris Agreement," December 2015.
[9] Avery Fellow, "Investors Demand Climate Risk Disclosure," Bloomberg, February 2013.
[10] Sustainability Accounting Standards Board (SASB), *SASB Climate Risk Technical Bulletin#: TB001-10182016*, October 2016.
[11] Mercer LLC, *Investing in a Time of Climate Change,* 2015.
[12] Mark Carney, "Breaking the tragedy of the horizon—climate change and financial stability," September 29, 2015.
[13] "Communiqué from the G20 Finance Ministers and Central Bank Governors Meeting in Washington, D.C. April 16-17, 2015," April 2015.

areas for possible further work, and the possible roles the FSB and others could play in taking that work forward. The discussions continually returned to a common theme: the need for better information."[14]

In most G20 jurisdictions, companies with public debt or equity have a legal obligation to disclose material risks in their financial reports—including material climate-related risks. However, the absence of a standardized framework for disclosing climate-related financial risks makes it difficult for organizations to determine what information should be included in their filings and how it should be presented. Even when reporting similar climate-related information, disclosures are often difficult to compare due to variances in mandatory and voluntary frameworks. The resulting fragmentation in reporting practices and lack of focus on financial impacts have prevented investors, lenders, insurance underwriters, and other users of disclosures from accessing complete information that can inform their economic decisions. Furthermore, because financial-sector organizations' disclosures depend, in part, on those from the companies in which they invest or lend, regulators face challenges in using financial-sector organizations' existing disclosures to determine system-wide exposures to climate-related risks.

In response, the FSB established the industry-led Task Force on Climate-related Financial Disclosures (TCFD or Task Force) in December 2015 to design a set of recommendations for consistent "disclosures that will help financial market participants understand their climate-related risks."[15] See Box 1 (p. 3) for more information on the Task Force.

2. The Task Force's Remit

The FSB called on the Task Force to develop climate-related disclosures that "could promote more informed investment, credit [or lending], and insurance underwriting decisions" and, in turn, "would enable stakeholders to understand better the concentrations of carbon-related assets in the financial sector and the financial system's exposures to climate-related risks."[16,17] The FSB noted that disclosures by the financial sector in particular would "foster an early assessment of these risks" and "facilitate market discipline." Such disclosures would also "provide a source of data that can be analyzed at a systemic level, to facilitate authorities' assessments of the materiality of any risks posed by climate change to the financial sector, and the channels through which this is most likely to be transmitted."[18]

The FSB also emphasized that "any disclosure recommendations by the Task Force would be voluntary, would need to incorporate the principle of materiality and would need to weigh the balance of costs and benefits."[19] As a result, in devising a principle-based framework for voluntary disclosure, the Task Force sought to balance the needs of the users of disclosures with the challenges faced by the preparers. The FSB further stated that the Task Force's climate-related financial disclosure recommendations should not "add to the already well developed body of existing disclosure schemes."[20] In response, the Task Force drew from existing disclosure frameworks where possible and appropriate.

The FSB also noted the Task Force should determine whether the target audience of users of climate-related financial disclosures should extend beyond investors, lenders, and insurance underwriters. Investors, lenders, and insurance underwriters ("primary users") are the appropriate target audience. These primary users assume the financial risk and reward of the

[14] FSB, "FSB to establish Task Force on Climate-related Financial Disclosures," December 4, 2015.
[15] Ibid.
[16] FSB, "Proposal for a Disclosure Task Force on Climate-Related Risks," November 9, 2015.
[17] The term carbon-related assets is not well defined, but is generally considered to refer to assets or organizations with relatively high direct or indirect GHG emissions. The Task Force believes further work is needed on defining carbon-related assets and potential financial impacts.
[18] FSB, "Proposal for a Disclosure Task Force on Climate-Related Risks," November 9, 2015.
[19] Ibid.
[20] Ibid.

decisions they make. The Task Force recognizes that many other organizations, including credit rating agencies, equity analysts, stock exchanges, investment consultants, and proxy advisors also use climate-related financial disclosures, allowing them to push information through the credit and investment chain and contribute to the better pricing of risks by investors, lenders, and insurance underwriters. These organizations, in principle, depend on the same types of information as primary users.

This report presents the Task Force's recommendations for climate-related financial disclosures and includes supporting information on climate-related risks and opportunities, scenario analysis, and industry feedback that the Task Force considered in developing and then finalizing its recommendations. In addition, the Task Force developed a "stand-alone" document—Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures (Annex)—for organizations to use when preparing disclosures consistent with the recommendations. The Annex provides supplemental guidance for the financial sector as well as for non-financial groups potentially most affected by climate change and the transition to a lower-carbon economy. The supplemental guidance assists preparers by providing additional context and suggestions for implementing the recommended disclosures.

The Task Force's recommendations provide a foundation for climate-related financial disclosures and aim to be ambitious, but also practical for near-term adoption. The Task Force expects that reporting of climate-related risks and opportunities will evolve over time as organizations, investors, and others contribute to the quality and consistency of the information disclosed.

Box 1

Task Force on Climate-related Financial Disclosures

The Task Force membership, first announced on January 21, 2016, has international representation and spans various types of organizations, including banks, insurance companies, asset managers, pension funds, large non-financial companies, accounting and consulting firms, and credit rating agencies—a unique collaborative partnership between the users and preparers of financial reports.

In its work, the Task Force drew on its members' expertise, stakeholder engagement, and existing climate-related disclosure regimes to develop a singular, accessible framework for climate-related financial disclosure. See Appendix 1 for a list of the Task Force members and Appendix 2 for more information on the Task Force's approach.

The Task Force is comprised of 32 global members representing a broad range of economic sectors and financial markets and a careful balance of users and preparers of climate-related financial disclosures.

B Climate-Related Risks, Opportunities, and Financial Impacts

B Climate-Related Risks, Opportunities, and Financial Impacts

Through its work, the Task Force identified a growing demand by investors, lenders, insurance underwriters, and other stakeholders for decision-useful, climate-related financial information. Improved disclosure of climate-related risks and opportunities will provide investors, lenders, insurance underwriters, and other stakeholders with the metrics and information needed to undertake robust and consistent analyses of the potential financial impacts of climate change.

The Task Force found that while several climate-related disclosure frameworks have emerged across different jurisdictions in an effort to meet the growing demand for such information, there is a need for a standardized framework to promote alignment across existing regimes and G20 jurisdictions and to provide a common framework for climate-related financial disclosures. An important element of such a framework is the consistent categorization of climate-related risks and opportunities. As a result, the Task Force defined categories for climate-related risks and climate-related opportunities. The Task Force's recommendations serve to encourage organizations to evaluate and disclose, as part of their annual financial filing preparation and reporting processes, the climate-related risks and opportunities that are most pertinent to their business activities. The main climate-related risks and opportunities that organizations should consider are described below and in Tables 1 and 2 (pp. 10-11).

1. Climate-Related Risks

The Task Force divided climate-related risks into two major categories: (1) risks related to the *transition* to a lower-carbon economy and (2) risks related to the *physical* impacts of climate change.

a. Transition Risks

Transitioning to a lower-carbon economy may entail extensive policy, legal, technology, and market changes to address mitigation and adaptation requirements related to climate change. Depending on the nature, speed, and focus of these changes, transition risks may pose varying levels of financial and reputational risk to organizations.

Policy and Legal Risks

Policy actions around climate change continue to evolve. Their objectives generally fall into two categories—policy actions that attempt to constrain actions that contribute to the adverse effects of climate change or policy actions that seek to promote adaptation to climate change. Some examples include implementing carbon-pricing mechanisms to reduce GHG emissions, shifting energy use toward lower emission sources, adopting energy-efficiency solutions, encouraging greater water efficiency measures, and promoting more sustainable land-use practices. The risk associated with and financial impact of policy changes depend on the nature and timing of the policy change.[21]

Another important risk is litigation or legal risk. Recent years have seen an increase in climate-related litigation claims being brought before the courts by property owners, municipalities, states, insurers, shareholders, and public interest organizations.[22] Reasons for such litigation include the failure of organizations to mitigate impacts of climate change, failure to adapt to climate change, and the insufficiency of disclosure around material financial risks. As the value of loss and damage arising from climate change grows, litigation risk is also likely to increase.

[21] Organizations should assess not only the potential direct effects of policy actions on their operations, but also the potential second and third order effects on their supply and distribution chains.

[22] Peter Seley, "Emerging Trends in Climate Change Litigation," *Law 360,* March 7, 2016.

Technology Risk

Technological improvements or innovations that support the transition to a lower-carbon, energy-efficient economic system can have a significant impact on organizations. For example, the development and use of emerging technologies such as renewable energy, battery storage, energy efficiency, and carbon capture and storage will affect the competitiveness of certain organizations, their production and distribution costs, and ultimately the demand for their products and services from end users. To the extent that new technology displaces old systems and disrupts some parts of the existing economic system, winners and losers will emerge from this "creative destruction" process. The timing of technology development and deployment, however, is a key uncertainty in assessing technology risk.

Market Risk

While the ways in which markets could be affected by climate change are varied and complex, one of the major ways is through shifts in supply and demand for certain commodities, products, and services as climate-related risks and opportunities are increasingly taken into account.

Reputation Risk

Climate change has been identified as a potential source of reputational risk tied to changing customer or community perceptions of an organization's contribution to or detraction from the transition to a lower-carbon economy.

b. Physical Risks

Physical risks resulting from climate change can be event driven (acute) or longer-term shifts (chronic) in climate patterns. Physical risks may have financial implications for organizations, such as direct damage to assets and indirect impacts from supply chain disruption. Organizations' financial performance may also be affected by changes in water availability, sourcing, and quality; food security; and extreme temperature changes affecting organizations' premises, operations, supply chain, transport needs, and employee safety.

Acute Risk

Acute physical risks refer to those that are event-driven, including increased severity of extreme weather events, such as cyclones, hurricanes, or floods.

Chronic Risk

Chronic physical risks refer to longer-term shifts in climate patterns (e.g., sustained higher temperatures) that may cause sea level rise or chronic heat waves.

2. Climate-Related Opportunities

Efforts to mitigate and adapt to climate change also produce opportunities for organizations, for example, through resource efficiency and cost savings, the adoption of low-emission energy sources, the development of new products and services, access to new markets, and building resilience along the supply chain. Climate-related opportunities will vary depending on the region, market, and industry in which an organization operates. The Task Force identified several areas of opportunity as described below.

a. Resource Efficiency

There is growing evidence and examples of organizations that have successfully reduced operating costs by improving efficiency across their production and distribution processes, buildings, machinery/appliances, and transport/mobility—in particular in relation to energy efficiency but also including broader materials, water, and waste management.[23] Such actions can

[23] UNEP and Copenhagen Centre for Energy Efficiency, *Best Practices and Case Studies for Industrial Energy Efficiency Improvement*, February 16, 2016.

result in direct cost savings to organizations' operations over the medium to long term and contribute to the global efforts to curb emissions.[24] Innovation in technology is assisting this transition; such innovation includes developing efficient heating solutions and circular economy solutions, making advances in LED lighting technology and industrial motor technology, retrofitting buildings, employing geothermal power, offering water usage and treatment solutions, and developing electric vehicles.[25]

b. Energy Source

According to the International Energy Agency (IEA), to meet global emission-reduction goals, countries will need to transition a major percentage of their energy generation to low emission alternatives such as wind, solar, wave, tidal, hydro, geothermal, nuclear, biofuels, and carbon capture and storage.[26] For the fifth year in a row, investments in renewable energy capacity have exceeded investments in fossil fuel generation.[27] The trend toward decentralized clean energy sources, rapidly declining costs, improved storage capabilities, and subsequent global adoption of these technologies are significant. Organizations that shift their energy usage toward low emission energy sources could potentially save on annual energy costs.[28]

c. Products and Services

Organizations that innovate and develop new low-emission products and services may improve their competitive position and capitalize on shifting consumer and producer preferences. Some examples include consumer goods and services that place greater emphasis on a product's carbon footprint in its marketing and labeling (e.g., travel, food, beverage and consumer staples, mobility, printing, fashion, and recycling services) and producer goods that place emphasis on reducing emissions (e.g., adoption of energy-efficiency measures along the supply chain).

d. Markets

Organizations that pro-actively seek opportunities in new markets or types of assets may be able to diversify their activities and better position themselves for the transition to a lower-carbon economy. In particular, opportunities exist for organizations to access new markets through collaborating with governments, development banks, small-scale local entrepreneurs, and community groups in developed and developing countries as they work to shift to a lower-carbon economy.[29] New opportunities can also be captured through underwriting or financing green bonds and infrastructure (e.g., low-emission energy production, energy efficiency, grid connectivity, or transport networks).

e. Resilience

The concept of climate resilience involves organizations developing adaptive capacity to respond to climate change to better manage the associated risks and seize opportunities, including the ability to respond to transition risks and physical risks. Opportunities include improving efficiency, designing new production processes, and developing new products. Opportunities related to resilience may be especially relevant for organizations with long-lived fixed assets or extensive supply or distribution networks; those that depend critically on utility and infrastructure networks or natural resources in their value chain; and those that may require longer-term financing and investment.

[24] Environmental Protection Agency Victoria (EPA Victoria), "Resource Efficiency Case Studies: Lower your Impact."

[25] As described by Pearce and Turner, circular economy refers to a system in which resource input and waste, emission, and energy leakage are minimized. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. This is in contrast to a linear economy which is a "take, make, dispose" model of production.

[26] IEA, "Global energy investment down 8% in 2015 with flows signaling move towards cleaner energy," September 14, 2016.

[27] Frankfurt School-United Nations Environmental Programme Centre and Bloomberg New Energy Finance, "Global Trends in Renewable Energy Investment 2017," 2017.

[28] Ceres, "Power Forward 3.0: How the largest US companies are capturing business value while addressing climate change," 2017.

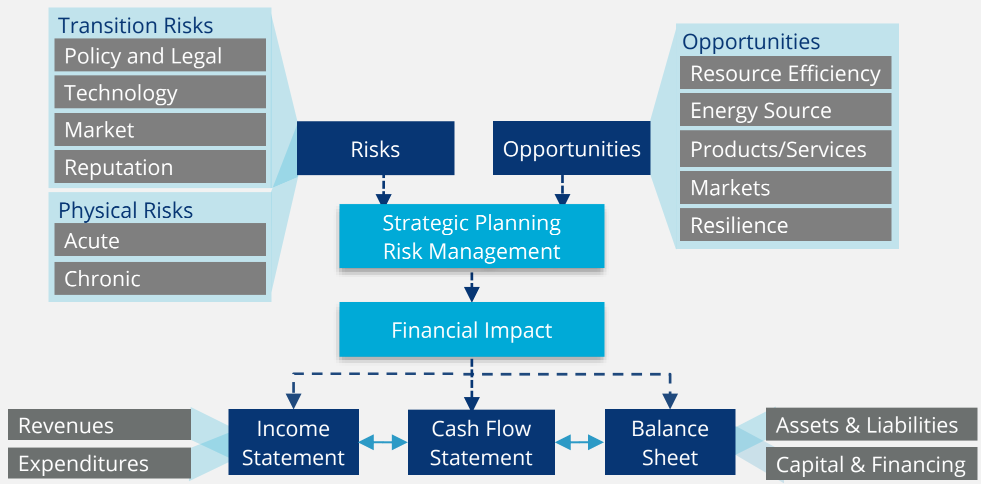
[29] G20 Green Finance Study Group. *G20 Green Finance Synthesis Report*. 2016. The proposal to launch the Green Finance Study Group was adopted by the G20 Finance Ministers and Central Bank Deputies in December 2015.

3. Financial Impacts

Better disclosure of the financial impacts of climate-related risks and opportunities on an organization is a key goal of the Task Force's work. In order to make more informed financial decisions, investors, lenders, and insurance underwriters need to understand how climate-related risks and opportunities are likely to impact an organization's future financial position as reflected in its income statement, cash flow statement, and balance sheet as outlined in Figure 1. While climate change affects nearly all economic sectors, the level and type of exposure and the impact of climate-related risks differs by sector, industry, geography, and organization.[30]

Figure 1

Climate-Related Risks, Opportunities, and Financial Impact



Fundamentally, the financial impacts of climate-related issues on an organization are driven by the specific climate-related risks and opportunities to which the organization is exposed and its strategic and risk management decisions on managing those risks (i.e., mitigate, transfer, accept, or control) and seizing those opportunities. The Task Force has identified four major categories, described in Figure 2 (p. 9), through which climate-related risks and opportunities may affect an organization's current and future financial positions.

The financial impacts of climate-related issues on organizations are not always clear or direct, and, for many organizations, identifying the issues, assessing potential impacts, and ensuring material issues are reflected in financial filings may be challenging. Key reasons for this are likely because of (1) limited knowledge of climate-related issues within organizations; (2) the tendency to focus mainly on near-term risks without paying adequate attention to risks that may arise in the longer term; and (3) the difficulty in quantifying the financial effects of climate-related issues.[31] To assist organizations in identifying climate-related issues and their impacts, the Task Force developed Table 1 (p. 10), which provides examples of climate-related risks and their potential financial impacts, and Table 2 (p. 11), which provides examples of climate-related opportunities and their potential financial impacts. In addition, Section A.4 in the Annex provides more information on the major categories of financial impacts—revenues, expenditures, assets and liabilities, and capital and financing—that are likely to be most relevant for specific industries.

[30] SASB research demonstrates that 72 out of 79 Sustainable Industry Classification System (SICS™) industries are significantly affected in some way by climate-related risk.

[31] World Business Council for Sustainable Development, "Sustainability and enterprise risk management: The first step towards integration." January 18, 2017.

Figure 2

Major Categories of Financial Impact

Income Statement	Balance Sheet
Revenues. Transition and physical risks may affect demand for products and services. Organizations should consider the potential impact on revenues and identify potential opportunities for enhancing or developing new revenues. In particular, given the emergence and likely growth of carbon pricing as a mechanism to regulate emissions, it is important for affected industries to consider the potential impacts of such pricing on business revenues. **Expenditures.** An organization's response to climate-related risks and opportunities may depend, in part, on the organization's cost structure. Lower-cost suppliers may be more resilient to changes in cost resulting from climate-related issues and more flexible in their ability to address such issues. By providing an indication of their cost structure and flexibility to adapt, organizations can better inform investors about their investment potential. It is also helpful for investors to understand capital expenditure plans and the level of debt or equity needed to fund these plans. The resilience of such plans should be considered bearing in mind organizations' flexibility to shift capital and the willingness of capital markets to fund organizations exposed to significant levels of climate-related risks. Transparency of these plans may provide greater access to capital markets or improved financing terms.	**Assets and Liabilities.** Supply and demand changes from changes in policies, technology, and market dynamics related to climate change could affect the valuation of organizations' assets and liabilities. Use of long-lived assets and, where relevant, reserves may be particularly affected by climate-related issues. It is important for organizations to provide an indication of the potential climate-related impact on their assets and liabilities, particularly long-lived assets. This should focus on existing and committed future activities and decisions requiring new investment, restructuring, write-downs, or impairment. **Capital and Financing.** Climate-related risks and opportunities may change the profile of an organization's debt and equity structure, either by increasing debt levels to compensate for reduced operating cash flows or for new capital expenditures or R&D. It may also affect the ability to raise new debt or refinance existing debt, or reduce the tenor of borrowing available to the organization. There could also be changes to capital and reserves from operating losses, asset write-downs, or the need to raise new equity to meet investment.

The Task Force encourages organizations to undertake both historical and forward-looking analyses when considering the potential financial impacts of climate change, with greater focus on forward-looking analyses as the efforts to mitigate and adapt to climate change are without historical precedent. This is one of the reasons the Task Force believes scenario analysis is important for organizations to consider incorporating into their strategic planning or risk management practices.

Table 1

Examples of Climate-Related Risks and Potential Financial Impacts

Type	Climate-Related Risks[32]	Potential Financial Impacts
Transition Risks	**Policy and Legal**	
	– Increased pricing of GHG emissions – Enhanced emissions-reporting obligations – Mandates on and regulation of existing products and services – Exposure to litigation	– Increased operating costs (e.g., higher compliance costs, increased insurance premiums) – Write-offs, asset impairment, and early retirement of existing assets due to policy changes – Increased costs and/or reduced demand for products and services resulting from fines and judgments
	Technology	
	– Substitution of existing products and services with lower emissions options – Unsuccessful investment in new technologies – Costs to transition to lower emissions technology	– Write-offs and early retirement of existing assets – Reduced demand for products and services – Research and development (R&D) expenditures in new and alternative technologies – Capital investments in technology development – Costs to adopt/deploy new practices and processes
	Market	
	– Changing customer behavior – Uncertainty in market signals – Increased cost of raw materials	– Reduced demand for goods and services due to shift in consumer preferences – Increased production costs due to changing input prices (e.g., energy, water) and output requirements (e.g., waste treatment) – Abrupt and unexpected shifts in energy costs – Change in revenue mix and sources, resulting in decreased revenues – Re-pricing of assets (e.g., fossil fuel reserves, land valuations, securities valuations)
	Reputation	
	– Shifts in consumer preferences – Stigmatization of sector – Increased stakeholder concern or negative stakeholder feedback	– Reduced revenue from decreased demand for goods/services – Reduced revenue from decreased production capacity (e.g., delayed planning approvals, supply chain interruptions) – Reduced revenue from negative impacts on workforce management and planning (e.g., employee attraction and retention) – Reduction in capital availability
Physical Risks	**Acute** – Increased severity of extreme weather events such as cyclones and floods **Chronic** – Changes in precipitation patterns and extreme variability in weather patterns – Rising mean temperatures – Rising sea levels	– Reduced revenue from decreased production capacity (e.g., transport difficulties, supply chain interruptions) – Reduced revenue and higher costs from negative impacts on workforce (e.g., health, safety, absenteeism) – Write-offs and early retirement of existing assets (e.g., damage to property and assets in "high-risk" locations) – Increased operating costs (e.g., inadequate water supply for hydroelectric plants or to cool nuclear and fossil fuel plants) – Increased capital costs (e.g., damage to facilities) – Reduced revenues from lower sales/output – Increased insurance premiums and potential for reduced availability of insurance on assets in "high-risk" locations

[32] The sub-category risks described under each major category are not mutually exclusive, and some overlap exists.

Table 2

Examples of Climate-Related Opportunities and Potential Financial Impacts

Type	Climate-Related Opportunities[33]	Potential Financial Impacts
Resource Efficiency	– Use of more efficient modes of transport – Use of more efficient production and distribution processes – Use of recycling – Move to more efficient buildings – Reduced water usage and consumption	– Reduced operating costs (e.g., through efficiency gains and cost reductions) – Increased production capacity, resulting in increased revenues – Increased value of fixed assets (e.g., highly rated energy-efficient buildings) – Benefits to workforce management and planning (e.g., improved health and safety, employee satisfaction) resulting in lower costs
Energy Source	– Use of lower-emission sources of energy – Use of supportive policy incentives – Use of new technologies – Participation in carbon market – Shift toward decentralized energy generation	– Reduced operational costs (e.g., through use of lowest cost abatement) – Reduced exposure to future fossil fuel price increases – Reduced exposure to GHG emissions and therefore less sensitivity to changes in cost of carbon – Returns on investment in low-emission technology – Increased capital availability (e.g., as more investors favor lower-emissions producers) – Reputational benefits resulting in increased demand for goods/services
Products and Services	– Development and/or expansion of low emission goods and services – Development of climate adaptation and insurance risk solutions – Development of new products or services through R&D and innovation – Ability to diversify business activities – Shift in consumer preferences	– Increased revenue through demand for lower emissions products and services – Increased revenue through new solutions to adaptation needs (e.g., insurance risk transfer products and services) – Better competitive position to reflect shifting consumer preferences, resulting in increased revenues
Markets	– Access to new markets – Use of public-sector incentives – Access to new assets and locations needing insurance coverage	– Increased revenues through access to new and emerging markets (e.g., partnerships with governments, development banks) – Increased diversification of financial assets (e.g., green bonds and infrastructure)
Resilience	– Participation in renewable energy programs and adoption of energy-efficiency measures – Resource substitutes/diversification	– Increased market valuation through resilience planning (e.g., infrastructure, land, buildings) – Increased reliability of supply chain and ability to operate under various conditions – Increased revenue through new products and services related to ensuring resiliency

[33] The opportunity categories are not mutually exclusive, and some overlap exists.

C Recommendations and Guidance

C Recommendations and Guidance

1. Overview of Recommendations and Guidance

To fulfill its remit, the Task Force developed four widely adoptable recommendations on climate-related financial disclosures applicable to organizations across sectors and jurisdictions. In developing its recommendations, the Task Force considered the challenges for preparers of disclosures as well as the benefits of such disclosures to investors, lenders, and insurance underwriters. To achieve this balance, the Task Force engaged in significant outreach and consultation with users and preparers of disclosures and drew upon existing climate-related disclosure regimes. The insights gained from the outreach and consultations directly informed the development of the recommendations.

The Task Force structured its recommendations around four thematic areas that represent core elements of how organizations operate—governance, strategy, risk management, and metrics and targets. The four overarching recommendations are supported by key climate-related financial disclosures—referred to as recommended disclosures—that build out the framework with information that will help investors and others understand how reporting organizations think about and assess climate-related risks and opportunities. In addition, there is guidance to support all organizations in developing climate-related financial disclosures consistent with the recommendations and recommended disclosures as well as *supplemental* guidance for specific sectors. The structure is depicted in Figure 3 below, and the Task Force's recommendations and supporting recommended disclosures are presented in Figure 4 (p. 14).

Figure 3

Recommendations and Guidance

Recommendations
Four widely adoptable recommendations tied to: governance, strategy, risk management, and metrics and targets

Recommended Disclosures
Specific recommended disclosures organizations should include in their financial filings to provide decision-useful information

Guidance for All Sectors
Guidance providing context and suggestions for implementing the recommended disclosures for all organizations

Supplemental Guidance for Certain Sectors
Guidance that highlights important considerations for certain sectors and provides a fuller picture of potential climate-related financial impacts in those sectors

Supplemental guidance is provided for the financial sector and for non-financial sectors potentially most affected by climate change

The Task Force's supplemental guidance is included in the Annex and covers the financial sector as well as non-financial industries potentially most affected by climate change and the transition to a lower-carbon economy (referred to as non-financial groups). The supplemental guidance provides these preparers with additional context and suggestions for implementing the recommended disclosures and should be used in conjunction with the guidance for all sectors.

Figure 4

Recommendations and Supporting Recommended Disclosures

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.	Disclose how the organization identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.
Recommended Disclosures	**Recommended Disclosures**	**Recommended Disclosures**	**Recommended Disclosures**
a) Describe the board's oversight of climate-related risks and opportunities.	a) Describe the climate-related risks and opportunities the organization has identified over the short, medium, and long term.	a) Describe the organization's processes for identifying and assessing climate-related risks.	a) Disclose the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process.
b) Describe management's role in assessing and managing climate-related risks and opportunities.	b) Describe the impact of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning.	b) Describe the organization's processes for managing climate-related risks.	b) Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks.
	c) Describe the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.	c) Describe how processes for identifying, assessing, and managing climate-related risks are integrated into the organization's overall risk management.	c) Describe the targets used by the organization to manage climate-related risks and opportunities and performance against targets.

Figure 5 provides a mapping of the recommendations (governance, strategy, risk management, and metrics and targets) and recommended disclosures (a, b, c) for which supplemental guidance was developed for the financial sector and non-financial groups.

- **Financial Sector.** The Task Force developed supplemental guidance for the financial sector, which it organized into four major industries largely based on activities performed. The four industries are banks (lending), insurance companies (underwriting), asset managers (asset management), and asset owners, which include public- and private-sector pension plans, endowments, and foundations (investing).[34] The Task Force believes that disclosures by the financial sector could foster an early assessment of climate-related risks and opportunities, improve pricing of climate-related risks, and lead to more informed capital allocation decisions.

- **Non-Financial Groups.** The Task Force developed supplemental guidance for non-financial industries that account for the largest proportion of GHG emissions, energy usage, and water usage. These industries were organized into four groups (i.e., non-financial groups)—Energy; Materials and Buildings; Transportation; and Agriculture, Food, and Forest Products—based on similarities in climate-related risks as shown in Box 2 (p. 16). While this supplemental guidance focuses on a subset of non-financial industries, organizations in other industries with similar business activities may wish to review and consider the issues and topics contained in the supplemental guidance.

Figure 5

Supplemental Guidance for Financial Sector and Non-Financial Groups

		Governance		Strategy			Risk Management			Metrics and Targets		
	Industries and Groups	a)	b)	a)	b)	c)	a)	b)	c)	a)	b)	c)
Financial	Banks			■			■			■		
	Insurance Companies				■	■	■	■		■		
	Asset Owners				■	■	■	■		■	■	
	Asset Managers				■		■	■		■	■	
Non-Financial	Energy				■	■				■		
	Transportation				■	■				■		
	Materials and Buildings				■	■				■		
	Agriculture, Food, and Forest Products				■	■				■		

[34] The use of the term "insurance companies" in this report includes re-insurers.

Box 2

Determination of Non-Financial Groups

In an effort to focus supplemental guidance on those non-financial sectors and industries with the highest likelihood of climate-related financial impacts, the Task Force assessed three factors most likely to be affected by both transition risk (policy and legal, technology, market, and reputation) and physical risk (acute and chronic)—GHG emissions, energy usage, and water usage.

The underlying premise in using these three factors is that climate-related physical and transition risks will likely manifest themselves primarily and broadly in the form of constraints on GHG emissions, effects on energy production and usage, and effects on water availability, usage, and quality. Other factors, such as waste management and land use, are also important, but may not be as determinative across a wide range of industries or may be captured in one of the primary categories.

In taking this approach, the Task Force consulted a number of sources regarding the ranking of various sectors and industries according to these three factors. The various rankings were used to determine an overall set of sectors and industries that have significant exposure to transition or physical risks related to GHG emissions, energy, or water. The sectors and industries were grouped into four categories of industries that have similar economic activities and climate-related exposures.

These four groups and their associated industries are intended to be indicative of the economic activities associated with these industries rather than definitive industry categories. Other industries with similar activities and climate-related exposures should consider the supplemental guidance as well.

The Task Force validated its approach using a variety of sources, including:

1. The TCFD Phase I report public consultation, soliciting more than 200 responses which ranked Energy, Utilities, Materials, Industrials and Consumer Staples/Discretionary, in that order, as the Global Industry Classification Standard (GICS) sectors most important for disclosure guidelines to cover.

2. Numerous sector-specific disclosure guidance documents to understand various breakdowns by economic activity, sector, and industries, including from the following sources: CDP, GHG Protocol, Global Real Estate Sustainability Benchmark (GRESB), Global Reporting Initiative (GRI), Institutional Investors Group on Climate Change (IIGCC), IPIECA (the global oil and gas industry association for environmental and social issues), and the Sustainability Accounting Standards Board (SASB).

3. The Intergovernmental Panel on Climate Change (IPCC) report "Climate Change 2014 – Mitigation of Climate Change" that provides an analysis of global direct and indirect emissions by economic sector. The IPCC analysis highlights the dominant emissions-producing sectors as Energy; Industry; Agriculture, Forestry, and Other Land Use; and Transportation and Buildings (Commercial and Residential).

4. Research and documentation from non-governmental organizations (NGOs) and industry organizations that provide information on which industries have the highest exposures to climate change, including those from Cambridge Institute of Sustainability Leadership, China's National Development and Reform Commission (NDRC), Environmental Resources Management (ERM), IEA, Moody's, S&P Global Ratings, and WRI/UNEPFI.

Based on its assessment, the Task Force identified the four groups and their associated industries, listed in the table below, as those that would most benefit from supplemental guidance.

Energy	Transportation	Materials and Buildings	Agriculture, Food, and Forest Products
– Oil and Gas – Coal – Electric Utilities	– Air Freight – Passenger Air Transportation – Maritime Transportation – Rail Transportation – Trucking Services – Automobiles and Components	– Metals and Mining – Chemicals – Construction Materials – Capital Goods – Real Estate Management and Development	– Beverages – Agriculture – Packaged Foods and Meats – Paper and Forest Products

2. Implementing the Recommendations

a. Scope of Coverage

To promote more informed investing, lending, and insurance underwriting decisions, the Task Force recommends all organizations with public debt or equity implement its recommendations. Because climate-related issues are relevant for other types of organizations as well, the Task Force encourages all organizations to implement these recommendations. In particular, the Task Force believes that asset managers and asset owners, including public- and private-sector pension plans, endowments, and foundations, should implement its recommendations so that their clients and beneficiaries may better understand the performance of their assets, consider the risks of their investments, and make more informed investment choices.

b. Location of Disclosures and Materiality

The Task Force recommends that organizations provide climate-related financial disclosures in their mainstream (i.e., public) annual financial filings.[35] In most G20 jurisdictions, public companies have a legal obligation to disclose material information in their financial filings—including material climate-related information; and the Task Force's recommendations are intended to help organizations meet existing disclosure obligations more effectively.[36] The Task Force's recommendations were developed to apply broadly across sectors and jurisdictions and should not be seen as superseding national disclosure requirements. Importantly, organizations should make financial disclosures in accordance with their national disclosure requirements. If certain elements of the recommendations are incompatible with national disclosure requirements for financial filings, the Task Force encourages organizations to disclose those elements in other official company reports that are issued at least annually, widely distributed and available to investors and others, and subject to internal governance processes that are the same or substantially similar to those used for financial reporting.

The Task Force recognizes that most information included in financial filings is subject to a materiality assessment. However, because climate-related risk is a non-diversifiable risk that affects nearly all industries, many investors believe it requires special attention. For example, in assessing organizations' financial and operating results, many investors want insight into the governance and risk management context in which such results are achieved. The Task Force believes disclosures related to its Governance and Risk Management recommendations directly address this need for context and should be included in annual financial filings.

For disclosures related to the Strategy and Metrics and Targets recommendations, the Task Force believes organizations should provide such information in annual financial filings when the information is deemed material. Certain organizations—those in the four non-financial groups that have more than one billion U.S. dollar equivalent (USDE) in annual revenue—should consider disclosing such information in other reports when the information is not deemed material and not included in financial filings.[37] Because these organizations are more likely than others to be financially impacted over time, investors are interested in monitoring how these organizations' strategies evolve.

[35] Financial filings refer to the annual reporting packages in which organizations are required to deliver their audited financial results under the corporate, compliance, or securities laws of the jurisdictions in which they operate. While reporting requirements differ internationally, financial filings generally contain financial statements and other information such as governance statements and management commentary.

[36] The Task Force encourages organizations where climate-related issues could be material in the future to begin disclosing climate-related financial information outside financial filings to facilitate the incorporation of such information into financial filings once climate-related issues are determined to be material.

[37] The Task Force chose a one billion USDE annual revenue threshold because it captures organizations responsible for over 90 percent of Scope 1 and 2 GHG emissions in the industries represented by the four non-financial groups (about 2,250 organizations out of roughly 15,000).

The Task Force recognizes reporting by asset managers and asset owners is intended to satisfy the needs of clients, beneficiaries, regulators, and oversight bodies and follows a format that is generally different from corporate financial reporting. For purposes of adopting the Task Force's recommendations, asset managers and asset owners should use their existing means of financial reporting to their clients and beneficiaries where relevant and where feasible. Likewise, asset managers and asset owners should consider materiality in the context of their respective mandates and investment performance for clients and beneficiaries.[38]

The Task Force believes that climate-related financial disclosures should be subject to appropriate internal governance processes. Since these disclosures should be included in annual financial filings, the governance processes should be similar to those used for existing financial reporting and would likely involve review by the chief financial officer and audit committee, as appropriate. The Task Force recognizes that some organizations may provide some or all of their climate-related financial disclosures in reports other than financial filings. This may occur because the organizations are not required to issue public financial reports (e.g., some asset managers and asset owners). In such situations, organizations should follow internal governance processes that are the same or substantially similar to those used for financial reporting.

c. Principles for Effective Disclosures

To underpin its recommendations and help guide current and future developments in climate-related financial reporting, the Task Force developed seven principles for effective disclosure (Figure 6), which are described more fully in Appendix 3. When used by organizations in preparing their climate-related financial disclosures, these principles can help achieve high-quality and decision-useful disclosures that enable users to understand the impact of climate change on organizations. The Task Force encourages organizations to consider these principles as they develop climate-related financial disclosures.

Figure 6

Principles for Effective Disclosures

1 Disclosures should represent relevant information

2 Disclosures should be specific and complete

3 Disclosures should be clear, balanced, and understandable

4 Disclosures should be consistent over time

5 Disclosures should be comparable among companies within a sector, industry, or portfolio

6 Disclosures should be reliable, verifiable, and objective

7 Disclosures should be provided on a timely basis

The Task Force's disclosure principles are largely consistent with internationally accepted frameworks for financial reporting and are generally applicable to most providers of financial disclosures. The principles are designed to assist organizations in making clear the linkages between climate-related issues and their governance, strategy, risk management, and metrics and targets.

[38] The Task Force recommends asset managers and asset owners include carbon footprinting information in their reporting to clients and beneficiaries, as described in Section D of the Annex, to support the assessment and management of climate-related risks.

3. Guidance for All Sectors

The Task Force has developed guidance to support all organizations in developing climate-related financial disclosures consistent with its recommendations and recommended disclosures. The guidance assists preparers by providing context and suggestions for implementing the recommended disclosures. Recognizing organizations have differing levels of capacity to disclose under the recommendations, the guidance provides descriptions of the types of information that should be disclosed or considered.

a. Governance

Investors, lenders, insurance underwriters, and other users of climate-related financial disclosures (collectively referred to as "investors and other stakeholders") are interested in understanding the role an organization's board plays in overseeing climate-related issues as well as management's role in assessing and managing those issues. Such information supports evaluations of whether climate-related issues receive appropriate board and management attention.

A
Introduction

B
Climate-Related Risks, Opportunities, and Financial Impacts

C
Recommendations and Guidance

D
Scenario Analysis and Climate-Related Issues

E
Key Issues Considered and Areas for Further Work

F
Conclusion

Appendices

Governance

Disclose the organization's governance around climate-related risks and opportunities.

Recommended Disclosure	Guidance for All Sectors
Recommended Disclosure a) Describe the board's oversight of climate-related risks and opportunities.	**Guidance for All Sectors** In describing the board's oversight of climate-related issues, organizations should consider including a discussion of the following: – processes and frequency by which the board and/or board committees (e.g., audit, risk, or other committees) are informed about climate-related issues, – whether the board and/or board committees consider climate-related issues when reviewing and guiding strategy, major plans of action, risk management policies, annual budgets, and business plans as well as setting the organization's performance objectives, monitoring implementation and performance, and overseeing major capital expenditures, acquisitions, and divestitures, and – how the board monitors and oversees progress against goals and targets for addressing climate-related issues.
Recommended Disclosure b) Describe management's role in assessing and managing climate-related risks and opportunities.	**Guidance for All Sectors** In describing management's role related to the assessment and management of climate-related issues, organizations should consider including the following information: – whether the organization has assigned climate-related responsibilities to management-level positions or committees; and, if so, whether such management positions or committees report to the board or a committee of the board and whether those responsibilities include assessing and/or managing climate-related issues, – a description of the associated organizational structure(s), – processes by which management is informed about climate-related issues, and – how management (through specific positions and/or management committees) monitors climate-related issues.

b. Strategy

Investors and other stakeholders need to understand how climate-related issues may affect an organization's businesses, strategy, and financial planning over the short, medium, and long term. Such information is used to inform expectations about the future performance of an organization.

Strategy

Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.

Recommended Disclosure a) Describe the climate-related risks and opportunities the organization has identified over the short, medium, and long term.	**Guidance for All Sectors** Organizations should provide the following information: – a description of what they consider to be the relevant short-, medium-, and long-term time horizons, taking into consideration the useful life of the organization's assets or infrastructure and the fact that climate-related issues often manifest themselves over the medium and longer terms, – a description of the specific climate-related issues for each time horizon (short, medium, and long term) that could have a material financial impact on the organization, and – a description of the process(es) used to determine which risks and opportunities could have a material financial impact on the organization. Organizations should consider providing a description of their risks and opportunities by sector and/or geography, as appropriate. In describing climate-related issues, organizations should refer to Tables 1 and 2 (pp. 10-11).
Recommended Disclosure b) Describe the impact of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning.	**Guidance for All Sectors** Building on recommended disclosure (a), organizations should discuss how identified climate-related issues have affected their businesses, strategy, and financial planning. Organizations should consider including the impact on their businesses and strategy in the following areas: – Products and services – Supply chain and/or value chain – Adaptation and mitigation activities – Investment in research and development – Operations (including types of operations and location of facilities) Organizations should describe how climate-related issues serve as an input to their financial planning process, the time period(s) used, and how these risks and opportunities are prioritized. Organizations' disclosures should reflect a holistic picture of the interdependencies among the factors that affect their ability to create value over time. Organizations should also consider including in their disclosures the impact on financial planning in the following areas: – Operating costs and revenues – Capital expenditures and capital allocation – Acquisitions or divestments – Access to capital If climate-related scenarios were used to inform the organization's strategy and financial planning, such scenarios should be described.

Strategy

Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.

Recommended Disclosure	Guidance for All Sectors
Recommended Disclosure c) Describe the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.	**Guidance for All Sectors** Organizations should describe how resilient their strategies are to climate-related risks and opportunities, taking into consideration a transition to a lower-carbon economy consistent with a 2°C or lower scenario and, where relevant to the organization, scenarios consistent with increased physical climate-related risks. Organizations should consider discussing: – where they believe their strategies may be affected by climate-related risks and opportunities; – how their strategies might change to address such potential risks and opportunities; and – the climate-related scenarios and associated time horizon(s) considered. Refer to Section D for information on applying scenarios to forward-looking analysis.

c. Risk Management

Investors and other stakeholders need to understand how an organization's climate-related risks are identified, assessed, and managed and whether those processes are integrated into existing risk management processes. Such information supports users of climate-related financial disclosures in evaluating the organization's overall risk profile and risk management activities.

Risk Management

Disclose how the organization identifies, assesses, and manages climate-related risks.

Recommended Disclosure	Guidance for All Sectors
Recommended Disclosure a) Describe the organization's processes for identifying and assessing climate-related risks.	**Guidance for All Sectors** Organizations should describe their risk management processes for identifying and assessing climate-related risks. An important aspect of this description is how organizations determine the relative significance of climate-related risks in relation to other risks. Organizations should describe whether they consider existing and emerging regulatory requirements related to climate change (e.g., limits on emissions) as well as other relevant factors considered. Organizations should also consider disclosing the following: – processes for assessing the potential size and scope of identified climate-related risks and – definitions of risk terminology used or references to existing risk classification frameworks used.
Recommended Disclosure b) Describe the organization's processes for managing climate-related risks.	**Guidance for All Sectors** Organizations should describe their processes for managing climate-related risks, including how they make decisions to mitigate, transfer, accept, or control those risks. In addition, organizations should describe their processes for prioritizing climate-related risks, including how materiality determinations are made within their organizations. In describing their processes for managing climate-related risks, organizations should address the risks included in Tables 1 and 2 (pp. 10-11), as appropriate.

Risk Management

Disclose how the organization identifies, assesses, and manages climate-related risks.

Recommended Disclosure c) Describe how processes for identifying, assessing, and managing climate-related risks are integrated into the organization's overall risk management.	**Guidance for All Sectors** Organizations should describe how their processes for identifying, assessing, and managing climate-related risks are integrated into their overall risk management.

d. Metrics and Targets

Investors and other stakeholders need to understand how an organization measures and monitors its climate-related risks and opportunities. Access to the metrics and targets used by an organization allows investors and other stakeholders to better assess the organization's potential risk-adjusted returns, ability to meet financial obligations, general exposure to climate-related issues, and progress in managing or adapting to those issues. They also provide a basis upon which investors and other stakeholders can compare organizations within a sector or industry.

Metrics and Targets

Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.

Recommended Disclosure a) Disclose the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process.	**Guidance for All Sectors** Organizations should provide the key metrics used to measure and manage climate-related risks and opportunities, as described in Tables 1 and 2 (pp. 10-11). Organizations should consider including metrics on climate-related risks associated with water, energy, land use, and waste management where relevant and applicable. Where climate-related issues are material, organizations should consider describing whether and how related performance metrics are incorporated into remuneration policies. Where relevant, organizations should provide their internal carbon prices as well as climate-related opportunity metrics such as revenue from products and services designed for a lower-carbon economy. Metrics should be provided for historical periods to allow for trend analysis. In addition, where not apparent, organizations should provide a description of the methodologies used to calculate or estimate climate-related metrics.
Recommended Disclosure b) Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks.	**Guidance for All Sectors** Organizations should provide their Scope 1 and Scope 2 GHG emissions and, if appropriate, Scope 3 GHG emissions and the related risks.[39] GHG emissions should be calculated in line with the GHG Protocol methodology to allow for aggregation and comparability across organizations and jurisdictions.[40] As appropriate, organizations should consider providing related, generally accepted industry-specific GHG efficiency ratios.[41] GHG emissions and associated metrics should be provided for historical

[39] Emissions are a prime driver of rising global temperatures and, as such, are a key focal point of policy, regulatory, market, and technology responses to limit climate change. As a result, organizations with significant emissions are likely to be impacted more significantly by transition risk than other organizations. In addition, current or future constraints on emissions, either directly by emission restrictions or indirectly through carbon budgets, may impact organizations financially.

[40] While challenges remain, the GHG Protocol methodology is the most widely recognized and used international standard for calculating GHG emissions. Organizations may use national reporting methodologies if they are consistent with the GHG Protocol methodology.

[41] For industries with high energy consumption, metrics related to emission intensity are important to provide. For example, emissions per unit of economic output (e.g., unit of production, number of employees, or value-added) is widely used. See the Annex for examples of metrics.

Metrics and Targets

Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.

	periods to allow for trend analysis. In addition, where not apparent, organizations should provide a description of the methodologies used to calculate or estimate the metrics.
Recommended Disclosure c) Describe the targets used by the organization to manage climate-related risks and opportunities and performance against targets.	**Guidance for All Sectors** Organizations should describe their key climate-related targets such as those related to GHG emissions, water usage, energy usage, etc., in line with anticipated regulatory requirements or market constraints or other goals. Other goals may include efficiency or financial goals, financial loss tolerances, avoided GHG emissions through the entire product life cycle, or net revenue goals for products and services designed for a lower-carbon economy. In describing their targets, organizations should consider including the following: – whether the target is absolute or intensity based, – time frames over which the target applies, – base year from which progress is measured, and – key performance indicators used to assess progress against targets. Where not apparent, organizations should provide a description of the methodologies used to calculate targets and measures.

A
Introduction

B
Climate-Related Risks, Opportunities, and Financial Impacts

C
Recommendations and Guidance

D
Scenario Analysis and Climate-Related Issues

E
Key Issues Considered and Areas for Further Work

F
Conclusion

Appendices

D Scenario Analysis and Climate-Related Issues

D Scenario Analysis and Climate-Related Issues

Some organizations are affected by risks associated with climate change today. However, for many organizations, the most significant effects of climate change are likely to emerge over the medium to longer term and their timing and magnitude are uncertain. This uncertainty presents challenges for individual organizations in understanding the potential effects of climate change on their businesses, strategies, and financial performance. To appropriately incorporate the potential effects in their planning processes, organizations need to consider how their climate-related risks and opportunities may evolve and the potential implications under different conditions. One way to do this is through scenario analysis.

Scenario analysis is a well-established method for developing strategic plans that are more flexible or robust to a range of plausible future states. The use of scenario analysis for assessing the potential business implications of climate-related risks and opportunities, however, is relatively recent. While several organizations use scenario analysis to assess the potential impact of climate change on their businesses, only a subset have disclosed their assessment of forward-looking implications publicly, either in sustainability reports or financial filings.[42]

The disclosure of organizations' forward-looking assessments of climate-related issues is important for investors and other stakeholders in understanding how vulnerable individual organizations are to transition and physical risks and how such vulnerabilities are or would be addressed. As a result, the Task Force believes that organizations should use scenario analysis to assess potential business, strategic, and financial implications of climate-related risks and opportunities and disclose those, as appropriate, in their annual financial filings.

Scenario analysis is an important and useful tool for understanding the strategic implications of climate-related risks and opportunities.

This section provides additional information on using scenario analysis as a tool to assess potential implications of climate-related risks and opportunities. In addition, a technical supplement, The Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities, on the Task Force's website provides further information on the types of climate-related scenarios, the application of scenario analysis, and the key challenges in implementing scenario analysis.

1. Overview of Scenario Analysis

Scenario analysis is a process for identifying and assessing the potential implications of a range of plausible future states under conditions of uncertainty. Scenarios are hypothetical constructs and not designed to deliver precise outcomes or forecasts. Instead, scenarios provide a way for organizations to consider how the future might look if certain trends continue or certain conditions are met. In the case of climate change, for example, scenarios allow an organization to explore and develop an understanding of how various combinations of climate-related risks, both transition and physical risks, may affect its businesses, strategies, and financial performance over time.

Scenario analysis can be qualitative, relying on descriptive, written narratives, or quantitative, relying on numerical data and models, or some combination of both. Qualitative scenario analysis

[42] Some organizations in the energy sector and some large investors have made public disclosures describing the results of their climate-related scenario analysis, including discussing how the transition might affect their current portfolios. In some instances, this information was published in financial filings.

explores relationships and trends for which little or no numerical data is available, while quantitative scenario analysis can be used to assess measurable trends and relationships using models and other analytical techniques.[43] Both rely on scenarios that are internally consistent, logical, and based on explicit assumptions and constraints that result in plausible future development paths.

As summarized in Figure 7, there are several reasons why scenario analysis is a useful tool for organizations in assessing the potential implications of climate-related risks and opportunities.

Figure 7

Reasons to Consider Using Scenario Analysis for Climate Change

1. Scenario analysis can help organizations consider issues, like climate change, that have the following characteristics:
   - Possible outcomes that are highly uncertain (e.g., the **physical** response of the climate and ecosystems to higher levels of GHG emissions in the atmosphere)
   - Outcomes that will play out over the medium to longer term (e.g., timing, distribution, and mechanisms of the **transition** to a lower-carbon economy)
   - Potential disruptive effects that, due to uncertainty and complexity, are substantial
2. Scenario analysis can enhance organizations' strategic conversations about the future by considering, in a more structured manner, what may unfold that is different from business-as-usual. Importantly, it broadens decision makers' thinking across a range of plausible scenarios, including scenarios where climate-related impacts can be significant.
3. Scenario analysis can help organizations frame and assess the potential range of plausible business, strategic, and financial impacts from climate change and the associated management actions that may need to be considered in strategic and financial plans. This may lead to more robust strategies under a wider range of uncertain future conditions.
4. Scenario analysis can help organizations identify indicators to monitor the external environment and better recognize when the environment is moving toward a different scenario state (or to a different stage along a scenario path). This allows organizations the opportunity to reassess and adjust their strategies and financial plans accordingly.[44]
5. Scenario analysis can assist investors in understanding the robustness of organizations' strategies and financial plans and in comparing risks and opportunities across organizations.

2. Exposure to Climate-Related Risks

The effects of climate change on specific sectors, industries, and individual organizations are highly variable. It is important, therefore, that all organizations consider applying a basic level of scenario analysis in their strategic planning and risk management processes. Organizations more significantly affected by transition risk (e.g., fossil fuel-based industries, energy-intensive manufacturers, and transportation activities) and/or physical risk (e.g., agriculture, transportation

[43] For example, see Mark D. A. Rounsevell, Marc J. Metzger, *Developing qualitative scenario storylines for environmental change assessment,* WIREs Climate Change 2010, 1: 606-619. doi: 10.1002/wcc.63, 2010 and Oliver Fricko, et. al., *Energy sector water use implications of a 2º C climate policy,* Environmental Research Letters, 11: 1-10, 2016.

[44] J.N. Maack, *Scenario analysis: a tool for task managers,* Social Analysis: selected tools and techniques, Social Development Papers, Number 36, the World Bank, June 2001, Washington, DC.

and building infrastructure, insurance, and tourism) should consider a more in-depth application of scenario analysis.

a. Exposure to Transition Risks

Transition risk scenarios are particularly relevant for resource-intensive organizations with high GHG emissions within their value chains, where policy actions, technology, or market changes aimed at emissions reductions, energy efficiency, subsidies or taxes, or other constraints or incentives may have a particularly direct effect.

A key type of transition risk scenario is a so-called 2°C scenario, which lays out a pathway and an emissions trajectory consistent with holding the increase in the global average temperature to 2°C above pre-industrial levels. In December 2015, nearly 200 governments agreed to strengthen the global response to the threat of climate change by "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels," referred to as the Paris Agreement.[45] As a result, a 2°C scenario provides a common reference point that is generally aligned with the objectives of the Paris Agreement and will support investors' evaluation of the potential magnitude and timing of transition-related implications for individual organizations; across different organizations within a sector; and across different sectors.

b. Exposure to Physical Risks

A wide range of organizations are exposed to climate-related physical risks. Physical climate-related scenarios are particularly relevant for organizations exposed to acute or chronic climate change, such as those with:

- long-lived, fixed assets;
- locations or operations in climate-sensitive regions (e.g., coastal and flood zones);
- reliance on availability of water; and
- value chains exposed to the above.

Physical risk scenarios generally identify extreme weather threats of moderate or higher risk before 2030 and a larger number and range of physical threats between 2030 and 2050. Although most climate models deliver scenario results for physical impacts beyond 2050, organizations typically focus on the consequences of physical risk scenarios over shorter time frames that reflect the lifetimes of their respective assets or liabilities, which vary across sectors and organizations.

3. Recommended Approach to Scenario Analysis

The Task Force believes that all organizations exposed to climate-related risks should consider (1) using scenario analysis to help inform their strategic and financial planning processes and (2) disclosing how resilient their strategies are to a range of plausible climate-related scenarios. The Task Force recognizes that, for many organizations, scenario analysis is or would be a largely qualitative exercise. However, organizations with more significant exposure to transition risk and/or physical risk should undertake more rigorous qualitative and, if relevant, quantitative scenario analysis with respect to key drivers and trends that affect their operations.

A critical aspect of scenario analysis is the selection of a set of scenarios (not just one) that covers a reasonable variety of future outcomes, both favorable and unfavorable. In this regard, the Task Force recommends organizations use a 2°C or lower scenario in addition to two or three other

[45] United Nations Framework Convention on Climate Change. "The Paris Agreement," December 2015.

scenarios most relevant to their circumstances, such as scenarios related to Nationally Determined Contributions (NDCs), physical climate-related scenarios, or other challenging scenarios.[46] In jurisdictions where NDCs are a commonly accepted guide for an energy and/or emissions pathway, NDCs may constitute particularly useful scenarios to include in an organization's suite of scenarios for conducting climate-related scenario analysis.

For an organization in the initial stages of implementing scenario analysis or with limited exposure to climate-related issues, the Task Force recommends disclosing how resilient, qualitatively or directionally, the organization's strategy and financial plans may be to a range of relevant climate change scenarios. This information helps investors, lenders, insurance underwriters, and other stakeholders understand the robustness of an organization's forward-looking strategy and financial plans across a range of possible future states.

Organizations with more significant exposure to climate-related issues should consider disclosing key assumptions and pathways related to the scenarios they use to allow users to understand the analytical process and its limitations. In particular, it is important to understand the critical parameters and assumptions that materially affect the conclusions drawn. As a result, the Task Force believes that organizations with significant climate-related exposures should *strive* to disclose the elements described in Figure 8.

Figure 8

Disclosure Considerations for Non-Financial Organizations

Organizations with more significant exposure to climate-related issues should consider disclosing key aspects of their scenario analysis, such as the ones described below.

1 The scenarios used, including the 2°C or lower scenario[47]

2 Critical input parameters, assumptions, and analytical choices for the scenarios used, including such factors as:

- Assumptions about possible technology responses and timing (e.g., evolution of products/services, the technology used to produce them, and costs to implement)
- Assumptions made around potential differences in input parameters across regions, countries, asset locations, and/or markets
- Approximate sensitivities to key assumptions

3 Time frames used for scenarios, including short-, medium-, and long-term milestones (e.g., how organizations consider timing of potential future implications under the scenarios used)

4 Information about the resiliency of the organization's strategy, including strategic performance implications under the various scenarios considered, potential qualitative or directional implications for the organization's value chain, capital allocation decisions, research and development focus, and potential material financial implications for the organization's operating results and/or financial position

[46] The Task Force's technical supplement, The Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities provides more information on scenario inputs, analytical assumptions and choices, and assessment and presentation of potential impacts.
[47] The objective of the Paris Agreement is to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C. The IEA is developing a 1.5°C scenario that organizations may find useful.

4. Applying Scenario Analysis

While the Task Force recognizes the complexities of scenario analysis and the potential resources needed to conduct it, organizations are encouraged to use scenario analysis to assess climate-related risks and opportunities. For organizations just beginning to use scenario analysis, a qualitative approach that progresses and deepens over time may be appropriate.[48] Greater rigor and sophistication in the use of data and quantitative models and analysis may be warranted for organizations with more extensive experience in conducting scenario analysis. Organizations may decide to use existing external scenarios and models (e.g., those provided by third-party vendors) or develop their own, in-house modeling capabilities. The choice of approach will depend on an organization's needs, resources, and capabilities.

In conducting scenario analysis, organizations should *strive* to achieve:

- transparency around parameters, assumptions, analytical approaches, and time frames;
- comparability of results across different scenarios and analytical approaches;
- adequate documentation for the methodology, assumptions, data sources, and analytics;
- consistency of methodology year over year;
- sound governance over scenario analysis conduct, validation, approval, and application; and
- effective disclosure of scenario analysis that will inform and promote a constructive dialogue between investors and organizations on the range of potential impacts and resilience of the organization's strategy under various plausible climate-related scenarios.

In applying scenario analysis, organizations should consider general implications for their strategies, capital allocation, and costs and revenues, both at an enterprise-wide level and at the level of specific regions and markets where specific implications of climate change for the organization are likely to arise. Financial-sector organizations should consider using scenario analysis to evaluate the potential impact of climate-related scenarios on individual assets or investments, investments or assets in a particular sector or region, or underwriting activities.

The Task Force's supplemental guidance recognizes that organizations will be at different levels of experience in using scenario analysis. However, it is important for organizations to use scenario analysis and develop the necessary organizational skills and capabilities to assess climate-related risks and opportunities, with the expectation that organizations will evolve and deepen their use of scenario analysis over time. The objective is to assist investors and other stakeholders in better understanding:

- the degree of robustness of the organization's strategy and financial plans under different plausible future states of the world;
- how the organization may be positioning itself to take advantage of opportunities and plans to mitigate or adapt to climate-related risks; and
- how the organization is challenging itself to think strategically about longer-term climate-related risks and opportunities.

[48] Organizations considering undertaking scenario analysis may wish to conduct various sensitivity analyses around key climate factors as a precursor to scenario analysis, recognizing that sensitivity analysis and scenario analysis are different, but complementary, processes.

5. Challenges and Benefits of Conducting Scenario Analysis

Scenario analysis is a well-established method for developing strategic plans that are more flexible and robust to a range of plausible future states. As previously discussed (Figure 7, p. 26) it is particularly useful for assessing issues with possible outcomes that are highly uncertain, that play out over the medium to longer term, and that are potentially disruptive. Scenario analysis can help to better frame strategic issues, assess the range of potential management actions that may be needed, engage more productively in strategic conversations, and identify indicators to monitor the external environment. Importantly, climate-related scenario analysis can provide the foundation for more effective engagement with investors on an organization's strategic and business resiliency.

Conducting climate-related scenario analysis, however, is not without challenges. First, most scenarios have been developed for global and macro assessments of potential climate-related impacts that can inform policy makers. These climate-related scenarios do not always provide the ideal level of transparency, range of data outputs, and functionality of tools that would facilitate their use in a business or investment context.

Second, the availability and granularity of data can be a challenge for organizations attempting to assess various energy and technology pathways or carbon constraints in different jurisdictions and geographic locations.

Third, the use of climate-related scenario analysis to assess potential business implications is still at an early stage. Although a handful of the largest organizations and investors are using climate-related scenario analysis as part of their strategic planning and risk management processes, many organizations are just beginning to explore its use. Sharing experiences and approaches to climate-related scenario analysis across organizations, therefore, is critical to advancing the use of climate-related scenario analysis. Organizations may be able to play an important role in this regard by facilitating information and experience exchanges among themselves; collectively developing tools, data sets, and methodologies; and working to set standards. Organizations across many different sectors will inevitably need to learn by doing. Some may seek guidance from other industry participants and experts on how to apply climate-related scenarios to make forward-looking analyses of climate-related risks and opportunities.

Addressing these challenges and advancing the use of climate-related scenario analysis will require further work. These challenges, however, are not insurmountable and can be addressed. Organizations should undertake scenario analysis in the near term to capture the important benefits for assessing climate-related risks and opportunities and improve their capabilities as tools and data progress over time.

E Key Issues Considered and Areas for Further Work

E Key Issues Considered and Areas for Further Work

The diverse perspectives of Task Force members as well as outreach efforts, including two public consultations, resulting in over 500 responses, hundreds of industry interviews, several focus groups, and multiple webinars, provided valuable insight into the challenges that different organizations—both financial and non-financial—may encounter in preparing disclosures consistent with the Task Force's recommendations. The Task Force considered these issues and others in developing and then finalizing its recommendations and sought to balance the burden of disclosure on preparers with the need for consistent and decision-useful information for users (i.e., investors, lenders, and insurance underwriters). This section describes the key issues considered by the Task Force, significant public feedback received by the Task Force related to those issues, the ultimate disposition of the issues, and, in some cases, areas where further work may be warranted. Figure 9 summarizes areas the Task Force identified, through its own analysis as well as through public feedback, as warranting further research and analysis or the development of methodologies and standards.

Figure 9
Key Areas for Further Work

Relationship to Other Reporting Initiatives	Encourage standard setting organizations and others to actively work toward greater alignment of frameworks and to support adoption
Scenario Analysis	Further develop applicable 2°C or lower transition scenarios and supporting outputs, tools, and user interfaces Develop broadly accepted methodologies, datasets, and tools for scenario-based evaluation of physical risk by organizations Make datasets and tools publicly available and provide commonly available platforms for scenario analysis
Data Availability and Quality and Financial Impact	Undertake further research and analysis to better understand and measure how climate-related issues translate into potential financial impacts for organizations in financial and non-financial sectors Improve data quality and further develop standardized metrics for the financial sector, including better defining carbon-related assets and developing metrics that address a broader range of climate-related risks and opportunities Increase organizations' understanding of climate-related risks and opportunities
Example Disclosures[49]	Provide example disclosures to assist preparers in developing disclosures consistent with the Task Force's recommendations

[49] In response to the second consultation, organizations asked for example disclosures to gain a better understanding of how the recommended information may be disclosed. The Task Force acknowledges the development of these examples as an area of further work.

1. Relationship to Other Reporting Initiatives

Through the Task Force's outreach efforts, some organizations expressed concern that multiple disclosure frameworks and mandatory reporting requirements increase the administrative burden of disclosure efforts. Specifically, the additional time, cost, and effort required to analyze and disclose new climate-related information could penalize those with less capacity to respond.

The Task Force considered existing voluntary and mandatory climate-related reporting frameworks in developing its recommendations and provides information in the Annex on the alignment of existing frameworks, including those developed by the CDP (formerly the Carbon Disclosure Project), Climate Disclosure Standards Board (CDSB), the Global Reporting Initiative (GRI), the International Integrated Reporting Council (IIRC), and the Sustainability Accounting Standards Board (SASB), with the Task Force's recommended disclosures. The Task Force expects preparers disclosing climate-related information under other regimes will be able to use existing processes and content when developing disclosures based on the Task Force's recommendations.

The Task Force's recommendations provide a common set of principles that should help existing disclosure regimes come into closer alignment over time. Preparers, users, and other stakeholders share a common interest in encouraging such alignment as it relieves a burden for reporting entities, reduces fragmented disclosure, and provides greater comparability for users. The Task Force also encourages standard setting bodies to support adoption of the recommendations and alignment with the recommended disclosures.

2. Location of Disclosures and Materiality

In considering possible reporting venues, the Task Force reviewed existing regimes for climate-related disclosures across G20 countries. While many G20 countries have rules or regulatory guidance that require climate-related disclosure for organizations, most are *not* explicitly focused on climate-related *financial* information.[50] In addition, the locations of these disclosures vary significantly and range from surveys sent to regulators to sustainability reports to annual financial filings (see Appendix 4).

The Task Force also reviewed financial filing requirements applicable to public companies across G20 countries and found that in most G20 countries, issuers have a legal obligation to disclose material information in their financial reports—which includes material, climate-related information. Such reporting may take the form of a general disclosure of material information, but many jurisdictions require disclosure of material information in specific sections of the financial filing (e.g., in a discussion on risk factors).[51]

Based on its review, the Task Force determined that preparers of climate-related financial disclosures should provide such disclosures in their mainstream (i.e., public) annual financial filings.[52] The Task Force believes publication of climate-related financial information in mainstream financial filings will foster broader utilization of such disclosures, promoting an informed understanding of climate-related issues by investors and others, and support shareholder engagement. Importantly, in determining whether information is material, the Task Force believes organizations should determine materiality for climate-related issues consistent with how they determine the materiality of other information included in their financial filings. In addition, the Task Force cautions organizations against prematurely concluding that climate-

[50] Organization for Economic Co-operation and Development (OECD) and CDSB, *Climate Change Disclosure in G20 Countries: Stocktaking of Corporate Reporting Schemes,* November 18, 2015.

[51] N. Ganci, S. Hammer, T. Reilly, and P. Rodel*, Environmental and Climate Change Disclosure under the Securities Laws: A Multijurisdictional Survey,* Debevoise & Plimpton, March 2016.

[52] To the extent climate-related disclosures are provided outside of financial filings, organizations are encouraged to align the release of such reports with their financial filings.

related risks and opportunities are not material based on perceptions of the longer-term nature of some climate-related risks.

As part of the Task Force's second public consultation, some organizations expressed concern about disclosing information in financial filings that is not clearly tied to an assessment of materiality. The Task Force recognizes organizations' concerns about disclosing information in annual financial filings that is not clearly tied to an assessment of materiality. However, the Task Force believes disclosures related to the Governance and Risk Management recommendations should be provided in annual financial filings. Because climate-related risk is a non-diversifiable risk that affects nearly all sectors, many investors believe it requires special attention. For example, in assessing organizations' financial and operating results, many investors want insight into the governance and risk management context in which such results are achieved. The Task Force believes disclosures related to its Governance and Risk Management recommendations directly address this need for context and should be included in annual financial filings.

For disclosures related to the Strategy and Metrics and Targets recommendations, the Task Force believes organizations should provide such information in annual financial filings when the information is deemed material. Certain organizations—those in the four non-financial groups that have more than one billion USDE in annual revenue—should consider disclosing information related to these recommendations in other reports when the information is not deemed material and not included in financial filings.[53,54] Because these organizations are more likely than others to be affected financially over time due to their significant GHG emissions or energy or water dependencies, investors are interested in monitoring how the organizations' strategies evolve.

In addition, the Task Force recognizes reporting by asset managers and asset owners to their clients and beneficiaries, respectively, generally occurs outside mainstream financial filings (Figure 10). For purposes of adopting the Task Force's recommendations, asset managers and asset owners should use their existing channels of financial reporting to their clients and beneficiaries where relevant and feasible. Likewise, asset managers and asset owners should consider materiality in the context of their respective mandates and investment performance for clients and beneficiaries.

Figure 10

Reporting by Asset Owners

The financial reporting requirements and practices of asset owners vary widely and differ from what is required of organizations with public debt or equity. Some asset owners have no public reporting, while others provide extensive public reporting. For purposes of adopting the Task Force's recommendations, asset owners should use their existing channels of financial reporting to their beneficiaries and others where relevant and feasible.

Reporting by Asset Managers

Reporting to clients by asset managers also takes different forms, depending on the requirements of the client and the types of investments made. For example, an investor in a mutual fund might receive quarterly, or download from the asset manager's website, a "fund fact sheet" that reports, among other information, the top holdings by value, the top performers by returns, and the carbon footprint of the portfolio against a stated benchmark. An investor in a segregated account might receive more detailed reporting, including items such as the aggregate carbon intensity of the portfolio compared with a benchmark, the portfolio's exposure to green revenue (and how this changes over time), or insight into portfolio positioning under different climate scenarios. The Task Force appreciates that climate-related risk reporting by asset managers is in the very early stages and encourages progress and innovation by the industry.

[53] The Task Force chose a one billion USDE annual revenue threshold because it captures organizations responsible for over 90% of Scope 1 and 2 GHG emissions in the industries represented by the four non-financial groups (about 2,250 organizations out of roughly 15,000).

[54] "Other reports" should be official company reports that are issued at least annually, widely distributed and available to investors and others, and subject to internal governance processes that are substantially similar to those used for financial reporting.

3. Scenario Analysis

As part of the Task Force's second public consultation, many organizations said scenario analysis is a useful tool to help assess risks and understand potential implications of climate change; however, they also identified areas where the Task Force's recommendations and guidance could be improved. In particular, organizations asked the Task Force to identify standardized climate-related scenarios for organizations to use and clarify the information related to scenarios that should be disclosed. They also noted expectations around disclosures and climate-related scenario analysis should be proportionate to the size of the reporting entity and not onerous for smaller organizations. In addition, some organizations noted that the disclosures related to strategy could put organizations at greater risk of litigation given the high degree of uncertainty around the future timing and magnitude of climate-related impacts.

In finalizing its recommendations and guidance, the Task Force clarified organizations should describe how resilient their strategies are to climate-related risks and opportunities, taking into consideration a transition to a lower-carbon economy consistent with a 2°C or lower scenario and, where relevant, scenarios consistent with more extreme physical risks. To address concerns about proportionality, the Task Force established a threshold for organizations in the four non-financial groups that should perform more robust scenario analysis and disclose additional information on the resiliency of their strategies.

On the issue of recommending specific standardized or reference climate-related scenarios for organizations to use, Task Force members agreed that while such an approach is intuitively appealing, it is not a practical solution at this time. Existing, publicly available climate-related scenarios are not structured or defined in such a way that they can be easily applied consistently across different industries or across organizations within an industry.

The Task Force recognizes that incorporating scenario analysis into strategic planning processes will improve over time as organizations "learn by doing." To facilitate progress in this area, the Task Force encourages further work as follows:

- further developing 2°C or lower transition scenarios that can be applied to specific industries and geographies along with supporting outputs, tools, and user interfaces;
- developing broadly accepted methodologies, data sets, and tools for scenario-based evaluation of physical risk by organizations;
- making these data sets and tools publicly available to facilitate use by organizations, reduce organizational transaction costs, minimize gaps between jurisdictions in terms of technical expertise, enhance comparability of climate-related risk assessments by organizations, and help ensure comparability for investors; and
- creating more industry specific (financial and non-financial) guidance for preparers and users of climate-related scenarios.

4. Data Availability and Quality and Financial Impact

The Task Force developed supplemental guidance for the four non-financial groups that account for the largest proportion of GHG emissions, energy usage, and water usage; and, as part of that supplemental guidance, the Task Force included several illustrative metrics around factors that may be indicative of potential financial implications for climate-related risks and opportunities. As part of the second public consultation, several organizations provided feedback on the illustrative metrics, and common themes included (1) improving the comparability and consistency of the metrics, (2) clarifying the links among the metrics, climate-related risks and opportunities, and potential financial implications, (3) simplifying the metrics, and (4) providing additional guidance on the metrics, including how to calculate key metrics. Organizations also raised concerns about the lack of standardized data and metrics in the financial sector, which complicates preparers' ability to develop decision-useful metrics and users' ability to compare metrics across organizations.

The Task Force recognizes these concerns as well as broader challenges related to data availability and quality, as described below.

- The gaps in emissions measurement methodologies, including Scope 3 emissions and product life-cycle emissions methodologies, make reliable and accurate estimates difficult.[55,56]
- The lack of robust and cost-effective tools to quantify the potential impact of climate-related risks and opportunities at the asset and project level makes aggregation across an organization's activities or investment portfolios problematic and costly.
- The need to consider the variability of climate-related impacts across and within different sectors and markets further complicates the process (and magnifies the cost) of assessing potential climate-related financial impacts.
- The high degree of uncertainty around the timing and magnitude of climate-related risks makes it difficult to determine and disclose the potential impacts with precision.

In finalizing its supplemental guidance, the Task Force addressed the redundancy of the metrics; simplified the non-financial illustrative metrics tables; ensured consistent terminology was used; and clarified the links between the metrics, climate-related risks and opportunities, and potential financial implications. In addition, the Task Force encourages further research and analysis by sector and industry experts to (1) better understand and measure how climate-related issues translate into potential financial impacts; (2) develop standardized metrics for the financial sector, including better defining carbon-related assets; and (3) increase organizations' understanding of climate-related risks and opportunities. As it relates to the broader challenges with data quality and availability, the Task Force encourages preparers to include in their disclosures a description of gaps, limitations, and assumptions made as part of their assessment of climate-related issues.

5. GHG Emissions Associated with Investments

In its supplemental guidance for asset owners and asset managers issued on December 14, 2016, the Task Force asked such organizations to provide GHG emissions associated with each fund, product, or investment strategy normalized for every million of the reporting currency invested. As part of the Task Force's public consultation as well as in discussions with preparers, some asset owners and asset managers expressed concern about reporting on GHG emissions related to their own or their clients' investments given the current data challenges and existing accounting guidance on how to measure and report GHG emissions associated with investments. In particular, they voiced concerns about the accuracy and completeness of the reported data and limited application of the metric to asset classes beyond public equities. Organizations also highlighted that GHG emissions associated with investments cannot be used as a sole indicator for investment decisions (i.e., additional metrics are needed) and that the metric can fluctuate with share price movements since it uses investors' proportional share of total equity.[57]

In consideration of the feedback received, the Task Force has replaced the GHG emissions associated with investments metric in the supplemental guidance for asset owners and asset managers with a weighted average carbon intensity metric. The Task Force believes the weighted

[55] Scope 3 emissions are all indirect emissions that occur in the value chain of the reporting company, including both upstream and downstream emissions. See Greenhouse Gas Protocol, "Calculation Tools, FAQ."

[56] Product life cycle emissions are all the emissions associated with the production and use of a specific product, including emissions from raw materials, manufacture, transport, storage, sale, use, and disposal. See Greenhouse Gas Protocol, "Calculation Tools, FAQ."

[57] Because the metric uses investors' proportional share of total equity, increases in the underlying companies' share prices, *all else equal*, will result in a decrease in the carbon footprinting number even though GHG emissions are unchanged.

average carbon intensity metric, which measures exposure to carbon-intensive companies, addresses many of the concerns raised. For example, the metric can be applied across asset classes, is fairly simple to calculate, and does not use investors' proportional share of total equity and, therefore, is not sensitive to share price movements.

The Task Force acknowledges the challenges and limitations of current carbon footprinting metrics, including that such metrics should not necessarily be interpreted as risk metrics. Nevertheless, the Task Force views the reporting of weighted average carbon intensity as a first step and expects disclosure of this information to prompt important advancements in the development of decision-useful, climate-related risk metrics. In this regard, the Task Force encourages asset owners and asset managers to provide other metrics they believe are useful for decision making along with a description of the methodology used. The Task Force recognizes that some asset owners and asset managers may be able to report the weighted average carbon intensity and other metrics on only a portion of their investments given data availability and methodological issues. Nonetheless, increasing the number of organizations reporting this type of information should help speed the development of better climate-related risk metrics.

6. Remuneration

In the supplemental guidance for the Energy Group, the Task Force asked such organizations to consider disclosing whether and how performance metrics, including links to remuneration policies, take into consideration climate-related risks and opportunities. As part of its second public consultation, the Task Force asked whether the guidance should extend to organizations beyond those in the Energy group and, if so, to which types of organizations. The majority of organizations that commented on this issue responded that the guidance should be extended to other organizations; and many suggested that the guidance should apply to organizations more likely to be affected by climate-related risks. In consideration of the feedback received, the Task Force revised its guidance to ask organizations, where climate-related risks are material, to consider describing whether and how related performance metrics are incorporated into remuneration policies.

7. Accounting Considerations

As part of its work, the Task Force considered the interconnectivity of its recommendations with existing financial statement and disclosure requirements. The Task Force determined that the two primary accounting standard setting bodies, the International Accounting Standards Board (IASB) and the Financial Accounting Standards Board (FASB), have issued standards to address risks and uncertainties affecting companies. Both International Accounting Standard (IAS) 37 "Provisions, Contingent Liabilities and Contingent Assets" and Accounting Standards Codification (ASC) 450 "Contingencies" provide guidance on how to account for and disclose contingencies. Additionally, IAS 36 "Impairment of Assets" and ASC 360 "Long-lived Asset Impairment" provide guidance on assessing the impairment of long-lived assets. The disclosures of both contingencies and management's assessment and evaluation of long-lived assets for potential impairment are critically important in assisting stakeholders in understanding an organization's ability to meet future reported earnings and cash flow goals.

In most G20 countries, financial executives will likely recognize that the Task Force's disclosure recommendations should result in more quantitative financial disclosures, particularly disclosure of metrics, about the financial impact that climate-related risks have or could have on an organization. Specifically, asset impairments may result from assets adversely impacted by the effects of climate change and/or additional liabilities may need to be recorded to account for regulatory fines and penalties resulting from enhanced regulatory standards. Additionally, cash flows from operations, net income, and access to capital could all be impacted by the effects of climate-related risks (and opportunities). Therefore, financial executives (e.g., chief financial officers, chief accounting officers, and controllers) should be involved in the organization's evaluation of climate-related risks and opportunities and the efforts undertaken to manage the risks and maximize the opportunities. Finally, careful consideration should be given to the linkage between scenario analyses performed to assess the resilience of an organization's strategy to climate-related risks and opportunities (as suggested in the Task Force's recommendations) and assumptions underlying cash flow analyses used to assess asset (e.g., goodwill, intangibles, and fixed assets) impairments.

8. Time Frames for Short, Medium, and Long Term

As part of the Task Force's second public consultation, some organizations asked the Task Force to define specific ranges for short, medium, and long term. Because the timing of climate-related impacts on organizations will vary, the Task Force believes specifying time frames across sectors for short, medium, and long term could hinder organizations' consideration of climate-related risks and opportunities specific to their businesses. The Task Force is, therefore, not defining time frames and encourages preparers to decide how to define their own time frames according to the life of their assets, the profile of the climate-related risks they face, and the sectors and geographies in which they operate.

In assessing climate-related issues, organizations should be sensitive to the time frames used to conduct their assessments. While many organizations conduct operational and financial planning over a 1-2 year time frame and strategic and capital planning over a 2-5 year time frame, climate-related risks may have implications for an organization over a longer period. It is, therefore, important for organizations to consider the appropriate time frames when assessing climate-related risks.

9. Scope of Coverage

To promote more informed investing, lending, and insurance underwriting decisions, the Task Force recommends all financial and non-financial organizations with public debt and/or equity adopt its recommendations.[58] Because climate-related risks and opportunities are relevant for organizations across all sectors, the Task Force encourages all organizations to adopt these recommendations. In addition, the Task Force believes that asset managers and asset owners, including public- and private-sector pension plans, endowments, and foundations, should implement its recommendations. The Task Force believes climate-related financial information should be provided to asset managers' clients and asset owners' beneficiaries so that they may better understand the performance of their assets, consider the risks of their investments, and make more informed investment choices.

Consistent with existing global stewardship frameworks, asset owners should engage with the organizations in which they invest to encourage adoption of these recommendations. They should also ask their asset managers to adopt these recommendations. Asset owners' expectations in relation to climate-related risk reporting from organizations and asset managers are likely to evolve as data availability and quality improves, understanding of climate-related risk increases, and risk measurement methodologies are further developed.

The Task Force recognizes that several asset owners expressed concern about being identified as the potential "policing body" charged with ensuring adoption of the Task Force's recommendations by asset managers and underlying organizations. The Task Force appreciates that expectations must be reasonable and that asset owners have many competing priorities, but

A
Introduction

B
Climate-Related Risks, Opportunities, and Financial Impacts

C
Recommendations and Guidance

D
Scenario Analysis and Climate-Related Issues

E
Key Issues Considered and Areas for Further Work

F
Conclusion

Appendices

[58] Thresholds for climate-related financial disclosures should be aligned to the financial disclosure requirements more broadly in the jurisdictions where a preparer is incorporated and/or operates and is required to make financial disclosures.

encourages them to help drive adoption of the recommendations. Because asset owners and asset managers sit at the top of the investment chain, they have an important role to play in influencing the organizations in which they invest to provide better climate-related financial disclosures.

10. Organizational Ownership

Some organizations have not formalized responsibility for climate-related risk assessment and management. Even for organizations with clearly assigned responsibilities for climate-related issues, the relationship between those responsible for climate-related risk (e.g., "environmental, social and governance" experts, chief investment officers) and those in the finance function can range from regularly scheduled interactions and exchanges of information to minimal or no interaction. According to some preparers, lack of clarity around responsibility for climate-related risk assessments and management, compounded by a lack of integration into organizations' financial reporting processes, could adversely affect implementation of the recommendations.

The Task Force believes that by encouraging disclosure of climate-related financial information in public financial filings, coordination between organizations' climate-related risk experts and the finance function will improve. Similar to the way organizations are evolving to include cyber security issues in their strategic and financial planning efforts, so too should they evolve for climate-related issues.

F Conclusion

F Conclusion

The Task Force's recommendations are a foundation for improved reporting of climate-related issues in mainstream financial filings with several resulting benefits (outlined in Figure 11). The recommendations aim to be ambitious, but also practical for near-term adoption. The Task Force expects that reporting of climate-related risks and opportunities will evolve over time as organizations, investors, and others contribute to the quality and consistency of the information disclosed.

Figure 11

Benefits of Recommendations

- Foundation for immediate adoption and flexible enough to accommodate evolving practices
- Promote board and senior management engagement on climate-related issues
- Bring the "future" nature of issues into the present through scenario analysis
- Support understanding of financial sector's exposure to climate-related risks
- Designed to solicit decision-useful, forward-looking information on financial impacts

1. Evolution of Climate-Related Financial Disclosures

The Task Force recognizes that challenges exist, but all types of organizations can develop disclosures consistent with its recommendations. The recommendations provide a foundation for immediate adoption and are flexible enough to accommodate evolving practices. As understanding, data analytics, and modeling of climate-related issues become more widespread, disclosures can mature accordingly.

Organizations already reporting climate-related financial information under other frameworks may be well positioned to disclose under this framework immediately and are encouraged to do so. For such organizations, significant effort has gone into developing processes and collecting information needed for disclosing under these regimes. The Task Force expects these organizations will be able to use existing processes when providing disclosures in annual financial filings based on the Task Force's recommendations.[59,60] Those with less experience can begin by considering and disclosing how climate-related issues may be relevant in their current governance, strategy, and risk management practices. This initial level of disclosure will allow investors to review, recognize, and understand how organizations consider climate-related issues and their potential financial impact.

Importantly, the Task Force recognizes organizations need to make financial disclosures in accordance with their national disclosure requirements. To the extent certain elements of the recommendations are incompatible with national disclosure requirements for financial filings, the Task Force encourages organizations to disclose those elements through other reports. Such other reports should be official company reports that are issued at least annually, widely distributed and available to investors and others, and subject to internal governance processes that are the same or substantially similar to those used for financial reporting.

2. Widespread Adoption Critical

In the Task Force's view, the success of its recommendations depends on near-term, widespread adoption by organizations in the financial and non-financial sectors. Through widespread adoption, financial risks and opportunities related to climate change will become a natural part of

[59] The Task Force recognizes the structure and content of financial filings differs across jurisdictions and, therefore, believes organizations are in the best position to determine where and how the recommended disclosures should be incorporated in financial filings.

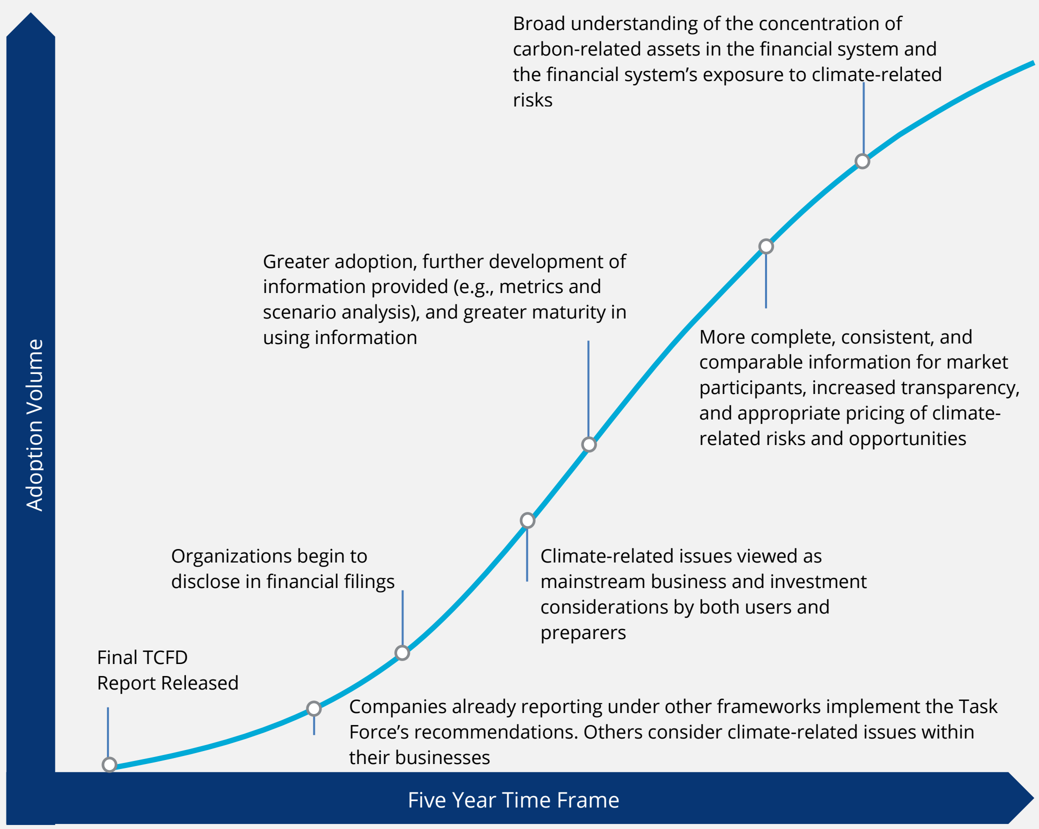
[60] The Task Force encourages organizations where climate-related issues could be material in the future to begin disclosing climate-related financial information outside financial filings to facilitate the incorporation of such information into financial filings once climate-related issues are determined to be material.

organizations' risk management and strategic planning processes. As this occurs, organizations' and investors' understanding of the potential financial implications associated with transitioning to a lower-carbon economy and physical risks will grow, information will become more decision-useful, and risks and opportunities will be more accurately priced, allowing for the more efficient allocation of capital. Figure 12 outlines a possible path for implementation.

Widespread adoption of the recommendations will require ongoing leadership by the G20 and its member countries. Such leadership is essential to continue to make the link between these recommendations and the achievements of global climate objectives. Leadership from the FSB is also critical to underscore the importance of better climate-related financial disclosures for the functioning of the financial system.

Figure 12

Implementation Path *(Illustrative)*



The Task Force is not alone in its work. A variety of stakeholders, including stock exchanges, investment consultants, credit rating agencies, and others can provide valuable contributions toward adoption of the recommendations. The Task Force believes that advocacy for these standards will be necessary for widespread adoption, including educating organizations that will disclose climate-related financial information and those that will use those disclosures to make financial decisions. To this end, the Task Force notes that strong support by the FSB and G20 authorities would have a positive impact on implementation. With the FSB's extension of the Task Force through September 2018, the Task Force will work to encourage adoption of the recommendations and support the FSB and G20 authorities in promoting the advancement of climate-related financial disclosures.

Appendices

Appendix 1: Task Force Members

Chairman and Vice Chairs

Michael Bloomberg
Chair
Founder
Bloomberg LP and Bloomberg Philanthropies

Denise Pavarina
Vice Chair
Executive Director
Banco Bradesco

Graeme Pitkethly
Vice Chair
Chief Financial Officer
Unilever

Christian Thimann
Vice Chair
Group Head of Regulation, Sustainability, and Insurance Foresight
AXA

Yeo Lian Sim
Vice Chair
Special Adviser, Diversity
Singapore Exchange

Members

Jane Ambachtsheer
Partner, Chair – Responsible Investment
Mercer

Matt Arnold
Managing Director and Global Head of Sustainable Finance
JPMorgan Chase & Co.

Wim Bartels
Partner Corporate Reporting
KPMG

Bruno Bertocci
Managing Director, Head of Sustainable Investors
UBS Asset Management

David Blood
Senior Partner
Generation Investment Management

Richard Cantor
Chief Risk Officer, Moody's Corporation
Chief Credit Officer, Moody's Investor Service

Koushik Chatterjee
Group Executive Director, Finance and Corporate
Tata Group

Eric Dugelay
Global Leader, Sustainability Services
Deloitte

Liliana Franco
Director, Accounting Organization and Methods
Air Liquide Group

Udo Hartmann
Senior Manager, Group Environmental Protection & Energy Management
Daimler

Neil Hawkins
Corporate Vice President and Chief Sustainability Officer
The Dow Chemical Company

Thomas Kusterer
Chief Financial Officer
EnBW Energie Baden-Württemberg AG

Diane Larsen
Audit Partner, Global Professional Practice
EY

Stephanie Leaist
Managing Director, Head of Sustainable Investing
Canada Pension Plan Investment Board

Mark Lewis
Managing Director, Head of European Utilities Equity Research
Barclays

Eloy Lindeijer
Chief, Investment Management, member Executive Committee
PGGM

Members *(continued)*

Ruixia Liu
General Manager, Risk Department
Industrial and Commercial Bank of China

Giuseppe Ricci
Chief Refining and Marketing Officer
ENI

Andreas Spiegel
Head Group Sustainability Risk
Swiss Re

Fiona Wild
Vice President, Sustainability and Climate Change
BHP Billiton

Jon Williams
Partner, Sustainability and Climate Change
PwC

Masaaki Nagamura
Head, Corporate Social Responsibility
Tokio Marine Holdings

Martin Skancke
Chair, Risk Committee
Storebrand

Steve Waygood
Chief Responsible Investment Officer
Aviva Investors

Michael Wilkins
Managing Director, Environmental & Climate Risk Research
S&P Global Ratings

Deborah Winshel
Managing Director, Global Head of Impact Investing
BlackRock

Special Adviser

Russell Picot
Chair, Audit and Risk Committee, LifeSight
Board Chair, HSBC Bank (UK) Pension Scheme Trustee
Former Group Chief Accounting Officer, HSBC

Secretariat

Mary Schapiro
Special Advisor to the Chair
Former Chair, U.S. Securities and Exchange Commission

Curtis Ravenel
Global Head, Sustainable Business & Finance
Bloomberg LP

Stacy Coleman
Managing Director
Promontory Financial Group, an IBM Company

Mara Childress
Principal
Promontory Financial Group, an IBM Company

Didem Nisanci
Managing Director
Promontory Financial Group, an IBM Company

Jeff Stehm
Director
Promontory Financial Group, an IBM Company

Veronika Henze
Head of Communications
Bloomberg New Energy Finance

Observers

Susan Nash
Member of Secretariat
Financial Stability Board

Rupert Thorne
Deputy to the Secretary General
Financial Stability Board

Joe Perry
Member of Secretariat
Financial Stability Board

Appendix 2: Task Force Objectives and Approach

1. Objectives

The Task Force engaged with key stakeholders throughout the development of its recommendations to ensure that its work would (1) promote alignment across existing disclosure regimes, (2) consider the perspectives of users and the concerns of preparers of climate-related financial disclosures, and (3) be efficiently implemented by organizations in their financial reporting.

2. Approach

In addition to the expertise of its members, a broad range of external resources informed the Task Force's recommendations, including existing voluntary and mandatory climate-related reporting frameworks, governance and risk management standards, government reports and research, expert resources, and various other stakeholders such as industry participants, trade associations, and non-governmental organizations (NGOs).

a. Leveraging Expertise

Task Force members come from a range of companies, including large financial companies, large non-financial companies, accounting and consulting firms, and credit rating agencies, and brought a range of practical experience, expertise, and global perspectives on preparing and using climate-related financial disclosures. Through eight plenary meetings, Task Force members contributed significantly to developing a consensus-based, industry-led approach to climate-related financial disclosure.

Due to the technically challenging and broad focus of its work, the Task Force also sought input from experts in the field of climate change, particularly in relation to scenario analysis. The Task Force engaged Environmental Resources Management (ERM) to inform its work by developing a technical paper on scenario analysis—The Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities. Several members of the Task Force, joined by representatives from 2° Investing Initiative (2°ii), Bloomberg New Energy Finance (BNEF), Bloomberg Quantitative Risk Experts, Carbon Tracker, CDP, and the London School of Economics and Political Science led a working group to oversee ERM's technical considerations. A workshop was also held with experts from Oxford Martin School. Additionally, the International Energy Agency (IEA) provided input regarding how scenario analysis can be conducted and used.

b. Research and Information Gathering

The Task Force's work drew on publications and research conducted by governments, NGOs, industry participants, as well as disclosure regimes with a focus on climate-related issues. The Task Force reviewed existing mandatory and voluntary reporting regimes for climate-related disclosure to identify commonalities and gaps across existing regimes and to determine areas meriting further research and analysis by the Task Force. The work of organizations regarded as standard setters, as well as several organizations active in developing reporting mechanisms for climate-related issues, served as the primary references for the Task Force in developing its recommendations and supporting guidance. The Task Force also considered resources related to sector-specific climate issues in the development of the supplemental guidance.

c. Outreach and Engagement

Engagement with users, preparers, and other stakeholders in relevant industries and sectors across G20 countries and other countries was important in developing the Task Force's recommendations. The Task Force conducted five types of engagement to support this effort: public consultation, industry interviews, focus groups, outreach events, and webinars.

Such engagement served two primary purposes: (1) to raise the level of awareness and educate stakeholders on the Task Force's work and (2) to solicit feedback from stakeholders on the Task Force's proposed recommended disclosures and supplemental guidance for specific sectors. In total, more than 2,700 individuals in 43 countries were included in the Task Force's outreach and engagement (Figure A2.1).

Public Consultations

The Task Force conducted two public consultations. The first followed the April 1, 2016 publication of the Task Force's Phase I Report, which set out the scope and high-level objectives for the Task Force's work. The Task Force solicited input to guide the development of its recommendations for voluntary climate-related financial disclosures. In total, 203 participants from 24 countries responded to the first public consultation. Respondents represented the financial sector, non-financial sectors, NGOs, and other organizations. Public consultation comments indicated support for disclosures on scenario analysis as well as disclosures tailored for specific sectors. Key themes from the first public consultation, which informed the Task Force's recommendations and guidance, are included in Table A2.1 (p. 48).

Figure A2.1

Outreach and Engagement

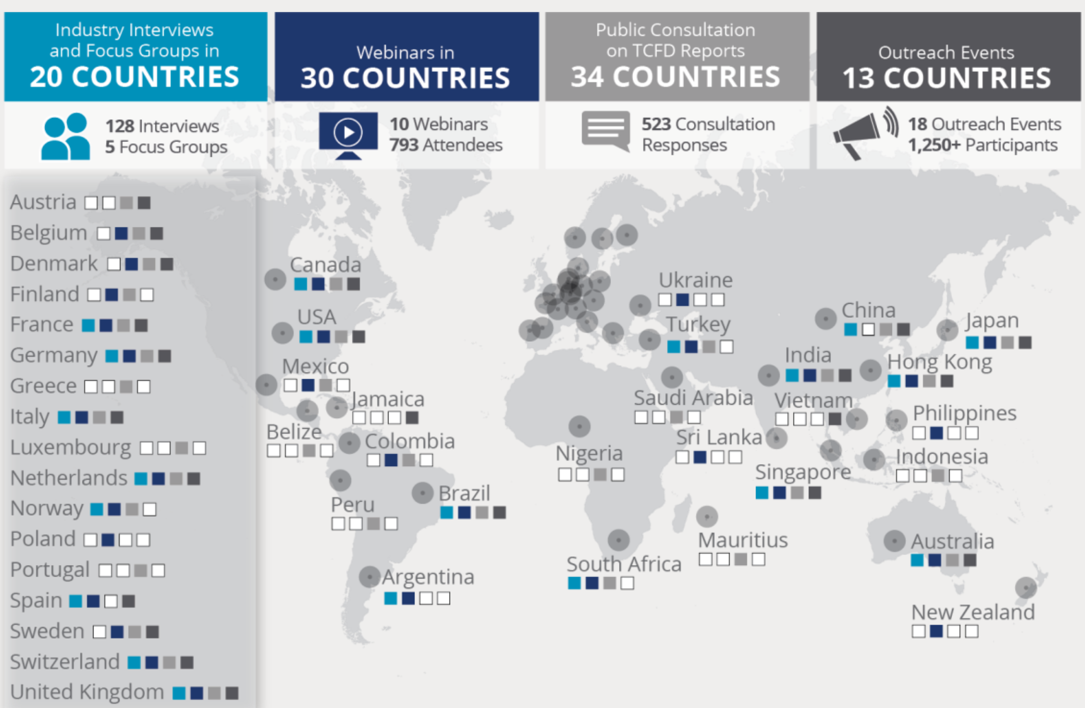


Table A2.1

Key Themes of First Public Consultation (Scope of Work)

Key Themes	Survey Response	
Components of Disclosures	The majority of respondents were in agreement that disclosures should: – be forward-looking, – address the ability to achieve targets, with strategies for achievement, and – align with material risks.	
Sector-Specific Disclosures	Respondents were in favor of disclosures for specific sectors	62%
Scenario Analysis	Respondents see scenario analysis as a key component of disclosure	96%

A second public consultation followed the release of the Task Force's report in December 2016. The Task Force conducted the second consultation through an online questionnaire designed to gather feedback on the recommendations, guidance, and key issues identified by the Task Force. The Task Force received 306 responses to its online questionnaire and 59 comment letters on the recommendations and guidance from a variety of organizations in 30 countries.[61] The majority of responses came from Europe (57 percent), followed by North America (20 percent), Asia Pacific (19 percent), South America (four percent), and the Middle East/Africa (less than one percent). Fourty-five percent of respondents provided perspective as users of disclosure, 44 percent as preparers of disclosure, and 11 percent as "other." Respondents came from the financial sector (43 percent), non-financial sectors (18 percent), or other types of organizations (39 percent).[62]

Table A2.2

Responses to Second Public Consultation Questions

Questions	Respondent	Percent Responding "Useful"
How useful are the recommendations and guidance for all sectors in preparing disclosures?	Preparers	75%
How useful is the supplemental guidance in preparing disclosures?	Preparers	66%
If organizations disclose the recommended information, how useful would it be for decision making?	Users	77%
How useful is a description of potential performance across a range of scenarios to understanding climate-related impacts on an organization's businesses, strategy, and financial planning?	Financial	74%
	Non-Financial	17%
	Other	86%
How useful are the illustrative examples of metrics and targets?	Financial	74%
	Non-Financial	33%
	Other	72%
How useful would the disclosure of GHG emissions associated with investments be for economic decision-making?	Financial	68%
	Other	74%

[61] Of the 59 respondents that submitted comment letters, 45 also completed the online questionnaire, resulting in a total of 320 unique responses.

[62] The other types of organizations included research and advocacy NGOs; standard setting NGOs; data analytics, consulting, and research organizations; academia; and accounting associations.

Overall, respondents were generally supportive of the Task Force's recommendations as shown in Table A2.2 (p. 48); however, several provided specific and constructive feedback on the report. The key themes from this feedback are included in Table A2.3. For additional information regarding the results of the second public consultation, please view the TCFD Public Consultation Summary 2017 on the Task Force's website.

Table A2.3

Key Themes of Second Public Consultation (Recommendations)

Key Themes	
Materiality and Location of Disclosures	Clarifying which recommended disclosures depend on materiality assessment and providing flexibility for organizations to provide some or all disclosures in reports other than financial filings.
Scenario Analysis	Improving ease of implementation, and comparability of scenario analysis by specifying standard scenario(s) and providing additional guidance and tools.
Metrics for the Financial Sector	Encouraging further development and standardization of metrics for the financial sector.
Metrics for Non-Financial Sectors	Improving comparability and consistency of the illustrative metrics for non-financial sectors, clarifying the links to financial impact and climate-related risks and opportunities.
Implementation	Providing disclosure examples to support preparers in developing relevant climate-related financial disclosures.

Industry Interviews and Focus Groups

Prior to the December 2016 release of the Task Force's report for public consultation, the Task Force conducted 128 industry interviews with users and preparers of financial statements to gather feedback regarding the Task Force's draft recommendations, supplemental guidance for certain sectors, and other considerations. Industry interview participants included chief financial officers, investment officers, other finance and accounting officers, risk officers, sustainability officers, and others. Forty-three percent of the participants held finance, legal, or risk positions and 39 percent held environmental or sustainability roles.

Task Force representatives conducted two rounds of industry interviews. The initial round of interviews focused on the recommendations and guidance; the second round emphasized specific recommendations and sector-specific guidance. Organizations invited to participate in the interviews met two primary criteria: (1) represented industry and sector leaders likely to be impacted by climate-related risks and opportunities and (2) provided geographic diversity to ensure coverage from each G20 and Financial Stability Board (FSB) represented country.

The interviews provided valuable information that informed the Task Force's recommendations and guidance as reflected in the report issued for public consultation in December 2016. Industry interview themes were consistent with those identified in the second public consultation. Preparers raised concerns about the relationship of the Task Force's recommendations to other reporting initiatives and the accuracy and reliability of information requested. Users commented that establishing consistency in metrics would be beneficial, acknowledged data quality challenges, and provided thoughts on scenario analysis (e.g., would like preparers to use of a range of scenarios, interested in knowing how scenario analysis is used in the organization).

Subsequent to the December 2016 release of the Task Force's report for public consultation, the Task Force conducted five focus groups with 32 individuals from six countries representing organizations in specific sectors and industries to solicit feedback on scenario analysis and carbon footprinting metrics. In the two focus groups for the financial sector, participants expressed support for the Task Force's work, noting current challenges related to quality and consistency in reported climate-related information. Asset owners and asset managers also provided feedback on the benefits and limitations of different carbon footprinting metrics. In the three focus groups for non-financial sectors, participants in oil and gas and utilities industries provided specific feedback on their use of scenario analysis and challenges related to disclosing certain information in financial filings.

Outreach Events

The Task Force sponsored 18 public outreach events in 13 countries, and Task Force members presented the recommendations at 91 other events including conferences, forums, and meetings sponsored by industry associations, NGOs, government agencies, corporations, and other organizations. The 18 Task Force-sponsored events informed stakeholders of the Task Force's work and recommendations and included panel discussions and keynote speeches by prominent climate-risk and financial experts. Attendees included representatives of financial and non-financial organizations who spanned a variety of corporate functions, including strategy, risk, accounting, portfolio and investment management, corporate sustainability, as well as representatives from industry associations, NGOs, government agencies, research providers, academia, accounting and consulting firms, and media.

Webinars

Prior to the release of the report in December 2016 for public consultation, the Task Force offered seven webinars to educate and increase awareness of the Task Force's efforts as well as to collect additional feedback. Of the seven webinars, the Task Force hosted four webinars and participated in three additional webinars by partnering with the following organizations: Business for Social Responsibility, Global Financial Markets Association, and the National Association of Corporate Directors. These webinars served to supplement the in-person outreach events and offered global stakeholders, regardless of location, an opportunity to engage with the Task Force. The webinars included 538 attendees representing 365 organizations across 23 countries. After the release of the report, the Task Force held three webinars to present its recommendations and to solicit additional feedback. The three webinars included 255 attendees representing 209 organizations across 25 countries. In total, the Task Force offered ten webinars, reaching 793 attendees across 30 countries.

Appendix 3: Fundamental Principles for Effective Disclosure

To underpin its recommendations and help guide current and future developments in climate-related financial reporting, the Task Force developed a set of principles for effective disclosure.[63] As understanding of, and approaches to, climate-related issues evolve over time, so too will climate-related financial reporting. These principles can help achieve high-quality and decision-useful disclosures that enable users to understand the impact of climate change on organizations. The Task Force encourages organizations adopting its recommendations to consider these principles as they develop climate-related financial disclosures.

The Task Force's disclosure principles are largely consistent with other mainstream, internationally accepted frameworks for financial reporting and are generally applicable to most providers of financial disclosures. They are informed by the qualitative and quantitative characteristics of financial information and further the overall goals of producing disclosures that are consistent, comparable, reliable, clear, and efficient, as highlighted by the FSB in establishing the Task Force. The principles, taken together, are designed to assist organizations in making clear the linkages and connections between climate-related issues and their governance, strategy, risk management, and metrics and targets.

Principle 1: Disclosures should present relevant information

The organization should provide information specific to the potential impact of climate-related risks and opportunities on its markets, businesses, corporate or investment strategy, financial statements, and future cash flows.

- Disclosures should be eliminated if they are immaterial or redundant to avoid obscuring relevant information. However, when a particular risk or issue attracts investor and market interest or attention, it may be helpful for the organization to include a statement that the risk or issue is not significant. This shows that the risk or issue has been considered and has not been overlooked.
- Disclosures should be presented in sufficient detail to enable users to assess the organization's exposure and approach to addressing climate-related issues, while understanding that the type of information, the way in which it is presented, and the accompanying notes will differ between organizations and will be subject to change over time.
- Climate-related impacts can occur over the short, medium, and long term. Organizations can experience chronic, gradual impacts (such as impacts due to shifting temperature patterns), as well as acute, abrupt disruptive impacts (such as impacts from flooding, drought, or sudden regulatory actions). An organization should provide information from the perspective of the potential impact of climate-related issues on value creation, taking into account and addressing the different time frames and types of impacts.
- Organizations should avoid generic or boilerplate disclosures that do not add value to users' understanding of issues. Furthermore, any proposed metrics should adequately describe or serve as a proxy for risk or performance and reflect how an organization manages the risk and opportunities.

[63] These principles are adapted from those included in the Enhanced Disclosure Task Force's "Enhancing the Risk Disclosures of Banks."

Principle 2: Disclosures should be specific and complete

- An organization's reporting should provide a thorough overview of its exposure to potential climate-related impacts; the potential nature and size of such impacts; the organization's governance, strategy, processes for managing climate-related risks, and performance with respect to managing climate-related risks and opportunities.
- To be sufficiently comprehensive, disclosures should contain historical and future-oriented information in order to allow users to evaluate their previous expectations relative to actual performance and assess possible future financial implications.
- For quantitative information, the disclosure should include an explanation of the definition and scope applied. For future-oriented data, this includes clarification of the key assumptions used. Forward-looking quantitative disclosure should align with data used by the organization for investment decision making and risk management.
- Any scenario analyses should be based on data or other information used by the organization for investment decision making and risk management. Where appropriate, the organization should also demonstrate the effect on selected risk metrics or exposures to changes in the key underlying methodologies and assumptions, both in qualitative and quantitative terms.

Principle 3: Disclosures should be clear, balanced, and understandable

- Disclosures should be written with the objective of communicating financial information that serves the needs of a range of financial sector users (e.g., investors, lenders, insurers, and others). This requires reporting at a level beyond compliance with minimum requirements. The disclosures should be sufficiently granular to inform sophisticated users, but should also provide concise information for those who are less specialized. Clear communication will allow users to identify key information efficiently.
- Disclosures should show an appropriate balance between qualitative and quantitative information and use text, numbers, and graphical presentations as appropriate.
- Fair and balanced narrative explanations should provide insight into the meaning of quantitative disclosures, including the changes or developments they portray over time. Furthermore, balanced narrative explanations require that risks as well as opportunities be portrayed in a manner that is free from bias.
- Disclosures should provide straightforward explanations of issues. Terms used in the disclosures should be explained or defined for a proper understanding by the users.

Principle 4: Disclosures should be consistent over time

- Disclosures should be consistent over time to enable users to understand the development and/or evolution of the impact of climate-related issues on the organization's business. Disclosures should be presented using consistent formats, language, and metrics from period to period to allow for inter-period comparisons. Presenting comparative information is preferred; however, in some situations it may be preferable to include a new disclosure even if comparative information cannot be prepared or restated.
- Changes in disclosures and related approaches or formats (e.g., due to shifting climate-related issues and evolution of risk practices, governance, measurement methodologies, or accounting practices) can be expected due to the relative immaturity of climate-related disclosures. Any such changes should be explained.

Principle 5: Disclosures should be comparable among organizations within a sector, industry, or portfolio

- Disclosures should allow for meaningful comparisons of strategy, business activities, risks, and performance across organizations and within sectors and jurisdictions.
- The level of detail provided in disclosures should enable comparison and benchmarking of risks across sectors and at the portfolio level, where appropriate.
- The placement of reporting would ideally be consistent across organizations—i.e., in financial filings—in order to facilitate easy access to the relevant information.

Principle 6: Disclosures should be reliable, verifiable, and objective

- Disclosures should provide high-quality reliable information. They should be accurate and neutral—i.e., free from bias.
- Future-oriented disclosures will inherently involve the organization's judgment (which should be adequately explained). To the extent possible, disclosures should be based on objective data and use best-in-class measurement methodologies, which would include common industry practice as it evolves.
- Disclosures should be defined, collected, recorded, and analyzed in such a way that the information reported is verifiable to ensure it is high quality. For future-oriented information, this means assumptions used can be traced back to their sources. This does not imply a requirement for independent external assurance; however, disclosures should be subject to internal governance processes that are the same or substantially similar to those used for financial reporting.

Principle 7: Disclosures should be provided on a timely basis

- Information should be delivered to users or updated in a timely manner using appropriate media on, at least, an annual basis within the mainstream financial report.
- Climate-related risks can result in disruptive events. In case of such events with a material financial impact, the organization should provide a timely update of climate-related disclosures as appropriate.

Reporters may encounter tension in the application of the fundamental principles set out above. For example, an organization may update a methodology to meet the comparability principle, which could then result in a conflict with the principle of consistency. Tension can also arise within a single principle. For example, Principle 6 states that disclosures should be verifiable, but assumptions made about future-oriented disclosures often require significant judgment by management that is difficult to verify. Such tensions are inevitable given the wide-ranging and sometimes competing needs of users and preparers of disclosures. Organizations should aim to find an appropriate balance of disclosures that reasonably satisfy the recommendations and principles while avoiding overwhelming users with unnecessary information.

Appendix 4: Select Disclosure Frameworks

To the extent there is corporate reporting of climate-related issues, it happens through a multitude of mandatory and voluntary schemes. Although a complete and comprehensive survey of existing schemes is beyond the scope of this report, the Task Force on Climate-related Financial Disclosures (TCFD or Task Force) considered a broad range of existing frameworks, both voluntary and mandatory. The tables in Appendix 4 outline select disclosure frameworks considered by the Task Force and describe a few key characteristics of each framework, including whether disclosures are mandatory or voluntary, what type of information is reported, who the target reporters and target audiences are, where the disclosed information is placed, and whether there are specified materiality standards.[64] These disclosure frameworks were chosen to illustrate the broad range of disclosure regimes around the world; the tables are broken out into disclosure frameworks sponsored by governments, stock exchanges, and non-governmental organizations (NGOs).

The information presented in the tables below (A4.1, A4.2, and A4.3) is based on information released by governments, stock exchanges, and standard setters and is supplemented by the United Nations Environment Programme (UNEP), "The Financial System We Need: Aligning the Financial System with Sustainable Development," October 2015, and the Organization for Economic Co-operation and Development (OECD), "Report to G20 Finance Ministers and Central Bank Governors," September 2015.

[64] These tables were originally included in the Task Force's Phase I Report and have been updated where appropriate.

Table A4.1

Select Disclosure Frameworks: Governments

Region: Framework	Target Reporter	Target Audience	Mandatory or Voluntary	Materiality Standard	Types of Climate-Related Information	Disclosure Location	External Assurance Required
Australia: National Greenhouse and Energy Reporting Act (2007)	Financial and non-financial firms that meet emissions or energy production or consumption thresholds	General public	Mandatory if thresholds are met	Based on emissions above a certain threshold	GHG emissions, energy consumption, and energy production	Report to government	Regulator may, by written notice to corporation, require an audit of its disclosures
European Union (EU): EU Directive 2014/95 regarding disclosure of non-financial and diversity information (2014)	Financial and non-financial firms that meet size criteria (i.e., have more than 500 employees)	Investors, consumers, and other stakeholders	Mandatory; applicable for the financial year starting on Jan. 1, 2017 or during the 2017 calendar year	None specified	Land use, water use, GHG emissions, use of materials, and energy use	Corporate financial report or separate report (published with financial report or on website six months after the balance sheet date and referenced in financial report)	Member States must require that statutory auditor checks whether the non-financial statement has been provided Member States may require independent assurance for information in non-financial statement
France: Article 173, Energy Transition Law (2015)	Listed financial and non-financial firms Additional requirements for institutional investors	Investors, general public	Mandatory	None specified	Risks related to climate change, consequences of climate change on the company's activities and use of goods and services it produces. Institutional investors: GHG emissions and contribution to goal of limiting global warming	Annual report and website	Mandatory review on the consistency of the disclosure by an independent third party, such as a statutory auditor
India: National Voluntary Guidelines on Social, Environmental, and Economic Responsibilities of Business (2011)	Financial and non-financial firms	Investors, general public	Voluntary	None specified	Significant risk, goals and targets for improving performance, materials, energy consumption, water, discharge of effluents, GHG emissions, and biodiversity	Not specified; companies may furnish a report or letter from owner/chief executive officer	Guidelines include third-party assurance as a "leadership indicator" of company's progress in implementing the principles

Table A4.1

Select Disclosure Frameworks: Governments *(continued)*

Region: Framework	Target Reporter	Target Audience	Mandatory or Voluntary	Materiality Standard	Types of Climate-Related Information	Disclosure Location	External Assurance Required
United Kingdom: Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013	Financial and non-financial firms that are "Quoted Companies," as defined by the Companies Act 2006	Investors / shareholders ("members of the company")	Mandatory	Information is material if its omission or misrepresentation could influence the economic decisions shareholders take on the basis of the annual report as a whole (section 5 of the UK FRC June 2014 Guidance on the Strategic Report)	The main trends and factors likely to affect the future development, performance, and position of the company's business, environmental matters (including the impact of the company's business on the environment), and GHG emissions	Strategic Report and Directors' Report	Not required, but statutory auditor must state in report on the company's annual accounts whether in the auditor's opinion the information given in the Strategic Report and the Directors' Report for the financial year for which the accounts are prepared is consistent with those accounts
United States: NAICs, 2010 Insurer Climate Risk Disclosure Survey	Insurers meeting certain premium thresholds - $100M in 2015	Regulators	Mandatory if thresholds are met	None specified	General disclosures about climate change-related risk management and investment management	Survey sent to state regulators	Not specified
United States: SEC Guidance Regarding Disclosure Related to Climate Change	Financial and non-financial firms subject to Securities and Exchange Commission (SEC) reporting requirements	Investors	Mandatory	US securities law definition	Climate-related material risks and factors that can affect or have affected the company's financial condition, such as regulations, treaties and agreements, business trends, and physical impacts	Annual and other reports required to be filed with SEC	Depends on assurance requirements for information disclosed

Table A4.2

Select Disclosure Frameworks: Exchange Listing Requirements and Indices

Region: Framework	Target Reporter	Target Audience	Mandatory or Voluntary	Materiality Standard	Types of Climate-Related Information	Disclosure Location	External Assurance Required
Australia: Australia Securities Exchange Listing Requirement 4.10.3; Corporate Governance Principles and Recommendations (2014)	Listed financial and non-financial firms	Investors	Mandatory (comply or explain)	A real possibility that the risk in question could substantively impact the listed entity's ability to create or preserve value for security holders over the short, medium or long term	General disclosure of material environmental risks	Annual report must include either the corporate governance statement or company website link to the corporate governance statement on company's website	Not specified, may depend on assurance requirements for annual report
Brazil: Stock Exchange (BM&FBovespa) Recommendation of report or explain (2012)	Listed financial and non-financial firms	Investors, regulator	Voluntary (comply or explain)	Criteria explained in Reference Form (Annex 24) of the Instruction CVM nº 480/09	Social and environmental information including methodology used, if audited/reviewed by an independent entity, and link to information (i.e., webpage)	Discretion of company	Not specified
China: Shenzhen Stock Exchange Social Responsibility Instructions to Listed Companies (2006)	Listed financial and non-financial firms	Investors	Voluntary: social responsibilities Mandatory: pollutant discharge	None specified	Waste generation, resource consumption, and pollutants	Not specified	Not specified; companies shall allocate dedicated human resources for regular inspection of implementation of environmental protection policies
Singapore: Singapore Exchange Listing Rules 711A & 711B and Sustainability Reporting Guide (2016) ("Guide")	Listed financial and non-financial firms	Investors	Mandatory (comply or explain)	Guidance provided in the Guide, paragraphs 4.7-4.11	Material environmental, social, and governance factors, performance, targets, and related information specified in the Guide	Annual report or standalone report, disclosed through SGXNet reporting platform and company website	Not required

Table A4.2

Select Disclosure Frameworks: Exchange Listing Requirements and Indices *(continued)*

Region: Framework	Target Reporter	Target Audience	Mandatory or Voluntary	Materiality Standard	Types of Climate-Related Information	Disclosure Location	External Assurance Required
South Africa: Johannesburg Stock Exchange Listing Requirement Paragraph 8.63; King Code of Governance Principles (2009)	Listed financial and non-financial firms	Investors	Mandatory; (comply or explain)	None specified	General disclosure regarding sustainability performance	Annual report	Required
World, regional, and country-specific indices: S&P Dow Jones Indices Sustainability Index, Sample Questionnaires	Financial and non-financial firms	Investors	Voluntary	None specified	GHG emissions, SOx emissions, energy consumption, water, waste generation, environmental violations, electricity purchased, biodiversity, and mineral waste management	Nonpublic	Disclose whether external assurance was provided and whether it was pursuant to a recognized standard

Table A4.3

Select Disclosure Frameworks: Non-Governmental Organizations

Click for November 2018 Update

Framework	Target Reporter	Target Audience	Mandatory or Voluntary	Materiality Standard	Types of Climate-Related Information	Disclosure Location	External Assurance Required
Global: Asset Owners Disclosure Project 2017 Global Climate Risk Survey	Pension funds, insurers, sovereign wealth funds ≥$2bn AUM	Asset managers, investment industry, government	Voluntary	None specified	Information on whether climate change issues are integrated in investment policies, engagement efforts, portfolio emissions intensity for scope 1 emissions, climate change-related portfolio risk mitigation actions	Survey responses; respondents are asked whether responses may be made public	Disclose whether external assurance was provided
Global: CDP Annual Questionnaire (2016)	Financial and non-financial firms	Investors	Voluntary	None specified	Information on risk management procedures related to climate change risks and opportunities, energy use, and GHG emissions (Scope 1-3)	CDP database	Encouraged; information requested about verification and third party certification
Global: CDSB CDSB Framework for Reporting Environmental Information & Natural Capital	Financial and non-financial firms	Investors	Voluntary	Environmental information is material if (1) the environmental impacts or results it describes are, due to their size and nature, expected to have a significant positive or negative effect on the organization's current, past or future financial condition and operational results and its ability to execute its strategy or (2) omitting, misstating, or mis-interpreting it could influence decisions that users of mainstream reports make about the organization	Environmental policies, strategy, and targets, including the indicators, plans, and timelines used to assess performance; material environmental risks and opportunities affecting the organization; governance of environmental policies, strategy, and information; and quantitative and qualitative results on material sources of environmental impact	Annual reporting packages in which organizations are required to deliver their audited financial results under the corporate, compliance or securities laws of the country in which they operate	Not required, but disclose if assurance has been provided over whether reported environmental information is in conformance with the CDSB Framework

Table A4.3

Select Disclosure Frameworks: Non-Governmental Organizations *(continued)*

Click for November 2018 Update

Framework	Target Reporter	Target Audience	Mandatory or Voluntary	Materiality Standard	Types of Climate-Related Information	Disclosure Location	External Assurance Required
Global: CDSB Climate Change Reporting Framework, Ed. 1.1 (2012)	Financial and non-financial firms	Investors	Voluntary	Allow "investors to see major trends and significant events related to climate change that affect or have the potential to affect the company's financial condition and/or its ability to achieve its strategy"	The extent to which performance is affected by climate-related risks and opportunities; governance processes for addressing those effects; exposure to significant climate-related issues; strategy or plan to address the issues; and GHG emissions	Annual reporting packages in which organizations are required to deliver their audited financial results under the corporate, compliance or securities laws of the territory or territories in which they operate	Not required unless International Standards on Auditing 720 requires the auditor of financial statements to read information accompanying them to identify material inconsistencies between the audited financial statements and accompanying information
Global: GRESB Infrastructure Asset Assessment & Real Estate Assessment	Real estate asset/portfolio owners	Investors and industry stakeholders	Voluntary	None specified	Real estate sector-specific requirements related to fuel, energy, and water consumption and efficiencies as well as low-carbon products	Data collected through the GRESB Real Estate Assessment disclosed to participants themselves and: • for non-listed property funds and companies, to those of that company or fund's investors that are GRESB Investor Members; • for listed real estate companies, to all GRESB Investor Members that invest in listed real estate securities.	Not required, but disclose whether external assurance was provided
Global: GRI Sustainability Reporting Standards (2016)	Organizations of any size, type, sector, or geographic location	All stakeholders	Voluntary	Topics that reflect the reporting organization's significant economic, environmental, and social impacts or substantively influence the decisions of stakeholders	Materials, energy, water, biodiversity, emissions, effluents and waste, environmental compliance, and supplier environmental assessment	Stand-alone sustainability reports or annual reports or other published materials that include sustainability information	Not required, but advised

Table A4.3

Select Disclosure Frameworks: Non-Governmental Organizations *(continued)*

Click for November 2018 Update

Framework	Target Reporter	Target Audience	Mandatory or Voluntary	Materiality Standard	Types of Climate-Related Information	Disclosure Location	External Assurance Required
Global: IIGCC Oil & Gas (2010)	Oil and gas industries	Investors	Voluntary	None specified	GHG emissions and clean technologies data	Not specified	Not specified
Automotive (2009)	Automotive industry	Investors	Voluntary	None specified	GHG emissions and clean technologies data	Company's discretion	Not specified
Electric Utilities (2008)	Electrical utilities	Investors	Voluntary	None specified	GHG emissions and electricity production	Company's discretion	Disclose how GHG emissions information was verified
Global: IIRC International Integrated Reporting Framework (2013)	Public companies traded on international exchanges	Investors	Voluntary	Substantively affect the company's ability to create value over the short, medium, and long term	General challenges related to climate change, loss of ecosystems, and resource shortages	Standalone sustainability or integrated report	Not specified; discussion paper released on issues relating to assurance
Global: IPIECA Oil and gas industry guidance on voluntary sustainability reporting	Oil and gas industries	All stakeholders	Voluntary	Material sustainability issues are those that, in the view of company management and its external stakeholders, affect the company's performance or strategy and/or assessments or decisions about the company	Energy consumption	Sustainability reporting	Not required, but encouraged
Global: PRI Reporting Framework (2016)	Investors	Investors	Voluntary	None specified	Investor practices	Transparency report	Not specified
United States: SASB Conceptual Framework (2013) and SASB Standards (Various)	Public companies traded on US exchanges	Investors	Voluntary	A substantial likelihood that the disclosure of the omitted fact would have been viewed by the reasonable investor as having significantly altered the "total mix" of the information made available	Information on sustainability topics that are deemed material, standardized metrics tailored by industry	SEC filings	Depends on assurance requirements for information disclosed

Appendix 5: Glossary and Abbreviations

Glossary

BOARD OF DIRECTORS (or BOARD) refers to a body of elected or appointed members who jointly oversee the activities of a company or organization. Some countries use a two-tiered system where "board" refers to the "supervisory board" while "key executives" refers to the "management board."[65]

CLIMATE-RELATED OPPORTUNITY refers to the potential positive impacts related to climate change on an organization. Efforts to mitigate and adapt to climate change can produce opportunities for organizations, such as through resource efficiency and cost savings, the adoption and utilization of low-emission energy sources, the development of new products and services, and building resilience along the supply chain. Climate-related opportunities will vary depending on the region, market, and industry in which an organization operates.

CLIMATE-RELATED RISK refers to the potential negative impacts of climate change on an organization. Physical risks emanating from climate change can be event-driven (acute) such as increased severity of extreme weather events (e.g., cyclones, droughts, floods, and fires). They can also relate to longer-term shifts (chronic) in precipitation and temperature and increased variability in weather patterns (e.g., sea level rise). Climate-related risks can also be associated with the transition to a lower-carbon global economy, the most common of which relate to policy and legal actions, technology changes, market responses, and reputational considerations.

FINANCIAL FILINGS refer to the annual reporting packages in which organizations are required to deliver their audited financial results under the corporate, compliance, or securities laws of the jurisdictions in which they operate. While reporting requirements differ internationally, financial filings generally contain financial statements and other information such as governance statements and management commentary.[66]

FINANCIAL PLANNING refers to an organization's consideration of how it will achieve and fund its objectives and strategic goals. The process of financial planning allows organizations to assess future financial positions and determine how resources can be utilized in pursuit of short- and long-term objectives. As part of financial planning, organizations often create "financial plans" that outline the specific actions, assets, and resources (including capital) necessary to achieve these objectives over a 1-5 year period. However, financial planning is broader than the development of a financial plan as it includes long-term capital allocation and other considerations that may extend beyond the typical 3-5 year financial plan (e.g., investment, research and development, manufacturing, and markets).

GOVERNANCE refers to "the system by which an organization is directed and controlled in the interests of shareholders and other stakeholders."[67] "Governance involves a set of relationships between an organization's management, its board, its shareholders, and other stakeholders. Governance provides the structure and processes through which the objectives of the organization are set, progress against performance is monitored, and results are evaluated."[68]

[65] OECD, *G20/OECD Principles of Corporate Governance,* OECD Publishing, Paris, 2015.
[66] Based on Climate Disclosure Standards Board, "CDSB Framework for Reporting Environmental Information and Natural Capital," June 2015.
[67] A. Cadbury, *Report of the Committee on the Financial Aspects of Corporate Governance*, London, 1992.
[68] OECD, *G20/OECD Principles of Corporate Governance*, OECD Publishing, Paris, 2015.

GREENHOUSE GAS (GHG) EMISSIONS SCOPE LEVELS[69]

- **Scope 1** refers to all direct GHG emissions.
- **Scope 2** refers to indirect GHG emissions from consumption of purchased electricity, heat, or steam.
- **Scope 3** refers to other indirect emissions not covered in Scope 2 that occur in the value chain of the reporting company, including both upstream and downstream emissions. Scope 3 emissions could include: the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g., transmission and distribution losses), outsourced activities, and waste disposal. [70]

INTERNAL CARBON PRICE is an internally developed estimated cost of carbon emissions. Internal carbon pricing can be used as a planning tool to help identify revenue opportunities and risks, as an incentive to drive energy efficiencies to reduce costs, and to guide capital investment decisions.

MANAGEMENT refers to those positions an organization views as executive or senior management positions and that are generally separate from the board.

NATIONALLY DETERMINED CONTRIBUTION (NDC) refers to the post-2020 actions that a country intends to take under the international climate agreement adopted in Paris.

ORGANIZATION refers to the group, company, or companies, and other entities for which consolidated financial statements are prepared, including subsidiaries and jointly controlled entities.

PUBLICLY AVAILABLE 2°C SCENARIO refers to a 2°C scenario that is (1) used/referenced and issued by an independent body; (2) wherever possible, supported by publicly available datasets; (3) updated on a regular basis; and (4) linked to functional tools (e.g., visualizers, calculators, and mapping tools) that can be applied by organizations. 2°C scenarios that presently meet these criteria include: IEA 2DS, IEA 450, Deep Decarbonization Pathways Project, and International Renewable Energy Agency.

RISK MANAGEMENT refers to a set of processes that are carried out by an organization's board and management to support the achievement of the organization's objectives by addressing its risks and managing the combined potential impact of those risks.

SCENARIO ANALYSIS is a process for identifying and assessing a potential range of outcomes of future events under conditions of uncertainty. In the case of climate change, for example, scenarios allow an organization to explore and develop an understanding of how the physical and transition risks of climate change may impact its businesses, strategies, and financial performance over time.

SECTOR refers to a segment of organizations performing similar business activities in an economy. A sector generally refers to a large segment of the economy or grouping of business types, while "industry" is used to describe more specific groupings of organizations within a sector.

STRATEGY refers to an organization's desired future state. An organization's strategy establishes a foundation against which it can monitor and measure its progress in reaching that desired state. Strategy formulation generally involves establishing the purpose and scope of the

[69] World Resources Institute and World Business Council for Sustainable Development, *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (Revised Edition),* March 2004.
[70] IPCC, *Climate Change 2014 Mitigation of Climate Change,* Cambridge University Press, 2014.

organization's activities and the nature of its businesses, taking into account the risks and opportunities it faces and the environment in which it operates.

SUSTAINABILITY REPORT is an organizational report that gives information about economic, environmental, social, and governance performance and impacts. For companies and organizations, sustainability —the ability to be long-lasting or permanent—is based on performance and impacts in these four key areas.

VALUE CHAIN refers to the upstream and downstream life cycle of a product, process, or service, including material sourcing, production, consumption, and disposal/recycling. Upstream activities include operations that relate to the initial stages of producing a good or service (e.g., material sourcing, material processing, supplier activities). Downstream activities include operations that relate to processing the materials into a finished product and delivering it to the end user (e.g., transportation, distribution, and consumption).

Abbreviations

2°C —2° Celsius

ASC—Accounting Standards Codification

BNEF—Bloomberg New Energy Finance

CDSB—Climate Disclosure Standards Board

ERM—Environmental Resources Management

EU—European Union

FASB—Financial Accounting Standards Board

FSB—Financial Stability Board

G20—Group of 20

GHG—Greenhouse gas

GICS—Global Industry Classification Standard

GRI—Global Reporting Initiative

IAS—International Accounting Standard

IASB—International Accounting Standards Board

IEA—International Energy Agency

IIGCC—Institutional Investors Group on Climate Change

IIRC—International Integrated Reporting Council

IPCC—Intergovernmental Panel on Climate Change

NGO—Non-governmental organization

OECD—Organization for Economic Co-operation and Development

R&D—Research and development

SASB—Sustainability Accounting Standards Board

TCFD—Task Force on Climate-related Financial Disclosures

UN—United Nations

UNEP—United Nations Environment Programme

USDE—U.S. Dollar Equivalent

WRI—World Resources Institute

Appendix 6: References

"Communiqué from the G20 Finance Ministers and Central Bank Governors Meeting in Washington, D.C. April 16-17, 2015." April 2015. www.g20.org.tr/wp-content/uploads/2015/04/April-G20-FMCBG-Communique-Final.pdf.

Cadbury, A. *Report of the Committee on the Financial Aspects of Corporate Governance.* London, 1992. www.ecgi.org/codes/documents/cadbury.pdf.

Carney, Mark. "Breaking the tragedy of the horizon—climate change and financial stability." September 29, 2015. www.bankofengland.co.uk/publications/Pages/speeches/2015/844.aspx.

Ceres. "Power Forward 3.0: How the largest US companies are capturing business value while addressing climate change." 2017. https://www.worldwildlife.org/publications/power-forward-3-0-how-the-largest-us-companies-are-capturing-business-value-while-addressing-climate-change.

Climate Disclosure Standards Board (CDSB). "CDSB Framework for Reporting Environmental Information and Natural Capital." June 2015. www.cdsb.net/sites/cdsbnet/files/cdsb_framework_for_reporting_environmental_information_natural_capital.pdf.

Economist Intelligence Unit. "The Cost of Inaction: Recognising the Value at Risk from Climate Change." 2015. https://www.eiuperspectives.economist.com/sustainability/cost-inaction.

Enhanced Disclosure Task Force. *Enhancing the Risk Disclosures of Banks.* October 2012. www.fsb.org/wp-content/uploads/r_121029.pdf.

Environmental Protection Agency Victoria (EPA Victoria). "Resource Efficiency Case Studies, Lower your impact." www.epa.vic.gov.au/business-and-industry/lower-your-impact/resource-efficiency/case-studies.

Fellow, Avery. "Investors Demand Climate Risk Disclosure." *Bloomberg,* February 2013. www.bloomberg.com/news/2013-02-25/investors-demand-climate-risk-disclosure-in-2013-proxies.html.

Frankfurt School-United Nations Environmental Programme Centre and Bloomberg New Energy Finance. "Global Trends in Renewable Energy Investment 2017." 2017. fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2017.pdf.

Fricko, Oliver et. al. *Energy sector water use implications of a 2° C climate policy.* Environmental Research Letters, 11: 1-10, 2016. www.cd-links.org/wp-content/uploads/2016/06/Fricko-et-al-2016.pdf.

FSB. "FSB to establish Task Force on Climate-related Financial Disclosures." December 4, 2015. www.fsb-tcfd.org/wp-content/uploads/2016/01/12-4-2015-Climate-change-task-force-press-release.pdf.

FSB. "Proposal for a Disclosure Task Force on Climate-Related Risks." November 9, 2015. www.fsb.org/wp-content/uploads/Disclosure-task-force-on-climate-related-risks.pdf.

G20 Green Finance Study Group. *G20 Green Finance Synthesis Report.* 2016. unepinquiry.org/wp-content/uploads/2016/09/Synthesis_Report_Full_EN.pdf.

Ganci, N., S. Hammer, T. Reilly, and P. Rodel. *Environmental and Climate Change Disclosure under the Securities Laws: A Multijurisdictional Survey.* Debevoise & Plimpton, March 2016. www.debevoise.com/insights/publications/2016/03/environmental-and-climate-change-disclosure.

Greenhouse Gas Protocol. "Calculation Tools, FAQ." ghgprotocol.org/calculationg-tools-faq.

Intergovernmental Panel on Climate Change (IPCC). *Fifth Assessment Report (AR5),* Cambridge University Press, 2014. http://www.ipcc.ch/report/ar5/.

IPCC. *Climate Change 2014 Mitigation of Climate Change.* Cambridge University Press, 2014.

International Energy Agency (IEA). "Global energy investment down 8% in 2015 with flows signaling move towards cleaner energy." September 14, 2016. www.iea.org/newsroom/news/2016/september/global-energy-investment-down-8-in-2015-with-flows-signalling-move-towards-clean.html.

IEA. *World Energy Outlook Special Briefing for COP21*. 2015. www.iea.org/media/news/WEO_INDC_Paper_Final_WEB.PDF.

Maack, J. *Scenario Analysis: A Tool for Task Managers.* Social Analysis: selected tools and techniques, Social Development Papers, Number 36, the World Bank, June 2001, Washington, DC. siteresources.worldbank.org/INTPSIA/Resources/ 490023-1121114603600/13053_scenarioanalysis.pdf.

Mercer LLC. *Investing in a Time of Climate Change.* 2015. www.mercer.com/our-thinking/investing-in-a-time-of-climate-change.html.

Organization for Economic Co-operation and Development (OECD) and Climate Disclosure Standards Board (CDSB). *Climate Change Disclosure in G20 Countries: Stocktaking of Corporate Reporting Schemes.* November 18, 2015. www.oecd.org/investment/corporate-climate-change-disclosure-report.htm.

OECD. *G20/OECD Principles of Corporate Governance*. OECD Publishing, Paris, 2015. dx.doi.org/10.1787/9789264236882-en.

Pearce, David W. and R. Kerry Turner. "Economics of Natural Resources and the Environment." Johns Hopkins University Press. 1989. ISBN 978-0801839870.

Rounsevell, Mark D. A. and Marc J Metzger. *Developing qualitative scenario storylines for environmental change assessment.* WIREs Climate Change 2010, 1: 606-619. doi: 10.1002/wcc.63, 2010. wires.wiley.com/WileyCDA/WiresArticle/wisId-WCC63.html.

Seley, Peter. "Emerging Trends in Climate Change Litigation." *Law 360.* March 7, 2016. www.law360.com/articles/766214/emerging-trends-in-climate-change-litigation.

Sustainability Accounting Standards Board (SASB). *SASB Climate Risk Technical Bulletin#: TB001-10182016.* October, 2016. library.sasb.org/climate-risk-technical-bulletin.

Task Force on Climate-related Financial Disclosures. *Phase I Report of the Task Force on Climate-related Financial Disclosures.* March 31, 2016. www.fsb-tcfd.org/wp-content/uploads/2016/03/Phase_I_Report_v15.pdf.

United Nations Environment Programme (UNEP). *The Financial System We Need: Aligning the Financial System with Sustainable Development.* 2015. http://unepinquiry.org/wp-content/uploads/2015/11/The_Financial_System_We_Need_EN.pdf.

UNEP and Copenhagen Centre for Energy Efficiency. *Best Practices and Case Studies for Industrial Energy Efficiency Improvement.* February 16, 2016. www.energyefficiencycentre.org/Nyheder/Nyhed?id=b2bedb2b-05a3-444f-ae5e-55ee3c8f1a68.

United Nations Framework Convention on Climate Change. "The Paris Agreement," December 2015. unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf.

World Business Council for Sustainable Development. "Sustainability and enterprise risk management: The first step towards integration." January 18, 2017. www.wbcsd.org/contentwbc/download/2548/31131.

World Resources Institute and World Business Council for Sustainable Development. *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard,* (Revised Edition). March 2004. www.ghgprotocol.org/standards/corporate-standard.

Annex 590

“Climate change and insurance – How boards can respond to emerging supervisory expectations”, *Deloitte*, 2020

Deloitte.

CENTRE *for*
REGULATORY
STRATEGY
EMEA

Climate change and insurance

How boards can respond to emerging supervisory expectations

Contents

1. Foreword – who is this report for, and what does it set out to do?

Climate change is a key concern across all sectors of the economy. Financial services regulators worldwide are moving to ensure that banks, insurers and asset managers identify risk exposures from climate change and establish strategies and adjust business models to manage them.

Insurers, with their often longer term time horizons, hold a unique position in the climate change debate because, unlike any other sector, climate change risk affects both the asset and liability sides of the insurance balance sheet. Moreover, insurers have amassed decades' of expertise in extreme risk pooling and management. Insurers are, therefore, simultaneously both more exposed to financial risks from climate change than many other financial institutions, and uniquely positioned to manage and mitigate the catastrophic effects that climate change could have on the economy and society.

Regulators will expect insurance Boards to pose robust challenge and provide effective oversight of climate change risks, drawing on external expertise, but guarding against over-reliance on it. Accordingly, this report analyses regulatory climate change expectations in the areas of risk identification and risk appetite, strategy and business model, capital modelling and stress testing, asset transition risk, governance and culture and conduct. It explores, at a practical and non-technical level, the various ways in which climate change risk may affect life and non-life insurers, and how, in that light, regulators expect Board members, in particular non-executive directors (NEDs), to challenge and oversee their firm's identification and management of climate change risk.

The report provides example challenge questions in each of these areas, and examples of positive and negative indicators that we think regulators are likely to use in assessing whether an insurer is responding adequately to its climate change risk profile.

This report's intention is to help insurers step up to this leadership role, in a manner that meets regulatory expectations.

This report is specifically targeted at insurance company boards, recognising the profound challenges they face in both meeting developing regulatory expectations and mitigating and responding to rapidly developing climate change risks.

2. Executive summary

Despite being some of the biggest investors in the economy with deep expertise in risk pooling, many insurers still have some way to go in getting to grips with how climate change will affect their business models in the medium to long term. This makes it all the more important that insurance Boards challenge their firms comprehensively on climate change risk, particularly in the areas we discuss in this report.

Climate change risk is present in all core insurance company functions. As these risks could crystallise suddenly, unpredictably, and in a non-linear fashion, it is vital that insurers are clear on their exposures and manage these appropriately. This is particularly important given the increasing focus on firms' accountability, transparency and disclosure when it comes to climate change risks. Individual executives and members of senior management will be held accountable if these are not appropriately managed.

There is a clear risk that asset and liability risks are managed in silos, creating "cognitive dissonance" or even conflicts of interest as well as inconsistent risk management strategies and approaches. *(A recent striking example of this "silo" challenge is pandemic risk which, in our experience, has featured in many firms' ORSA analyses but in relatively few business continuity plans.)*

The insurance industry is heavily reliant on external expertise and data in understanding and predicting potential future paths of climate change risk factors. This reliance is particularly marked in the area of climate change modelling but extends to other areas such as climate change stress testing and sustainable investment management. This reliance accentuates the risk of group-think and "herding" in firms' approach to climate change risk management and is therefore an issue on which firms' governance, and in particular NED challenge, should be strongly focussed.

Insurers are exposed to reputational risks and opportunities in how they respond and contribute to the climate change debate. Insurers are strongly positioned to influence the pace and nature of the transition to a low-carbon economy and take advantage of the commercial opportunities from climate change, through products, risk pooling expertise, investment, shareholder governance and proactive fair treatment of consumers, including for example through the appropriate disclosure of climate change risk and the offering of green products.

The fact that the regulatory framework is still developing should not stop insurers developing medium- to long-term strategies fit for their unique exposures and business models. Regulators will be wary of stoking bubbles or triggering transition risks through their policies, regulations and practical supervisory approach. But they are already actively looking for evidence of how the industry is adapting and responding to climate change risks and will factor that into their overall risk assessments of firms' governance and culture.

3. Summary of key findings

Section	Key findings	
Risk identification and risk appetite	Insurers have potentially large unknown asset and liability exposures.	Supervisors will focus on key areas of uncertainty including scope and coverage (for liability business in particular), second-order effects of physical risks and perils, and the effect of physical risks on investment risk.
	Once exposures have been determined, supervisors will look to insurers' risk appetites.	Supervisors will look at how insurers set climate risk appetite and capital allocation, as a key indicator that climate change risk exposures are measured and managed in line with the insurer's business strategy and risk appetite.
Strategy and business model	The strategic implications of failing to address risks may be severe.	Climate change is a strategic risk to insurers from both a balance sheet and reputational perspective, and should be addressed through a comprehensive strategy. Supervisors will, in particular, focus on inconsistencies between the management of assets and liabilities, resulting in a "cognitive dissonance".
	Insurers have a unique ability to address climate change risk strategically	Supervisors, and public opinion more widely, expect insurers to contribute meaningfully to the climate change debate and response given their expertise in catastrophe management and their importance as investors. How insurers respond could create potential reputational risks and/or benefits for insurers.
	Increased demand and changes to underlying risks will affect the price of insurance	Pricing and reserve adequacy are key concerns for supervisors, and are heightened by climate change risks. Primary areas of concern will include the potential for some risks to become uninsurable, the effect of climate change risks on pricing and product mix, and robust oversight where advanced analytics are deployed.
	Climate change may change the dynamics of reinsurance and risk transfers	The dynamics of traditional reinsurance and risk transfers may change in ways that are difficult to predict. Supervisors will scrutinise, in particular, increasing concentration and credit risk exposures to reinsurers, and uncertainty as to how reinsurance will respond to climate change related events.

Section	Key findings	
Capital modelling and stress testing	Defining plausible but severe stresses and scenarios is difficult but necessary	Supervisors will focus on stress testing to understand insurers' resilience to climate change risks. Areas of supervisory focus will likely be the severity and robustness of scenarios, how these compare to and build on industry-wide stress tests, and how comprehensively they cover insurers' unique risk exposures.
	Climate change could lead to significantly increased model risk	Given its non-linear nature, climate change could challenge established model methods, assumptions and calibrations and materially increase model risk. Particular areas of supervisory concern could include correlation and diversification, data adequacy, and over-reliance on third party vendor models and external expertise.
Asset transition risk	Transitioning to a greener investment portfolio may not be straightforward	Insurers will need to take strategic decisions in some uncertain areas if they are to transition to "greener" investment portfolios and avoid being left with stranded carbon-intensive assets. Particular challenges include defining what is sustainable/green in the circumstances of the individual insurer and ensuring sufficient portfolio yields to avoid policyholder detriment.
Governance and culture	Supervisors see governance as key to successful management of climate change risks	Supervisors expect climate change to be "mainstreamed" into risk management and internal controls. They will look for a clear escalation and decision making framework for climate change risks, including tangible evidence that risks are assessed, monitored, managed and reported at all appropriate levels.
	Overall culture and "tone from the top" are important to regulators	Supervisors expect a board-led culture that encourages serious consideration of climate change issues across the organisation. Supervisors will focus on the "tone from the top", and in time can be expected to test understanding of, and attitudes towards, climate change risk issues at different levels of the firm.
Conduct	Climate change may lead to a surge in conduct-related issues for insurers	Climate change could increase conduct risks in ways that are currently relatively unexplored. While the current supervisory focus is on disclosures and the availability of "green" products and services, future focus areas may include the effect of transition risk on consumers, and effective stewardship.
	Greenwashing is likely to be an area of particular concern	Firms should anticipate supervisory action on risks that non-sustainable products, activities or services are "green-washed[1]". Supervisory attention will likely fall on marketing and distribution to consumers.

4. How are insurers exposed to climate change risk?

Importantly, while some insurance exposures to climate change risk are relatively established and recognised, insurers may also have exposures that are less obvious, and therefore more difficult to identify and manage. For example, on the liability side, insurers may experience a rise in claims costs across several different types of insurance products as extreme weather events become more frequent and severe. This includes more traditional catastrophe-type risk insurance products but also general liability-type insurance covers. On the asset side, insurers as major investors in the wider economy may experience losses in value of certain types of investments, and in some cases may be left with de-valued, stranded or illiquid carbon-intensive assets.

Insurers are thus the only type of financial institution exposed to all three of the different risk factors commonly discussed by regulators (physical, transition, and liability risk[2]).

4.1 Physical risk

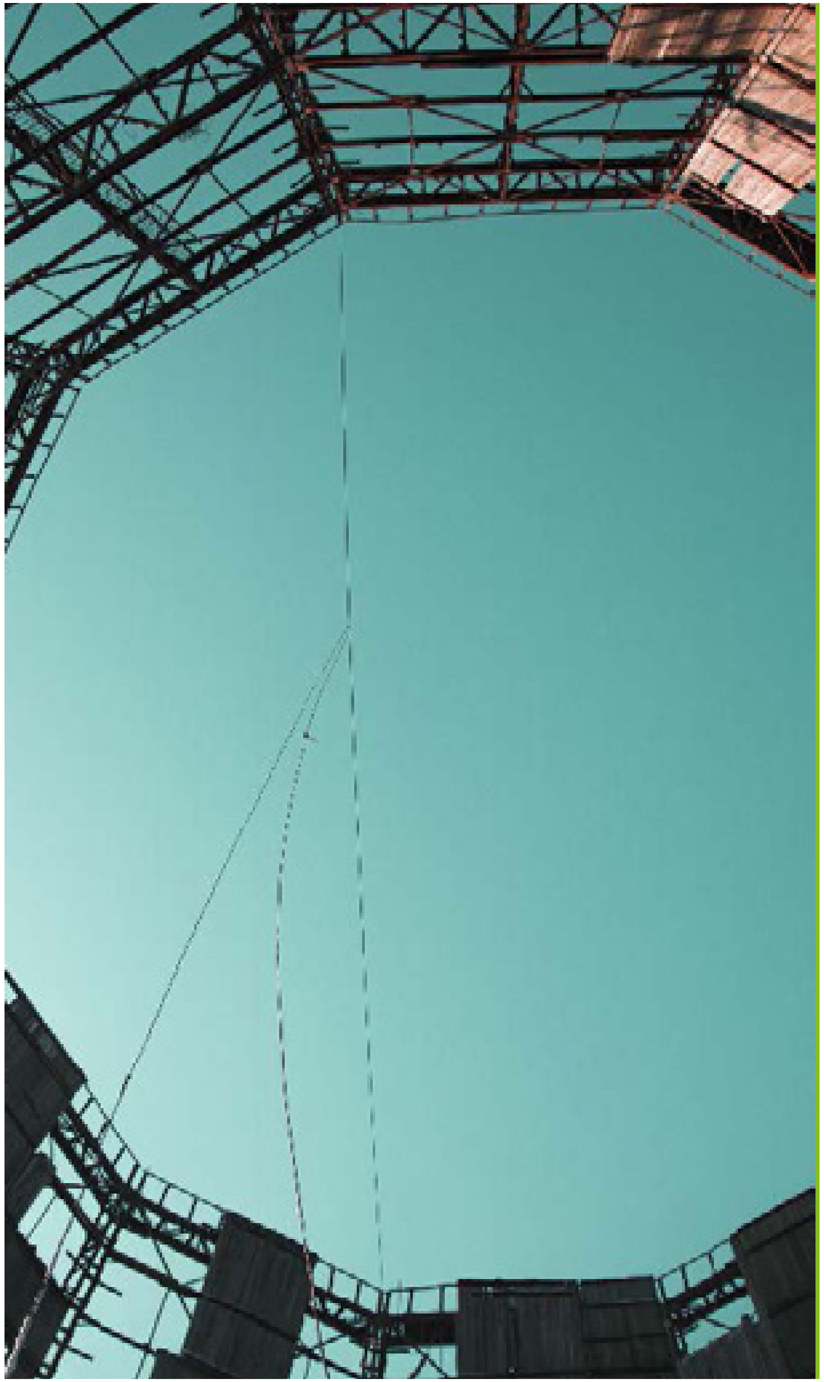
Definition

The *"first-order risks which arise from weather-related events, such as floods and storms. They comprise impacts directly resulting from such events, such as damage to property, and also those that may arise indirectly through subsequent events"*[3].

Illustrative example

- An international insurer has a diversified portfolio with exposure ranging from traditional Property and Casualty (P&C) business to more specialist classes such as agriculture, spread across a variety of geographical locations. The insurer insures a factory located in the United States. The insurance policy includes both physical damage and business interruption cover. A severe hurricane leads to severe flooding in the area, physically damaging core functions of the factory and also leads to interruptions up the factory's supply chain. The insurer also insures a field of crops in a nearby area, which has been materially damaged as a result of increased heavy rains from the hurricane, leading to flooding of farmlands. The premiums charged for both policies did not take into account changing climatic conditions including more frequent and severe flooding as a result of climate change, meaning claims are materially higher than anticipated: i.e. there is now a mismatch between the premiums charged and the underlying risks.
- The same insurer also has investments in international real estate and infrastructure. The real estate investments are coincidentally located in an area in the UK that is becoming increasingly prone to flooding. The investments therefore lose value as they suffer more frequent and severe damage, compounded by damage to rental prospects and the local economy as businesses shift away from the flood-prone area.

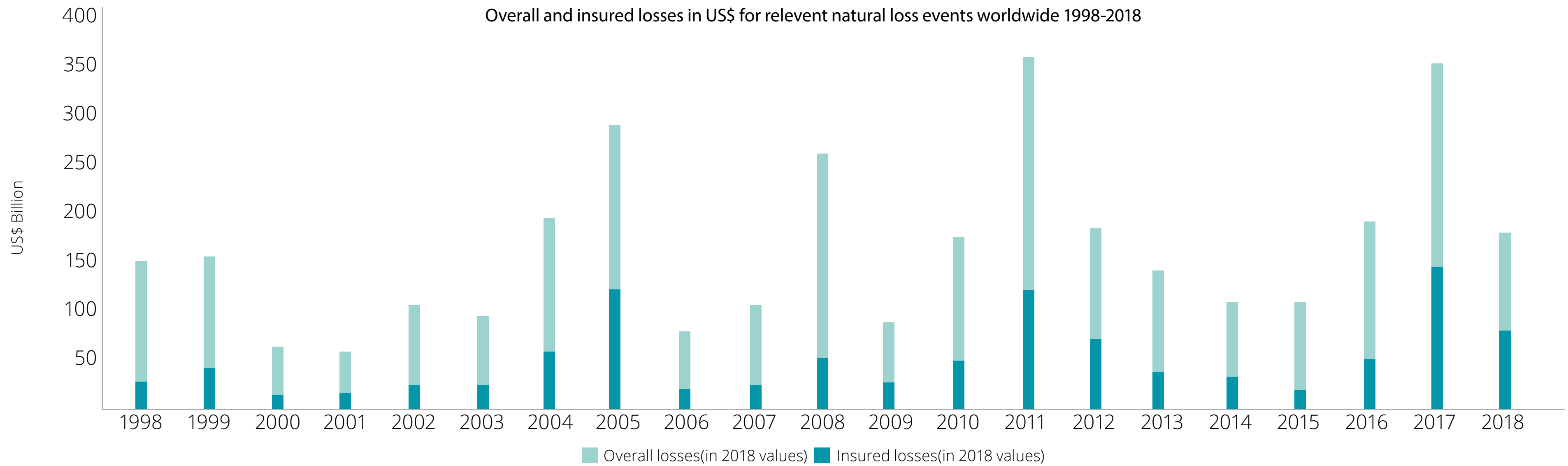
Physical risk is currently the best understood risk factor affecting insurance, given in particular non-life insurers' large exposures to natural catastrophe risks (mainly through property, but also energy and marine, aviation and transportation insurance).



Evidence suggests that natural catastrophes are increasing in severity and frequency, partly as a result of climate change. This is steadily increasing insurance claims for both more obvious primary physical risks and more-difficult-to-identify second-order physical risks. Second-order claims may arise in lines of business such as financial loss, agriculture and political risk[4]. In addition to higher claims costs, increased claims frequencies can also pose significant operational challenges for insurers and brokers, for example to meet increased demand for claims handling.

The graphs below detail the increase in the overall and on the next page insured loss amounts, and number of natural catastrophes over a 20 year period between 1998 and 2018. Notably, with only a few exceptions, overall losses from catastrophes are generally higher the last ten years compared to the previous decade, while the number of severe events has also trended upwards during the same time period.

While 2019 was more benign than previous years, natural catastrophes still accounted for USD133bn economic losses (and USD50bn of insured losses)[11].



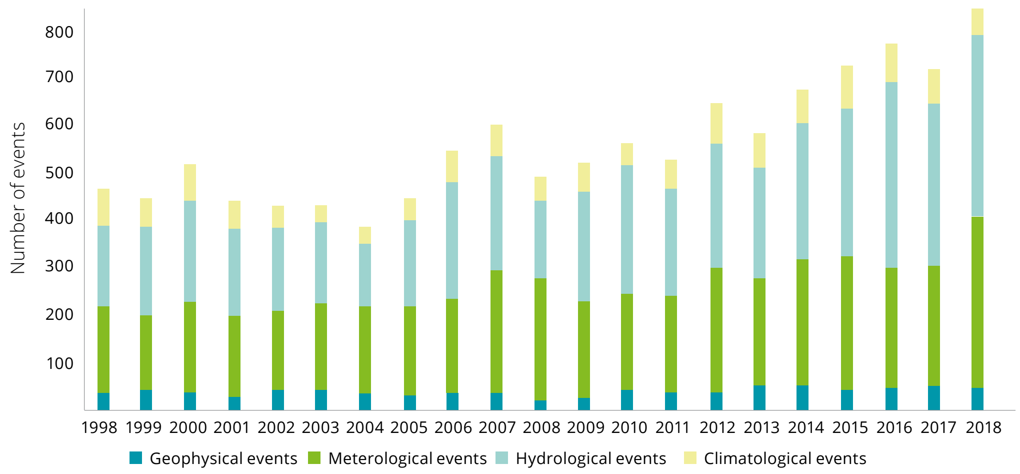
Statistics from Munich Re's NatCas Service[10]

The physical risk factor also affects life insurers. Long term health factors, for example from heatwaves, floods, droughts and fires, could lead to significant changes in longevity, morbidity and mortality. Climate change could also extend the transmission season and geographical range for many infectious diseases[5], so further increasing insurers' mortality risk (although potentially simultaneously decreasing their longevity risk). Secondary effects affecting life insurers' liabilities could include climate change-related developments such as migration, urbanisation, and access to clean water[6] as these could all lead to changes in, for example, life expectancy patterns.

On the asset side, insurers' property investments may lose value due to physical damage by for example floods, or property becoming too expensive to rent or buy given the additional cost of insurance involved. Properties may also lose value due to potential future effects of climate change, including for example through proximity to flood plains or coastal erosion. In the extreme scenario, certain properties may even become 'uninsurable' due to the increased underlying present or future risks, and therefore impossible to rent or buy. Additionally, there may be changes in wider economic sentiment following an extreme weather event[7], which could affect the value of certain investments including property. Due to the uncertain weather patterns and correlations brought about by climate change, investments previously deemed "safe", such as the credit rating of sovereign/municipal bonds[8], may lose value. Insurers may also experience second-order effects on the asset side that are less immediately obvious. For example, climate change could affect the performance of loans and credit to households and Small to Medium Enterprises (SMEs) or firms' changing credit risk profiles[9]. Insurers may also experience significant counterparty risks from issuers of financial instruments being exposed to both physical and transition risks.

The 2011 Thai floods resulted in USD12bn of insurance payments including claims arising from second-order effects such as supply chain interruption of global manufacturing firms[12].

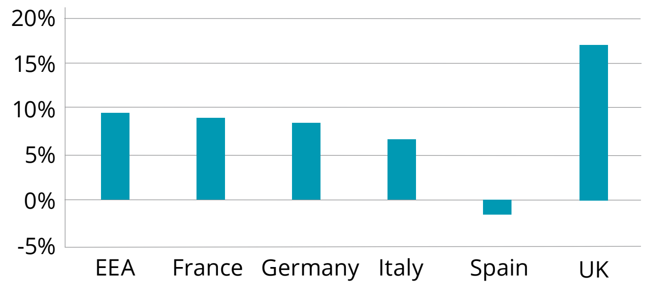
Number of relevent natural loss events worldwide 1998-2018



Statistics from Munich Re's NatCas Service[13]

The graph below shows that insurers' overall investment portfolio allocation to real estate has increased over a three-year period in the EEA as a whole but particularly in the UK. This means that insurers are potentially quite significantly exposed to physical asset risk from climate change.

% Change in insurer exposure ratio to real estate assets: 201704 to 201903



Deloitte graph, with data from EIOPA[14]

4.2 Transition risk

Definition

The "*financial risks which could arise for insurance firms from the transition to a lower-carbon economy*"[15].

Illustrative example

- An insurer is a specialist underwriter providing different types of energy insurance covers for onshore and offshore oil and gas companies. As investors and consumers change their preferences, reflecting greater awareness of climate and environmental issues, this traditional, carbon-intensive part of the energy industry is dwindling and becoming smaller in size. The insurer faces a situation where it may lose business due to its direct connection with the oil and gas sector.
- The same insurer also invests part of its investment portfolio in carbon-intensive energy sectors. These investments decline in value and become less marketable as investors move increasingly away from carbon-intensive investments. As a result, the insurer faces the options of either maintaining the carbon-intensive holdings which yield a lower return than previously, or pay the additional cost to re-allocate (transition) these to another sector.

While less well-understood than physical risk, transition risk is evolving as a key focus for regulators across EMEA. Transition risk might be triggered by, for example, policy and technological change, making it difficult for insurers to predict and manage given that triggers are external and political and may thus be inherently unpredictable.

Transition risk may particularly affect specialist insurers in sectors such as energy, shipping and other carbon-intensive industries. These sectors could shrink significantly as the world transitions to a low-carbon economy, which could in turn lead to reduced premium income for general insurers heavily exposed to these industries. For example, firms providing cargo insurance for oil companies could end up suffering from

7%.

of overall premiums at Lloyd's of London were related to energy in 2015[16]

30%.

of global seaborne trade in 2016 by volume is estimated have been in oil and gas[17]

a reduction in oil trade as a result of climate change.

Insurers may also hold investments in or affected by the carbon-economy, for example in traditional carbon-intensive energy sectors and infrastructure. Although a majority of insurers have recently pulled out of coal investments, many remain exposed to other energy sectors such as utilities and oil. Coal is only the first of many carbon-intensive sectors to experience the shift, other sectors such as transportation are likely to follow. Given the absolute size of insurers' investment portfolios, carbon-exposures represent a significant amount of holdings that are potentially at risk of being stranded due to transition risk, or looking to be re-allocated at a cost.

Insurers' overall investment portfolios, often hypothecated in large part to long term liabilities, may also be sensitive to sudden changes in investor sentiment or market expectations, and may force them to sell before maturity.

4.3 Liability risk

Definition

The "*risks that could arise for insurance firms from parties who have suffered loss and damage from climate change, and then seek to recover losses from others who they believe may have been responsible*"[18].

Illustrative example

- An insurer provides Directors' and Officers' ("D&O") liability insurance to the directors of a large, well-known bank. The directors are successfully sued by the bank's shareholders for having failed to disclose appropriately certain aspects of its climate change exposures and policies. This in turn sets a precedent for other similar cases to be brought against other banks insured by the insurer.

Liability risk is probably the climate change risk factor that has featured least prominently in market and regulatory discussion so far. It affects principally insurers exposed to general liability lines of business (such as D&O, public liability, errors & omissions and employer's liability insurance). History has shown that new emerging general liability-type claims "can be more disruptive to the insurance industry than losses caused by individual extreme weather events"[19]. This was for example the case with the surge in asbestos- and pollution- related claims during the 1980s and 1990s which eventually led to total unexpected losses of over USD85bn[20].

Climate change-related litigation is however increasing, particularly in the US but also increasingly elsewhere, with varying legal outcomes. Most defendants are governments, but lawsuits also increasingly target the highest greenhouse-gas-emitting companies[21]. This could lead to a surge in liability-type claims, in particular from D&O insurance policies which cover insureds for losses as a result of legal action from alleged wrongful acts.

In 2018, New York City sued some of the world's largest publically-listed oil companies for contributing to climate change. This case was dismissed on the grounds that climate change must be addressed through federal regulation and foreign policy. It does, nevertheless, illustrate a trend of using climate change litigation as a tool to influence policy outcomes and corporate behaviour as well as to gain financial compensation.

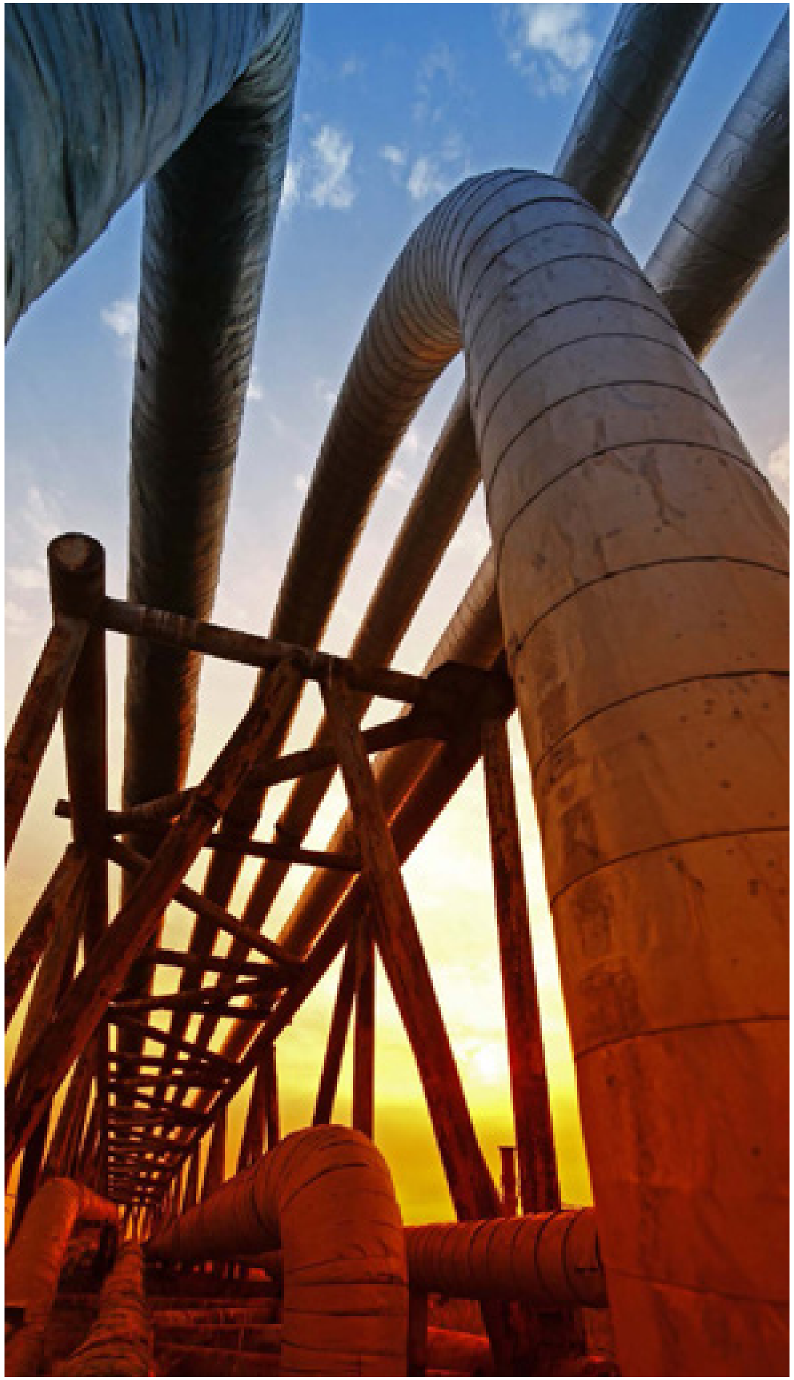
5. Risk identification and risk appetite

5.1 Insurers have potentially large unknown asset and liability exposures

Overview

Insurers are potentially significantly exposed to climate change risks from both an asset and liability perspective. Supervisors are likely to focus on the following key areas of uncertainty when assessing how firms have identified their climate change exposures:

- The determination of scope of cover for existing and future insurance policies, i.e. whether and how these will and should respond to future claims due to climate change. Supervisors will likely be interested in general liability-type policies in particular, given statistics and history suggest that liability claims can be more disruptive to the insurance industry over time than individual extreme loss events[22], as demonstrated by the asbestosis-related liability claims that led to significant challenges for the Lloyd's market in the 1990s.
- The considerable uncertainty as to how second-order effects of physical risks and perils might impact assets and liabilities. For example, regulators will want assurance that firms understand to what extent severe weather events could lead to business interruption claims in supply chains, or could affect urbanisation and migration patterns that influence disease patterns for life insurers. On the asset side, they will want firms to assess how severe weather events could impact the performance of for example household loans.
- How physical risk factors may lead to investments currently thought "safe" becoming more risky as a result of climate change. Supervisors will likely want firms to examine how changing weather patterns may lead to for example changes in the credit ratings of sovereign or municipal bonds[23].



Positive supervisory indicators

- The insurer has performed a ground-up assessment of the full nature and extent of potential asset and liability exposures to climate change risk.
- Material areas of uncertainty have been identified and documented.
- The firm has conducted deep dive reviews of some of its most material climate change risk exposures.
- A process has been established to re-visit material risk exposures periodically or in light of new developments.
- The scope of insurance cover on existing policies potentially exposed to climate change-linked events is regularly reviewed and challenged.
- Where insurers have general liability exposures, there is regular monitoring of worldwide litigation developments that may set precedent for climate change-related liability disputes.
- Climate change-related accumulation risk in the investment portfolio is regularly tracked according to a set of key metrics.
- Climate change considerations are incorporated into all relevant processes such as supplier due diligence and business planning.

Negative supervisory indicators

- Existing assumptions about asset and liability exposures are not challenged.
- The Board adopts a "wait and see" approach to climate change risk.
- Underwriting/reserving/claims departments work in silos to identify risk exposures.
- There are no defined metrics to track transition and physical climate change risk exposures in the investment portfolio in line with agreed investment risk appetite.

Questions for Boards

How do we know we have looked widely enough for potential climate change risk exposures and mapped these against different scenarios?

Are we too reliant on our usual processes and sources of risk identification and expertise?

What hitherto unidentified exposures have we actually identified? Do those give us any indication of where/how we might look for others?

When is it necessary for us to take action in order to mitigate potential adverse impacts of climate change that have not yet materialised?

What would our underwriters be worried about if they were insuring us?

What is our level of confidence in the exposures we have identified, and what is the margin of uncertainty?

Are there any areas of the business that we think will not be affected by climate change? Why? Have we challenged these assumptions sufficiently?

What lessons about our risk exposures can we learn from class actions?

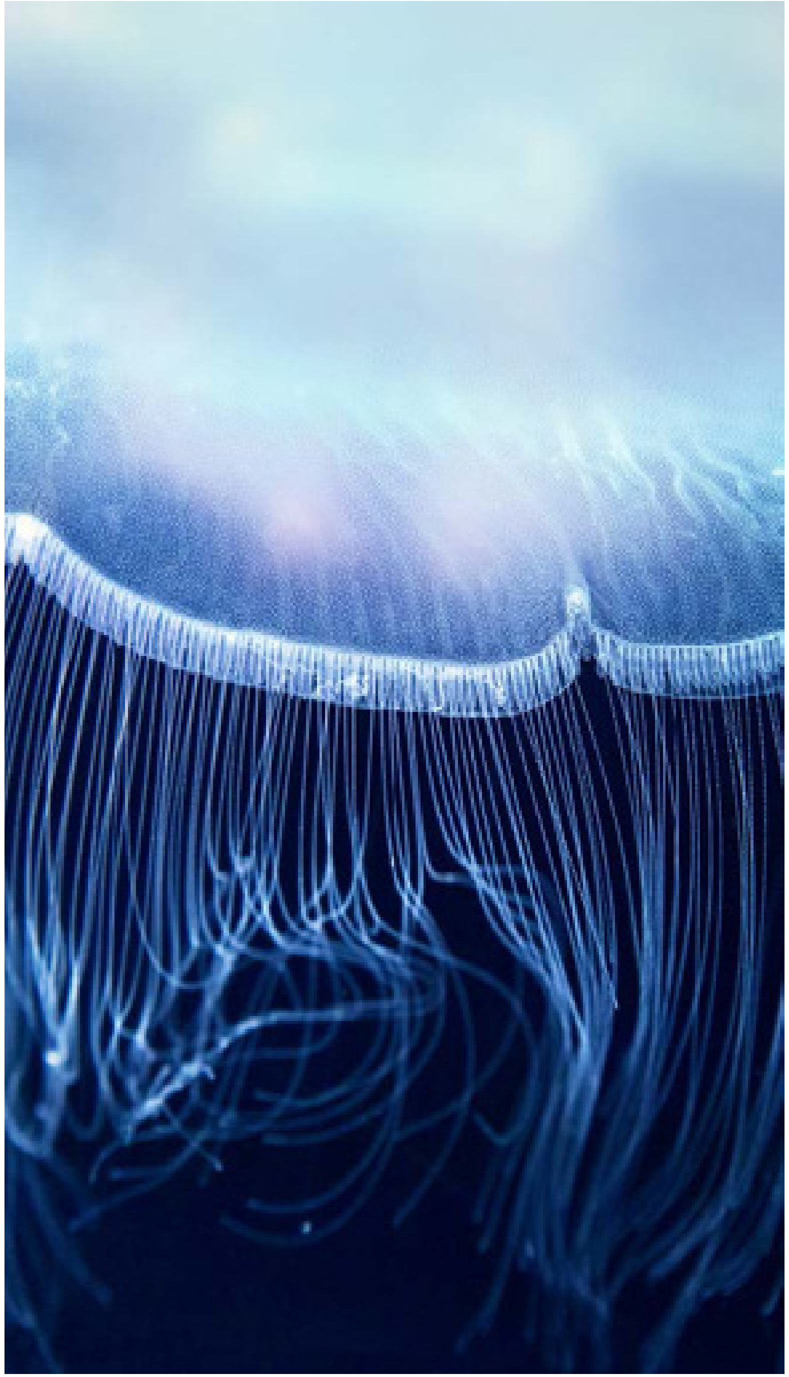
Do we need to buy reinsurance against any of the new risks we have identified?

5.2 Once exposures have been determined, supervisors will look to insurers' risk appetites

Overview

Supervisors will examine how insurers have incorporated climate change into their risk appetite frameworks, as a first step in understanding how identified exposures are managed.

- Risk appetite statements are key to regulators as they go to the heart of how firms manage their risk exposures. For example, in its July 2020 Dear CEO letter[24], the PRA in the UK clarified that by the end of 2021, firms should be able to demonstrate how they have embedded climate risk management within their frameworks to identify, measure, monitor, manage and report on their exposure to climate risks against a well-defined risk appetite that considers the current balance sheet and business model risk.
- The PRA has also published its minimum expectations with regards to the content of firms' risk appetite statements in the context of climate change risk. For example, the PRA expects firms' risk appetites to include the risk exposure limits and thresholds for the financial risks that the firm is willing to bear, and should take into account factors such as the long-term financial interests of the firm, and how decisions today affect future financial risks[25]. Firms should also take into account the results of stress and scenario testing, considering both longer and shorter time horizons, when setting the risk appetite. The PRA will also want to see evidence that Boards address and oversee climate change in line with its business strategy and overall risk appetite.
- Firms should also consider a longer than usual time horizon when establishing a climate change risk appetite. The Climate Financial Risk Forum (CFRF), for example, specifies that while risk appetite statements generally tend to 3-5 years, in the context of climate change, "[a] mature risk appetite should (...) consider the impacts over a longer period, e.g. a 30-year timeframe with interim milestones that will evolve as more knowledge is gained"[26].



Positive supervisory indicators

- Climate change risk exposure limits and thresholds are incorporated into the firm's wider risk appetite.
- Factors such as long-term financial interests of the firm and results of stress and scenario testing have been taken into account when integrating climate change into risk appetite.
- The Board has challenged, discussed and approved the climate change risk appetite and reviews it regularly in light of new risk exposures.
- The Board monitors actual exposures against risk appetite thresholds, and this is evidenced in relevant Board management information and meeting minutes.

Negative supervisory indicators

- Climate change is mentioned only superficially in the insurer's risk appetite.
- No clear definition of the firm's actual tolerance for specific climate change risks. Exposure limits or capital allocations have not changed as a result of a changed climate change risk appetite.
- Absence of evidence of independent discussion and challenge of climate change risk appetite by the Board.
- Lack of measurable key metrics to monitor how climate change risk is managed against overall risk appetite.
- Climate change risk appetite reflects broad sentiments and trends, rather than being based on a thorough process of evaluation.

Questions for Boards

How do the changes to our risk appetite and risk exposure limits map to the climate change risks we have identified and how they affect our existing risk universe and risk profile?

How have changes to risk appetite affected our capital management plan? If there is no capital impact, how is that justified?

What management actions have we identified to manage climate change risks, and what triggers do we monitor?

How objective and robust are the metrics that we use to monitor climate change risk exposures against risk appetite?

Do we review our climate change risk appetite sufficiently frequently?

What management information do we have to understand where we sit against our climate risk appetite(s)?

6. Strategy and business model

6.1 The strategic implications of failing to address risks may be severe

Overview

Failure to address climate change risks and respond to changing market demand risks harming an insurer's financial performance, competitiveness and market share. In this context, regulators are likely to probe some key strategic concerns:

- The "cognitive dissonance" in how insurers manage underwriting versus investment activities. Supervisors will want to see comprehensive, long-term strategies that consider all the different aspects of climate change risk, and a consistent approach to climate change risk that takes into account available insight on both the asset and liability sides of the business. Supervisors will be wary of firms' core business functions dealing with climate change in silos, and will look for inconsistencies in the treatment of climate change risk across different work streams. A recent example of this type of inconsistency relates to pandemic risk, which, in our experience, has been featured in several firms' ORSA analyses but not always in their business continuity plans. Firms should ensure that all types of risks, including climate change risk, are consistently covered and analysed across all parts of the organisation.
- The potential conflicts of interest between physical risks on the asset side versus the liability side of the balance sheet. For example, withdrawal of insurance in certain areas because of changing physical risks could lead to reduced mortgage lending, causing a reduction in property values and eventually some properties being abandoned altogether[27], as well as potential material conduct risks. Supervisors will expect firms to be aware of conflicts of interest and have a strategy in place to manage the risks they pose to both prudential and conduct regulatory concerns.

"The PRA is increasingly focused on cognitive dissonance in some insurers whose careful management of climate change risks on the liability side of their balance sheet is not always matched by similar considerations on the asset side[28]"

Mark Carney
former Governor of the Bank of England

Positive supervisory indicators

- Business planning and strategy documents evidence that climate change risk has been taken into account across all core areas of the business.
- Management and staff participate in cross-functional working groups or secondments between core areas of the business to encourage collaboration.
- Feedback loops share ideas and insight between different areas of the business.

Negative supervisory indicators

- Absence of climate change strategy, or climate change strategy exists as a separate document that is not linked to wider firm strategy, for example it only covers underwriting.
- Lack of collaboration on climate change risks across the business.
- All relevant expertise on climate change sits in one function, such as underwriting or risk management.

Questions for Boards

Are our valuation assumptions for assets and liabilities consistent, to the extent they are affected by climate change risk?

Is our strategy being 'led' by external policy, our competitors, or market expectations?

Are we contributing to or at risk from a valuation bubble?

Are we taking strategic decisions without understanding what they imply for other parts of our business, such as our investment or underwriting strategies?

6.2 Insurers have a unique ability to address climate change risk strategically

Overview

Several regulators have pointed out that insurers' expertise in risk pooling and catastrophe management, as well as their ability to address climate risk from both sides of the balance sheet, place them in a unique position to contribute meaningfully to the climate change debate and response.

- Insurers can usefully play a role in closing both the low carbon investment and the climate protection gaps, as they are large enough investors to shift the market, and can contribute to innovative measures to pool climate change risk (e.g. through Public-Private Partnerships). Supervisors therefore expect insurers to play a key role in the management and mitigation of climate change.
- Insurers should also factor in reputational benefits and/or risks, given the topic's importance in the media and among consumers. There is growing evidence to suggest that consumers are willing to pay more for products and services that are sustainable, creating a potential advantage to being seen as a 'leader' on climate and sustainability issues. Leading the charge will be critical for insurers' continuing social licence to operate. Climate change also presents new commercial opportunities for insurers, which they should take advantage of, including for example underwriting opportunities for renewable energy sources, or climate parametric products.

Positive supervisory indicators

- The Board has debated and adopted a defined position within the climate change debate, for example on its sustainability objectives and approach to achieving them.
- Internal and external communications and marketing materials explain the insurer's position and strategy on climate change and sustainability and comply with disclosure regulations and market expectations.

Negative supervisory indicators

- Ill-defined external position with regards to climate change, causing confusion both internally and among customers as to the firm's position and strategy.

Questions for Boards

Are we doing the right thing?

Do any of our carbon exposures put our reputation at risk, or expose us to legal or class action risk?

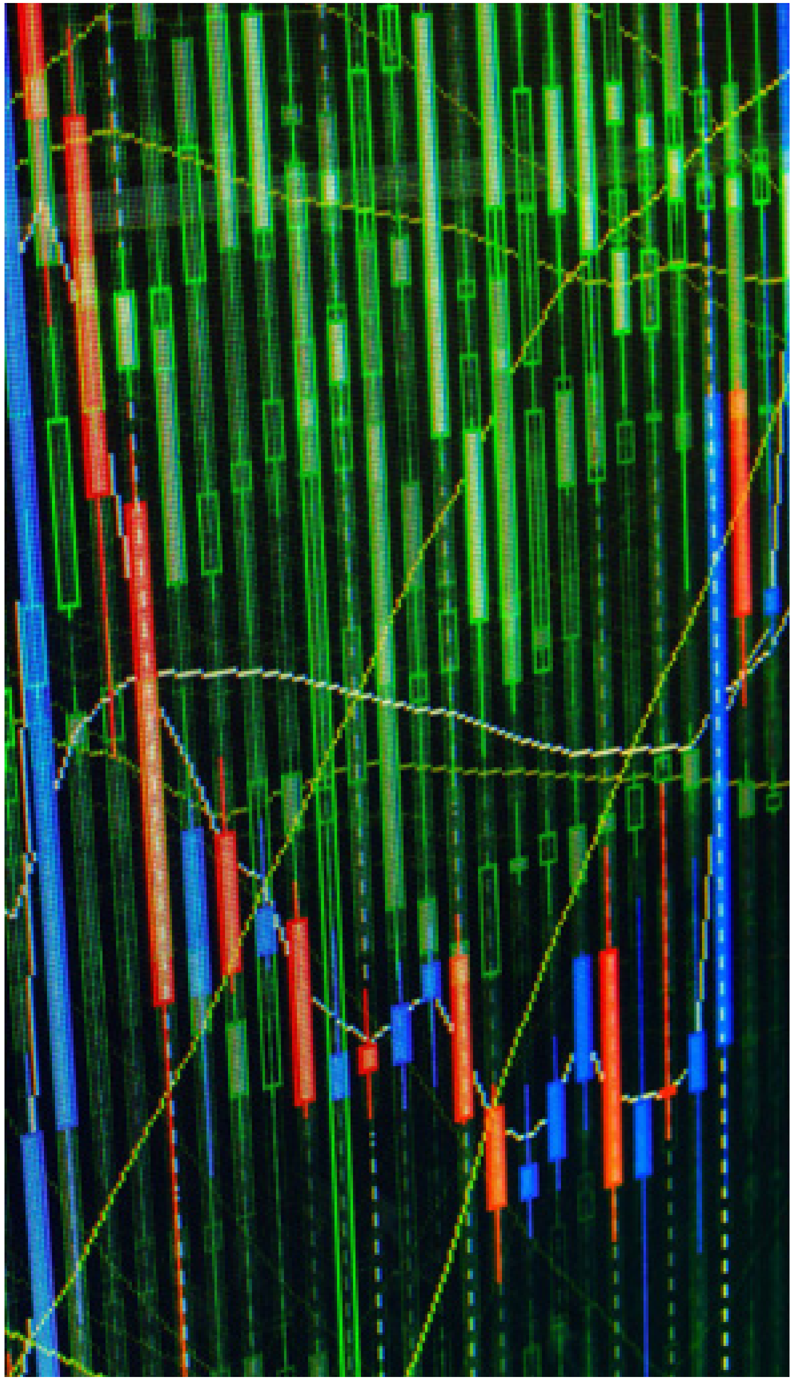
How could we be clearer about our strategy?

What is the most impactful thing we could do to tackle climate change risk, given all the options and resources available to us?

What are firms in other sectors doing about this? What can we learn, and where do we have opportunities to do things differently?

Do our climate change disclosures meet the market's and our regulator's expectations for a firm of our size and type?

6.3 Increased demand and changes to underlying risks will affect the price of insurance



Overview

In the absence of other factors, more extreme, frequent and volatile severe weather events would be expected to lead to heightened insurable risks, and therefore an increase in insurance premiums over time. Insurers will need to price and reserve for changing risks without harming their competitiveness by overpricing, and will need to consider how changing demand and pricing may affect their overall strategic business mixes in the short to medium term. Pricing and reserve adequacy are perennial concerns for supervisors, which have already been heightened by climate change risk. In particular, supervisors are likely to focus on the following areas of pricing and reserving risk:

- Extreme climate change scenarios could make some risks uninsurable, which may also turn insurance price increases into a social issue[29]. Insurers should challenge their business models to understand the factors that may drive technical prices to non-viable levels, and the implications of this for their business models and reputations.
- How transition risk affects the pricing of traditional energy insurance (e.g. oil and gas). Second-order risks may include whether underwriters have relevant expertise to diversify into other classes of business, for example renewables, if this is the insurer's strategy.
- Risks that may be created by the use of advanced analytics to improve risk selection and pricing[30]. As an increasing number of firms deploy advanced analytics tools in their pricing, supervisors are likely to focus on the oversight of these tools and the new risks they may create.

Positive supervisory indicators

- Relevant climate change-related risk factors are factored into pricing when policies renew. This could include offering incentives for risk reduction, e.g. through loss preventive measures[31].
- Management encourages underwriting discipline and rate adequacy by regularly challenging underwriting processes, controls, key judgments and assumptions.
- Material exposures to traditional energy lines of business are clearly identified and analysed.
- Management test the firm's resilience to liability transition risk through regular stress and scenario testing.
- Regular checks are performed to examine consistency with overall market pricing.
- Climate change considerations are explicitly considered when undertaking class of business reviews.

Negative supervisory indicators

- Pricing audit trail provides no documented evidence that climate change risk has been considered in pricing and underwriting.
- Board meeting minutes evidence no challenge to underwriting on climate change risks.
- The board does not consider the impact of climate change risks on its overall product mix as part of the business planning process.
- Pricing models have no clear feedback loops for climate change risk factors for affected classes of business or at the level of individual policies.

Questions for Boards

What trends have we seen in technical pricing, and how do these correlate to changes in climate change risk factors?

Is our pricing consistent with the market, and if so to what extent is that justified?

Are there lines of business in which we are gaining or losing market share? Why is this?

Are there lines of business that we should plan to leave or enter?

Do our pricing models for relevant classes of business contain explicit feedback loops for climate change considerations?

6.4 Climate change may change the dynamics of reinsurance and risk transfers

Overview

Climate change may change the dynamics of insurance risk transfers in ways that are difficult to predict. Supervisors are likely to be most concerned about, and therefore scrutinise firms' strategies in relation to:

- Increased concentration risk and credit risk exposure to major reinsurers as they take on more climate change-related risk, leading potentially to heightened earnings and capital volatility. Insurers will need to consider to what extent these risks offset reductions to insurance risk capital. A slowdown in growth in the ILS market could increase dependence on traditional reinsurance markets further.
- Uncertainty as to how traditional reinsurance will respond to climate change related events of different severities. For example, while catastrophe losses in 2017 and 2018 were over USD240bn, a large share of losses were retained by primary insurers due to larger retentions coupled with smaller individual catastrophe events[32]. Supervisors will look for insurers to capture potential uncertainties arising from their reinsurance programmes in stress testing.

Positive supervisory indicators

- Regular review of the adequacy of current reinsurance and alternative capital arrangements takes climate change risks into account.
- The overall dependency on reinsurance arrangements and/or specific reinsurers' credit ratings is included in stress tests.
- The insurer explores new ways to manage tail risks, for example if the cost of reinsurance increases.
- Risk mitigation tools are diversified to avoid excessive risk accumulation.

Negative supervisory indicators

- Over-reliance on a single reinsurer or alternative capital provider to mitigate extreme tail risk.
- Reliance on existing risk mitigation strategies is not stress tested, and no management actions are identified.

Questions for Boards

Would our current reinsurance strategy continue to work if global temperatures rise 2 degrees, or 3 degrees? What scenario testing have we carried out to validate this?

What alternative sources of reinsurance or risk transfer are available if our credit risk exposure to our reinsurance programme provider exceeds our credit risk appetite?

What reinsurance protection do we have against significantly increased attritional/non-catastrophe losses? Are there other contractual arrangements that may prevent our risk mitigation being effective in certain circumstances?

Do we have potential significant new areas of risk exposure as a result of climate change which aren't covered by our existing reinsurance programme?

What would be the effect on capital if we had to bring reinsured risk back onto the balance sheet?

7. Capital modelling and stress testing

7.1 Defining plausible but severe stresses and scenarios is difficult but necessary

Overview

Regulators are increasingly focused across financial services on climate stress and scenario testing. As firms continue to build their stress testing capabilities, supervisors are likely to explore the following areas in more detail:

- How firms develop suitable and sufficiently-encompassing stresses and scenarios. Industry-wide stress tests (for example, the Bank of England's Biennial Exploratory Scenario ("BES")[33]) and other available external information are likely to provide useful starting points (or benchmarks) for firms stressing physical and transition risks. The PRA in its July 2020 Dear CEO letter[34] on managing climate-related financial risk, for example, suggests that firms may wish to use these standard, reference scenarios or tailor scenarios to their own unique circumstances.
- Liability risks that may, accordingly, be harder for many firms to stress, as these have usually been excluded from industry-wide stress tests so far. Supervisors will want to see firms use tools and expertise at their disposal to produce stress and scenario tests that reflect their unique exposures.
- Whether the applied scenarios are sufficiently severe while also realistic. Climate change risks are continually evolving and may develop in non-linear ways, making it difficult to determine time horizons and the return periods for certain events. Supervisors will scrutinise firms' assumptions carefully in order to ensure robustness of climate stress testing.

Positive supervisory indicators

- Stress testing builds on industry-wide stress tests to reflect the insurer's unique exposures to climate change risk.
- Management regularly explore different kinds of stress and scenario tests, including reverse stress tests.
- Stress tests are performed over both longer and shorter time horizons and stress a number of different variables simultaneously.
- The ORSA discusses key dependencies, assumptions and relevant management actions.

Negative supervisory indicators

- Climate change stress test results show very little or no impact on the firm's capital or financial performance.
- Climate change stress testing is conducted in isolation, without considering external information available.
- Stress testing does not include different variables or take into account aggregation of multiple risks.

Questions for Boards

What are the risks that could affect us the most that are not captured by our stress testing?

In what circumstances could second order risks become material?

What assumptions are our capital and results most sensitive to? Could they develop in ways we haven't anticipated?

Are we clear about the assumptions and expert judgements we are making in carrying out or stress and scenario testing?

How could we make our scenarios more comprehensive?

Does our management action plan constitute an adequate response to the risks identified by our stress and scenario testing?

Are there changes we should make today to prevent the build-up of risks that could be significant in the future?

What improvements would we expect to make to modelling climate risks as we gain more experience and access to data improves?

7.2 Climate change could lead to significantly increased model risk

Overview

While insurers have modelled risk exposures for decades, climate change puts into question existing modelling methods and assumptions given the possibility for non-linear increases in frequency and severity of extreme weather events. Supervisors will likely focus on the following areas with regards to firms' modelling of climate change risk:

- The impact of climate change on correlations and diversification between different risk and capital components. Material understatement of capital requirements is likely to be a significant concern for supervisors.
- Inaccurate or incomplete data, given catastrophe data is likely to be based on past events and hence does not reflect future non-linear weather patterns. Insurers may also lack granular geographical data on investments and loans sufficient to estimate exposures to physical risks[35]. Supervisors will want to understand how firms mitigate the risk of incomplete and inaccurate data on both the asset and liability side of the business.
- The risks of over-reliance on third-party model vendors and external expertise. Third party models and expertise are valuable inputs for many insurers. However, over-reliance could create concentration risks or risks of "group think", and third-party models may not cover less established perils or geographical areas[36], both key areas of concern for supervisors.
- Potential model risks arising from firms' use of advanced analytics. The most advanced insurers are already partnering with fintech and weather analytics firms in order to model their exposures to climate change risk. Advanced modelling techniques may be more difficult for non-specialists to understand, and can lead to some non-traditional model risks (for example, where models use dynamic calibration), which supervisors are likely to scrutinise.

Positive supervisory indicators

- The firm has identified models sensitive to climate change risk across its model inventory.
- Modelling assumptions and methodologies sensitive to climate change risk are regularly challenged.
- The firm consults with industry experts, risk modelling firms, academia and other key stakeholders and experts on climate change risk.
- Model developers are incentivised to capture risks accurately, including those from climate change risk.
- Climate change insights are shared and reflected in all relevant models.
- The model validation function has sufficient access to expertise on climate change and climate change risk modelling.
- The firm has a strategy to address identified data limitations, and applies model loadings in the meantime.

Negative supervisory indicators

- The firm relies without challenge on a small number of modelling tools and sources of information on climate change risk.
- Climate change risk is modelled in isolation, without considering external information, expertise and research.
- Climate change risk factors are taken into account inconsistently across the firm's different models.
- The firm lacks relevant expertise to challenge and independently validate climate change risk.
- Model developers are incentivised to ignore or down-play climate change risk.

Questions for Boards

How have we identified which of our models use assumptions or methodologies sensitive to climate change risk?

By how much would key risk factors need to shift before we could no longer rely on critical models?

In what ways are we dependent on external expertise or expert judgment? How have we challenged those judgments?

What would need to change in order to bring our correlation assumptions and methodology into question? How sensitive are model results to correlation and diversification assumptions?

Are we updating for climate change risk consistently across our portfolio of models?

Does model validation have access to sufficient climate change expertise to validate our models effectively?

Where are our biggest data risks and limitations? What allowances have we made for data limitations within model calibrations?

What incentives are there for model developers to attempt to capture climate change risk? How might climate change risks affect the remuneration and bonuses we pay to model developers and users?

8. Asset transition risk

8.1 Transitioning to a greener investment portfolio may not be straightforward

Overview

As many as two thirds of insurers are already incorporating sustainability considerations in some shape or form in their investment decisions[38]. However, the concept of transitioning to a "greener" investment portfolio poses significant challenges and requires insurers to take strategic decisions in some uncertain areas. In our view, the following represent some of the most significant areas of difficulty, on which we would expect supervisors and insurers to be most focused initially:

- Outliers aside, it is challenging to determine what constitutes a "green" or "sustainable" investment. The EU taxonomy should provide some clarity in terms of formal definitions, but may also trigger transition risk if it encourages firms to prioritise certain sets of investments. In our view, it is important for insurers to develop comprehensive investment strategies that capture their individual potential for correlations and conflicts of interest between asset and liability risks, notwithstanding the important potential role of the taxonomy. When developing these strategies, insurers will also have to bear in mind the different shades of investments between "green" and "brown".
- Insurers may find that there are insufficient green investments paying adequate returns in order to meet investment objectives in the short term. This problem could potentially be compounded if regulators introduce "green-supporting" and/or "brown-penalising" factors, as is under consideration by the European Commission[39], which could risk creating bubbles in certain asset classes.
- Supervisors will expect investment decisions to avoid the risk of detriment to policyholders, e.g. investments should still yield a return sufficient to meet the insurers' liabilities, and should not expose policyholders unduly to capital risks.
- Certain investments, such as infrastructure investments, could be more materially affected by transition risk than others, for example through disruption, interruption, or extra costs required to make the infrastructure "greener". Life insurers applying the Matching Adjustment (MA) may be particularly exposed to these types of investments, given their potential suitability, at face value, to match long term liabilities. Supervisors will expect insurers to stress test these investments, and to develop viable strategies to manage these potential risks.

A survey of the world's 80 largest insurers with assets under management (AUM) of USD15trn found that on average only 1% of total AUM are allocated to low-carbon investments[37].

Positive supervisory indicators

- The Board has made an informed decision as to the integration of sustainability/ESG criteria into its investment framework.
- The sustainability/ESG strategy is reflected in the insurer's investment risk appetite.
- The insurer has considered to what extent its investment strategies might need to reflect the ESG expectations of different groups of policyholders.
- The insurer has clearly communicated its ESG investment approach to policyholders.
- Metrics to monitor key investment exposures to climate change risk have been established.
- There is regular monitoring of the 5 transition triggers as defined by the PRA[40] and frequent re-assessment of whether investment strategy should change as a result.
- Investment managers consider the outputs of climate change-related disclosures of relevant key financial counterparties.

Negative supervisory indicators

- There is no strategy in place to mitigate potential transition risks to carbon-intensive assets.
- A lack of an in-house view on what investments should be considered "sustainable" for the purposes of investment strategy.
- Investment appetite and guidelines are unclear with respect to ESG/sustainable investing.
- Absence of appropriate monitoring metrics with regards to investment appetite and transition triggers.

Questions for Boards

Do we have enough data and expertise to make informed investment decisions with regards to climate change risk?

What is the track record of the sustainable investments and green technologies that we are building exposure to?

What risks does a green investment portfolio expose us to over the long term, for example to asset obsolescence, or uncertainty around length of economic life for green technologies? How do these risks compare to the risks of a "traditional" investment portfolio?

What premium are we paying for green investments, and is it justified?

Are we being caught up in a "green bubble" or being pushed into taking action?

How will our sustainable investment strategy affect our approach to asset/liability matching?

Does our investment strategy expose us to reputational risks?

How do we use climate change-related disclosures of key counterparties in our decision making?

9. Governance and culture

9.1 Supervisors see governance as key to successful management of climate change risks

Overview

The challenges posed by climate change need to be addressed at all relevant levels within a firm through appropriate governance arrangements. Supervisors have suggested that climate change needs to be "mainstreamed", i.e. firms need to integrate climate risks across mainstream risk management functions and internal controls[41]. This could be achieved for example by firms aligning remuneration with climate change by incentivising and rewarding individuals and teams who engage in regular debate and discussion on climate change. Supervisors will look for tangible evidence that climate change risks are assessed, monitored, managed and reported at all appropriate levels. In particular, supervisors will expect that:

- The Board has the appropriate competency to regularly challenge and act upon information on climate change risks, and digs deeper on specific areas of climate change where there is less engagement. Akin to the "use test" supervisors apply when approving internal models, supervisors will expect climate change-related information to influence decisions, for example on risk appetite, economic capital and strategy.
- The Board allocates responsibility for oversight of climate change risk to relevant senior individual(s). For example, the UK PRA has requested Boards to allocate responsibility for identifying and managing financial risks from climate change to the most appropriate Senior Management Function (SMF). In jurisdictions where this is not a formal requirement, supervisors will nonetheless look for appropriate ownership and accountability of climate change risk.

Positive supervisory indicators

- The Board is systematically informed about climate change risk impact across the organisation, and challenges and investigates areas of uncertainty.
- The climate change risk strategy is reflected consistently in organisational arrangements.
- The insurer has established mechanisms for effective cross-collaboration of teams on climate change risk.
- There is clear accountability with regards to climate change risk.
- Responsibility for oversight of climate change risk has been allocated to a relevant member of senior management, who regularly reports to the Board.
- The Board has agreed an approach to integrate sustainability into decision-making for the "non-financial" part of remuneration assessments.
- Negative and positive behaviours in the context of the overall climate change strategy influence remuneration outcomes.

Negative supervisory indicators

- The Board does not challenge, or constantly defers to a single individual with regards to climate change issues.
- There is no clear accountability for climate change risk issues.
- Discussion of climate change at Board-level is narrowly focused, for example by considering only one particular aspect of climate change risk (e.g. underwriting or investment strategy).
- The Board does not take clear decisions on climate change risk issues.
- Climate change strategy is not driven by the Board, but rather emerges and is implemented in a 'bottom-up' fashion in various departments.
- Climate change strategy is not understood or implemented consistently across the organisation.

Questions for Boards

Do we discuss climate change enough?

Do we consider climate change throughout our decision making?

Are there important decisions on how we manage climate change risk that we are not taking?

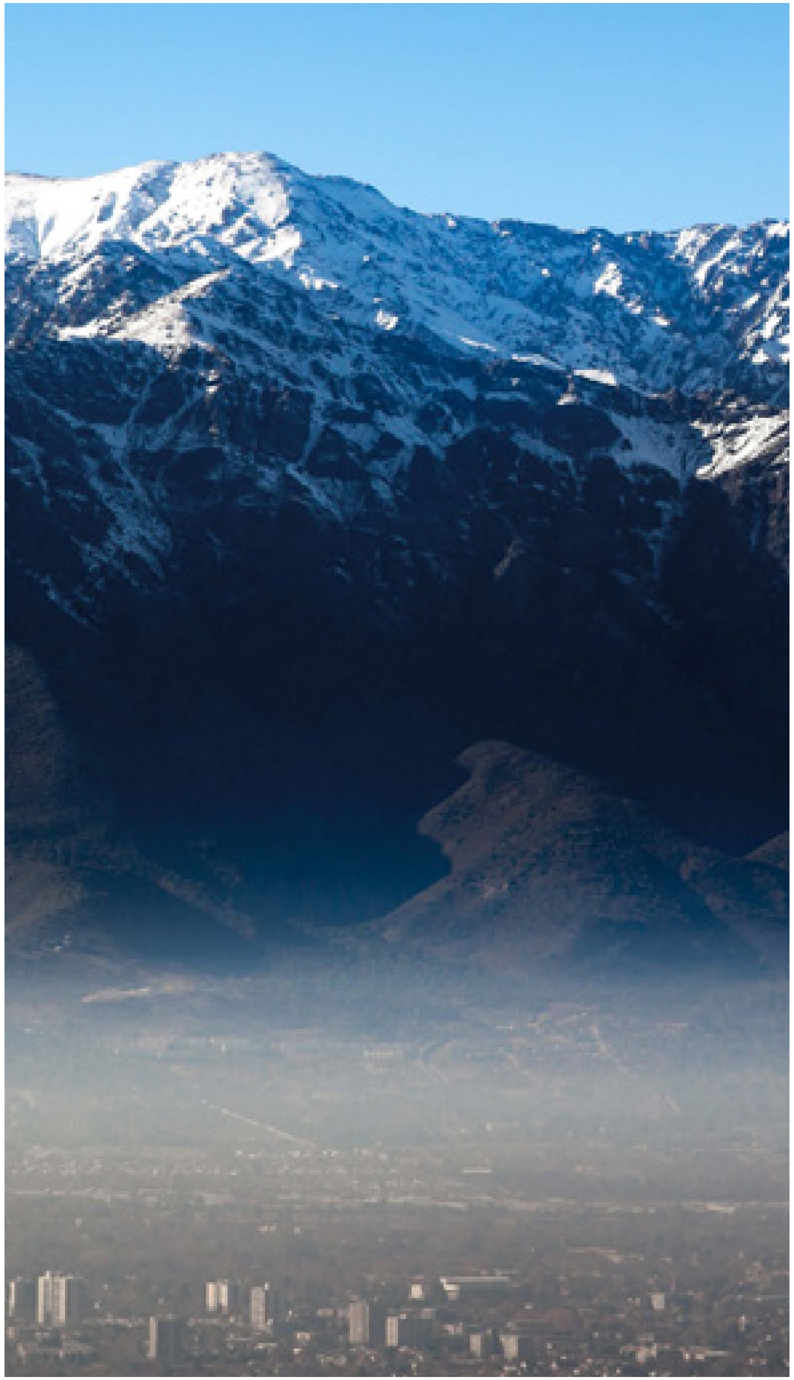
Do we need more skills on the Board in order to challenge climate change issues effectively?

Do we really understand what our management teams and departments are doing in relation to climate change risk?

Do our performance assessment and bonus processes encourage staff to manage climate change risk over the long term?

How does our Board effectiveness review assess how effective we are in tackling climate change risks?

9.2 Overall culture and "tone from the top" are important to regulators



Overview

Supervisors will be keen to see the Board encourage a culture that takes seriously the financial risks from climate change. In particular:

- Supervisors are likely to examine how the Board sets a "tone from the top" which facilitates and encourages climate change discussions.
- Supervisors will expect the Board to communicate to the entire business the importance of climate risk, as well as playing a pivotal role in setting the firm's strategy and response to it.
- In time, supervisors can be expected to test the understanding and embeddedness of climate risk considerations at all levels of the firm, across all three lines of defence, and will be alert to any evidence of mindsets and behaviours that treat climate risk initiatives as "tick box" exercises.

Positive supervisory indicators

- The Board has consciously set out to provide a "tone from the top" which demonstrates strong leadership and related action in relation to climate risk.
- The Board role-models the behaviours it expects from other parts of the organisation.
- The Board and senior management frequently discuss culture and receive regular culture management Information (MI).
- The importance of climate risk, and the firm's strategy for addressing it, are communicated to staff at all levels of the firm through, for example, internal communications and townhall meetings.
- Firm-wide surveys are regularly used to explore staff's understanding of firm culture in the context of climate change, and produce recommendations for improvements where deficient.

Negative supervisory indicators

- Climate change is not included in Board MI or discussed at some or any levels within the insurer.
- Board members and/or staff are unsure about how climate change will impact the business and its customers.
- No effort has been made to on-board and train departmental heads on the firm's climate change strategy.
- Staff are reluctant to deliver "bad news" relating to climate change risks (e.g. in terms of exposure management).

Questions for Boards

What objective evidence do we have (e.g. from MI or surveys) of our staff's attitude to climate change risks?

Is the message we receive from management and staff on climate change issues better or worse than we would expect?

Are there material climate issues that we would expect to have been escalated to us that have not been?

Are our views and approach on climate change issues sufficiently visible to the rest of the organisation?

10. Conduct

10.1 Climate change may lead to a surge in conduct-related issues for insurers

Overview

The implications of climate change for conduct risk are still relatively unexplored. However, going forward, we expect supervisors to pay increasing attention to climate change risk issues in the context of firm conduct, including in the following areas:

- The conduct implications of transition risk for certain consumers. For example, policyholders may suffer from de-valuations of stranded carbon-intensive assets backing savings and pensions business.[42] Transition risk could also lead to consumers not previously affected by climate change suddenly being at material risk, for example as certain properties previously thought to be located in low-risk areas suddenly experience physical damage from flooding. Insurers may see conflicts of interest arise between underwriting and prudential considerations and conduct concerns. For example, withdrawing insurance from certain areas materially affected by changing weather patterns may be prudent from an underwriting perspective, but could lead to significant detriment for customers who may find themselves unable to obtain or renew insurance.
- The effective disclosure and oversight of sustainability/ESG factors with regards to investments. For example, work is underway at EU level to mandate firms, including insurers, to include questions about their clients' ESG preferences in questionnaires and suitability assessments, to act in accordance with those preferences and to disclose to their clients how those preferences will be fulfilled[43]. The ESAs are currently consulting on proposed draft RTSs on sustainability-related disclosures[44], while ESMA's guidelines on disclosure requirements under the Prospectus Regulation[45], which apply when firms issue securities to the public or are admitted for trading, require firms to provide disclosure on relevant ESG matters. Though the focus so far has mostly been on asset-side related disclosures, it will also become increasingly important for insurers to consider how climate change-related risks to both side of the balance sheet may compound each other[46].
- The FCA is also working to establish a framework for effective stewardship (involving asset owners and managers "making informed decisions about where to invest, and proactive oversight of assets once invested"[47]), which will be relevant for large insurance companies with outsourced investment managers.

The Financial Conduct Authority (FCA) in the UK has outlined three specific broad key outcomes that it wants financial services firms to achieve. These are relevant to insurers as they not only supply insurance-linked investment and pension products to the market, but also as they carry significant investment:

- Issuers providing markets with reliable information about material exposures to climate change;
- Firms integrating consideration of material climate change risk into their business, risk and investment decisions; and
- Consumers having access to green finance products and services and receive the appropriate information with regards to their investments[48]

Positive supervisory indicators

- The insurer has identified where new risks to consumers might arise and where these might pose conduct risks, and has developed a plan to deal proactively with those risks.
- The insurer has identified conduct-related risks that might pose reputational risks, and has an agreed plan to deal with these risks.
- The insurer models potential implications of climate change risk for policyholders, particularly how these vary according to product and customer profile.
- A stewardship strategy has been established in line with the long-term interest of policyholders, and is subject to robust oversight.

Negative supervisory indicators

- Lack of overall understanding of where conduct risk might arise in the context of climate change.
- Lack of specific action and/or management action planning to manage climate change conduct risks.
- Lack of oversight of climate change-related conduct risks posed by outsourced activities, in particular asset management.

Questions for Boards

In what ways are customer outcomes from our products most affected by transition risk?

How have we informed our customers about our sustainable investment strategy and how it might affect their investment return over time?

Can we be confident that all of our customer communications on climate change are adequately clear and transparent?

How confident are we that our customers are satisfied with our approach to sustainability?

Do the policies we've sold remain appropriate for our target customers given climate change risks? What steps have we taken to make sure our policyholders understand this?

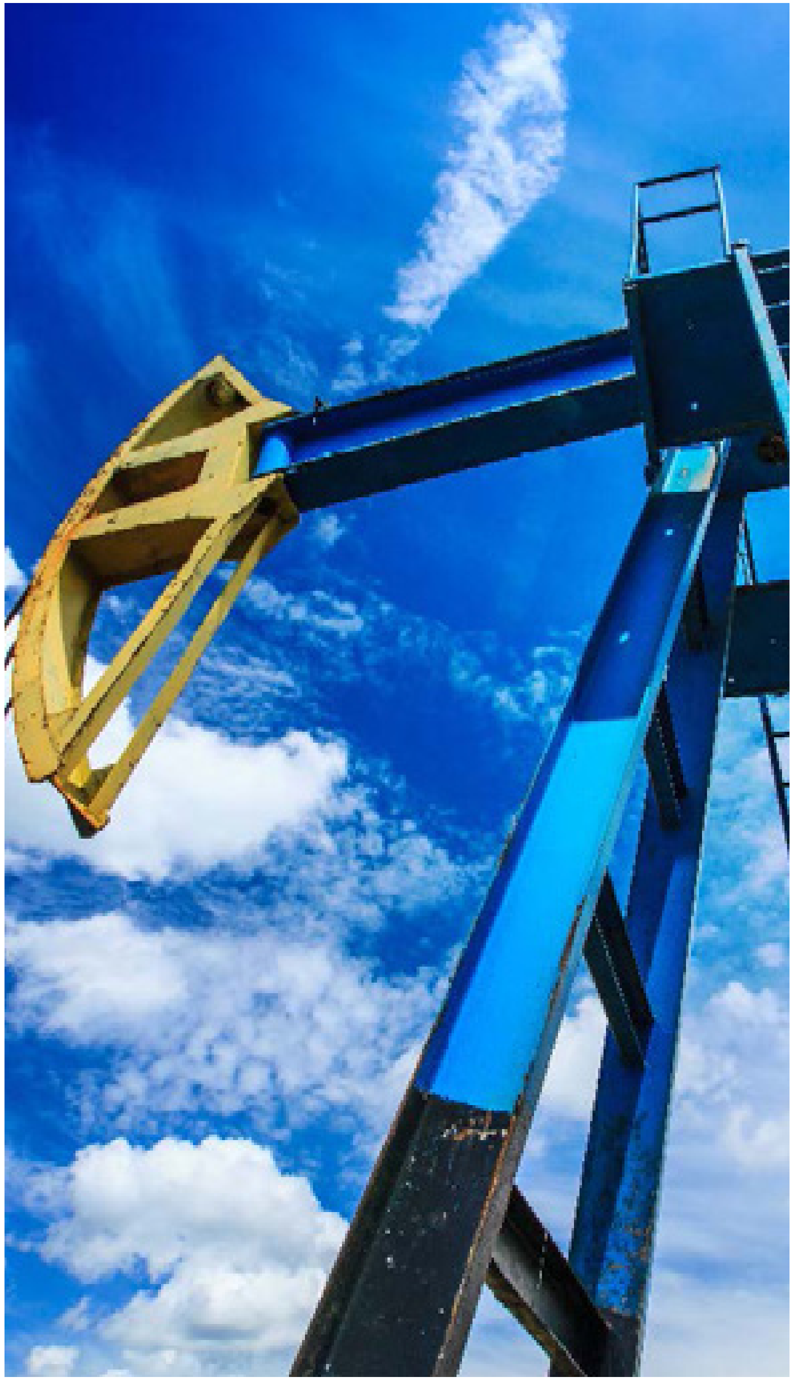
In what areas are we most reliant on third parties/outsourcers to prevent harm to our customers?

10.2“Greenwashing” is likely to be an area of particular concern

Overview

The rise of popularity of ESG investing has led to a focus by conduct supervisors on “greenwashing.

- “Greenwashing” is defined by the UK FCA as “marketing that portrays an organisation’s products, activities or policies as producing positive environmental outcomes when this is not the case”[49]. Emerging European-wide disclosure requirements, along with the EU taxonomy regulation, are intended in part to help prevent the risks of greenwashing. At EU level, the Ecolabelling initiative[50] under the European Commission’s Sustainable Finance Action Plan is also intended to make it easier to know whether a product is environmentally friendly, and is being developed for application to retail financial products.
- The FCA is currently carrying out further policy analysis on greenwashing and has indicated it will take action to address concerns as appropriate[51], for example in the form of formal guidance. As conduct regulators develop their thinking in these areas, relevant firms can expect further scrutiny and potentially regulatory intervention.



Positive supervisory indicators

- The insurer has implemented a framework for how to market and sell green products throughout the supply chain.
- Marketing materials are regularly reviewed in order to avoid products being presented in a way that could be misconstrued.

Negative supervisory indicators

- There is ambiguity in the insurer's own definition of what constitutes "green" assets.
- Lack of in-house guidelines with regards to marketing of green products.

Questions for Boards

Are we describing the ESG outcomes, methodologies and impacts that our products deliver clearly and fairly?

Is our process for determining if a product is "green" sufficiently robust?

How do our "green" products benchmark against others in the market?

How do we demonstrate the sustainable credentials and performance of our products?

Does our sustainability assessment take account of second order effects, for example non-sustainable practices by those who administer, distribute and use our products?

Endnotes

1 https://www.fca.org.uk/publication/feedback/fs19-6.pdf

2 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

3 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

4 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

5 https://www.swissre.com/institute/research/sonar/sonar2019.html

6 https://www.swissre.com/institute/research/sonar/sonar2019.html

7 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

8 https://www.iaisweb.org/page/consultations/closed-consultations/2018/draft-issues-paper-on-climate-change-risks-to-the-insurance-sector

9 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

10 https://natcatservice.munichre.com/events/1

11 https://www.swissre.com/media/news-releases/nr-20191219-global-catastrophes-estimate.html

12 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

13 https://natcatservice.munichre.com/events/1

14 https://www.eiopa.europa.eu/tools-and-data/insurance-statistics_en

15 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

16 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

17 https://www.iaisweb.org/page/consultations/closed-consultations/2018/draft-issues-paper-on-climate-change-risks-to-the-insurance-sector

18 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

19 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

20 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

21 http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2019/07/GRI_Global-trends-in-climate-change-litigation-2019-snapshot-2.pdf

22 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

23 https://www.iaisweb.org/page/consultations/closed-consultations/2018/draft-issues-paper-on-climate-change-risks-to-the-insurance-sector//file/73565/sif-iais-issues-paper-on-climate-risk-to-the-insurance-sector-clean

24 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/letter/2020/managing-the-financial-risks-from-climate-change.pdf

25 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/supervisory-statement/2019/ss319.pdf

26 https://www.fca.org.uk/publication/corporate/climate-financial-risk-forum-guide-2020-risk-management-chapter.pdf

27 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

28 https://www.bankofengland.co.uk/-/media/boe/files/speech/2019/a-new-horizon-speech-by-mark-carney.pdf?la=en&hash=F63F8064E0408F038CABB1F29C58FB1A0CD0FE25

29 Munich Re

30 https://www2.deloitte.com/us/en/pages/financial-services/articles/insurance-companies-climate-change-risk.html

31 https://www.genevaassociation.org/research-topics/extreme-events-and-climate-risk/climate-change-and-insurance-industry-taking-action

32 http://thoughtleadership.aonbenfield.com/Documents/20190403-ab-analytics-rmo-april-2019.pdf

33 https://www.bankofengland.co.uk/-/media/boe/files/paper/2019/the-2021-biennial-exploratory-scenario-on-the-financial-risks-from-climate-change.pdf

34 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/letter/2020/managing-the-financial-risks-from-climate-change.pdf

35 https://www.iaisweb.org/page/consultations/closed-consultations/2018/draft-issues-paper-on-climate-change-risks-to-the-insurance-sector//file/73565/sif-iais-issues-paper-on-climate-risk-to-the-insurance-sector-clean

36 https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf

37 https://www.iaisweb.org/page/consultations/closed-consultations/2018/draft-issues-paper-on-climate-change-risks-to-the-insurance-sector//file/73565/sif-iais-issues-paper-on-climate-risk-to-the-insurance-sector-clean

38 https://www.blackrock.com/institutions/en-gb/literature/whitepaper/global-insurance-report-2019.pdf

39 https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance_en

40 These are defined by the BoE as policy and regulation, technological developments, changing investor preferences, occurrence of physical events and developments of climate science (https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf).

41 https://www.iaisweb.org/page/consultations/closed-consultations/2018/draft-issues-paper-on-climate-change-risks-to-the-insurance-sector//file/73565/sif-iais-issues-paper-on-climate-risk-to-the-insurance-sector-clean

42 As a point of comparison, EIOPA reports that the IORP sector has a high carbon footprint in equity investments (https://www.eiopa.europa.eu/occupational-pensions-stress-test-2019)

43 https://www.fca.org.uk/publication/feedback/fs19-6.pdf

44 https://www.esma.europa.eu/sites/default/files/jc_2020_16_-_joint_consultation_paper_on_esg_disclosures.pdf

45 https://www.esma.europa.eu/sites/default/files/library/esma31-62-1426_final_report_on_guidelines_on_prospectus_disclosure_requirements.pdf

46 https://www.fca.org.uk/publication/corporate/climate-financial-risk-forum-guide-2020-disclosures-chapter.pdf

47 https://www.fca.org.uk/publication/feedback/fs19-6.pdf

48 https://www.fca.org.uk/publication/feedback/fs19-6.pdf

49 https://www.fca.org.uk/publication/feedback/fs19-6.pdf

50 https://ec.europa.eu/environment/ecolabel/eu-ecolabel-for-consumers.html

51 https://www.fca.org.uk/publication/feedback/fs19-6.pdf

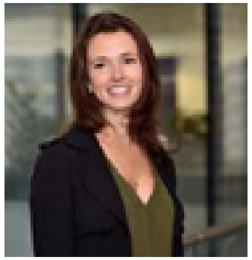
Contacts

Andrew Bulley
Partner
EMEA Centre for Regulatory Strategy
+44 20 7303 8760
abulley@deloitte.co.uk

Henry Jupe
Director
EMEA Centre for Regulatory Strategy
+44 20 7303 8972
hjupe@deloitte.co.uk

Linda Hedqvist
Manager
EMEA Centre for Regulatory Strategy
+44 20 7007 7333
lhedqvist@deloitte.co.uk

Katherine Lampen
Partner
Sustainable Finance
+44 20 7303 8380
klampen@deloitte.co.uk



Tasha Clarbour
Senior Manager
Sustainable Finance
+44 20 7303 8769
taclarbour@deloitte.co.uk

Matt Symes
Manager
Insurance Regulation & Risk
+44 20 7007 1907
mjsymes@deloitte.co.uk

Roger Simler
Partner
Consulting
+44 20 7303 3292
rsimler@deloitte.co.uk

CENTRE *for*
REGULATORY STRATEGY
EMEA

The Deloitte Centre for Regulatory Strategy is a powerful resource of information and insight, designed to assist financial institutions manage the complexity and convergence of rapidly increasing new regulation.

With regional hubs in the Americas, Asia Pacific and EMEA, the Centre combines the strength of Deloitte's regional and international network of experienced risk, regulatory, and industry professionals – including a deep roster of former regulators, industry specialists, and business advisers – with a rich understanding of the impact of regulations on business models and strategy.

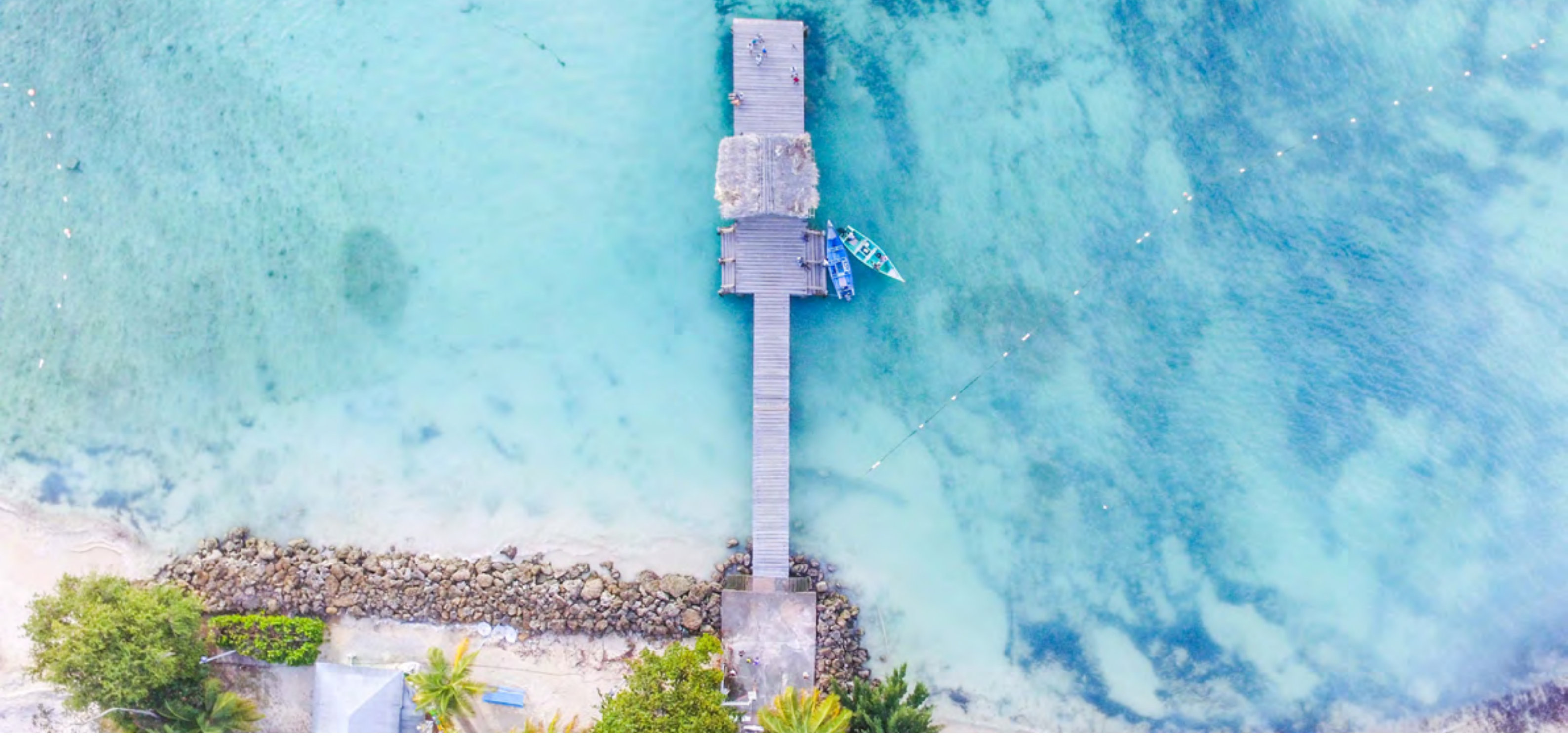
Deloitte.

Annex 591

"Climate Risk Insurance in the Caribbean: 20 lessons learned from the Climate Risk Adaptation and Insurance in the Caribbean (CRAIC) project", *Munich Climate Insurance Initiative*, 14 January 2021

CLIMATE RISK INSURANCE IN THE CARIBBEAN:

20 lessons learned from the Climate Risk Adaptation and Insurance in the Caribbean (CRAIC) project



MESSAGE FROM MCII: ABOUT CRAIC

Phase I of the CRAIC project, implemented between 2011 and 2014, was led by the Munich Climate Insurance Initiative (MCII) and implemented in partnership with CCRIF SPC (formerly The Caribbean Catastrophe Risk Insurance Facility), MicroEnsure, and Munich Re. Funding for the project under the International Climate Initiative (IKI) was supported by the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU). The CRAIC project was initiated to help target countries in the Caribbean region address some of the challenges posed by climate change and extreme weather events to sustainable development. The key deliverable of Phase I was to develop an index-based insurance product. After ongoing consultations with various key stakeholders including the project partners and CRAIC project advisory group, GK General Insurance Company and EC Global, these efforts materialized into the Livelihood Protection Policy (LPP) to offer protection against strong winds and heavy rainfall.

The concept was implemented in three pilot countries, based on feasibility studies carried out in Jamaica, Grenada and Saint Lucia. The CRAIC project helped to build an institutional framework for climate risk insurance (CRI) that is of great significance to the Caribbean region, because the local stakeholders involved in the first phase, GK General Insurance Company and EC Global, contributed significantly to this framework. In addition, the LPP also complemented the existing regional risk pool, CCRIF SPC. These products supported national partners in the region in developing cohesive national strategies for managing climate change by incorporating risk transfer mechanisms, such as CRI, within such strategies. Phase II of CRAIC took place from September 2017 until April 2020, where the project's partners worked to refine the trigger levels of the LPP and established a partnership with UN Volunteers to raise awareness on disaster risk management and the role of insurance. These lessons learned have been collected from the different stakeholders in Phase II of the project and include the perspectives of local insurers, NGOs, reinsurers, UN Volunteers, modeling agencies and implementers.

MESSAGE FROM CCRIF SPC:

CCRIF has been involved with the CRAIC Project since its beginning in 2014. CCRIF strongly supports the project, which was conceptualized to address climate change, adaptation and vulnerability by promoting weather-index-based insurance at the individual level, specifically for vulnerable groups. CRAIC's focus on microinsurance complements the parametric insurance instruments at the sovereign level which CCRIF provides to 19 Caribbean and three Central American governments.

Our work in the Caribbean allowed the project to leverage our relationships and engage governments of the region so that they could better understand the linkages between microinsurance and sovereign level climate risk insurance, and how both are important in closing the protection gap.

The project consortium learned many lessons along the way, and the CCRIF team is pleased to have been part of the development of this document that captures 20 key lessons we have learned over Phases I and II. These lessons learned will be key in the implementation of Phase III and would allow the project team to build on the best practices from the previous phases as well as focus on taking corrective action in areas that were not as successful, but for which there is now a more in-depth understanding in this relatively new and innovative area of climate risk insurance. Lessons learned have always been central to the project's agenda as they are a means to transfer knowledge and experiences, and to further North-South and South-South cooperation and exchange. These lessons learned will contribute to further success under the project, given that Phase II brought new and exciting possibilities and a general and growing excitement around parametric insurance, which were partly fueled by the 2017 hurricanes Irma and Maria.

MESSAGE FROM THE ILO'S IMPACT INSURANCE FACILITY:

The ILO's Impact Insurance Facility is pleased to work with CRAIC and collaborate with the project's partners to test new approaches to protecting small businesses as well as individual workers and households from natural disasters. Hopefully, the next time the region is struck by a hurricane, the backbone of the region's economy – the small business sector – will be able to benefit from insurance to quickly resume operations, providing valuable services to their communities while keeping workers employed. Individual workers will be able to protect their livelihoods and recover loss of income.

TABLE OF CONTENTS

ABBREVIATIONS

ARC	African Risk Capacity
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
CARICOM	Caribbean Community
CBOs	Community-Based Organizations
CCRIF SPC	formerly Caribbean Catastrophe Risk Insurance Facility
CRAIC	Climate Risk Adaptation and Insurance in the Caribbean
CRI	Climate Risk Insurance
CSR	Corporate Social Responsibility strategy
DaLA	Damage and Loss Assessments
DRM	Disaster Risk Management
GDP	Gross Domestic Product
GIIF	Global Index Insurance Facility
ICI	International Climate Initiative
ICRM	Integrated Climate Risk Management
ILO	International Labour Organization
LPP	Livelihood Protection Policy
MCII	Munich Climate Insurance Initiative
NAPs	National Adaptation Plans
NGO	Non-Governmental Organisation
PCRIC	Pacific Catastrophe Risk Insurance Company
PDNA	Post Disaster Needs Assessments
UN	United Nations
WMO	World Meteorological Organization

NATURAL HAZARDS IN THE CARIBBEAN

Countries in the Caribbean face a range of natural hazards, particularly tropical cyclones, excess rainfall, earthquakes and to a lesser extent volcanic risks. The region also faces secondary risks from flooding, landslides, storm surge and wave impacts, drought, and tsunamis. The most significant natural hazard in the Caribbean is tropical cyclones, largely due to their high frequency and severity in the region as well as their potential to hit many islands with a single storm. Tropical cyclones have had an inordinate impact on the economies of Caribbean countries, many of which depend on tourism and agriculture as their main economic drivers. With respect to hydro-meteorological hazards, climate change is expected to result in an increase in the frequency, intensity, and potential impact of these hazards. The changing climate can be considered to be a global driver of increasing disaster risk, and threatens to undermine many of the critical development gains being made by Caribbean countries.

ECONOMIC IMPACTS OF NATURAL HAZARDS

In these small islands and island states, single catastrophes can have a disproportionate effect on the economy, with hurricanes reported to have caused damage ranging from a low of 6 per cent of gross domestic product (GDP) to 200 per cent of national annual GDP, as was the case in Grenada and the Cayman Islands following Hurricane Ivan in 2004.[1] Hurricane Ivan was considered a watershed event in the Caribbean, impacting at least 9 countries and resulting in regional losses totaling over USD 6 billion for the event. The year 2017 was another defining moment for the Caribbean, after suffering the devastation caused by two category 5 hurricanes within 14 days of each other. Damage and losses due to these storms have been estimated at approximately USD130 billion and affected 18 countries, their populations and social and economic infrastructure. These catastrophic events resulted in the Caribbean Community (CARICOM) declaring its ambition to become the first climate resilient zone in the world.

Additionally, a 2017 Moody's report stated that the average annual damage from natural hazards over the period 1980-2015 was 1.5 per cent of GDP in emerging markets versus 0.3 per cent of GDP in developed economies. The average share of affected population over the same period was 3.0 per cent in emerging markets versus 0.4 per cent in developed economies.[2] The average share of affected population over the same period was 3.0 per cent in emerging markets versus 0.4 per cent in developed economies. In fact, the report further indicated that of the 20 most vulnerable countries globally, more than half are small island states across the Caribbean and Pacific regions—with these 20 countries bearing average losses between 2.1 per cent and 20.1 per cent of their respective GDP every year.

It is important to stress that whilst disasters have significantly impacted countries' economies leading to higher fiscal deficits and debt-to-GDP ratios, they have also impacted populations and key industries such as tourism, agriculture, fisheries and social sectors, including housing, schools and hospitals. A case in point is Dominica, in which damage totaled approximately USD 931 million and losses another USD

1 https://www.imf.org/en/News/Articles/2015/09/28/04/54/tr052505

2 https://www.eenews.net/assets/2016/11/30/document_cw_01.pdf

380 million following Hurricane Maria in 2017, amounting to about 225 per cent of their 2016 GDP or USD 1.31 billion in damage and loss. But the damage and loss was far more than economic damage. Over 90 per cent of the population was affected: 15 per cent of the country's housing stock was totally destroyed and 75 per cent partially damaged. Critical infrastructure—roads, bridges, water systems, electricity, telecommunications—was also significantly impacted. The impact on the agriculture and tourism sectors was also significant as these sectors were key to food security, economic activity and providing a livelihood for thousands. Importantly, these disasters also resulted in increasing poverty levels, as these events tend to have a disproportionate impacts on the poorer segments of the population, as well as on older individuals and children.

Left unchecked, the economic impact of disasters can generate large losses that disrupt long-run economic growth and development trajectories. To some extent, natural hazards can be compared to financial crises—both are typically exogenous events that represent covariate shocks across a country and its households. Economic damages from natural hazards can jeopardize the health of national economies at a level comparable to, or greater than, that of financial crises. However, natural hazards also destroy human and physical capital stocks—something that financial crises do not do. This therefore calls for consideration of hazards in development planning as an important priority for governments, businesses, communities and individuals in their pursuit of a sustainable future. It is also critical for the small island and coastal states of the Caribbean region to strengthen their capacity to prepare for and respond to these natural hazards as a means of reducing current and future vulnerabilities.

RESPONDING TO NATURAL HAZARDS IN THE CARIBBEAN

Up until about 10 - 12 years ago, disaster mitigation was touted as the most effective solution for preparations and response to natural hazards, with disaster mitigation focusing on building sea walls, improving building codes, building more resilient structures etc. While disaster mitigation is a necessary component of the disaster preparedness equation below, disaster risk financing and ecosystems management are also critical in how countries prepare to respond to natural hazards. Essentially then, the extent to which a country is prepared to respond to a natural hazard and its vulnerability level is a function of:

> *Disaster risk mitigation + ecosystem management + disaster risk financing + social protection strategies (including psychological impact of future disasters on our populations) = disaster preparedness.*[3]

In other words, countries can better prepare for natural hazards by incorporating risk mitigation, risk transfer and disaster risk financing into their disaster preparedness strategies through factoring in the potential impact of extreme events on their populations. Whilst countries often view "preparing" as an

3 An equation proposed by CCRIF to its members in terms of the elements that disaster preparedness should incorporate

expensive proposition, with resources allocated to the environment and disaster risk management sectors oftentimes being below optimal, countries need to be mindful that being inadequately prepared is far more costly when faced with a disaster.

CLIMATE RISK INSURANCE IN THE CARIBBEAN

The emergence of disaster risk financing efforts in the Caribbean began after Hurricane Ivan in 2004, when CARICOM Heads of Government approached the World Bank for assistance to design and implement a risk financing mechanism to support member governments and provide quick liquidity in the aftermath of disasters. This marked the beginning of what would become the CCRIF SPC, which was established in 2007 as the first insurance instrument to successfully develop parametric insurance policies backed by both traditional and capital markets—with 16 Caribbean governments as members. In the years since, CCRIF SPC has expanded its membership to include Central America and other Caribbean countries, and its current membership is 19 Caribbean governments and 3 Central American governments.

CCRIF SPC has demonstrated that disaster and climate risk insurance can effectively provide a level of financial protection for countries vulnerable to tropical cyclones, earthquakes and excess rainfall. Since its inception in 2007, CCRIF SPC has made 45 payouts totaling USD 163 million to 14 of its 22 member governments. CCRIF SPC's work and its parametric insurance cover are really about supporting governments to help their populations—communities, businesses, and key sectors such as education and agriculture. A rough assessment shows that over 2.5 million people in the Caribbean and Central America have benefitted from CCRIF's payouts after a hazard event.[4]

Use of payouts over the years has included providing food, shelter, and medicine to affected people; stabilizing drinking water plants; providing building materials for people to repair their homes; repairing critical infrastructure such as roads and bridges as a means of enabling movement and access in and out of communities; payment of government salaries for critical first responders to facilitate the injured being cared for; and support for the agriculture sector among others. CCRIF SPC cooperates at the sovereign level and its products are designed for governments. Four years after the establishment of CCRIF SPC, the Climate Risk Adaptation and Insurance in the Caribbean (CRAIC) project was launched in 2011 to focus on providing similar climate risk insurance products as CCRIF SPC, but focusing on the micro- and meso-levels.

4 https://www.ccrif.org/news/ccrif-expands-coverage-private-sector-launches-insurance-product-electric-utilities-caribbean

CLOSING THE PROTECTION GAP

Although insurance can play a critical role in helping individuals and a society recover from extreme natural hazards, 70 per cent of catastrophic losses around the world were uninsured in 2017.[5] Developing countries face a particularly grand challenge as the protection gap is larger in their countries than in developed countries. At the same time, these countries have fewer resources with which to respond to the naturally-induced disasters. In fact, in developed countries, insurance and capital markets are widely used to hedge the immediate adverse impacts of natural hazards. According to MunichRe, more than 40 per cent of the direct losses from natural hazards are insured in developed countries. At the same time, MunichRe estimates that less than 10 per cent of losses are covered by insurance in middle-income countries and less than 5 per cent are covered in low-income countries. Many individuals in these affected areas do not possess any form of insurance and often are unable to qualify for traditional indemnity insurance, such as property or crop insurance. Both CCRIF SPC and CRAIC are contributing to the overall objective of the G7 Climate Risk Insurance Initiative and the InsuResilience Global Partnership which aim to have 500 million poor and vulnerable people in developing countries benefiting from direct or indirect insurance by 2025. Parametric microinsurance products therefore provide a unique opportunity to help close the protection gap among the most vulnerable.

ABOUT THE CLIMATE RISK ADAPTATION AND INSURANCE IN THE CARIBBEAN PROJECT

The CRAIC project is implemented by the Munich Climate Insurance Initiative (MCII) together with its partners, CCRIF SPC, the International Labour Organisation's (ILO's) Impact Insurance Facility, DHI, and MunichRe. The CRAIC project was conceptualized to address climate change, adaptation, and vulnerability by promoting parametric insurance at the individual level as a disaster risk management instrument in the Caribbean. In order to reach this population, CRAIC developed a microinsurance product called the Livelihood Protection Policy (LPP). The CRAIC project is being implemented in five Caribbean countries: Belize, Grenada, Jamaica, Saint Lucia and Trinidad and Tobago. CRAIC is funded under the International Climate Initiative (IKI), which is supported by the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU).

---

5 https://www.munichre.com/content/dam/munichre/global/content-pieces/documents/TOPICS_GEO_2016-en4.pdf

A BRIEF ON THE LIVELIHOOD PROTECTION POLICY

Parametric (or index-based) insurance products are insurance contracts that make payments based on the intensity of an event (for example, hurricane wind speed, earthquake intensity, volume of rainfall) and the amount of loss calculated in a pre-agreed model caused by these events. Therefore payouts can be made very quickly after a hazard event. This is different from traditional insurance settlements that require an on-the-ground assessment of individual losses after an event before a payment can be made.

Weather-indexed microinsurance refers to policies typically designed for individuals which pay out after pre-determined triggers, such as excess rainfall or high wind speed, have been met. These payouts are free to be used for repairing damage to physical assets or to help individuals compensate for losses in livelihood.

The LPP is a parametric microinsurance product and an example of an ex-ante disaster risk financing tool. The LPP has been designed to help protect the livelihoods of vulnerable individuals such as smallholder farmers, tourism workers, fishers, market vendors and day laborers by providing quick cash payouts following extreme weather events (specifically, extreme winds and excess rainfall). These payouts are intended to provide some level of stability to clients' financial situation after severe storms, allowing them to avoid adopting adverse coping strategies that could lead them deeper into poverty while awaiting for help from external sources. The LPP is not only for individuals, but also community groups such as credit unions and farmers cooperatives who can purchase policies on behalf of their members. Governments are also being encouraged to incorporate the LPP as part of their social protection policy and strategy, so that they can quickly send a payout to those most in need via an existing cash transfer after an extreme event hits.

Similar to other parametric insurance products, the LPP is an insurance contract that makes payments based on the intensity of an event based on pre-agreed trigger values. Therefore payouts can be made very quickly after a natural hazard strikes. This is different from traditional indemnity insurance settlements that require an on-the-ground assessment of individual losses after an event before a payment can be made. The key features of traditional insurance are the onus of proof on the insured party to validate a loss, the power for the insurer to dispute a claim amount and the administrative burden involved in making a claim.

Payouts to policyholders under the LPP are disbursed between three and 14 days after an event. Since the LPP was launched in 2014, policyholders (mainly smallholder farmers) in Jamaica and Saint Lucia have received payouts allowing them to get back on their feet and realize concrete earnings from their

work as soon as possible after an event. For example, following Hurricane Matthew in 2016, individuals in Saint Lucia received payouts totaling USD 102,000 on their Livelihood Protection Policies.[6] The LPP is innovative and represents a first step in proactive planning for climate adaptation and is an effective mechanism to close the protection gap.

LESSONS LEARNED FROM THE CRAIC PROJECT: 2011 – 2018

Given that CRAIC was one of the first projects of its kind in the region, it was designed as a project focused on learning and continuous improvement. The CRAIC project consortium aimed to capture the lessons learned during implementation, build on best practices, and—when required—take corrective action along the way. The lessons learned by the CRAIC implementers are applicable to other small island and coastal states that have an interest in developing and implementing similar microinsurance schemes to support vulnerable populations. This publication of lessons learned is intended to encourage a culture of learning and knowledge sharing on climate and disaster risk insurance, vulnerability, and closing the protection gap.

The lessons learned under the CRAIC project are structured under four themes:

1. **Managing Expectations**
2. **Product Design**
3. **Market Development**
4. **Engagement for Sustainability**

6 https://www.ccrif.org/news/ccrif-completes-payments-totalling-us29-million-member-governments-affected-hurricane-matthew

THEME 1: Managing Expectations

When the CRAIC project first introduced the LPP to the Caribbean, there was significant interest in an insurance product that could indemnify low-income individuals after extreme weather events. However, although many CARICOM governments had been purchasing parametric coverage from CCRIF SPC for several years, the average citizen and (in many cases) the private sector were not familiar with parametric insurance. Other observations related to the LPP in the early years revealed that there was a limited understanding among both local insurers and the target population of how the index was calculated, the data sources used to build the model and how payouts were triggered. In addition, there was a lack of willingness to pay for the insurance premium after years when there was no payout. Without a comprehensive understanding of the policy conditions underpinning an insurance product, it becomes difficult to manage expectations especially when a policy does not trigger and therefore no payout is due. It is a well-established industry and regulatory standard that the clear communication of insurance benefits and claims conditions is critical for both consumer protection and satisfaction. The lessons learned related to managing expectations are presented below.

Lesson Learned #1
Education on parametric insurance is needed among the target population

Lesson Learned #2
Basis risk must be understood by government, insurers, distribution channels, and the target population for parametric insurance to be accepted

Lesson Learned #3
Policyholders must understand the elements and benefits of the actual policy and be provided with guidance when purchasing the product

Lessons Learned #4
Insurers and implementers must clearly communicate the benefits and limitations of parametric insurance

Managing Expectations

LESSON #1

EDUCATION ON PARAMETRIC INSURANCE
is needed among the target population

When most people think about insurance for natural hazards, they think about traditional property insurance. Property insurance is a type of indemnity insurance, which means that the insurance payout corresponds to the amount of loss that a policy holder has experienced. This common knowledge on indemnity insurance can make parametric insurance difficult to understand. People expect a loss adjustor to check the amount of damage after an event. Receiving an automatic payment regardless of the damage is still a new concept that can seem too good to be true. Likewise, the idea that a policy holder may not receive a payout even when they have experienced losses can be met with a lot of resistance at first.

There are many core concepts related to parametric insurance that must be clearly explained to the target population if they are to develop trust in the products. **Policy holders must understand that a payout amount is determined by the parametric model, and is correlated with the severity of the event**. They must also be aware that there may not be a payout after an extreme weather event if a trigger is not met. Clients should know that even if there is a payout, it will not be equal to the amount of actual losses they have experienced. Additionally, policyholders must be aware that a loss adjuster will not come to their house, business or farm to inspect the damage, but in the case of the LPP, a payout will automatically be sent to their bank account within 14 days if their policy is triggered. Since CRAIC caters to low-income and vulnerable people, it is also important that educational products and tools are designed to be compatible with the educational levels of the potential policyholders.

Managing Expectations

LESSON #2

BASIS RISK
must be understood by government, insurers, distribution channels, and the target population for parametric insurance to be accepted

Another important area that must be understood by policyholders is the concept of basis risk, which is an inherent characteristic of parametric insurance. According to the Global Index Insurance Facility (GIIF)'s Index Insurance Forum, basis risk arises in parametric insurance "when the index measurements do not match an insured's actual losses".[7] There are two forms of basis risk: in the first case, the policyholder does not receive a payout, or receives a payout that does not cover the amount of damage they have incurred; the second form occurs when an insurance policy is triggered even though the policyholder has not experienced any damage or receives a payout larger than the amount of damage they have incurred. Both forms of basis risk present a risk to insurers. In the first case, insurers run the risk of damaging their reputation when policyholders have suffered from an extreme weather event but the rainfall and wind speed were not high or sustained enough to trigger. In the second case the insurance may pay out more often or a larger amount than what is actually required by policy holders to recover from the event. The differences between payouts and experienced losses can lead to mistrust in the quality of the products, the validity of the parametric models and the insurance industry. Policyholders should understand that the design of the LPP seeks to minimize its level of basis risk, but that basis risk is still an inherent component of parametric insurance products.

7 https://indexinsuranceforum.org/faq/what-basis-risk

Managing Expectations

LESSON #3

Policyholders must understand the elements and benefits of the actual policy and be provided with GUIDANCE WHEN PURCHASING the product

Once individuals have decided to purchase a policy, they must understand exactly what it is that they are buying and what level of coverage they need for their specific circumstances. Guidance must be provided on premium pricing versus maximum payouts and potential policy options, how much coverage to purchase, etc. They must also be made aware of where they can purchase the policy, how they can receive payouts, and how they can renew their contract and make premium payments. If this information is too hard to find or too confusing, it could demotivate individuals from purchasing the insurance product.

Parametric insurance policies could increase access to loans from financial institutions if the lending institution has the options of using the insurance as a form of collateral. If a lending institution decides to use the insurance as a form of collateral, this must be clearly communicated to the policy holder.

Managing Expectations

LESSON #4

Insurers and implementers must clearly communicate the BENEFITS AND LIMITATIONS of parametric insurance

It also is important to ensure that policyholders understand insurance is not a silver bullet and disaster risk reduction measures must be incorporated to reduce their exposure, build resilience and thereby reduce the likelihood of incurring a large amount of losses after a natural hazard. **Policy holders should understand that risk transfer—of which insurance is only one tool—is only one part of an effective disaster risk management (DRM) strategy.**

Through education and training programming, implementers should work with policyholders to build awareness on the usefulness of parametric insurance and how it could be used alongside other measures to minimize their overall exposure to natural hazards. While insurers may not have much vested interest in building the capacity of policyholders in DRM, CRAIC has learned that NGOs, community groups, and government agencies are willing and can play an important role in incorporating information on risk transfer and insurance into their DRM training and other capacity building and awareness raising sessions to ensure that the target population understands the benefits and limitations of insurance.

THEME 2: Product Design

CRAIC designed the LPP initially to cover extreme rainfall and winds with standardized and limited payouts occurring at four different trigger levels. This simplified approach allowed insurers to be able to quickly and easily explain the product to potential clients. While the product was designed with the vulnerable population in mind, the product can be made available to anyone willing to purchase it, recognizing that all income groups in the Caribbean islands can be negatively affected by extreme weather events. This approach led to many valuable lessons on product design.

Lesson Learned #5
Continuously improving the parametric models that underpin policies to enhance product performance

Lesson Learned #6
Developing new products for different target groups

Lesson Learned #7
Adopt a segmented approach that involves product variety

Lessons Learned #8
Social protection: aligning microinsurance schemes with national social protection policies and strategies

Lessons Learned #9
Government can play a vital role in raising awareness of and educating on parametric insurance

Lessons Learned #10
Consider the use of multiple distribution channels for improving access to the products and receiving payouts

Lessons Learned #11
It is important for insurers to understand the target population: using customer-centric design to meet needs

Lessons Learned #12
Selling group policies is important to increase access to insurance and enhance sales

Product Design

LESSON #5

Continuously improving the parametric models that underpin policies to ENHANCE PRODUCT PERFORMANCE

One of the challenges that has impacted parametric insurance products is insufficient reliable and accurate historical data for different perils such as wind, rain, or drought. Long term, high quality historical data is a key requirement to developing parametric products that can be reasonably priced and have a low amount of basis risk. However, the data is often scattered across sources of varying quality and accuracy, and oftentimes the data may be difficult to assess. Moreover, the validation of parametric models require using historical records that often do not exist. If an insurer does not have enough data to create a high quality model, they may add a malus as an extra premium (basically loading the premium) to the product to compensate for uncertainty. This malus is then passed on to the buyer of the product through a higher price.

To improve the accuracy of parametric models, insurers can regularly incorporate new and improved (e.g. higher resolution images or more granular) data into risk models and product updates. For example, using data with higher resolution would allow for products to be more accurately paid out and lower the amount of basis risk. Parametric models also need to take into account the future predicted trends of these losses in light of climate change. Governments can also help by systematically collecting weather data as well as damage records that may come from Damage and Loss Assessments (DaLA) or Post Disaster Needs Assessments (PDNA). Weather data should be in accordance with the World Meteorological Organization (WMO)'s standards, as this would make the data comparable to other sources and allow for greater analysis.

Product Design

LESSON #6

Developing new products for DIFFERENT TARGET GROUPS

In order to meet the needs of different target populations, it may be prudent to tweak products. For example, a product designed for farmers may not be applicable to fisherfolk who are often affected by waves that can prevent them from going out to sea. The LPP paid out according to wind speed and rainfall levels, and the fact that it did not have an additional trigger for waves may have made it an unattractive option for some fisherfolk. In other words, **insurers should recognize that different vulnerable groups may have varying needs and their livelihoods could be affected by varying perils.** Products can be differentiated by hazard, price, trigger levels, value added features, premium frequency and payout amounts. Similarly, the needs of men and women may differ, and implementers should incorporate gender considerations into the product design, recognizing that women are often more impacted by extreme weather events. Designing products to meet the needs of different target markets could result in closing the protection gap even at a faster rate as one would ensure that there is higher levels of access.

Insurers can also work to minimize the impact of basis risk of different groups by augmenting policies with ground-truth mechanisms and secondary triggers, such as having specific individuals check the damages in an area after an event or using additional data sources, and by continually improving the data sets in the risk models. Moreover, it is important to investigate how hybrid insurance products, which combine components of both parametric and indemnity insurance products can be used to mitigate basis risk. For example, if a large groups of farmers have all been affected by an event, but the trigger level was not met, the insurer could conduct an audit to determine if the amount of damage warrants a payout.

Product Design

LESSON #7

Adopt a SEGMENTED APPROACH that involves product variety

The more perils that are included in a parametric insurance product, the more expensive it will be. Similarly, the lower the triggers, the more often it will pay out and thus the more expensive it will be. Parametric products are priced according to these different risks. For example, if an insurer decides to the lower wind speed, or to lower the amount of rain fall needed to trigger a payout, the product will become more expensive. **Parametric microinsurance hence needs to be correctly priced and meet the needs of the client and the insurer if it is to be commercially viable.** Depending on an individual's risk profile, they may want a product that triggers at lower wind speed levels, as they are still affected by low wind speeds. It is thus important to understand different target groups' risk profiles in order to make sure that products meet their needs.

It is important to note that higher prices may make the product unaffordable for the lowest income groups and the vulnerable. This knowledge has allowed CRAIC to focus on developing two new product varieties:

- **Government-sponsored** or subsidized policies for specific targets groups that are low-income, highly exposed, or vulnerable to extreme weather events or those who work in critical sectors such as agricultural, could be beneficial. Governments could do this by paying for part of the insurance premium, eliminating value-added taxes on insurance or leveraging existing cooperative groups to distribute group policies.

- **Bundling insurance** with non-insurance products, such as credit, may increase client value. Such products can protect financial institutions from extreme weather events by allowing insurance payouts to go towards paying back the policy holder's loan. This extra security for the financial institution can also allow them to lend to individuals whose income is affected by climate risks, increasing the supply of credit. Alternatively, parametric products could be bundled with other forms of insurance, such as life insurance, in creasing the value of or the product for policy holders.

Product Design

LESSON #8

SOCIAL PROTECTION:
aligning microinsurance schemes with national social protection policies and strategies

Market-based approaches struggle to reach the poor due to several reasons. The first is that it can be difficult to reach lower income groups that are located in remote areas, as high time and travel costs are required to reach them. Moreover, the lower income groups might be in need of financial literacy in order to understand the types of banking and insurance instruments they are presented with. Additionally, if some individuals do not actively use a bank account, they may experience difficulties purchasing insurance, regularly paying premium and receiving payouts because parametric insurance products often require these bank accounts in order to have the insurer transfer the payout.

Governments should consider how insurance can be leveraged to enhance the social protection systems in responding to natural hazards and extreme weather risks. Incorporating parametric insurance into a social protection scheme could allow governments to provide support more quickly after an event, preventing the aftermath of the event from worsening. This strategy could also help families from falling into a poverty trap and can reduce vulnerability. **Further, by linking micro insurance with social protection, governments can also reduce the financial burden of disaster response, and prevent themselves from having to reallocate budgets moving resources away from other development priorities.**

Product Design

LESSON #9

GOVERNMENT can play a vital role in raising awareness of and educating on parametric insurance

Governments have a large role to play in increasing awareness on the products through their work with different target groups through ministries working on agricultural, fisheries, and social development. For example, many governments in the Caribbean have agricultural extension officers in place, who work closely with farmers in areas ranging from educating on new climate-resilient farming techniques to finding new markets for their produce and helping them create linkages with other sectors such as tourism. Agricultural extension officers are excellent partners to bring the message of CRI to the farmers as they hold a high level of trust.

The government's support could lead to lower insurance pricing, as the insurer will not be required to increase the cost of the insurance premium to cover high marketing and outreach costs. Local governments can also support insurers by providing information on how groups in their town and parish are affected by natural hazards. They could also provide the platform, through community and outreach events, for insurers to present and raise awareness on insurance and the role it can play in helping people quickly recover from extreme weather events. For example, insurers in Saint Lucia presented a short skit on the LPP during one of the town's community events, allowing the audience to learn about insurance in an entertaining and engaging way.

Lastly, at the policy level, ministerial champions and regulators are instrumental for a new insurance product. Without the support of insurance regulators, the development and rolling out of new products can take considerably more time.

Product Design

LESSON #10

CONSIDER THE USE OF MULTIPLE DISTRIBUTION CHANNELS for improving access to the products and receiving payouts

Microinsurance often targets people who have not been covered by insurance before or who operate outside of the financial system. These individuals may also not have access to banking systems and digital technologies such as online banking. The CRAIC project has realized the importance of using multiple distribution channels to reach more people, including people in rural areas who may not have much access to financial institutions. The CRAIC project also learned the importance of insurers leveraging commonly-accessed distribution channels that reach the target population to enhance sales.

For example, by using credit unions and banks as distribution channels, financial inclusion and local agency networks increase access to insurance along with other services. However, the product must be designed to also add value for the distributor. For a bank to sell insurance policies as part of their services, they will need to be compensated for the margin, extra training, and education that will be required. Without appropriate compensation, financial institutions may not put much effort or resources into the sale of CRI products.

Product Design

LESSON #11

It is important for insurers to understand the target population: USING CUSTOMER-CENTRIC DESIGN to meet needs

During the design phase, it is essential for insurers to consider how potential policyholders will purchase and pay for the insurance policy. **Aligning premium payment dates with the policyholders' income streams is one way to improve affordability and enhance uptake.** For example, many farmers earn most of their income during the harvest season. It would therefore be prudent for insurers to investigate if they could facilitate the collection of premiums during this time period when farmers have the liquidity to pay for such an insurance. Other target groups such as fishermen or tourism workers will have different times when they have more funds at hand, which is why insurers should investigate when the different groups are most willing and able to pay. Alternatively, allowing premiums to be paid on a monthly or even weekly basis rather than requiring an annual lump sum also makes the product more accessible for those working in sectors with more volatile income streams.

Product Design

LESSON #12

Selling GROUP POLICIES is important to increase access to insurance and enhance sales

Cooperatives, businesses, associations and organizations can act as an aggregator for group policies on behalf of their members. Under the CRAIC project, many of these organizations have shown interest in group policies. **A group policy is a viable way to increase access to insurance and enhance sales**. It can be sold to the group (the insured), preventing the insurer from having to register each member (the beneficiary) individually. A group policy therefore has lower administrative costs than individual policies, which can make coverage cheaper overall for each contributing member of the group.

If group and individual sales are to be offered alongside each other in a country, a discount could be applied to the group premium to create an incentive for group leaders to consider purchasing a group policy on behalf of their members. Individual sales may not be viable for all insurers, so covering multiple individuals through a single group insurance contract may be a key to success in terms of increasing scale.

THEME 3: Market Development

In addition to the actual design of a product, CRAIC needed to develop the market for these types of insurance solutions. Most insurers in the target countries were accustomed to working with higher income clients and had limited experience targeting lower income groups. New approaches for marketing, selling and distributing to these individuals thus needed to be developed.

Lesson Learned #13
Local NGOs and Community-Based Organizations (CBOs) have an important role to play in lowering the cost of insurance

Lesson Learned #14
Creating competition in the market: creating success without picking winners

Lesson Learned #15
Incorporating the use of technology and digital solutions to facilitate sales and distribution of products and payouts

Lessons Learned #16
The importance of communication as a tool to build trust in insurance cannot be underscored:

Lessons Learned #17
Local insurers need to align climate risk microinsurance to their overall business strategy

Market Development

LESSON #13

Local NGOS AND COMMUNITY-BASED ORGANIZATIONS (CBOS) have an important role to play in lowering the cost of insurance

Implementers should seek to strengthen general insurance awareness and capacity through training and technical assistance. For some individuals, parametric insurance is the first form of insurance they have ever purchased. There is hence often the need for people to receive some form of financial education to better make decision on savings, loans, insurance and overall risk diversification. **Without this education component, potential clients could misunderstand how parametric insurance can most effectively be used to complement their other risk management strategies**.

Under the CRAIC project, it became clear that policyholders often had confidence in and worked closely together with local NGOs and CBOs. These organizations often work together with communities to train them on disaster risk reduction and management. By integrating information on disaster risk financing and parametric insurance into their DRM training, NGOs and CBOs can help raise general awareness of insurance solutions and how they can contribute to accelerating recovery efforts after extreme events. Moreover, by explaining to the local population how parametric insurance differs from traditional forms of insurance, community members can better evaluate if parameter insurance is an appropriate solution for them.

By having local NGOs and CBOs introduce these topics, insurers will not have to spend as much time conducting their own educational and training sessions, reducing their marketing and advertising costs. This, in turn, will be reflected in the pricing of the insurance product. When marketing and advertising costs can be lowered, the product offering can become cheaper.

Market Development

LESSON #14

Creating COMPETITION IN THE MARKET: creating success without picking winners

Introducing competition among insurers and distribution channels can provide the impetus for insurance companies to advertise, educate and sensitize at a greater scale to increase their market share and motivate innovations in product offerings and outreach techniques. Moreover, insurers can differentiate themselves by specializing in certain types of products and solutions that are most suitable for a specific subset of the overall target group. Different insurers could also increase the availability of insurance in several regions and communities through their varied distribution channels. **Creating competition could also benefit the industry by catalyzing competitive pricing**. Regional risk diversification could also be enhanced if multiple insurers enter this line of business.

For example, some insurers may have a strong customer base that works in the tourism industry or is located in one region. The insurer can consider what perils most affect the livelihoods of these tourism workers and develop a product that would protect them against these risks. Other insurers that work closely with the agricultural sector can investigate which types of products and/or add-ons would be most beneficial to farmers or fishers. By creating specialized products, insurers can differentiate themselves from their competitors and target the market segments they see as more aligned to their overall business strategy.

Market Development

LESSON #15

Incorporating the use of TECHNOLOGY AND DIGITAL SOLUTIONS to facilitate sales and distribution of products and payouts

Digital technologies can play a role in customer acquisition as well as the sales and distributions of policies and payouts. Parametric insurance often has a high technical price, as the likelihood of an extreme weather event occurring is quite high in some regions. **Thus, insurers must strive to keep additional sales costs as low as possible in order to maintain the affordability of the product**. Digitalized insurance solutions continue to advance and develop so that access to digital financial services increases. For example, in some countries insurance can be sold through web or phone application, which helps reduce sales costs. Similarly, if payouts can be made directly to policy holders' phones or bank accounts, the payout times will be reduced, allowing families to access and use the funds right when they need them.

It should be noted that exclusively using digital solutions has the potential to exclude certain target populations, such as the elderly or lower income groups who may not regularly use these technologies or have access to internet services. Insurers should investigate which groups could be targeted, and determine how sales agents could better use digital solutions when making their first sales while developing alternative methods for other groups. Renewals and keeping in touch with the customers through demand-oriented service messages could also be done both digitally and in person. Regulators play a key role in creating an enabling environment for digital access to finance.

Market Development

LESSON #16

The importance of COMMUNICATION AS A TOOL to build trust in insurance cannot be underscored

One of the reasons individuals may choose not to purchase an insurance product is because of their lack of trust in insurance, which can stem from a lack of understanding and knowledge on how insurance works or from negative stories they have heard about insurance agencies from their families and friends.

It is very important for the insurer to utilize communication tools to continuously engage potential clients. Under the CRAIC Project, emphasis was placed on a range of communication activities to bring about awareness of the project and the product among the target populations. The CRAIC project employed UN volunteers to engage communities and also published a range of publications, videos in indigenous languages, as well as disseminated press releases when there were success stories to be told. **Hearing about the experiences of their neighbors and community members can help raise awareness of the parametric insurance products and build trust in insurance**. Insurers can advertise these payout stories through written brochures, radio interviews, and other social media channels. Through this dissemination of experiences, individuals will have an improved understanding of how the product works and when it pays out, increasing their trust in the product and the insurance agency.

Market Development

LESSON #17

Local insurers need to align climate risk microinsurance to their overall BUSINESS STRATEGY

Microinsurance should not be seen by local insurers, reinsurers and distribution partners as part of their corporate social responsibility (CSR) strategy. If insurers see parametric and microinsurance only as a part of CSR, they may discontinue the product when business challenges arise. Rather, **insurers should align microinsurance products to their core business strategy**, **viewing it as an opportunity to engage with new clients who can potentially purchase other products that they may have on offer**, **creating a win-win situation**. By aligning microinsurance to their overall business strategy, insurers may be more willing to invest their time and resources into product development and roll out, increasing their dedication to the success of the product. Their commitment to each step of the product development and sales will be instrumental in ensuring that it can satisfy customer needs.

It is the responsibility of implementers to communicate expected associated staff, marketing, and sales costs clearly to business partners. Expectations must be realistic, however, noting that this market segment is nascent and will take several years to mature.

THEME 4: Engagement for Sustainability

The CRAIC project brought together partners from the private sector, public sector and academia to implement its project activities. Having a diverse group of stakeholders is key to a successful project implementation and achieving project outcomes, as each stakeholder has a key role to play. Governments provide the enabling environment in which innovation can take place through their regulations. They are also key in institutionalizing new approaches and in reaching specific groups through their networks. Academia, particularly universities located in the region, assist by carrying out research and collecting the data that is needed for model development and product design. Researchers that have already conducted research on vulnerability in the region offer particularly useful insights into the target populations. Lastly, the private sector is key to developing innovative insurance solutions, using their experiences to create tailored products to meet local demand.

Lesson Learned #18
Integration of insurance: promoting Integrated Climate Risk Management (ICRM)

Lesson Learned #19
Sustainability: integrating microinsurance into country and regional institutions

Lesson Learned #20
Engagement with governments: embedding insurance into National Adaptation Plans (NAPs)

LESSON #18

Integration of insurance: promoting INTEGRATED CLIMATE RISK MANAGEMENT (ICRM)

Most governments have detailed DRM plans explaining the actions the government and its citizens should take in the prevention, preparedness, response, and recovery phases. What is often less emphasized is the role of risk retention and risk transfer. It is nonetheless vitally important for governments to educate their citizens on the financial tools that could help them better manage their own risks.

Depending on the risk profile of certain groups and their vulnerabilities to certain hazards, governments should explain how different financial tools could benefit them. While loans might seem like an attractive option after an extreme event strikes, individuals should understand the challenges associated with taking out additional credit, as their productivity levels after the event will likely be lower, making it difficult to pay back the loan. Alternatively, if they pay for parametric insurance when they have cash on hand, this can result in them quickly receiving a payout after the event. Lastly, depending on how severely one's income sources will be impacted by different perils, relying on savings could also be an option. **By integrating risk retention and risk transfer into their overall DRM approach, governments and individuals can ensure that they are making the best financial decision for their specific situation**.

Market Development

LESSON #19

SUSTAINABILITY: integrating microinsurance into country and regional institutions

The aim of the LPP is to increase resilience to naturally-induced catastrophes in the Caribbean region. Likewise, regional risk pools such as CCRIF SPC, the African Risk Capacity (ARC) and the Pacific Catastrophe Risk Insurance Company (PCRIC) have worked to provide governments with support after extreme events using parametric insurance products. By integrating the programme and insurance solutions into government institutions or regional risk pools, implementers can:

1) Learn from the experience of the risk pools
2) Investigate how models can be leveraged for the macro and micro level
3) Use the similar risk models to avoid discrepancies on the micro and macro level
4) Create more transparency in how the product works

Implementers seeking to create sustainable parametric microinsurance schemes and products should consider how they can be integrated into country and regional institutions. Implementers may also want to reach out to regional risk pools to see how microinsurance can be integrated into their offering to governments. This approach can better serve the target populations and contribute to closing the climate risk protection gap.[8]

8 https://www.insuresilience.org/wp-content/uploads/2019/09/The-Future-of-Disaster-Risk-Pooling-for-Developing-Countries.pdf

Market Development

LESSON #20

ENGAGEMENT WITH GOVERNMENTS: embedding insurance into National Adaptation Plans (NAPs)

Few of the current country DRM and National Adaptation Plans (NAPs) include a comprehensive disaster risk financing plan outlining the instruments they plan to employ in different scenarios. However, **it has been well-noted that disasters have devastating financial impacts on countries' economies and can derail their development efforts, setting them back a number of years**.

For this reason, it is vital for countries to include a disaster risk financing strategy as part of their overall NAPs and development plans. Countries that are highly vulnerable to extreme weather events know the types of effects a hurricane or earthquake can have on their society after having experienced such events themselves, or witnessed them striking their neighbors. These plans should address not only what

instruments the government would pursue when they have to quickly respond after a disaster, but should also include a strategy on how they can best aid different segments of the population, including through the promotion of market-based insurance solutions for those who can afford them. For those people with a limited amount of savings or whose livelihood is greatly affected by certain natural hazards, the government can consider how to best provide immediate support. Governments should investigate how parametric insurance can be used to target these highly vulnerable groups so that they receive financial aid quickly after an event and expedite the rebuilding and recovery process.

CONCLUSION

The CRAIC project is entering a new phase in 2020, where the project team will be applying the lessons learned through new and strategic practices. The CRAIC project will be working on managing expectations by working closely together with governments to provide trainings and set up an education plan for potential beneficiaries so they understand what parametric insurance is, how it works and how it can help them better manage risks. The CRAIC project will also work on the product design by working together with modelers to design differentiated products for different groups. It will also work on market development by creating partnerships with local organizations who can help provide education. Lastly, the CRAIC project is excited to have CCRIF SPC take on a more leading role in the project, bringing their extensive experience in parametric insurance, education on insurance and regional development to the project countries.

About MCII

The Munich Climate Insurance Initiative was initiated as a charitable organisation by representatives of insurers, research institutes and NGOs in April 2005 in response to the growing realization that insurance solutions can play a role in adaptation to climate change, as suggested in the UN Framework Convention on Climate Change and the Kyoto Protocol. This initiative is hosted at the United Nations University Institute for Environment and Human Security (UNU-EHS). As a leading think tank on climate change and insurance, MCII is focused on developing solutions for the risks posed by climate change for the poorest and most vulnerable people in developing countries.

FOLLOW US ON TWITTER: @_MCII_
EMAIL US: MCII@EHS.UNU.EDU

For more information about the Climate Risk Adaptation and Insurance in the Caribbean project contact: mcii@ehs.unu.edu

http://www.climate-insurance.org/projects/climate-risk-adaptation-and-insurance-in-the-caribbean/

CCRIF SPC The Caribbean Catastrophe Risk Insurance Facility

ILO

IMPACT INSURANCE

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

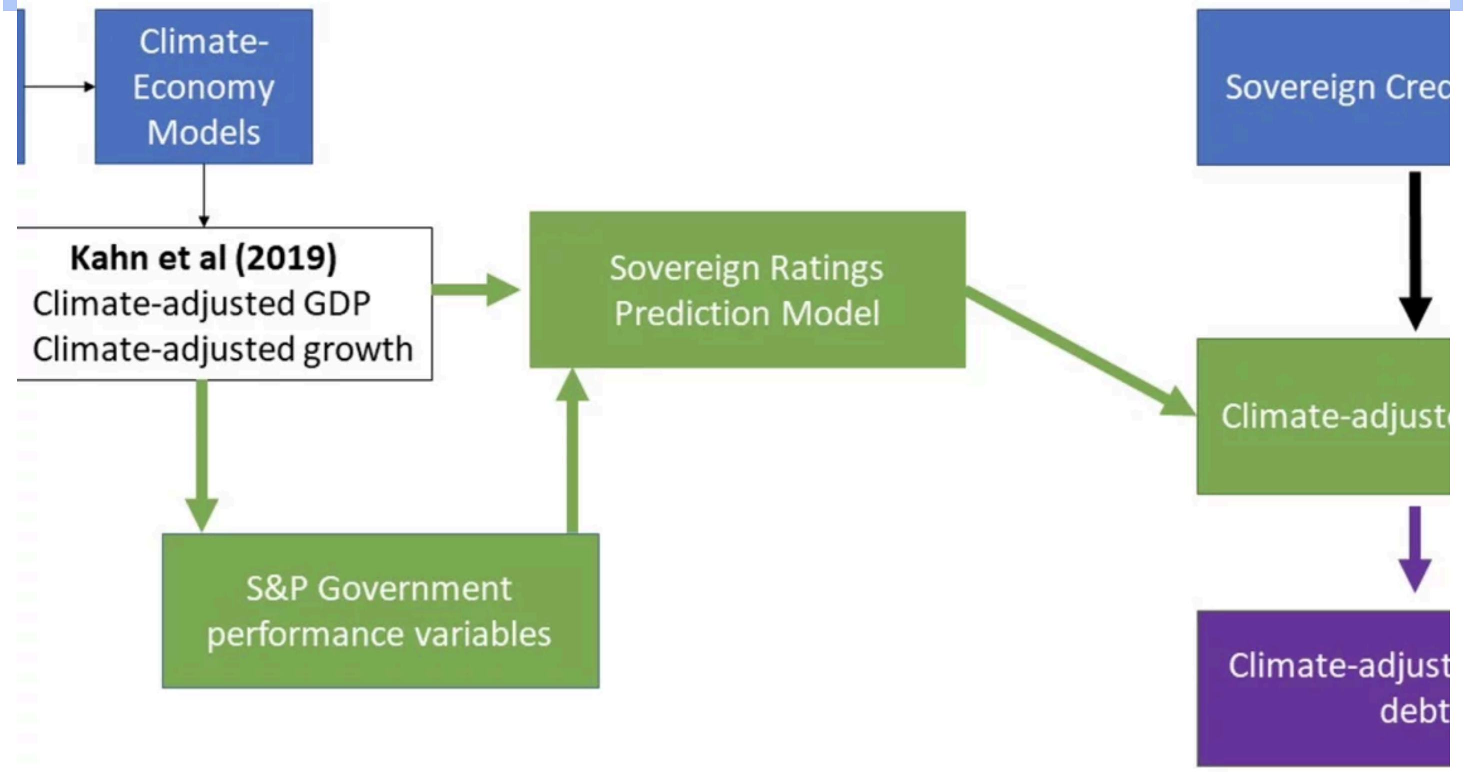
based on a decision of the Parliament of the Federal Republic of Germany

MCII

To find out more visit: www.climate-insurance.org

Annex 592

"Rising temperatures, melting ratings", *VOX EU*, 25 March 2021



VOXEU COLUMN | ENVIRONMENT | FINANCIAL MARKETS

Rising temperatures, melting ratings

Kamiar Mohaddes, Moritz Kraemer, Matt Burke, Patrycja Klusak, Matthew Agarwala / 25 Mar 2021

Enthusiasm for 'greening the financial system' is welcome, but does the explosion of 'green' finance indicators reflect the science? This column reports research that uses artificial intelligence to construct the world's first 'climate smart' sovereign credit rating. The results warn of climate-driven downgrades as early as 2030.

AUTHORS


Kamiar Mohaddes


Moritz Kraemer


Matt Burke


Patrycja Klusak


Matthew Agarwala

Climate change is "the biggest market failure the world has seen" (Stern 2008), with wide-ranging implications for stability – financial, economic, political, social and environmental. As estimates of the economic consequences of climate change continue to grow, financial markets and business leaders face increasing pressure to factor climate risks into decision-making.

Climate change will hit markets from all directions. In boardrooms and at AGMs, what were once token whispers of eco-marketing have become serious discussions of extreme weather events, reputational risks, activist movements (from shareholders and consumers), regulatory and transition risks, asset stranding and environmental litigation. In response, investors and regulators are calling for climate risk disclosures and a clear demonstration that portfolios and business models are consistent with the Paris Climate Agreement. Central bankers,1 finance ministers,2 the IMF3 and UN4 are in on the action (e.g. Brunnermeier and Landau 2020).

All this enthusiasm for 'greening the financial system' is welcome, but a fundamental challenge remains: financial decision-makers lack the necessary information (e.g. Edmans 2021). It is not enough to know that climate change is bad. Markets need credible, digestible information on how climate change translates into material risks. Instead, an explosion of environmental, social and governance (ESG) ratings and voluntary, ad hoc, unregulated corporate climate disclosures has created a confusing world of unfamiliar, incomparable, and conflicting metrics.

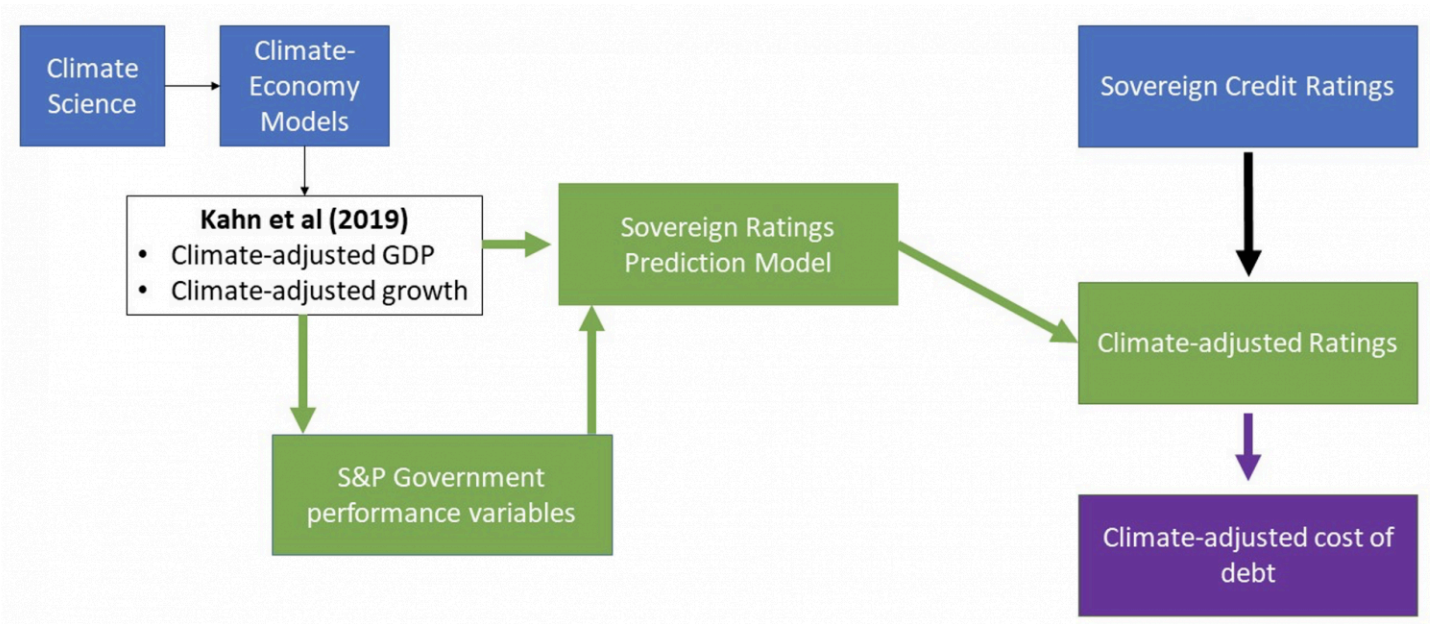
A chief concern is the lack of scientific foundations in risk disclosures (e.g. Fiedler et al 2021). It is easy to see why. Climate models operate at global scales and project impacts over decades and centuries. Financial models do not. How should a high-frequency trading algorithm (think nanosecond resolution) adjust to the possibility that climate may reduce global output in 2100 by 10%? How should corporate climate disclosure address issues largely beyond their control, such as the carbon intensity of the national electricity grid, or the direction of government flood strategies?

Most disclosures present companies as if they are independent of their physical (geographical) and macroeconomic surroundings. But this ignores crucial context. Climate change does not just affect firms individually, it affects countries and economies systemically. No corporate climate risk assessment is complete without also considering the effect of climate on sovereigns. Without scientific credibility, economic evidence and decision-ready metrics, the field of green finance is open to charges of greenwash.5 Getting it wrong will be costly.

This is what motivated us to bridge the gap between climate science and real-world financial indicators (Klusak et al 2021). Rather than constructing a new metric, we focused on one that is eminently familiar to financial decision-makers: the sovereign credit rating.6 By linking climate science with economic models and real-world best practice in sovereign ratings, we simulate the effect of climate change on sovereign credit ratings for 108 countries under three different warming scenarios (see Figure 1).

We were guided by a single overarching principle: to remain as close as possible to climate science, economics and real-world practice in the field of sovereign credit ratings. To the best of our knowledge, we are the first to simulate the effect of future climate change on sovereign credit ratings. Our approach means we can evaluate the effect of climate on ratings under various climate-economic scenarios and can provide initial estimates of the effects of climate-induced sovereign downgrades on the cost of public and corporate debt around the world.

Figure 1 Bridging the gap between climate science and financial indicators



Notes: Blue boxes (top row) represent the status quo in climate science, climate-economics, and sovereign credit ratings. Economic models translate scientific projections of temperature and precipitation changes into macroeconomic impacts (white box). Green boxes and arrows describe our novel approach to closing the remaining gap between climate economics and ratings.

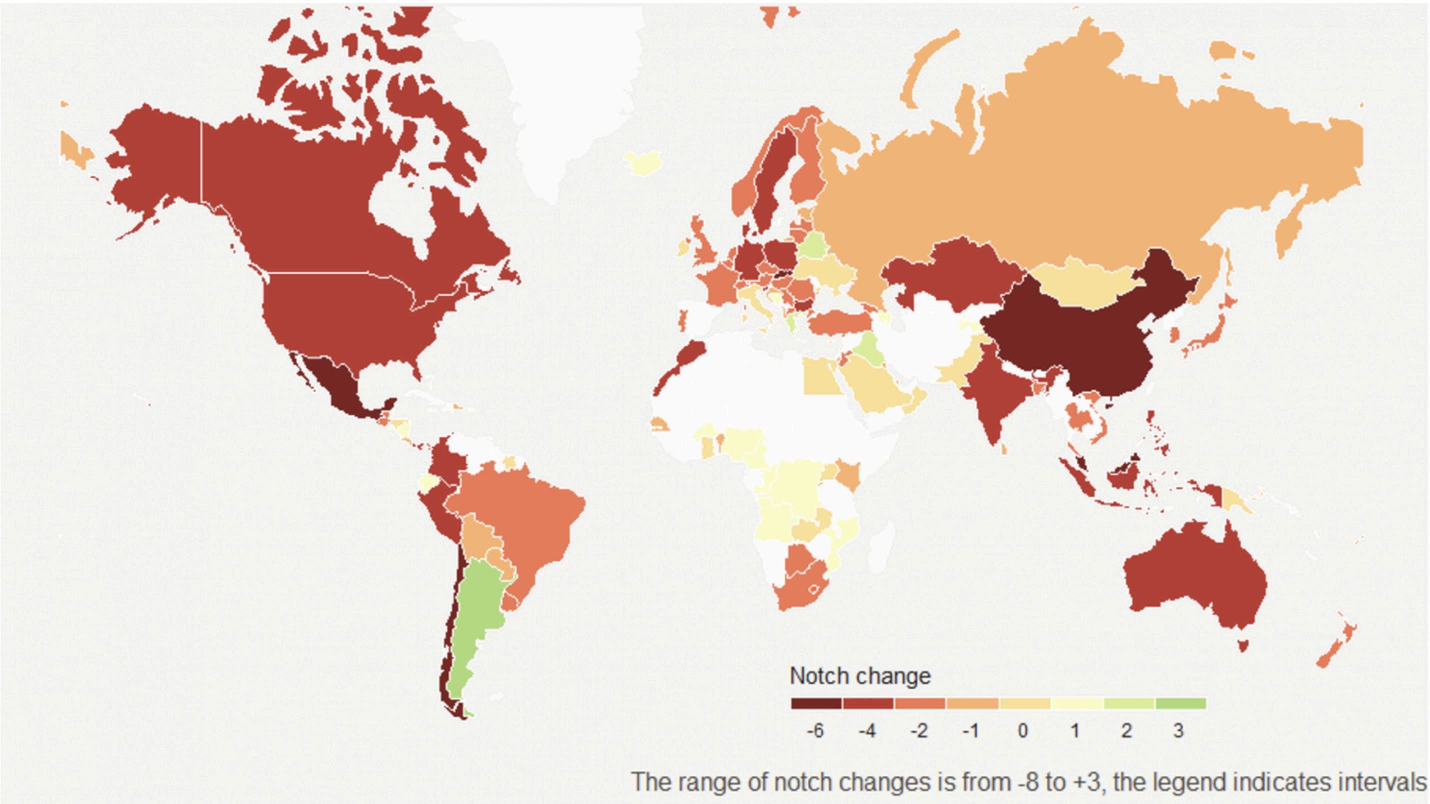
To this end, we develop a random forest machine learning model to predict sovereign credit ratings and training it on ratings issued by S&P (one of the largest credit ratings agencies) from 2015 to 2020. Next, we combine climate economic models and S&P's own natural disaster risk assessments to develop a set of climate-adjusted data describing various warming scenarios. We feed these climate-adjusted macroeconomic data into our ratings prediction model to simulate the effect of climate change on sovereign ratings. Finally, we calculate the additional cost of corporate and sovereign capital due to climate-induced sovereign downgrades (Figure 1, purple).

We focus on sovereign ratings because they are decision-ready. This is distinct from ESG ratings, which, even if backed by credible science, still require investors to determine how they relate to material risk. In contrast, sovereign ratings are already used in a range of financial decision-making contexts (for example, under Basel II rules, ratings directly affect the capital requirements of banks and insurance companies). They cover over US$66 trillion in sovereign debt, acting as 'gatekeepers' to global financial markets. Sovereign downgrades increase the cost of both public and corporate debt, influencing overall economic performance and significantly affecting fiscal sustainability.

We document three key empirical findings. In contrast to much of the climate-economics literature, we find material impacts of climate change as early as 2030. Under RCP 8.5 (a high emissions scenario that closely traces recent historical emissions), we find that 63 sovereigns suffer climate-induced sovereign downgrades of approximately 1.02 notches by 2030, rising to 80 sovereigns facing an average downgrade of 2.48 notches by 2100 (on a 20-notch scale).

Figure 2 depicts the magnitude and geographical distribution of sovereign ratings changes predicted by our model by 2100 under RCP 8.5, showing that the most affected nations include Chile, China, Slovakia, Malaysia, Mexico, India, Peru and Canada all exceeding 5 notch downgrades. More importantly, our results show that virtually all countries, whether rich or poor, hot or cold, will suffer downgrades if the current trajectory of carbon emissions is maintained.

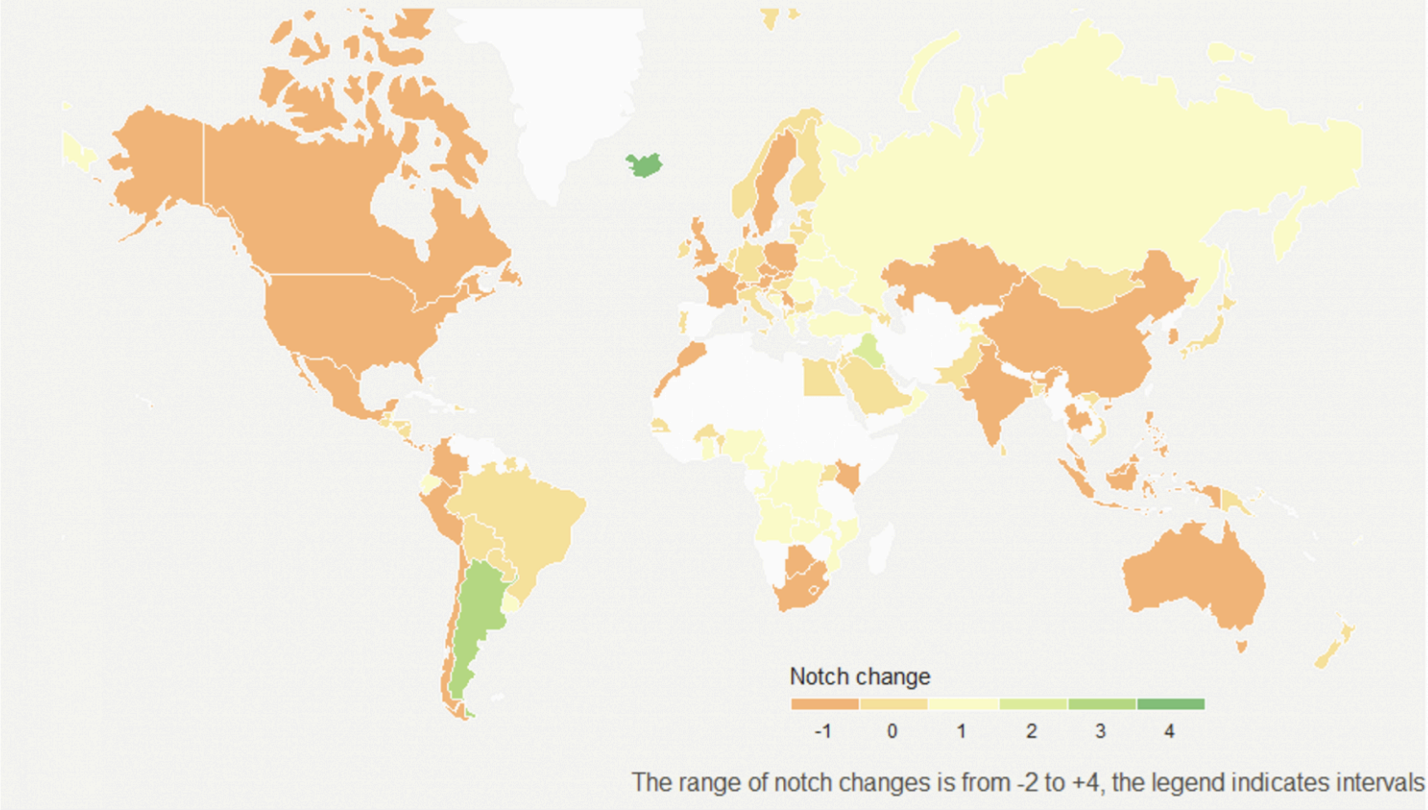
Figure 2 Global climate-induced sovereign ratings changes (2100, RCP 8.5)



Second, our data strongly suggest that stringent climate policy consistent with the Paris Climate Agreement will result in minimal impacts of climate on ratings – with an average downgrade of just 0.65 notches by 2100. Figure 3 shows that the most affected countries are Chile and China with climate-induced sovereign downgrades of 2.56 and 2.05 notches, respectively.

Third, we calculate the additional costs to sovereign debt – best interpreted as increases in annual interest payments due to climate-induced sovereign downgrades – in our sample to be between $22–33 billion under RCP 2.6 (low emissions), rising to $137–205 billion under RCP 8.5. These translate to additional annual costs of servicing corporate debt ranging from US$7.2–12.6 billion under RCP 2.6, and US$35.8–62.6 billion under RCP 8.5.

Figure 3 Global climate-induced sovereign ratings changes (2100, RCP 2.6)



There are caveats. Due to a lack of scientifically credible quantitative estimates of how climate change will impact social and political factors, these are excluded from our model (Oswald and Stern 2019). Thus, our findings should be considered as conservative.

Moreover, our results should be understood as scenario-based simulations rather than predictions. High emissions scenarios (e.g. RCP8.5) closely track recent observed trajectories and remain useful over near- to midterm timescales (Schwalm et al 2020). But the pace of renewables deployment and climate policy (e.g. regulations banning sales of new petrol and diesel vehicles) offer hope that future trajectories may fall closer to low emissions scenarios such as RCP 2.6 (Hausfather and Peters 2020). We do not comment on the relative probabilities of any given warming scenario playing out in practice.

Despite these caveats, our results are qualitatively similar when changing the time series of ratings used to train the prediction model, restricting the sample to investment grade sovereigns, and varying assumptions about the degree of temperature volatility within the baseline climate-economic model.

The key take-home messages are that it is possible to 'do climate finance' without compromising on scientific credibility, economic rigour or decision-readiness. Existing climate science and economics can support credible, decision-ready green finance indicators. This research is of interest to investors, sovereigns and credit ratings agencies alike. Governments issue ever-longer dated bonds, of which life insurance companies and pension funds are eager buyers, thus enabling them to match their own long-term liabilities. Therefore, investors should consider the long-term creditworthiness of sovereign issuers.

Currently there is no reliable yardstick for assessing sovereign creditworthiness beyond the current decade and this research fills this gap. Data on adaptation and resilience will be increasingly important. National statistical offices could play a decisive role, using the recently adopted UN System of Environmental Economic Accounts – Ecosystem Accounts (SEEA-EA)7 as a framework for tracing environmental investments and expenditure.

Our study offers a first methodological approach to extend the long-term rating to an ultra-long-term reality. Based on the methodology applied here, future research could focus on developing ultra-long ratings not only for sovereigns but also for other issuers including corporates.

References

Brunnermeier, M K and J-P Landau (2020), "Central Banks and Climate Change", VoxEU.org, 15 January.

Edmans, A (2021), "The Dangers of Sustainability Metrics", VoxEU.org, 11 February.

Fiedler, T, A J Pitman, K Mackenzie, N Wood, C Jakob and S E Perkins-Kirkpatrick (2021), "Business Risk and the Emergence of Climate Analytics", *Nature Climate Change* 11: 87–94.

Hausfather, Z and G P Peters (2020), "Emissions - the "Business as Usual" Story is Misleading", *Nature* 577: 618–620.

Kahn, M E, K Mohaddes, R N Ng, M H Pesaran, M Raissi and J C Yang (2019), "Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis", NBER Working Paper 26167.

Klusak, P, M Agarwala, M Burke, M Kraemer and K Mohaddes (2021), "Rising Temperatures, Falling Ratings: The Effect of Climate Change on Sovereign Creditworthiness", Bennett Institute Working Paper.

Oswald, A and N Stern (2019), "Why are Economists Letting Down the World on Climate Change?", VoxEU.org, 17 September.

Schwalm, C R, S Glendon and P B Duffy (2020), "RCP8.5 tracks cumulative CO2 emissions", *Proceedings of the National Academy of Sciences of the United States of America* 117(33): 19656–19657.

Stern, N (2008), "The Economics of Climate Change", *American Economic Review* 98: 1-37.

Endnotes

1 https://www.ngfs.net/en

2 https://www.financeministersforclimate.org/

3 https://www.imf.org/en/Topics/climate-change

4 https://www.unepfi.org/

5 https://www.ft.com/content/74888921-368d-42e1-91cd-c3c8ce64a05e

6 https://www.spglobal.com/ratings/en/about/intro-to-credit-ratings

7 https://seea.un.org/ecosystem-accounting

Climate change and central banks: Introducing the expectations channel

Schoenle, Dietrich

VOXEU COLUMN / 22 MAR 2021

Central banks and climate change

Landau, Brunnermeier

VOXEU COLUMN / 15 JAN 2020

Why are economists letting down the world on climate change?

Stern, Oswald

VOXEU COLUMN / 17 SEP 2019

AUTHORS

Kamiar Mohaddes
Macroeconomist, Judge Business School, University Of Cambridge

Moritz Kraemer
Chief Economist and Head of Research, LBBW Bank; Senior Fellow of the Center for Sustainable Finance, Soas University Of London

Matt Burke
Research Assistant, Bennett Institute for Public Policy; PhD candidate, University Of East Anglia

Patrycja Klusak
Affiliated Researcher, Bennett Institute for Public Policy, University Of Cambridge; Lecturer in Banking and Finance, University Of East Anglia

Matthew Agarwala
Project Leader, Wealth Economy project, Bennett Institute for Public Policy, University Of Cambridge

THEMES

ENVIRONMENT | FINANCIAL MARKETS

KEYWORDS

CLIMATE CHANGE | GREEN FINANCE INDICATORS | SOVEREIGN CREDIT RATINGS

SHARE

Annex 593

"Tackling sovereign debt for effective climate action: Towards a European agenda", Briefing Note No. 147, *European Centre for Development Policy Management*, May 2022 ecdpm Making policies work

BRIEFING NOTE No. 147

Tackling sovereign debt for effective climate action:

TOWARDS A EUROPEAN AGENDA

By Karim Karaki and Alfonso Medinilla

May 2022

This policy brief provides eight recommendations that the EU could pursue to tackle debt sustainability in the Global South and maintain the momentum for ambitious climate action.

There has been no shortage of warnings on the unsustainable debt burden in the Global South. 40% of African countries today are in, or at high risk of, debt distress. This debt crisis is linked to the climate crisis. The effects of climate change push countries to borrow more and drive up the costs of capital, leading to a vicious cycle between sovereign debt and climate risk.

Effective global climate action requires a rapid increase in the mobilisation of international climate finance, as well as fiscal space and affordable capital to implement far-reaching economic reforms. Both are increasingly out of reach for a growing number of countries.

While EU member states only hold some of the cards when it comes to debt restructuring and relief, they can play a role in moving the agenda out of its current deadlock. However, they will need to shift gears in their diplomatic action ahead of COP27, coordinating positions and working towards strong new commitments on debt reform.

Introduction

More than 25 years after the launch of the multilateral Highly Indebted Poor Countries initiative (HIPC), the Global South is facing a new debt sustainability crisis. The debt service obligations of developing countries not only constrain their economic recovery and development, but also limit the prospects for building back better and lower the ambitions for global climate action.

The current debt crisis is linked to the climate crisis. The effects of climate change push countries to borrow more and drive up the costs of capital, leading to a vicious cycle between sovereign debt and climate risk. Five of the top ten countries most at risk from climate change-related disasters are already in debt distress or at high risk of becoming so (IEED 2022). Effective global climate action requires a rapid increase in the mobilisation of international climate finance, yet it also requires fiscal space and affordable capital to implement far-reaching economic reforms and climate mitigation/adaptation measures. Both are increasingly out of reach for a growing number of countries.

Things will get worse with the global fallout of the Ukraine war. Food and energy price shocks are hitting cash-strapped economies harder, increasing the risk of countries defaulting. Sri Lanka was the first country to default on its payments in 2022, and may be followed by Egypt, Tunisia, Ghana and Ethiopia later this year (Donnan at al. 2022).

While there has been no shortage of warnings on the unsustainable debt burden in the Global South and African countries, actions have been slow and incomplete. Multilateral institutions, countries and the private sector will need to move quickly and decisively to tackle debt sustainability in the Global South to maintain the momentum for ambitious climate action. However, this is easier said than done.

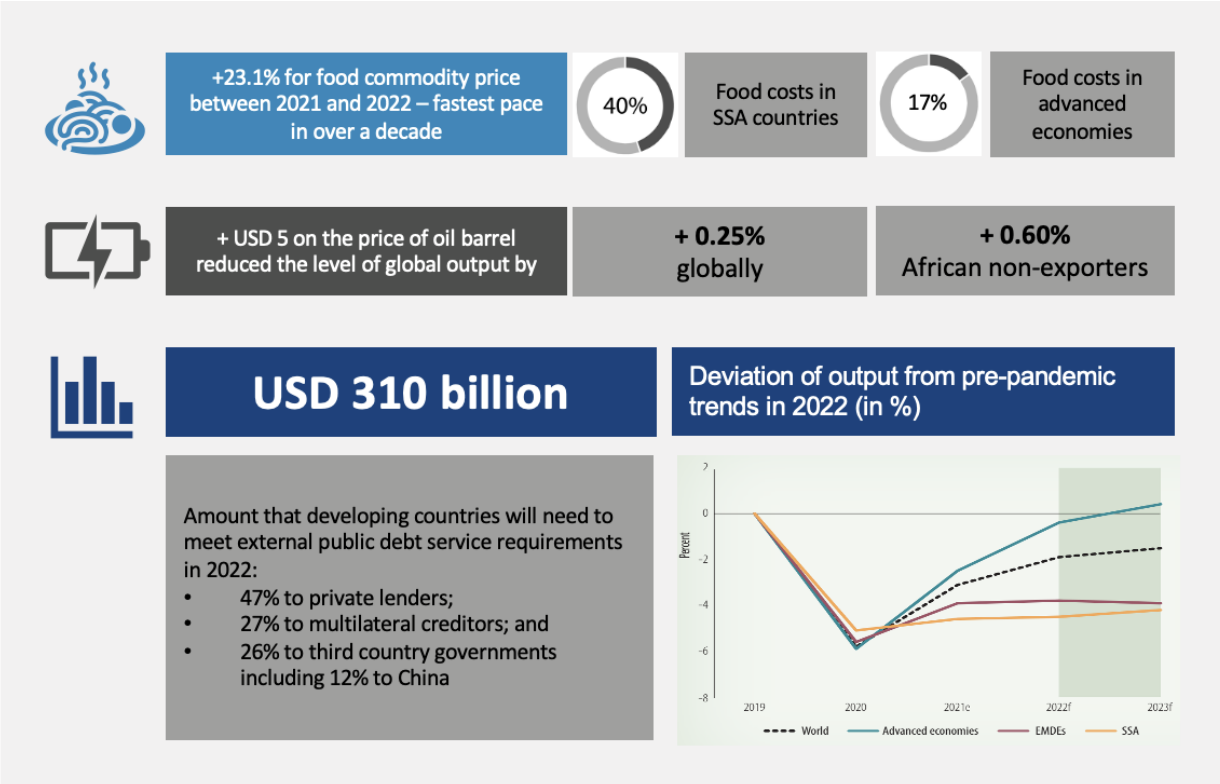
This note takes a closer look at the debt sustainability of African countries, 40% of which are already in, or at high risk, of debt distress (IMF 2022). It examines current multilateral initiatives for debt relief and explores options for a European agenda to tackle sovereign debt for climate outcomes.

1. Starting from the back: Africa's sovereign debt landscape in 2022

Sovereign debt levels in Africa were on the rise before the COVID-19 crisis. Between 2013 and 2018, the number of countries at high risk of debt distress had more than doubled, from 8 to 18 (World Bank 2018). Countries like the Central African Republic, Chad and Ethiopia entered the pandemic with record levels of sovereign debt (World Bank 2022).[1]

Many African countries further increased their sovereign debt throughout the pandemic in order to mitigate the social and economic impacts of the crisis (Heitzig et al. 2021). Africa is also particularly vulnerable to the economic fallout of the Ukraine crisis through rising food and fuel prices, lower tourism revenues, and potentially more difficulty accessing international capital markets (Georgieva 2022). Weakened growth prospects of emerging markets and developing countries will translate into reduced government revenues and will see the economic recovery of developing countries further lag behind that of advanced economies (Pazarbasioglu and Reinhart 2022; IMF 2022b; World Bank 2021). The relatively stronger US dollar in the first half of 2022 also affects (African) developing countries with weaker currencies, and their capacities to pay back dollar-denominated debt (Stubbington and Duguid 2022).

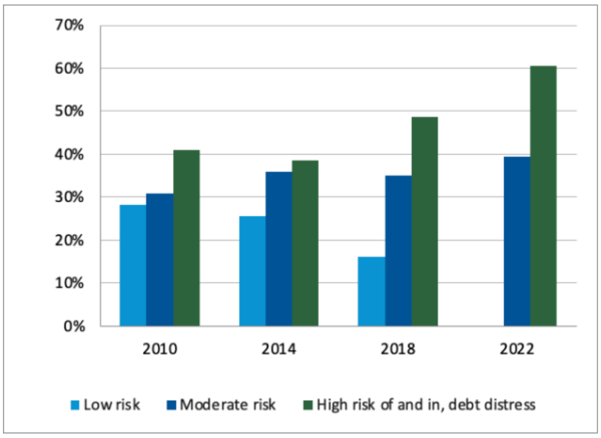
Figure 1: Impact of the Ukraine-Russia conflict on African economies[2]



Source: Data from McNair 2022; McNair 2022a; World Bank 2022a

Debt is not bad per se, but it has to be sustainable. To ensure the sustainability of sovereign debt, loans need to be linked to projects that provide economic (and ideally social and environmental) returns measured with an output multiplier greater than one (Calderón and Zeufack 2020). Debt for consumption is rarely sustainable, it shifts the risks and needs faced today to future government revenues, most of which will be used for servicing debt. Between 2015 and 2020, the external debt service obligations of 16 African countries more than doubled, and the average Sub-Saharan African external debt service to exports ratio increased from 13% to 21% (World Bank 2022b). Today, Ghana, Zambia and Angola are paying more than 25% of their government resources alone, 9.7 % more than in 2015 (Volz et al. 2021). As a result, the average debt-to-GDP ratio of those countries jumped from 49.2% in 2015 to 67.4% in 2020, while 23 African countries are now considered to be at high risk (or already in) debt distress (IMF 2022a) (see figure below).

Figure 2: World Bank and IMF debt sustainability assessment ratings for Sub-Saharan Africa



Source: Based on IMF (2022) and World Bank (2018)

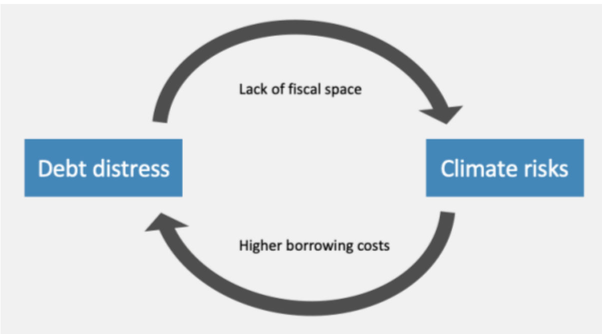
The cost of capital for African countries also continues to go up. During the pandemic, over 60% of African sovereigns suffered from credit-rating downgrades[3], which is the highest regional average (Fofack 2021). Moody's in February downgraded Ghana from B3 to a CAA1 rating[4] (Sovereign 2022). The persistently overinflated risk perception assigned to the region by credit agencies like Standard and Poor's, Moody's and

Fitch has been shown to underestimate African economies' macroeconomic fundamentals and growth prospects (Fofack 2021). These 'perception premiums' severely limits access to affordable capital, putting African countries at a structural disadvantage compared to parts of the world.[5]

1.1. The vicious cycle between debt and climate risks

African countries and economies are disproportionately affected by climate impacts (IPCC 2022). According to a recent estimate, the costs of adaptation in Sub-Saharan Africa alone will be between USD 30 billion and USD 50 billion each year for the next decade (WMO 2021). This will drive governments to further borrow to mitigate climate impacts. The weak sovereign credit ratings and therefore higher costs of most African countries means they are more likely to accumulate unsustainable debt when faced with climate shocks (Buhr et al. 2018). This can lead to a vicious cycle between debt distress and climate risks, where the effects of climate change gradually drive up the costs for countries to build climate resilience in the first place (See Figure 3). Recent analysis has also shown an existing correlation between climate change and the cost of capital, estimating that climate vulnerability increases the average cost of debt of developing countries[6] by 1.17% (Buhr et al. 2018). This so-called 'climate risk premium' is again a self-reinforcing dynamic, as the relatively higher cost of capital for climate vulnerable economies continues to constrain their ability to invest in adaptation and resilience, further increasing their vulnerability to increasingly frequent future climate shocks.

Figure 3: Vicious circle between debt distress and climate risks



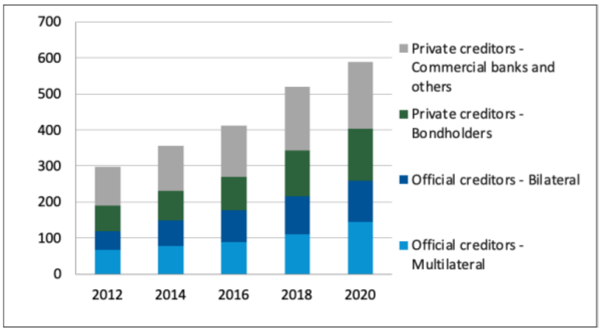
Source: Adapted from Essers et al. 2022

The interactions between climate risk, sovereign debt and the cost of both public and corporate capital are increasingly well understood. Yet climate risk is not systematically factored in traditional debt sustainability tools. The IMF and World Bank's Debt Sustainability Assessment (DSA) is criticised for failing to account for climate or other sustainability risks, and therefore employing overly optimistic scenarios (Volz et al. 2021). Others deplore that it lacks an assessment of the quality of sovereign debt stocks (Ryder 2021). Debt for quality investments resulting in an output multiplier greater than one in terms of economic, social and economic returns should not be assimilated to debt for consumption - going to non-productive assets. This should be considered when assessing debt sustainability.

1.2. A new debt landscape

The debt landscape has radically changed over the past decades. At the start of the Heavily Indebted Poor Countries (HIPC) Initiative in 1996, the Paris Club of 'traditional', Western bilateral creditors accounted for most of the sovereign debt of developing countries. Since then, developing countries have radically diversified their portfolio of creditors, relying heavily on Chinese loans and privately owned debt (through the issuance of bonds in capital markets). Addressing the question of debt sustainability therefore has become infinitely more complex, not only in the amount of bilateral and private creditors, but also in the modalities and terms these lenders apply.

Figure 4: Evolution of the Sub-Saharan debt creditor landscape (in USD billion)



Source: Based on World Bank 2022b

Chinese bilateral loans

Chinese loans have increased considerably in Africa since 2000. Boston University's Chinese Loans to Africa (CLA) Database tracked a total of 1,188 loan commitments worth USD 160 billion with 49 African governments between 2000 and 2020 (Hwang et al. 2022). While Chinese lending peaked in 2013[7] with the launch of the Belt and Road Initiative, the country remains the biggest bilateral lender in Sub-Saharan Africa, accounting for an estimated 62.1% of the region's bilateral external debt in 2020 (Bertrand and Zoghely 2022). Its official and commercial lending has been instrumental to the development of key infrastructure projects in Africa, however, it has also contributed to unsustainable debt accumulation in a number of countries, which might explain the more hesitant approach of Chinese lenders in the pre-pandemic years.

Chinese lending is substantially different from Paris-club lending, which in the past has made it very difficult to associate China to collective debt restructuring efforts. Chinese loans, particularly since 2015 tend to include confidentiality clauses preventing the debtor to reveal the term of the debt contracted (Gelpern et al. 2021). Loan contracts tend to be constructed in a way that maximises their repayment prospects. This includes for example controversial collateralised and resource backed loans[8], using lendercontrolled revenue accounts (Gelpern et al. 2021; Usman 2021), but also so called 'no paris club clauses', which prohibit the borrower from seeking restructuring through any multilateral process. This approach in essence allows China to seek preferential repayment, it is also a decisive rejection of what it calls a "global debt governance system dominated by the 'Paris Club - IMF - World Bank' structure of the West" (Unofficial statement 2021).

Box 1: Debt transparency

While multilateral and Paris Club loans are fairly easy to track, this is not the case for Chinese and other non-Paris Club creditors. This also means that the full extent of the liabilities of developing countries is often unknown, both to (potential) creditors and to credit rating agencies (Pazarbasioglu and Reinhart 2022). The issue of hidden debts also extends beyond bilateral loans to for example the external borrowing by state-owned or guaranteed enterprises, which is not always present in standardised reporting. In addition, the rise of these hidden debts has also led to an increasing number of 'unrecorded' defaults and restructurings of Chinese held debts (Horn et al. 2022). Global debt transparency is a moving target, and in absence of a legitimate and jointly owned global framework, analysts tend rely on partial evidence, even if a growing number of research initiatives[9] is helping to lift the veil off of public debt in developing countries.

China does not eschew debt restructuring, but it has long preferred a bilateral and case-by-case approach. Since the pandemic, China has reportedly cancelled interest-free loans to 15 African countries that were set to mature in 2020[10], and offered up to USD 4.9 billion in repayment deferrals to Angola (CARI 2022). More recently, however, under the G20's Debt Service Suspension Initiative (DSSI), China has suspended over USD 1.3 billion in debt service payments worldwide, including in 16 African countries. China also participates in the Common Framework for debt treatment beyond the DSSI (CF), and recently agreed to participate in the creditor committee for Zambia (Ryder 2022).

Private creditors: bonds and banks

Following the cancellation of most debts owed to traditional creditors under the Heavily Indebted Poor Governments Initiative (HIPC) and Multilateral Debt Relief Initiatives (MDRI) in 2006, many African countries began issuing bonds in international markets to obtain a new line of credit (Sokpoh et al. 2022). In the early 2000s, African 'eurobonds' had low interest rates, yet after the 2008 financial crisis rates started going up, making private debt often more expensive to service than traditional public debt (Mukhopadhyay 2022).

Private creditor lending to Sub-Saharan African countries in 2020 amounted to USD 300 billion in 2020 (World Bank 2022c). Most private creditors - mainly bondholders and commercial banks, are based in G20 countries, and include large investment companies such as JP Morgan, Amundi, Blackrock, Alliance Bernstein and UBS Asset Management. For instance, Blackrock manages at least USD 15.6 billion in developing country bonds, representing 0.2% of its assets under management and returned USD 3.8 billion to its shareholders after making a record profit in 2020 (Vander Stichele 2020).

Private creditors, under the umbrella of the Institute of International Finance (IFF) or the Africa Private Creditor Working Group (AfricaPCWG), have so far declined to participate in debt relief and/or restructuring efforts, despite the calls from civil society organisations and IFIs. In Chad, for example, the World Bank has urged Glencore to participate in the debt restructuring (Diagana 2021). In Zambia, CSOs have called on Blackrock to participate in debt restructuring since the company owns USD 220 million in Zambian bonds (Debt Justice 2022; Inman 2022).

Private creditors are not part of the DSSI, which raises the concern that part of the relief efforts would be used to service private debt (Vander Stichele 2020).

The IFF proposes a voluntary participation (IFF 2022), claiming it maintains countries' access to intentional capital markets, (even if at very high interest rates), and that the contractual, legal, and logistical challenges would make it difficult to involve dispersed private bondholders in debt restructuring (Vander Stichele 2020). Neither the G20 nor the International Monetary Fund / World Bank have managed to secure any more ambitious private creditor involvement, which drives up the cost of multilateral and bilateral restructuring and further constrains efforts for tackling the debt crisis.

2. The limits of the multilateral solutions - an increasingly unavoidable crisis?

While there is increasing awareness of the current debt crisis, the international community's response has been hesitant and partial. Since the pandemic, however, a number of initiatives have been taken in the framework of the International Monetary Fund (IMF) and World Bank, and through the G20. Table 2 below gives a brief overview of the main multilateral initiatives.

Table 1: Overview of multilateral initiatives led by IMF/WB and the G20

Instruments	Description
Debt Service Suspension Initiative - DSSI (G20)	The Debt Service Suspension Initiative (May 2020 to December 2021), and offered temporary debt service suspensions to 73 eligible low and middle income countries. While only 46 of those applied, 31 out of the 37 eligible SSA countries did, generating just up to 1.8 billion in savings in 2020 - far below the USD 5.5 billion initially envisaged (Fuje et al. 2021). In some countries the DSSI allowed generating savings up to 4% to 5% of GDP (Angola, Mozambique and Dem Rep of Congo), the average projected savings for 2020-2021 for all African countries was below 1% of GDP (Fuje et al. 2021). While the DSSI was put in place very quickly, its overall impact fell short of its ambition, partly because private creditors refused to take part (Mukhopadhyay 2022).
Common Framework for debt treatment beyond the DSSI - CF (G20)	The Common Framework for debt treatment beyond the DSSI (CF) introduced in November 2020 aims to provide longer-term debt restructuring for DSSI eligible countries, consistent with debtor's capacity to pay and maintain essential spending needs (Ahmed and Brown 2022). A critical benefit of the common framework was the inclusion of China (and other newer creditors) along with the mostly Paris-club bilateral lenders. In theory, the common framework also calls on private creditors to provide comparable debt relief, yet it is unclear how this can be assured. Since its introduction, only Zambia, Chad, and Ethiopia have requested debt relief under the common framework. Thus far, none of the three countries have been able to complete the process (creditors committees have been formed in Chad and Ethiopia[11]), raising serious questions about the credibility, and political support base of the common framework.

(Re-)allocation of Special Drawing Rights - SDRs (IMF)	In August 2021, the IMF allocated USD 650 billion worth of special drawing rights (SDRs) – the Fund's reserve asset meant to boost its member countries' official reserves and liquidity in times of need. Since SDRs are allocated based on IMF quotas LICs received just USD 21 billion, with the lion's share (USD 375 billion) allocated to advanced economies. China pledged to reallocate 10 billion (25%) of its SDRs to Africa, while France, the G7 and the G20 have expressed the global ambition to reallocate USD 100 billion for countries most in need. This is yet to materialise, and many EU members are slow to strengthen their commitments (Bilal 2022). In April 2022, the IMF set up its Resilience and Sustainability Trust, a structure meant to help rechannel unused SDRs. So far, a total of USD 59.54 billion has been pledged by 13 countries, including five EU Member States (USD 22.7 billion) (ONE 2022). While this can be seen as a positive step, limited progress has been made in exploring alternative delivery mechanisms, for example using multilateral development banks.
The World Bank crisis response financing package (WB)	During the 2022 Spring Meetings, the World Bank announced a USD 170 billion crisis response financing package. This package, to be implemented by June 2023, focuses on supporting countries' fiscal, monetary, financial, social and structural policies and responses to the parallel crises of the COVID-19 pandemic, and the economic fallout of Russia's invasion of Ukraine (World Bank 2022c).

Progress through these multilateral channels has been slow and did not reach the needed (and expected) scale. Over a year after the introduction of the Common Framework, just three of the 73 eligible countries opted for this process, and none has yet completed the process. The SDR reallocation has not reached the scale announced, with less than USD 60 billion pledged out of the USD 100 billion and only 12 countries involved. As a result, African countries seem to be heading towards an unavoidable crisis.

The lack of progress, particularly under the common framework is due to a combination of technical and political issues that create disincentives for both creditors and debtors to engage. Contrary to the name, the common framework essentially operates on a case-by-case basis. There is also no precedent for the common framework, making it more difficult and risky for both creditors and debtors and creditors to engage. On the debtor side, countries fear that engaging in the common framework will downgrade their sovereign credit rating, making it harder for them to access international capital markets. In absence of a stronger coordination between borrowers, the disincentives to ask for restructuring tends to trump the benefits that could come from tackling debt sustainability earlier on.

On the creditor side, China favours bilateral solutions focusing on its own portfolio in a given country. While it responded to Zambia's request to join a common framework creditors committee, overall, it has limited direct incentives to engage with other creditors given that it uses its own set of tools (such as resource-backed loans) to reduce the repayment risk of its country portfolios. This also helps explain why China tends to go with an ad hoc approach to restructuring, independently of Paris Club restructurings (Chorzempa and Mazarei 2021).

Private creditors in turn have almost no incentive to join the common framework on a voluntary basis. On the contrary, high-risk jurisdictions offer potentially very high returns, especially if the bulk of investor risk is taken up by bilateral creditors. Private creditors are among the ones that are paid first in the event of a default. It is therefore highly unlikely that major private creditors will step in the absence of large-scale public pressure or an enforceable framework.

Box 2: When a country defaults, who collects first their due?

When governments borrow money, they are contractually obliged to pay interest and capital on those loans. If a payment is missed, governments (technically and/or contractually) default. Since the 1960s, around 147 governments have at some point defaulted on their debt service obligation (Beers et al. 2020). In the event of a sovereign default creditors will generally be paid in the following order (Schlegl et al. 2019):

1. Private creditors, including bondholders;
2. Senior creditors (often multilateral institutions such as the IMF and World Bank); and
3. Junior creditors (bilateral official creditors, banks and trade credit).

This ranking has been consistent over time, and affects the incentives for creditors to engage in debt restructuring. Private creditors in particular are least incentivised to contribute to collective solutions, an assessment that has been confirmed by the lack of private sector participation in the DSSI and common framework.

While the common framework shows a clear awareness of the more diverse debt landscape of developing countries today, it is very difficult to bring these all together in a way that meets their interests and expectations. While all have an interest in avoiding defaults, private creditors, and to some extent Chinese lenders risk losing out with a more concerted approach, especially one in which Paris club lenders and IFIs exert their dominance. The tools of the trade of the Paris club and IFIs are also not easily applicable to this more diverse landscape, making it very difficult to create a new momentum for collective debt relief.

As multilateral solutions fall short of their stated ambitions, the attention of the international community has all but fully shifted towards the Russian war in Ukraine. EU member states in particular have turned both eastward and inward, as they struggle to mitigate the energy shocks and food price crisis, towering inflation and the risk of further escalation of the war. In terms of external spending, the focus is now firmly on Ukraine and the Eastern neighbourhood, leaving little room for new and ambitious action in the Global South.

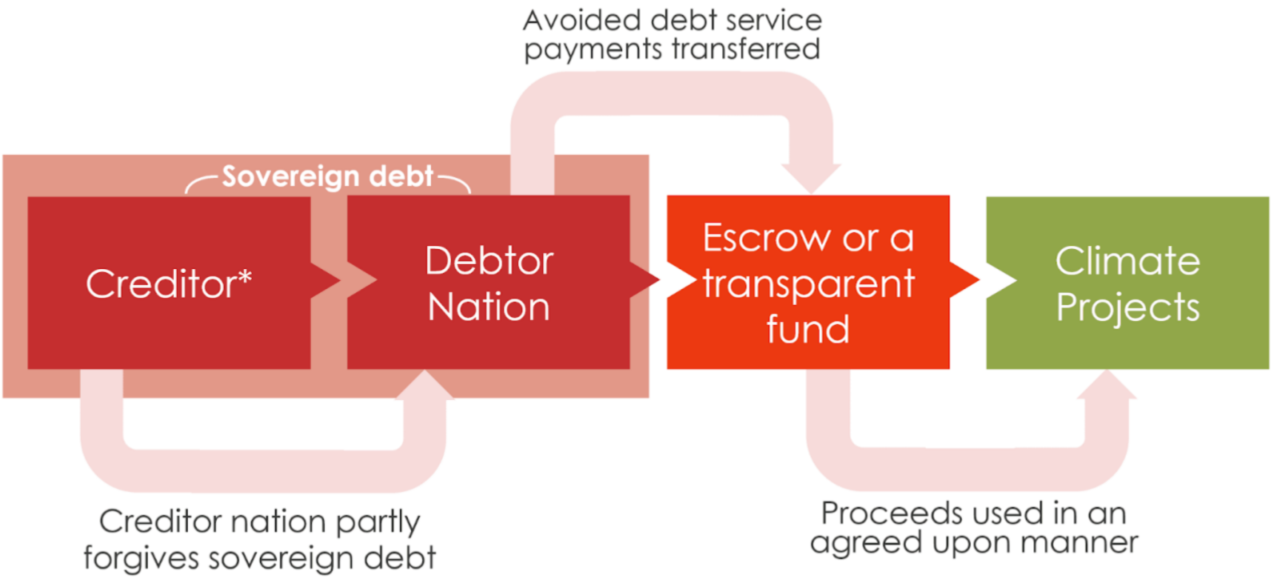
Overall, stakeholders looking to rekindle the multilateral momentum for debt restructuring (HIPC) are faced with not only a more complex sovereign debt landscape (involving new actors with different mandates and incentives), but also an ill-conducive environment for collective action. Multilateral initiatives addressing debt relief as they are designed and implemented, and given their pace of implementation and scale, do not seem to be fit for addressing the looming debt crisis in emerging and developing countries (including Africa), let alone investing in the green recovery.

3. Scaling up climate and nature-specific instruments

In 2020, climate objectives became central to the global economic recovery narrative, especially by the EU, the US, the G20, the IFIs, and the UN system. In practice, they remained peripheral to the overall structures for sovereign debt reform that were set up in the wake of the pandemic. In the margins of the global financial architecture, however, a number of steps were taken to explore a more structural link between climate action and sovereign debt which could set a precedent for future action on debt reform for climate outcomes.

Interest in climate-specific debt interventions, particularly debt-for-climate and debt-for-nature swaps has re-emerged in 2020. Swaps are a way to redirect funds from unsustainable debt servicing towards domestic action, thereby reducing indebtedness while freeing up fiscal space for much-needed green investments. A debt-for-climate swap is an agreement between a debtor country and its creditors, where the debtor gets i) to reduce its sovereign debt by agreeing with the creditor to cancel in full or partially its debt; and ii) redirect the debt service payments - through e.g. a special purpose vehicle (SPV), an escrow account or a trust fund - to finance investment in climate mitigation or adaptation projects (ESCAP75 2021). To ensure that such investments take place, a monitoring, reporting and verification framework is put in place (see figure below).

Figure 5: Debt-for-climate swaps explained



Source: Singh and Widge 2021

The idea of debt-for-climate/nature or debt-for-development swaps emerged in the 1990s. Bilateral Paris Club creditors used swaps to incentivise investments in the environmental, health and education sectors (Essers, 2022). However, the scale of these interventions was limited, and their use over time decreased. A recent critical example took place in Seychelles in 2018, where the government partnered with a private foundation the Nature Conservancy, UNDP and GEF, on a swap of USD 22 million official debt owed to Paris Club members. The swap involved a partial buyback of debt at discounted rates, as well as debt service payments feeding into a local trust that funds marine conservation efforts (Steele and Patel 2021; SSCOE 2019). The Seychelles deal serves as a proof of concept for the climate action community, and is often cited as a scalable example.

In 2021, the IMF put swaps back on the agenda with a commitment to work with the World Bank to 'advance' the option of debt-for-climate swaps ahead of COP26 (Shalal 2021). While this was warmly welcomed by civil society and climate activists, the institutions are yet to deliver a proposed workable architecture for green debt swaps (Shalal 2021a). In the past two years, civil society organisations have sought to facilitate the scaling up of debt-for-climate swaps by making technical proposals and guidelines. Notable examples include the Climate Policy Initiative's 'blueprint' for debt-for-climate swaps (Singh and Widge 2021), IIED's Guide for linking sovereign debt to climate and nature action (IIED et al. 2021), and SOAS' proposals for Brady-bond like transactions based on a climate-enhanced debt sustainability assessment (Volz et al. 2021). Several concrete initiatives are also underway. The Nature Conservancy worked with Belize on an upscaled swap following the Seychelles example (Owen 2022), which reduced the country's external debt by a significant 10`% of GDP (Owen 2022). The IIED is also working on designing concrete debt swap options with four West African countries: Cabo Verde, Guinea Bissau, Senegal and Mauritania (Kelley 2022).

Box 3: Blue and green bonds as part of the debt-for-climate swap modality.

The Seychelles and Belize swaps include a blue bonds scheme, which is a debt instrument earmarked for marine projects such as promoting biodiversity or contributing to sustainable fisheries. In both cases, the blue bonds came with a guarantee covering the interest payments, minimising risks for investors. Green bonds increasingly generate interest from development finance institutions (DFIs) and governments, for their potential to mobilise private capital towards (long-term) investments in the green recovery. Developing countries and emerging markets increasingly issue green bonds, creating a market that is forecasted to reach over USD 100 billion by 2023, more than double the USD 40 billion in 2020 (Dembele et al. 2021[12]). Development partners and international financial institutions (IFIs) actively support the development of the Green bond market in SSA countries, for example with the forthcoming EU Global Green Bond Initiative, as announced under the Global Gateway (EC 2022).

Debt-for-climate swaps in perspective

Debt-for-climate swaps have the potential to contribute to a global green and economic recovery and address climate change. They can help creditors strengthen their position and leadership in the sphere of climate finance, and offer an additional political incentive for international and European lenders to engage in a more ambitious debt relief agenda.

Using swaps as a climate-specific instrument, however, has a number of critical effects. Scaling up the use of debt swaps for climate outcomes can be counted as part of the developing countries' commitment to invest annually USD 100 billion in climate mitigation and adaptation in developing countries (ESCAP75 2021). A key risk therefore is that swaps become a substitute for fresh climate finance rather than an additional measure.

In addition, the focus on green / climate may not necessarily reflect domestic priorities for public expenditure, which are often more linked to social and economic transformation. This is often echoed by African stakeholders, some of which perceive this focus on green transition and climate action as a form of carbon colonialism (Ramachandran 2021), effectively claiming natural space in the developing world for reducing global emissions. In order to better link up to African and developing country priorities, international and European creditors could consider swaps with a larger scope including social and economic transformation objectives, ensuring that a debt swap for 'building back better' does not substitute other initiatives and commitments.

Looking at debt-for-climate swaps as major debt sustainability measure also comes with a number of technical difficulties, including:

- Debt-for-climate swaps tend to be small in scope and while they can have a key impact on climate outcomes, they tend to have a limited impact on the total debt burden of developing countries in question (Essers et al. 2022),
- Debt-for-climate swaps do not always build on existing mechanisms and structures. In some cases, they require the creation of highly complex parallel project structures, bypassing debtor's policies and systems.
- To create fiscal space, debt swap instruments require significant discounts and an adapted debt service schedule, which may not always be available.
- It is not always clear whether debt swaps generate additional resources for climate action in comparison to what governments had already planned. Essers et al. (2021) also highlight the risk of "greenwashing", i.e. presenting already budgeted climate activities as new projects.
- A debt swap could crowd out other sources of finance (such as ODA) that in some contexts may be more effective than a debt-for-climate swap instrument (ESCAP75 2021).

Debt swaps, therefore, are not a silver bullet for effective climate action in the context of debt distress. Given their generally limited scope and interest of creditors in this instrument (Shalal 2021a), they are also not an alternative for comprehensive debt restructuring for countries that face an acute risk of default. In small island developing states (SIDS) and (smaller) LICs like the Seychelles and Belize, they are seen to play a role in liberating funds for conservation and climate change adaptation, an experience that might be replicated in the Pacific (ESCAP75 2022). Beyond small economies they are perhaps best suited as a climate specific complementary measure, and specifically in middle income countries which do not have access to debt restructuring under for example the Common framework (Singh and Widge 2021).

One way to scale debt swaps is to use a system of green brady bonds, building on the experience of Latin American countries where USD 60 billion debt was forgiven in the 1990s (Vásquez 1996), and bringing private creditors into the debt restructuring process (Qian 2021; Weder Di Mauro 2021 Volz et al. 2021). In short, under a brady-style debt swap, indebted countries would be supported (partially guaranteed) to set up green brady bonds. Public and private creditors would then swap their bonds for these green brady bonds at a heavy discount, creating fiscal space for countries to spend on climate action (Weder Di Mauro 2021). Overall, while expectations for scaling debt swaps are high, the IMF and World Bank have been slow in proposing a framework for debt-for-climate swaps (Shalal 2021a). At the same time, privately-driven precentedents show that debt swaps can play a key role for climate and nature outcomes. While they should not become the central offer of international climate finance, they should be seen as part of a menu of climate interventions, to be used as a key additional measure.

4. Towards a European agenda on global green recovery and sovereign debt reform

While analysts and CSOs have raised the alarm since the start of the COVID-19 pandemic, progress on debt relief has been painstakingly slow, and the traditional coalitions and multilateral organisations appear to be unable to effectively address the changing global environment for sovereign debt.

If the EU wants to lead the pack on global climate action and climate finance, it will need to respond to the debilitating effects of debt distress in many developing countries. A structural lack of fiscal space can delay or severely limit the necessary domestic reforms and public investments for a green transition. This will eventually limit the returns and scalability of European green investments in developing countries, and lower the credibility of the EU as a global climate actor.

Timing is of the essence - the likelihood of developing country defaults increases as time goes by. Short-term measures can create temporary respite, yet rapid progress is needed to breathe new life into the multilateral debt relief agenda in order to avoid a new swathe of defaults. With COP27 around the corner, the EU and developed countries will need to address the failure of COP26 to respond to developing countries' demands. A forward-looking approach to global climate finance should include a response to debt distress in developing countries, and specifically Africa, where the EU has strong developmental as well as commercial interests in a swift and effective green transition.

At the same time, it is clear that the EU member states only hold some of the cards in this game[13]. Debt relief efforts since 2020 have been plagued by a severe collective action failure among both public and private creditors. EU actors can play a role to move the agenda out of its current deadlock, but they will need to shift gears in their diplomatic action ahead of COP27, coordinating positions and working towards strong new commitments on debt reform. They will also need to send a clear message on the need for private sector participation.

EU member states have a particular interest in:

1. **More effectively addressing short-term needs:** Rechanneling SDRs can provide in the short-term relief in the form of liquidity and balance of payment support. EU member states should rapidly meet their stated commitments, and push for innovative thinking on the mechanisms for rechanneling the SDRs beyond the IMF's Resilience Sustainability Trust, and through Multilateral Development Banks.

2. **Building a long-term vision and commitment for debt relief and reform of the international financial architecture**: The common framework provides an architecture that is available now, but it is held back by strong disincentives on both the creditor and debtor side. To avoid losing momentum, EU actors should seek new high-ambition coalitions for linking debt interventions with global climate action objectives, and work to address the administrative and political barriers within and beyond the international financial institutions for ambitious debt relief. This includes reforming debt sustainability assessments, accounting for a climate risk dimension, but also addressing the perverse effects of the dominant sovereign credit rating systems.

3. **Working with China towards a jointly owned agenda for debt restructuring:** while China is willing to participate in the G20's DSSI and common framework, it has little interest in participating in a Paris club and IMF/WB's led process. Instead of trying to bring China into existing debt governance structures, European creditors should work with China to design a new system for tackling debt sustainability collectively from the start.

4. **Rethinking the role of private creditors in debt restructuring**: Private creditors have thus far refused to take part in multilateral debt relief. The EU and member states could explore reform measures to incentivise or push private creditors to engage, including: encouraging or even mandating public disclosure by private creditors and bondholders and creating new mechanisms for public-private dialogue and collective action on debt restructuring; and supporting civil society organisations applying pressure on private creditors failing to take part in effective debt restructuring.

5. **Working with the IMF and World Bank to develop and use climate-specific debt instruments**: EU member states should work through the World Bank and IMF to operationalise debt for climate/nature swaps and exert pressure on the IMF to deliver its long-awaited architecture for debt swaps ahead of COP27. EU member states should also coordinate their positions and messaging on the need for climate-specific debt interventions in various other coalitions including the G20, and UNFCCC.

6. **Contributing to the implementation of debt swaps:** The EU and member states can help scale up debt for climate swaps, by using the EFSD+ under its External Action Guarantee (EAG), or member state mechanisms to cover interest payments of green bonds, de-risking the participation of creditors[14]. When supporting debt swaps, the EU and its Member States should prioritise using existing structures to help partner countries build their capacities both in managing debt and also investing in climate/nature.

7. **Supporting African and developing countries' agency in debt reform discussions:** Debt restructuring is traditionally a creditor-driven process that does not always take full account of the debtors' needs and priorities. To create a new momentum for ambitious debt reform, new initiatives should radically strengthen the capacity of African partners to engage in restructuring negotiations, and work with African institutions to develop a jointly owned agenda. This is critical for the sustainability, but also the credibility of any future debt intervention. Climate-specific instruments are even more dependent on country ownership, and should therefore not be presented as a top down form of conditionality, but as a collaborative way to address a common agenda. This also means aligning to debtor country priorities where possible and working through existing country structures.

8. **Strengthening EU leadership on climate finance:** Debt-for-climate/nature instruments should not be a substitute to EU climate commitments, but part of a radically more ambitious external climate finance agenda. Ahead of COP27, the focus should be on securing new commitments that can help regain the trust of developing countries, and strengthen the credibility of the EU in this field and its influence. The EU can mobilise a wide range of European actors, including the EIB, which is a leader in climate finance, and the experience of its Member States in greening their economy in a way that is both financially and environmentally sustainable.

References

African Markets. 2021. *Ghana plans to issue Africa's first social bond: what you must know*. The B&FT Online.

Ahmed, M. and Brown, H. 2022. *Fix the Common Framework for Debt Before It Is Too Late*. Washington (DC): Center for Global Development.

Beers, D., Jones, E. and Walsh, J. 2020. *BoC-BoE Sovereign Default Database: What's New in 2020?* Staff Analytical Note 2020-13. Ottawa: Bank of Canada.

Bilal, S. 2022. *EU countries should reallocate a share of their special drawing rights as a strong commitment at the EU-AU Summit*. Commentary. Maastricht: ECDPM.

Bertand, L. and Zoghely, S. 2021. *China's Position Among Lenders in Sub-Saharan Africa*. Tresor-Economics. No. 292. Paris: Ministère de l'Économie, des Finances, et de la Relance Direction générale du Trésor

Buhr, B., Volz, U., Donovan, C., Kling, Gerhard, L. Y., Murinde, V. and Pullin, N. 2018. *Climate Change and the Cost of Capital in Developing Countries*. London and Geneva: Imperial College London; SOAS University of London; UN Environment.

Calderón, C. and Zeufack, A. G. 2020. *Borrow with Sorrow? The Changing Risk Profile of Sub-Saharan Africa's Debt*. Policy Research Working paper no. 9137. Washington (DC): World Bank Group.

CARI. 2022. *Global Debt Relief Dashboard. Summary: Tracking Global Chinese Debt Relief In The Covid-19 Era*. Washington (DC): China Africa Research Initiative.

Caumes, A. and Merle C. 2021. *Republic of Benin's trailblazing €500m 12,5-Y inaugural issuance under its new SDG Bond Framework*. Paris: Natixis.

Chorzempa, M. and Mazarei, A. 2021. *Improving China's Participation in Resolving Developing-Country Debt Problems*. Policy Brief. 21-10. Washington (DC): Peterson Institute for International Economics.

Debt Justice. 2022. *BlackRock could make 110% profit out of Zambia's debt crisis*. Jubilee Debt Campaign. London: Debt Justice.

Dembele, F., Schwarz, R. and Horrocks, P. 2021. *Scaling up Green, Social, Sustainability and Sustainability-linked Bond Issuances in Developing Countries*. Paris: Organisation for Economic Co-operation and Development (OECD).

Diagana, O. 2021. *World Bank Urges Private Creditors to Deliver on Their Commitment to Debt Relief for Chad*. A Statement By Ousmane Diagana, Vice President, Western and Central Africa, The World Bank Group And Indermit S. Gill Vice President, Equitable Growth, Finance and Institutions, The World Bank Group. Washington (DC).

Donnan, S., Martin, E., Rosati, A. and Laghmari, J. 2022. Hunger and Blackouts Are Just the Start of an Emerging Economy Crisis. *Bloomberg*. Business. The Big Take. London: Bloomberg Europe.

EC. 2022. *EU-Africa: Global Gateway Investment Package*. Brussels: European Commission.

ESCAP75. 2021. *Debt-for-Climate Swaps as a Tool to Support the Implementation of the Paris Agreement*. Policy Brief. Bangkok: United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP).

ESCAP75. 2022.*Debt for Climate Swaps in the Pacific SIDS*. Workshop Paper. Advanced Copy. Bangkok: United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP).

Essers, D., Cassimon, D. and Prowse, M. 2022. Debt-for-climate swaps: Killing two birds with one stone? *Science Direct*. Global Environmental Change. Volume 71. 102407. Amsterdam: Elsevier.

Fofack, H. 2021. *The ruinous price for Africa of pernicious 'perception premiums' Unless fairer financing rules are implemented, historical biases will continue to sabotage sustainable development in the region.* B Africa Growth Initiative. Washington (DC): Brookings Institution.

Fuje, H., Ouattara, F. and Tiffin, A. 2021. *Has the DSSI Helped Lower Sovereign Spreads of Participating SSA Countries?* Washington (DC): International Monetary Fund.

Gelpern, A., Horn, S., Morris, S., Parks, B. and Trebesch, C. 2021. How China Lends. A Rare Look into 100 Debt Contracts with Foreign Governments. Washington (DC), Kiel, Williamsburg (VA) and London: Georgetown Law and Peterson Institute for International Economics, Kiel Institute for the World Economy and Kiel University, Center for Global Development, AidData and CEPR.

Georgieva, K. 2022. *Statement by IMF Managing Director Kristalina Georgieva at the Conclusion of a Meeting with UNECA and African Ministers of Finance and Central Bank Governors on the Impact of the Crisis in Ukraine*. Washington (DC): International Monetary Fund.

Heitzig, C., Uche Ordu, A. and Senbet, L. 2021. *Sub-Saharan Africa's debt problem. Mapping the pandemic effect and the way forward*. B Africa Growth Initiative. Washington (DC): Brookings Institution.

Horn, S., Reinhart, C. M. and Trebesch, C. 2022. *Hidden Defaults*. Policy Research Working paper no. 9925. Washington (DC): World Bank Group.

Hwang, J., Moses, O., Engel, L. and Shadbar, S. 2022. *Chinese Loans to Africa During the COVID-19 Pandemic*. GCI Policy Brief 012, 04/2022. Boston (MA): Boston University, Global Development Policy Center.

IIED. 2022. *Half of top ten countries most at risk from climate change already in or at high risk of entering* *debt distress*. Press Release. Biodiversity, Climate change, Sustainable markets. London: International Institute for Environment and Development.

IIED, Potomac Group LLC, UNECA, UNESCWA and UNDP. 2021. *Linking sovereign debt to climate and nature outcomes. A guide for debt managers and environmental decision makers*. London: International Institute for Environment and Development.

IIF. 2022. Member Institutions. Washington (DC): Institute of International Finance.

IMF. 2022. *List of LIC DSAs for PRGT-Eligible Countries. As of April 30, 2022*. Washington (DC): International Monetary Fund.

IMF. 2022a. *Government Debt (% of GDP)*. Washington (DC): International Monetary Fund.

IMF. 2022b. *IMF Media Roundtable on Ukraine*. IMF Videos. Washington (DC): International Monetary Fund.

Inman, P. 2022. BlackRock urged to delay debt repayments from crisis-torn Zambia. *The Guardian.* London.

IPCC WGII. *Climate Change 2022. Impact, Adaptation and Vulnerability. Summary for Policymakers.* Geneva: Intergovernmental Panel on Climate Change.

Kelly, L. 2021-2022. *Debt swaps for climate and nature outcomes in West Africa*. London: International Institute for Environment and Development.

Landers, C. and Aboneaaj, R. 2022. *Ghana Rages Against the Rating Agencies: G20, Take Notice*. Washington (DC): Center for Global Development.

McNair, D. 2022. *How the IMF and World Bank Can Support African Economies Hit Hard by Russia's Invasion of Ukraine*. New York (NY): Carnegie.

McNair, D. 2022a. Tweet on Tweeter.

Ministry of Finance of the republic of Ghana. 2022. *Moody's Downgrades Ghana's Rating to CAA1 and Stabilizes the Outlook*. Press Release. Accra.

Mukhopadhyay, A. 2022. *The Search for Sustainable Solutions to Debt Accumulation in Sub-Saharan Africa*. ORF Occasional Paper No. 349. Delhi: Observer Research Foundation.

ONE. 2022. *Data dive: Special Drawing Rights*. London: ONE.

Owen, N. 2022. *Belize: Swapping Debt for Nature*. IMF News. IMF Country Focus. Washington (DC): International Monetary Fund.

Pazarbasioglu, C. and Reinhart, C. 2022. *Shining a light on debt. For economic recovery and crisis prevention, hidden liabilities and their terms must be revealed*. Washington (DC): International Monetary Fund.

Qian, Y. 2021. Brady Bonds and the Potential for Debt Restructuring in the Post-Pandemic Era. GCI Working Paper no. 018. Boston (MA): Boston University, Global Development Policy Center.

Ramachandran, V. 2021. Rich Countries' Climate Policies Are Colonialism in Green. At COP26, developed-world governments are working to keep the global south poor. *FP*. Argument. Washington (DC): Foreign Policy magazine (FP).

Ryder, H. 2021. How multilaterals exaggerate Africa risk. *African Business*. London.

Ryder, H. 2022. China Will Help Restructure Zambia's Debt. What Exactly Does That Mean? *The Diplomat*. Washington (DC).

Savage, R. and Do Rosario, J. 2022. China committed to joining Zambia creditor committee, IMF's Georgieva says. *Reuters*. London.

Schlegl, M., Trebesch C. and Wright, M. L. J. 2019. *The Seniority Structure Of Sovereign Debt*. Working Paper Series. Working Paper 25793. Cambridge (MA): NBER.

Shalal, A. 2021. IMF, World Bank to unveil 'green debt swaps' option by November, Georgieva says. *Reuters*. London.

Shalal, A. 2021a. IMF struggling over long-awaited 'green debt swap' push as COP26 near. *Reuters*. London.

Singh, D. and Widge, V. 2021. *Debt for Climate Swaps. Supporting a Sustainable Recovery*. San Francisco (CA): Climate Policy initiative.

Sokpoh, A., Chirikure, N. and Braganza, J. R. 2022. *Africa's Debt Landscape: Scope for Sustainability*. Economy & Society. Policy Brief. Berlin: Africa Policy Research institute.

Sovereign. 2022. *Africa Union moves to set up Africa-owned credit rating agency*. News and Views. Gibraltar: Sovereign.

SSCOE. 2019. *Debt-for-Nature. Finance Swap*. Case Study. La Valletta: Commonwealth Small States Centre of Excellence.

Steele, P. and Patel, S. 2020. *Tackling the triple crisis Using debt swaps to address debt, climate and nature loss post-COVID-19*. Issue Paper Sept. 2020. London: International Institute for Environment and Development.

Stubbington, T. and Duguid, K. 2022. Soaring dollar raises spectre of 'reverse currency wars'. *The Financial Times*. Global Economy. London and New York (NY): The Financial Times.

Unofficial statement. 2021. Statement posted on several Chinese embassies' websites responding to Gelpern et al. 2021.

Usman, Z. 2021. *What Do We Know About Chinese Lending in Africa?* New York (NY): Carnegie.

Vander Stichele, M. 2021. *Will the G20 let private finance escape debt relief once again?* Amsterdam: SOMO.

Vásquez, I. 1996. The Brady Plan and Market-Based Solutions to Debt Crisis. *Cato Journal*. Vol. 16, no. 2. Washington (DC): Cato Institute.

Volz, U., Akhtar, S., Gallagher, K. P., Griffith-Jones, S., Haas, J. and Kraemer, M. 2021. *Debt Relief for a Green and Inclusive Recovery: Securing Private-Sector Participation and Creating Policy Space for Sustainable Development*. Berlin, London and Boston (MA): Heinrich-Böll-Stiftung, SOAS, University of London and Boston University.

WMO. 2021. *State of the Climate in Africa 2020*. WMO no. 1275. Geneva: World Meteorological Organization.

Weder Di Mauro, B. 2021. *Debt-for-Climate Swaps Make Sense*. Prague: Project Syndicate.

World Bank. 2018. *Africa's Pulse*. Serial, no. 17, April 2018. Washington (DC): World Bank.

World Bank. 2021. *Africa's Pulse. An Analysis of Issues Shaping Africa's Economic Future*. Serial, no. 24, October 2021. Washington (DC): World Bank.

World Bank. 2022. *World Development Report 2022: Finance for an Equitable Recovery*. Washington (DC): World Bank.

World Bank. 2022a. *Africa's Pulse. Boosting resilience: the future of social protection in Africa*. Serial, no. 25, April 2022. Washington (DC): World Bank.

World Bank. 2022b. *International Debt Statistics*. Washington (DC): World Bank.

World Bank. 2022c. *World Bank Group Response to Global Impacts of the War in Ukraine. A Proposed Roadmap.* Washington (DC): World Bank.

Endnotes

[1] The external debt stock in Sub-Saharan Africa increased on average by 57.4% between 2015 and 2020, reaching USD 702 billion in 2020 with heavily indebted poor countries like Senegal or Benin experiencing the largest increases (Heitzig at al. 2021). As a result, the average debt-to-GDP ratio of those countries jumped from 49.2% in 2015 to 67.4% in 2020, while 23 African countries are now considered to be at high risk (or already in) debt distress (IMF 2022a). While more recent data is not yet available, these trends are likely to be reinforced in 2021 and 2022.

[2] While this paper looks at the dynamics in Africa as a whole, a lot of the available statistics, particularly from the World Bank and the IMF continue to delink Sub-Saharan Africa and group North Africa with the Middle East. This provides a skewed image of African economic development, yet requires a broader methodological shift in research and institutions to address.

[3] Rating agencies also cautioned African countries against adopting large pandemic stimulus packages (Landers and Aboneaaj 2022).

[4] The decision was contested by Ghana (Ministry of Finance of the Republic of Ghana 2022), and while S&P maintained its B rating, the move still led to a fall by 3.4 cents on the dollar of some of Ghana's sovereign bonds and risks locking the country out of more affordable international capital markets.

[5] To address these so-called 'perception premiums' the African Union plans to set up an independent African Credit Rating Agency to provide alternative and complementing rating opinions for the continent (Sovereign 2022).

[6] Based on a sample of 25 developing countries across the world. See Buhr et al. 2018.

[7] Controlling for Angola, the continent's single largest Chinese borrower, which peaked in 2016. See Hwang et al. 2022.

[8] Resource-backed loans commit a borrowing country's future resource revenues to secure repayment.

[9] These include the AidData research lab at *William & Mary's Global Research Institute* (global), the China Africa Research Initiative at John Hopkins University (Africa) and more recently also *the China Overseas Finance Inventory Database* developed by Boston University in collaboration with WRI, all of which aims to address the lack of data on Chinese loans and investments in developing countries.

[10] Chinese interests-free loans tend to be small, and account for less than 5% of Africa's debt to China.

[11] Following the 2022 International Monetary Fund/World Bank Spring Meetings, China announced that it would participate in the creditor committee of Zambia, which is a step forward in terms of coordination between the Paris Club and non Paris Club creditors (Savage and Do Rosario 2022).

[12] African countries', including Ghana (African Markets 2021) and Benin (Caumes and Merle 2021) are also launching more general social and sustainability (SDG) bonds.

[13] Looking at the current state of play there is a need for further and in-depth analysis of the political economy of European positions and agendas in various fora (Bretton Woods Institutions, Paris Club, G20 and G7). There is also a need for better understanding the specific concerns and disincentives of EU member state treasuries, banks, DFIs, private creditors and how they might be overcome.

[14] The blue bond issued as part of the 2018 Seychelles debt swap was partially guaranteed up to USD 5 million by the World Bank.

About ECDPM

ECDPM is an independent 'think and do tank' working on international cooperation and development policy in Europe and Africa.

Since 1986 our staff members provide research and analysis, advice and practical support to policymakers and practitioners across Europe and Africa – to make policies work for sustainable and inclusive global development.

Our main areas of work include:

- EU foreign and development policy
- Migration and mobility
- Digital economy and governance
- AU-EU relations
- Peace, security and resilience
- Democratic governance
- Economic recovery and transformation
- Climate change and green transition
- African economic integration
- Sustainable food systems

For more information please visit www.ecdpm.org

This publication benefits from the structural support by ECDPM's institutional partners: Austria, Belgium, Denmark, Estonia, Finland, Ireland, Luxembourg, the Netherlands and Sweden, this publication benefits from specific support from the Open Society Foundations.

ISSN1571-7577

ecdpm

Making policies work

HEAD OFFICE
SIÈGE
Onze Lieve Vrouweplein 21
6211 HE Maastricht
The Netherlands *Pays Bas*
Tel +31 (0)43 350 29 00
Fax +31 (0)43 350 29 02

BRUSSELS OFFICE
BUREAU DE BRUXELLES
Rue Archimède 5
1000 Brussels *Bruxelles*
Belgium *Belgique*
Tel +32 (0)2 237 43 10
Fax +32 (0)2 237 43 19

info@ecdpm.org
www.ecdpm.org
KvK 41077447

Annex 593 bis

"Rating Methodology: Sovereigns", *Moody's Rating*, 22 November 2022

MOODY'S RATINGS

RATING METHODOLOGY
22 November 2022

TABLE OF CONTENTS

Analyst Contacts

Anne Van Praagh +1.212.553.3744
MD-Gbl Sovereign Risk
anne.vanpraagh@moodys.com

Marie Diron +44.20.7772.1968
MD-Sovereign Risk
marie.diron@moodys.com

Alejandro Olivo +1.212.553.3837
MD-Sovereign/Sub Sovereign
alejandro.olivo@moodys.com

Gene Fang +65.6398.8311
Associate Managing Director
gene.fang@moodys.com

Dietmar Hornung +49.69.70730.790
Associate Managing Director
dietmar.hornung@moodys.com

Mauro Leos +1.212.553.1947
Associate Managing Director
mauro.leos@moodys.com

» *Analyst Contacts continued on last page*

Rating Methodology

Sovereigns

This rating methodology replaces the *Sovereign Ratings Methodology* published in November 2019. While this methodology retains the same factors and sub-factors as the 2019 methodology, we have made a number of specific changes, including the following: In the Economic Strength factor, for the assessment of a sovereign's volatility in real gross domestic product (GDP) growth, the median absolute deviation (MAD) has replaced standard deviation; the Institutions and Governance Strength factor describes additional data that may be used to inform our assessment, and the specific inflation thresholds in the Monetary and Macroeconomic Policy Effectiveness sub-sub-factor were eliminated; several adjustments to the Fiscal Strength factor were modified to better reflect our analytical thinking, including the adjustments for debt trend, general government foreign currency debt, and government financial assets; for HIPC/IDA countries, we modified how the scorecard weights are used; in the Susceptibility to Event Risk factor, the four sub-factors were refined to promote consistency in our scoring; the revised methodology text describes the treatment of sovereigns that participate in official sector debt relief with and without private sector involvement and describes in more detail how environmental, social and governance (ESG) considerations are integrated into our credit analysis of sovereigns. We have also reordered and have made editorial updates to various sections of the methodology.

Scope

This methodology applies to sovereign governments globally.[1] A sovereign is the highest tier of government in a country, and we also refer to a central or federal government as the sovereign.

We also use this methodology to rate national central banks and the governments of certain specific jurisdictions that have significant autonomy on a range of policies.

Rating approach

In this rating methodology, we explain our general approach to assessing credit risk of sovereigns globally, including the qualitative and quantitative factors that are likely to affect rating outcomes in this sector. We seek to incorporate all material credit considerations in ratings and to take the most forward-looking perspective that visibility into these risks and mitigants permits.

The following schematic illustrates our general framework for the analysis of sovereigns, which includes the use of a scorecard.[2]

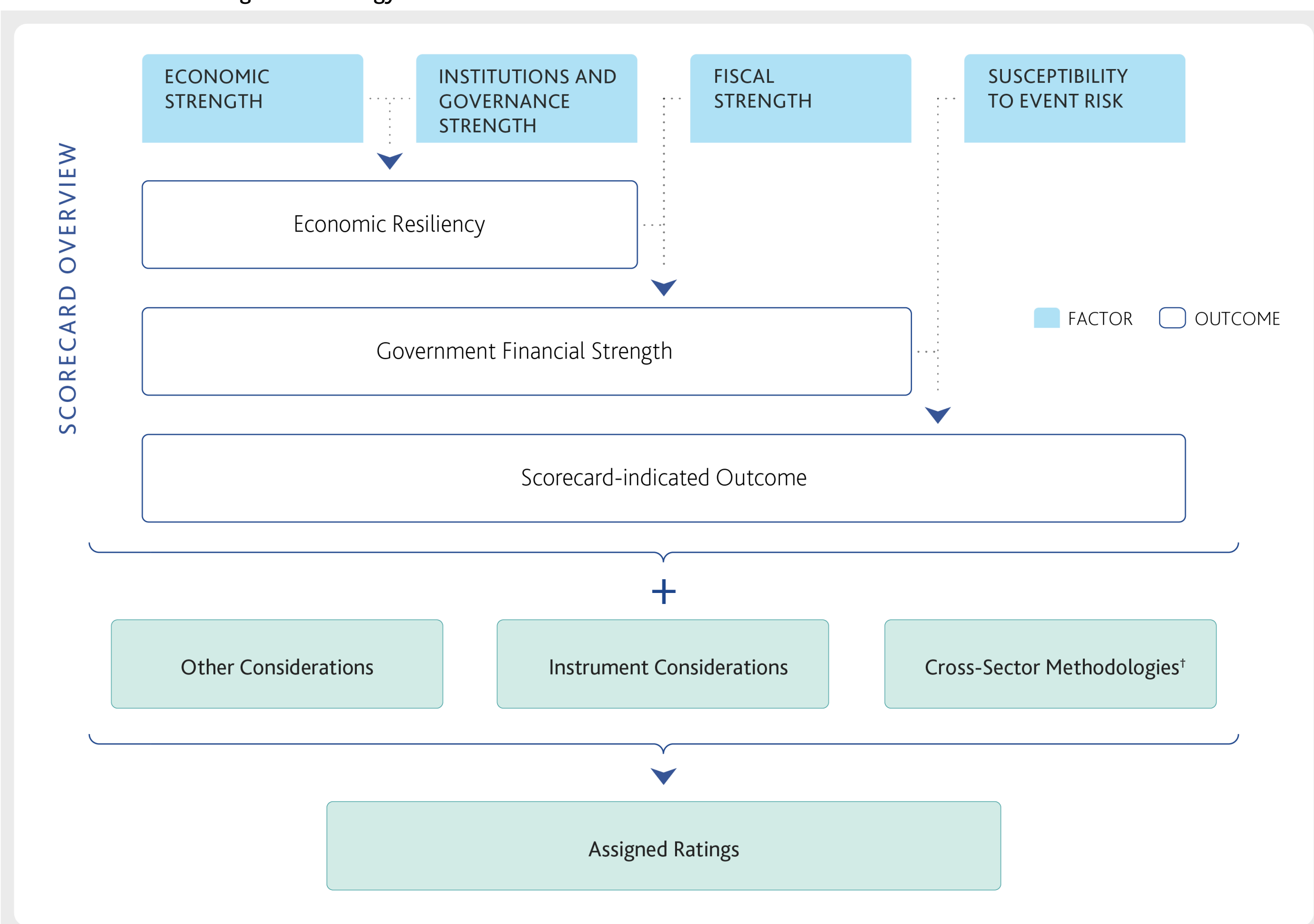
» Using equal weights, we combine the final scores of the Economic Strength and the Institutions and Governance Strength factors to arrive at the Economic Resiliency score.

» Using dynamic weights, we combine the Economic Resiliency Outcome with the final score of the Fiscal Strength factor to arrive at the Government Financial Strength score.

» We then consider a sovereign's susceptibility to event risk to arrive at a scorecard-indicated outcome, which is expressed as a range.

The scorecard-indicated outcome is not expected to match the actual rating for each issuer. For more information, see the "Other considerations" and "Limitations" sections.

Exhibit 1
Illustration of the sovereign methodology framework



† Some of the methodological considerations described in one or more cross-sector rating methodologies may be relevant to ratings in this sector. A link to a list of our sector and cross-sector methodologies can be found in the "Moody's related publications" section.
Source: Moody's Investors Service

Exhibit 2

Sovereign scorecard overview

<table>
<thead>
<tr><th>Factor</th><th>Sub-factor</th><th>Sub-factor Weighting</th><th colspan="2">Metric / Sub-sub-factor</th><th>Metric /Sub-sub-factor Weighting</th></tr>
</thead>
<tbody>
<tr><td rowspan="5">ECONOMIC STRENGTH</td><td rowspan="2">Growth Dynamics</td><td rowspan="2">35%</td><td colspan="2">Average Real GDP Growth</td><td>25%</td></tr>
<tr><td colspan="2">MAD Volatility in Real GDP Growth</td><td>10%</td></tr>
<tr><td>Scale of the Economy</td><td>30%</td><td colspan="2">Nominal GDP (US$ bn)</td><td>30%</td></tr>
<tr><td>National Income</td><td>35%</td><td colspan="2">GDP per Capita (PPP, Int. USD)</td><td>35%</td></tr>
<tr><td>Adjustment to Factor Score</td><td>0 to 9 notches</td><td colspan="2">Other</td><td></td></tr>
<tr><td rowspan="6">INSTITUTIONS AND GOVERNANCE STRENGTH</td><td rowspan="2">Quality of Institutions</td><td rowspan="2">40%</td><td colspan="2">Quality of Legislative and Executive Institutions</td><td>20%</td></tr>
<tr><td colspan="2">Strength of Civil Society and the Judiciary</td><td>20%</td></tr>
<tr><td rowspan="2">Policy Effectiveness</td><td rowspan="2">60%</td><td colspan="2">Fiscal Policy Effectiveness</td><td>30%</td></tr>
<tr><td colspan="2">Monetary and Macroeconomic Policy Effectiveness</td><td>30%</td></tr>
<tr><td rowspan="2">Adjustments to Factor Score</td><td>0 to 3 notches</td><td colspan="2">Government Default History and Track Record of Arrears</td><td></td></tr>
<tr><td>0 to 3 notches</td><td colspan="2">Other</td><td></td></tr>
<tr><td rowspan="10">FISCAL STRENGTH</td><td rowspan="2">Debt Burden</td><td rowspan="2">50%[1]</td><td colspan="2">General Government Debt / GDP</td><td>25%</td></tr>
<tr><td colspan="2">General Government Debt / Revenue</td><td>25%</td></tr>
<tr><td rowspan="2">Debt Affordability</td><td rowspan="2">50%[1]</td><td colspan="2">General Government Interest Payments / Revenue</td><td>25%</td></tr>
<tr><td colspan="2">General Government Interest Payments / GDP</td><td>25%</td></tr>
<tr><td rowspan="6">Adjustments to Factor Score</td><td rowspan="5">0 to 6 notches</td><td rowspan="2">Debt Trend</td><td>Historical Change in Debt Burden</td><td></td></tr>
<tr><td>Expected Change in Debt Burden</td><td></td></tr>
<tr><td colspan="2">General Government Foreign Currency Debt / GDP</td><td></td></tr>
<tr><td colspan="2">Other Non-Financial Public Sector Debt / GDP</td><td></td></tr>
<tr><td colspan="2">Government Financial Assets including Sovereign Wealth Funds / GDP</td><td></td></tr>
<tr><td>0 to 3 notches</td><td colspan="2">Other</td><td></td></tr>
<tr><td rowspan="9">SUSCEPTIBILITY TO EVENT RISK</td><td>Political Risk</td><td>Minimum Function[2]</td><td colspan="2">Domestic Political and Geopolitical Risk</td><td></td></tr>
<tr><td rowspan="2">Government Liquidity Risk</td><td>Minimum Function[2]</td><td colspan="2">Ease of Access to Funding</td><td></td></tr>
<tr><td>0 to 2 scoring categories</td><td colspan="2">Adjustment to Sub-factor Score High Refinancing Risk</td><td></td></tr>
<tr><td rowspan="3">Banking Sector Risk</td><td rowspan="2">Minimum Function[2]</td><td colspan="2">Risk of Banking Sector Credit Event (BSCE)</td><td></td></tr>
<tr><td colspan="2">Total Domestic Bank Assets / GDP</td><td></td></tr>
<tr><td>0 to 2 scoring categories</td><td colspan="2">Adjustment to Sub-factor Score</td><td></td></tr>
<tr><td rowspan="2">External Vulnerability Risk</td><td>Minimum Function[2]</td><td colspan="2">External Vulnerability Risk</td><td></td></tr>
<tr><td>0 to 2 scoring categories</td><td colspan="2">Adjustment to Sub-factor Score</td><td></td></tr>
<tr><td>Adjustment to Factor Score</td><td>0 to 2 scoring categories</td><td colspan="2"></td><td></td></tr>
</tbody>
</table>

1 For more details about how these weights may vary, please refer to our discussion on the “Treatment of Reserve Currency Countries and HIPC/IDA Countries” within the “Fiscal Strength” section of the methodology.
2 The aggregation of Political Risk, Government Liquidity Risk, Banking Sector Risk and External Vulnerability Risk follows a minimum function, i.e., as soon as one area of risk warrants an assessment of elevated risk, the country's overall Susceptibility to Event Risk is scored at that specific, elevated level.
Source: Moody's Investors Service

Sector overview

Sovereign debt is used to fund government operations. Most sovereigns issue a combination of bonds, bills, notes and loans, and their debt structures are based on capital market depth, market conditions and government preferences. In the vast majority of the world's debt capital markets, national governments are the largest borrowers, and their credit standing provides a benchmark for other issuers of debt.

Sovereigns have executive authority, including to incur debt. A number of characteristics distinguish sovereigns from other debtors. These characteristics include (i) a sovereign's ability to curb expenditures or increase tax revenues to service debt outstanding; (ii) the absence of a higher authority to compel debt resolution; and (iii) the high probability of survival even after an event of default — that is, countries rarely disappear.

How environmental, social and governance considerations are integrated into our analysis

ESG considerations are integrated into our credit analysis of sovereigns in various ways. Ratings incorporate our full view of ESG considerations, including those that are captured in the scorecard factors and those that are considered outside the scorecard.

The general principles underpinning our analysis of current and developing ESG risks and benefits and how we arrive at E, S and G issuer profile scores for sovereigns, which are inputs to ratings, are described in our cross-sector methodology.[3] Issuer profile scores provide a consistent way to express our assessment of ESG risks and benefits. Exhibit 3 shows the interrelationships among E, S and G and the four scorecard factors, which are also described in the "Discussion of the scorecard factors" section.

Environmental risks — which include carbon transition, physical climate risk, water management, waste and pollution, and natural capital considerations — primarily influence a sovereign's credit profile through their economic and fiscal impacts and reflect the effects of extreme weather or slowly materializing changes in climate and the availability of natural resources on economies and on government revenue and expenditure. Another channel of transmission of environmental risk is through efforts at a global level to reduce emissions of greenhouse gases, which will negatively affect demand and prices of hydrocarbon products, thus affecting the fiscal strength of hydrocarbon producers. For some sovereigns, environmental risk may also affect their susceptibility to event risks, for instance, where climate change raises political risk or where the transition to a low-carbon economy or a depletion of natural capital increases external vulnerability risk.

We seek to assess how social considerations — which include demographics, labor and income, education, housing, health and safety and access to basic services — are likely to affect sovereign creditworthiness. Social considerations have pervasive effects throughout a sovereign's credit profile. For example, the level and distribution of incomes may affect a sovereign's economic strength. Social considerations are also relevant to our assessment of the strength of a sovereign's institutions and governance, which greatly influence policy effectiveness and partly determine a government's capacity to fulfill social demands. Demographic trends have a material impact on fiscal strength, in particular where a population is aging rapidly. More generally, social considerations are likely to influence a government's fiscal policy settings and outcomes, on both the revenue and expenditure sides. Social risks are often closely related to political risk and may influence other aspects of a sovereign's susceptibility to event risk, such as when heightened social tensions, whether actual or perceived, increase government liquidity risk.

Governance relates to the framework and processes through which decisions are made and related actions are carried out. Governance is directly embedded in the Institutions and Governance Strength factor and may also influence a sovereign's economic strength, fiscal strength and susceptibility to event risk. For instance, strong governance mitigates susceptibility to event risk. It also contributes to higher growth potential and greater fiscal strength. As described in our cross-sector ESG methodology, our assessment of institutions and governance strength in the sovereign scorecard drives the governance issuer profile score for a sovereign.

Exhibit 3
How ESG considerations are integrated into our analysis

Factor	Sub-factor	Environmental IPS	Social IPS	Governance IPS
ECONOMIC STRENGTH	Growth Dynamics	●	●	●
	Scale of the Economy			
	National Income		●	
INSTITUTIONS AND GOVERNANCE STRENGTH	Quality of Institutions		●	●
	Policy Effectiveness		●	●
FISCAL STRENGTH	Debt Burden	●	●	
	Debt Affordability		●	●
SUSCEPTIBILITY TO EVENT RISK	Political Risk	●	●	●
	Government Liquidity Risk			●
	Banking Sector Risk			●
	External Vulnerability Risk	●		

Source: Moody's Investors Service

Sovereign scorecard

For general information about how we use the scorecard and for a discussion of scorecard mechanics, please see the “Using the scorecard to arrive at a scorecard-indicated outcome” section. The scorecard does not include or address every factor that a rating committee may consider in assigning ratings in this sector. Please see the “Other considerations” and “Limitations” sections.

The scorecard comprises four weighted factors. Some of these factors comprise sub-factors, metrics and sub-sub-factors, which may incorporate adjustments. In the “Discussion of the scorecard factors” section, we explain the typical drivers of adjustments.

The scorecard is oriented to the issuer rating. Scorecard-indicated outcomes are expressed as three-notch ranges on our alphanumeric rating scale. The assigned rating is expressed on our 21-point rating scale and is often but not always within the three-notch range.

We may apply notching adjustments to certain factor or sub-factor scores to incorporate considerations that, for a particular issuer, may not be fully reflected in the scorecard using the standard metrics, thresholds and weights. Final factor scores incorporate additional analytical judgment, reflecting that the scorecard may not always capture the nuances of a sovereign’s credit profile.

In the “Discussion of the scorecard factors” section, we explain the typical drivers of adjustments. We consider these drivers and, in a few cases, other drivers that meaningfully affect a sovereign in their totality to arrive at an adjusted factor or sub-factor score. Some adjustment drivers are inter-related, or are influenced by environmental, social and governance (ESG) considerations, but we avoid double-counting by taking an overall view of the factor or sub-factor score.

Exhibit 4
Sovereign scorecard

Factor: Economic Strength

Sub-factor	Metric	Metric Weight	aaa	aa1	aa2	aa3	a1	a2	a3	baa1	baa2	baa3	ba1	ba2	ba3	b1	b2	b3	caa1	caa2	caa3	ca
Growth Dynamics	Average Real GDP Growth (%) $_{t-4\text{ to }t+5}$ [*1]	25%	≥ 5.7	5.3 - 5.7	4.9 - 5.3	4.4 - 4.9	4 - 4.4	3.7 - 4	3.3 - 3.7	3 - 3.3	2.6 - 3	2.3 - 2.6	2 - 2.3	1.8 - 2	1.6 - 1.8	1.3 - 1.6	1.1 - 1.3	0.9 - 1.1	0.7 - 0.9	0.5 - 0.7	0.3 - 0.5	< 0.3
	MAD Volatility in Real GDP Growth (%) $_{t-9\text{ to }t}$ [*2]	10%	≤ 0.10	0.10 – 0.20	0.20 – 0.30	0.30 – 0.40	0.40 – 0.50	0.50 – 0.60	0.60 – 0.75	0.75 – 0.90	0.90 – 1.10	1.10 – 1.30	1.30 – 1.50	1.50 – 1.80	1.80 – 2.10	2.10 – 2.40	2.40 – 2.70	2.70 – 3.00	3.00 – 3.50	3.50 – 4.00	4.00 – 4.50	> 4.50
Scale of the Economy	Nominal GDP (US$ bn)[*3]	30%	≥ 1,000	750 - 1,000	600 - 750	450 - 600	330 - 450	250 - 330	190 - 250	140 - 190	100 - 140	80 - 100	60 - 80	45 - 60	35 - 45	26 - 35	20 - 26	15 - 20	10 - 15	8 - 10	6 - 8	< 6
National Income	GDP per capita (PPP, international USD)[*4]	35%	≥ 48,000	42,000 - 48,000	37,000 - 42,000	32,000 - 37,000	27,500 - 32,000	24,500 - 27,500	21,000 - 24,500	19,000 - 21,000	16,000 - 19,000	14,000 - 16,000	12,000 - 14,000	10,750 - 12,000	9,500 - 10,750	8,000 - 9,500	7,000 - 8,000	6,200 - 7,000	5,500 - 6,200	4,700 - 5,500	4,100 - 4,700	< 4,100

Adjustment to Factor Score
Other
0 to 9 notches

Factor: Institutions and Governance Strength										
Sub-factor	Sub-sub-factor	Sub-sub-factor Weight	aaa	aa	a	baa	ba	b	caa	ca
Quality of Institutions	Quality of Legislative and Executive Institutions	20%	Sovereigns in this category would generally have WGI scores for regulatory quality and government effectiveness above 1.5. Policy is legislated and implemented with the support of a highly professional, well-staffed and highly capable public administration with exceptionally deep bench strength. These institutions have demonstrated the flexibility to deal with changing circumstances and can absorb shocks while maintaining financial and economic stability.	Sovereigns in this category would generally have WGI scores for regulatory quality and government effectiveness between 1.5 and 1.0. Policy is legislated and implemented with the support of a generally professional and capable public administration, though in some cases it may face skill shortages in some areas or capacity constraints due to the country's size. These institutions can absorb shocks while maintaining financial and economic stability, but may be slow or tentative when dealing with changing circumstances.	Sovereigns in this category would generally have WGI scores for regulatory quality and government effectiveness between 1.0 and 0.5. Policy is legislated and implemented with the support of a generally professional and capable public administration, though in some cases it may face skill shortages in some areas or capacity constraints due to the country's size. These institutions can absorb shocks while maintaining financial and economic stability, but may be slow or tentative when dealing with changing circumstances.	Sovereigns in this category would generally have WGI scores for regulatory quality and government effectiveness between 0.5 and 0.0. The public administration has a core of highly capable and qualified professionals, but bench strength is not particularly deep. As a result, at times it may struggle to support policymaking and implementation. These institutions generally struggle to respond to shocks while maintaining financial and economic stability, and are slow or tentative when dealing with changing circumstances.	Sovereigns in this category would generally have WGI scores for regulatory quality and government effectiveness between 0.0 and -0.5. The public administration has a core of highly capable and qualified professionals, but bench strength is not particularly deep. As a result, at times it may struggle to support policymaking and implementation. These institutions generally struggle to respond to shocks while maintaining financial and economic stability, and are slow or tentative when dealing with changing circumstances.	Sovereigns in this category would generally have WGI scores for regulatory quality and government effectiveness between -0.5 and -1. The public administration often struggles to support policymaking and implementation. It often accumulates government arrears. These institutions have difficulty dealing with changing circumstances and have little or no ability to absorb shocks without creating social, fiscal, and/or economic instability.	Sovereigns in this category would generally have WGI scores for regulatory quality and government effectiveness between – 1.0 and -1.5. The public administration often struggles to support policymaking and implementation. It often accumulates government arrears. These institutions have difficulty dealing with changing circumstances and have little or no ability to absorb shocks without creating social, fiscal, and/or economic instability.	Sovereigns in this category would generally have WGI scores for regulatory quality and government effectiveness below -1.5. The public administration lacks technical skills in some key areas and is often not executing its functions. It exhibits weak willingness to pay creditors, and accumulates significant government arrears. These institutions have difficulty coping with even day-to-day management of the country and the population's fundamental economic and security needs.

Factor: Institutions and Governance Strength

Sub-factor	Sub-sub-factor	Sub-sub-factor Weight	aaa	aa	a	baa	ba	b	caa	ca
Quality of Institutions	Quality of Legislative and Executive Institutions	20%	Law-making occurs under a well-developed constitutional framework that is transparent and predictable. Data sets are timely, stable, comprehensive and are provided for all levels of government (central, regional, local, and social security). Politically independent governmental bodies, such as fiscal councils, have a strong voice in the policymaking process.	Law-making occurs under a well-developed constitutional framework that is transparent and predictable. Data reporting is comprehensive overall, but it may not be timely or may be subject to large revisions. Politically independent governmental bodies, such as fiscal councils, have a strong voice in the policymaking process.	Law-making occurs under a constitutional framework that is generally transparent and predictable. Data reporting is comprehensive overall, but it may not be timely or may be subject to large revisions. Politically independent governmental bodies, such as fiscal councils, are an input into the policymaking process.	Law-making occurs under a constitutional framework that is generally transparent and predictable. Data reporting is systematic but not comprehensive and may be subject to significant lags and revisions. There may also be recurrent questions about data reliability. Fiscal data is not reported for lower levels of government (regional, local, and social security). Politically independent governmental bodies, such as fiscal councils, are an input into the policymaking process.	Law-making occurs under a constitutional framework that may be somewhat opaque and unpredictable. Data reporting is systematic but not comprehensive and may be subject to significant lags and revisions. There may also be recurrent questions about data reliability. Fiscal data is not reported for lower levels of government (regional, local, and social security). Politically independent bodies do not have a meaningful voice in the policymaking process.	Law-making occurs under a constitutional framework that may be somewhat opaque and unpredictable. Data reporting of key fiscal and economic indicators is typically annual, can be erratic or incomprehensive, or data collection and provision are adversely affected by political influence over the collection and reporting process. Politically independent bodies do not have a meaningful voice in the policymaking process.	Law-making occurs under a legal framework that is opaque and unpredictable. Data reporting of key fiscal and economic indicators is typically annual, can be erratic or incomprehensive, or data collection and provision are adversely affected by political influence over the collection and reporting process. There are no politically independent actors participating in the policymaking process.	Law-making occurs under a legal framework that is opaque and unpredictable. Key data sets are unreliable or missing. There are no politically independent actors participating in the policymaking process.

Factor: Institutions and Governance Strength

Sub-factor	Sub-sub-factor	Sub-sub-factor Weight	aaa	aa	a	baa	ba	b	caa	ca
Quality of Institutions	Strength of Civil Society and the Judiciary	20%	WGI scores for voice and accountability, rule of law and control of corruption typically above 1.5. The enforcement of laws is highly predictable and consistent, including as they apply to the government itself. An effective balance of power and separation of powers is consistently and dependably maintained between branches of government, and judicial independence is maintained and respected. There are few instances of corruption that act to the detriment of the sovereign's credit profile. Judicial processes are impartial, contracts are enforced, and legal cases are resolved in a timely manner. Institutions in civil society consistently act as an effective check on the exercise of government power.	Generally have WGI scores for voice and accountability, rule of law and control of corruption typically between 1.5 and 1.0. The enforcement of laws is highly predictable and consistent, including as they apply to the government itself. An effective balance of power and separation of powers is consistently and dependably maintained between branches of government, and judicial independence is maintained and respected. There are few instances of corruption that act to the detriment of the sovereign's credit profile. Judicial processes are impartial, contracts are enforced, and legal cases are resolved in a timely manner. Institutions in civil society consistently act as an effective check on the exercise of government power.	Generally have WGI scores for voice and accountability, rule of law and control of corruption typically between 1.0 and 0.5. The enforcement of laws is usually predictable and consistent, including as they apply to the government itself. An effective balance of power and separation of powers is generally maintained between branches of government. However, judicial independence is not always maintained. Corruption can be a problem that acts to the detriment of the sovereign's credit profile. Judicial processes are impartial and contracts are enforced, but it often takes a long time for a case to be resolved in the courts. Civil society institutions often act as an effective check on the exercise of government power.	WGI scores for voice and accountability, rule of law and control of corruption typically between 0.5 and 0.0. The enforcement of laws is usually predictable and consistent, including as they apply to the government itself. An effective balance of power and separation of powers is generally maintained between branches of government. However, judicial independence is not always maintained. Corruption can be a problem that acts to the detriment of the sovereign's credit profile. Judicial processes are impartial and contracts are enforced, but it often takes a long time for a case to be resolved in the courts. Civil society institutions often act as an effective check on the exercise of government power.	WGI scores for voice and accountability, rule of law and control of corruption typically between 0.0 and -0.5. The enforcement of laws is only sometimes predictable and consistent. Checks on the exercise of government power are not consistently applied. The judiciary is subject to political influence in ways that affect the business climate or other aspects of the sovereign's credit profile. Corruption is a significant structural challenge that undermines policy formation, economic stability and/or social cohesion. There is evidence of judicial bias, and contract enforcement can be challenging. Civil society institutions exist, but have difficulty acting as an effective check on the exercise of government power.	WGI scores for voice and accountability, rule of law and control of corruption typically between -0.5 and -1.0. The enforcement of laws is only sometimes predictable and consistent. Checks on the exercise of government power are not consistently applied. The judiciary is subject to political influence in ways that affect the business climate or other aspects of the sovereign's credit profile. Corruption is a significant structural challenge that undermines policy formation, economic stability and/or social cohesion. There is evidence of judicial bias, and contract enforcement can be challenging. Civil society institutions exist, but have difficulty acting as an effective check on the exercise of government power.	WGI scores for voice and accountability, rule of law and control of corruption typically between -1.0 and -1.5. The enforcement of laws is usually unpredictable and inconsistent. There are few formal checks on the exercise of government power or the judiciary is not independent. Corruption is endemic and affects a wide range of policy choices. The courts system is ineffective. Civil society institutions either do not exist or have little discernable impact on the exercise of government power.	WGI scores for voice and accountability, rule of law and control of corruption typically below -1.5. The enforcement of laws is usually unpredictable and inconsistent. There are few formal checks on the exercise of government power or the judiciary is not independent. Corruption is endemic and affects a wide range of policy choices. The courts system is ineffective. Civil society institutions either do not exist or have little discernable impact on the exercise of government power.

Factor: Institutions and Governance Strength										
Sub-factor	Sub-sub-factor	Sub-sub-factor Weight	aaa	aa	a	baa	ba	b	caa	ca
Policy Effectiveness	Fiscal Policy Effectiveness	30%	Over several cycles, debt/GDP may have increased during recessions, but then decreased during periods of normal or high growth. The budget is and is expected to remain generally in a balance or in surplus position with flexibility to accommodate for the economic cycle. Fiscal targets or expenditure ceilings are observed or outperformed.	Over several cycles, debt/GDP may have increased during recessions, but then decreased during periods of normal or high growth. The budget is generally in balance or in a small deficit; or budget balances are generally consistent with a stable debt burden. The structure of government revenues and expenditures is relatively flexible, and tax evasion is not a major problem for fiscal policy formation. Fiscal targets or expenditure ceilings are observed or outperformed.	Over several cycles, debt/GDP will have generally increased during recessions, but then decreased slowly during periods of normal or high growth. The budget is generally in a balance or a small deficit; or budget balances are generally consistent with a stable debt burden. The structure of government revenues and expenditures is relatively flexible, and tax evasion is not a major problem for fiscal policy formation. Fiscal targets or expenditure ceilings are sometimes missed.	Over several cycles, debt/GDP will have generally increased during recessions, but then decreased slowly during periods of normal or high growth. The budget is generally in deficit; or budget balances are generally consistent with a gradual rise in the debt burden. The structure of government revenues and expenditures is relatively rigid. Tax evasion is a constraint on fiscal policy formation. Fiscal targets or expenditure ceilings are sometimes missed.	Over several cycles, debt/GDP will have generally increased materially during recessions, without meaningful decreases during periods of normal or high growth. The budget is generally in deficit; or budget balances are generally consistent with a gradual rise in the debt burden. The structure of government revenues and expenditures is relatively rigid. Tax evasion is a constraint on fiscal policy formation. Fiscal targets or expenditure ceilings are often missed.	Over several cycles, debt/GDP will have generally increased materially during recessions, without meaningful decreases during periods of normal or high growth. Budget deficits are the norm and tend to be large enough so that they add to the debt burden. The structure of government expenditures is highly rigid, and the government is reliant on a narrow range of revenue sources. The incidence of tax evasion is high and is a material constraint on fiscal policy formation. Fiscal targets or expenditure ceilings are often missed.	Over several cycles, debt/GDP will have increased on an unsustainable basis. Budget deficits are the norm and tend to be large enough so that they add to the debt burden. The structure of government expenditures is highly rigid, and the government is reliant on a narrow range of revenue sources. The incidence of tax evasion is high and is a material constraint on fiscal policy formation. Fiscal targets or expenditure ceilings do not exist.	Over several cycles, debt/GDP will have increased on an unsustainable basis. The government faces very significant constraints in formulating fiscal policy, including a very high incidence of tax evasion. Fiscal targets or expenditure ceilings do not exist.

Factor: Institutions and Governance Strength

Sub-factor	Sub-sub-factor	Sub-sub-factor Weight	aaa	aa	a	baa	ba	b	caa	ca
Policy Effectiveness	Fiscal Policy Effectiveness	30%	The medium-term policy planning process is highly robust. Revenues and expenditures are very stable, and a period of significant economic weakness does not prompt material and lasting deviations from the plan. There is a high degree of transparency in the government accounts, including guarantees and other contingent liabilities. Debt is well-structured and issuance is predictable, with extremely robust capacity and resources to mitigate risks proactively and manage risks arising from shocks.	Medium-term policy planning process results in government spending remaining largely stable in the outer years, except in periods of significant economic shock. There is a high degree of transparency in the government accounts, including guarantees and other contingent liabilities. Debt is well-structured and issuance is predictable, with extremely robust capacity and resources to mitigate risks proactively and manage risks arising from shocks.	Medium-term policy planning process results in government spending remaining largely stable in the outer years, except in periods of significant economic shock. There is a high degree of transparency in the government accounts, but information on guarantees and other contingent liabilities may not be available or fully transparent. Debt is well-structured but issuance is opportunistic, with robust capacity and resources to mitigate risks proactively and manage risks arising from shocks.	Fiscal policymaking is often reactive rather than the product of a structured, well-planned process. The medium-term policy planning process may result in government spending changing meaningfully and frequently throughout the budgeting horizon (including mid-year). Governments regularly adjust budget imbalances through sudden, unplanned cuts in capital spending. There is a high degree of transparency in the government accounts, but information on guarantees and other contingent liabilities may not be available or fully transparent. Debt is well-structured but issuance is opportunistic, with robust capacity and resources to mitigate risks proactively and manage risks arising from shocks.	Fiscal policymaking is often reactive rather than the product of a structured, well-planned process. The medium-term policy planning process may result in government spending changing meaningfully and frequently throughout the budgeting horizon (including mid-year). Governments regularly adjust budget imbalances through sudden, unplanned cuts in capital spending. There are material gaps in the transparency of government accounts, and information on guarantees and other contingent liabilities is generally not available. Debt structure carries significant unhedged risk. There is not a structured issuance plan in place, relying more heavily on opportunistic market access.	Fiscal policymaking is entirely reactive. There is no medium-term policy planning process, and government spending throughout the budgeting horizon (including mid-year) is subject to meaningful changes. Governments typically adjust budget balances through sudden, unplanned cuts in capital spending. There are material gaps in the transparency of government accounts, and information on guarantees and other contingent liabilities is generally not available. Debt structure carries significant unhedged risk. There is not a structured issuance plan in place, relying more heavily on opportunistic market access.	Fiscal policymaking is entirely reactive. There is no medium-term policy planning process, and government spending throughout the budgeting horizon (including mid-year) is subject to meaningful changes. Governments typically adjust budget balances through sudden, unplanned cuts in capital spending. Government accounts are opaque. Debt management is insufficiently effective to avoid very significant foreign exchange or interest rate risk and intermittent liquidity crises.	Fiscal policymaking is entirely reactive, and the government's ability to manage its finances is highly limited. Government spending decisions are ad hoc. Government accounts are opaque. Debt management is insufficiently effective to avoid significant foreign exchange or interest rate risk and intermittent liquidity crises.

Factor: Institutions and Governance Strength										
Sub-factor	Sub-sub-factor	Sub-sub-factor Weight	aaa	aa	a	baa	ba	b	caa	ca
Policy Effectiveness	Monetary and Macroeconomic Policy Effectiveness	30%	The authorities maintain price stability, avoid the buildup of macroeconomic imbalances, and are highly proactive in pursuing competitiveness-enhancing structural reforms. The central bank has a clear goal, the tools to implement the goal, and is credible in delivering against that goal. The central bank is independent. The authorities effectively use macroprudential tools to mitigate systemic capital, liquidity and credit risk without creating unintended distortions or imbalances in the financial system.	The authorities are generally proactive and forward-thinking in delivering price stability and in addressing macroeconomic imbalances, including pursuing structural reforms where needed. The central bank has a clear goal, the tools to implement the goal, and is credible in delivering against that goal. The central bank is independent. The authorities effectively use macroprudential tools to mitigate systemic capital, liquidity and credit risk without creating unintended distortions or imbalances in the financial system.	The authorities are generally proactive and forward-thinking in delivering price stability and in addressing macroeconomic imbalances, including pursuing structural reforms where needed. The central bank has a clear goal, the tools to implement the goal, and is largely credible in delivering against that goal, but structural features such as the depth and breadth of the financial sector or the economy's reliance on imported goods impair policy effectiveness. The authorities use macroprudential tools to mitigate systemic capital, liquidity and credit risk, but sometimes fail to avoid the buildup of imbalances in the financial system.	The authorities address challenges to price stability, macroeconomic imbalances and structural challenges in a reactive manner that is driven by short-term concerns. The central bank has a clear goal, the tools to implement the goal, and is largely credible in delivering against that goal, but structural features such as the depth and breadth of the financial sector or the economy's reliance on imported goods impair policy effectiveness. The authorities use macroprudential tools to mitigate systemic capital, liquidity and credit risk, but sometimes fail to avoid the buildup of imbalances in the financial system.	The authorities address challenges to price stability, macroeconomic imbalances and structural challenges in a reactive manner that is driven by short-term concerns. The central bank may not have a clear policy goal, and it lacks either the tools to implement monetary policy or is inconsistent in delivering the desired monetary policy outcomes. The government tends to interfere with the conduct of monetary policy. The authorities use macroprudential tools to mitigate systemic capital, liquidity and credit risk but struggle to avoid the buildup of imbalances in the financial system.	The authorities only address challenges to price stability, macroeconomic imbalances and structural challenges under duress, either from market forces or international bodies. The central bank may not have a clear policy goal, and it lacks either the tools to implement monetary policy or is inconsistent in delivering the desired monetary policy outcomes. The government tends to interfere with the conduct of monetary policy. The authorities use macroprudential tools to mitigate systemic capital, liquidity and credit risk but struggle to avoid the buildup of imbalances in the financial system.	The authorities only address challenges to price stability, macroeconomic imbalances and structural challenges under duress, either from market forces or international bodies. Central bank policymaking is ineffective, and the transmission of monetary policy to the economy is very weak. The authorities do not use macroprudential tools to mitigate systemic capital, liquidity and credit risk.	The authorities do not address challenges to price stability and macroeconomic imbalances or are ineffective in doing so. Central bank policymaking is ineffective, and the transmission of monetary policy to the economy is very weak. The authorities do not use macroprudential tools to mitigate systemic capital, liquidity and credit risk.

Factor: Institutions and Governance Strength										
Sub-factor	Sub-sub-factor	Sub-sub-factor Weight	aaa	aa	a	baa	ba	b	caa	ca
Policy Effectiveness	Monetary and Macroeconomic Policy Effectiveness	30%	The banking system is regulated in a way that effectively balances the need for the sector to support economic growth against the need to avoid excessive risk-taking. Regulatory competence is in line with the complexity of the financial system. There have been no systemic banking crises in the past decade.	The banking system is regulated in a way that effectively balances the need for the sector to support economic growth against the need to avoid excessive risk-taking. Regulatory competence is in line with the complexity of the financial system. There have been no systemic banking crises in the past decade.	The banking system is regulated in a way that effectively balances the need for the sector to support economic growth against the need to avoid excessive risk-taking. However, the regulator may suffer from skills shortages, lack of effective tools or may struggle to keep pace with the complexity of the financial system. There may have been a systemic banking crisis in the past decade.	The banking system is regulated in a way that effectively balances the need for the sector to support economic growth against the need to avoid excessive risk-taking. However, the regulator may suffer from skills shortages, lack of effective tools or may struggle to keep pace with the complexity of the financial system. There may have been a systemic banking crisis in the past decade.	The banking system is regulated in a way that either fails to support economic growth or allows excessive risk-taking to build up in the system. There may have been a systemic banking crisis in the past decade, and there is a moderate probability of a future crisis developing.	The banking system is regulated in a way that either fails to support economic growth or allows excessive risk-taking to build up in the system. There may have been a systemic banking crisis in the past decade, and there is a moderate probability of a future crisis developing.	Banking system regulation is weak, and these shortcomings keep the probability of a crisis developing in the sector at relatively high levels.	Banking system regulation is weak and these shortcomings keep the probability of a crisis developing in the sector at relatively high levels.

Adjustments to Factor Score
Government Default History and Track Record of Arrears
0 to 3 notches
Other
0 to 3 notches

Factor: Fiscal Strength																						
Sub-factor	Metric	Metric Weight[*9]	aaa	aa1	aa2	aa3	a1	a2	a3	baa1	baa2	baa3	ba1	ba2	ba3	b1	b2	b3	caa1	caa2	caa3	ca
Debt Burden	General Government Debt / GDP (%) [*5]	25%	≤ 5	5 - 20	20 - 30	30 - 35	35 - 40	40 - 45	45 - 50	50 - 55	55 - 60	60 - 65	65 - 70	70 - 75	75 - 80	80 - 90	90 - 100	100 - 120	120 - 130	130 - 140	140 - 150	> 150
	General Government Debt / Revenue (%)[*6]	25%	≤ 10	10 - 80	80 - 120	120 - 140	140 - 160	160 - 180	180 - 200	200 - 220	220 - 230	230 - 240	240 - 260	260 - 280	280 - 320	320 - 360	360 - 400	400 - 450	450 - 500	500 - 550	550 - 600	> 600
Debt Affordability	General Government Interest Payments / Revenue (%)[*7]	25%	≤ 1.5	1.5 - 3.5	3.5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 11.5	11.5 - 12	12 - 13	13 - 14	14 - 16	16 - 18	18 - 20	20 - 22.5	22.5 - 25	25 - 27.5	27.5 - 30	> 30
	General Government Interest Payments / GDP (%)[*8]	25%	≤ 0.25	0.25 - 1.0	1.0 - 1.5	1.5 - 1.75	1.75 - 2.0	2.0 - 2.25	2.25 - 2.5	2.5 - 2.75	2.75 - 3.0	3.0 - 3.15	3.15 - 3.25	3.25 - 3.5	3.5 - 4.0	4.0 - 4.5	4.5 - 5.0	5.0 - 6.0	6.0 - 6.5	6.5- 7.0	7.0 - 7.5	> 7.5

Adjustments to Factor Score
Debt Trend: Historical Change in the Debt Burden (t-8 to t)
Debt Trend: Expected Change in the Debt Burden (t to t+2)
General Government Foreign Currency Debt / GDP
Other Non-Financial Public Sector Debt / GDP
Government Financial Assets including Sovereign Wealth Funds / GDP
0 to 6 notches
Other
0 to 3 notches

Factor: Susceptibility to Event Risk									
Sub-factor	Sub-sub-factor	aaa	aa	a	baa	ba	b	caa	ca
Political Risk	Domestic Political and Geopolitical Risk	WGI for voice and accountability is typically above 1.5. WGI for Political Stability is typically above 1.5. Unemployment is typically low, and distribution of wealth and incomes is relatively uniform with little or no adverse impact on policy outcomes. There are no significant sources of social conflict that pose a material risk to political or economic outcomes. General consensus on credit-positive policy outcomes that endures through changes in government.	WGI for voice and accountability is typically between 1.5 and 1.0. WGI for Political Stability is typically between 1.5 and 1.0. Unemployment is typically low, and distribution of wealth and incomes is relatively uniform with little or no adverse impact on policy outcomes. There are no significant sources of social conflict that pose a material risk to political or economic outcomes. General consensus on credit-positive policy outcomes that endures through changes in government.	WGI for voice and accountability is typically between 1.0 and 0.5. WGI for Political Stability is typically between 1.0 and 0.5. Unemployment is typically moderate, and wealth and income is relatively uniform across the economy, but differences across regions, socioeconomic or other groups or changes over time may have an adverse impact on policy outcomes. There are some areas of religious, ethnic or social conflict that could materially influence political or economic outcomes. Changes in government may pose challenges to the continuity of credit-positive policy outcomes, or the ability to address credit weaknesses.	WGI for voice and accountability is typically between 0.5 and 0.0. WGI for Political Stability is typically between 0.5 and 0.0. Unemployment is typically moderate, and wealth and income is relatively uniform across the economy, but differences across regions, socioeconomic or other groups or changes over time may have an adverse impact on policy outcomes. There are some areas of religious, ethnic or social conflict that could materially influence political or economic outcomes. Changes in government may pose challenges to the continuity of credit-positive policy outcomes, or the ability to address credit weaknesses.	WGI for voice and accountability is typically between 0.0 and -0.5. WGI for Political Stability is typically between 0.0 and -0.5. Unemployment is typically high, and wealth and income is relatively unequal, and there may be deep religious, ethnic or social divisions in society. These tensions introduce a low but not insignificant probability of social tensions that could include violence and that could have a severe impact on policy outcomes. Changes in government routinely reduce policy predictability and raise the probability of credit-negative policies that could impact economic or fiscal outcomes.	WGI for voice and accountability is typically between -0.5 and -1.0. WGI for Political Stability is typically between -0.5 and -1.0. Unemployment is typically high, and wealth and income is relatively unequal, and there may be deep religious, ethnic or social divisions in society. These tensions introduce a low but not insignificant probability of social tensions that could include violence and that could have a severe impact on policy outcomes. Changes in government routinely reduce policy predictability and raise the probability of credit-negative policies that could impact economic or fiscal outcomes.	WGI for voice and accountability is typically between -1.0 and -1.5. WGI for Political Stability is typically between -1.0 and -1.5. There is mass unemployment, large disparities of wealth and income, communal tensions in some cases involving internal armed conflict, which severely disrupt or impair economic activity, policymaking and the orderly operation of government institutions. Changes in government or severely impaired administrative functions hamper policymaking with negative effects on economic and fiscal outcome.	WGI for voice and accountability is typically below -1.5. WGI for Political Stability is typically below -1.5. There is mass unemployment, large disparities of wealth and income, communal tensions in some cases involving internal armed conflict, which severely disrupt or impair economic activity, policymaking and the orderly operation of government institutions. Changes in government or severely impaired administrative functions hamper policymaking with negative effects on economic and fiscal outcome.

Factor: Susceptibility to Event Risk									
Sub-factor	Sub-sub-factor	aaa	aa	a	baa	ba	b	caa	ca
Political Risk	Domestic Political and Geopolitical Risk	Political transitions are routinely smooth, with negligible implications for the sovereign's credit profile. Generally harmonious geopolitical relationships and little interference from external actors. The country is not engaged in any armed or latent conflict that affects economic activity, fiscal outcomes or policymaking.	Political transitions are routinely smooth, with negligible implications for the sovereign's credit profile. Generally harmonious geopolitical relationships and little interference from external actors. The country is not engaged in any armed or latent conflict that affects economic activity, fiscal outcomes or policymaking.	Political transitions are generally orderly and rarely significantly impact the administrative functions of the bureaucracy. Sometimes tense geopolitical relationships that could have some limited impact on the sovereign's credit profile. Interference from external actors does not have a material credit impact. Although the country is not engaged in armed conflict, it may be exposed to the impact of armed conflict elsewhere or to a latent conflict, with a manageable impact on economic activity, fiscal outcomes or policymaking.	Political transitions are generally orderly and rarely significantly impact the administrative functions of the bureaucracy. Sometimes tense geopolitical relationships that could have some limited impact on the sovereign's credit profile. Interference from external actors does not have a material credit impact. Although the country is not engaged in armed conflict, it may be exposed to the impact of armed conflict elsewhere or to a latent conflict, with a manageable impact on economic activity, fiscal outcomes or policymaking.	There is a meaningful potential for succession or key-person risks, where government instability negatively impacts the administrative functions of the bureaucracy. The escalation of geopolitical tensions, possibly leading up to an armed conflict, has the potential to negatively impact economic activity, fiscal outcomes and funding conditions.	There is a meaningful potential for succession or key-person risks, where government instability negatively impacts the administrative functions of the bureaucracy. The escalation of geopolitical tensions, possibly leading up to an armed conflict, has the potential to negatively impact economic activity, fiscal outcomes and funding conditions.	The means for an orderly transfer of power is opaque or impaired, and there is significant risk that any succession will be disorderly and will damage the sovereign's credit profile. Highly contentious geopolitical relationships, which could include engagement in armed conflict, severely impair or disrupt economic activity, the ability to obtain financing or the orderly operation of institutions.	The means for an orderly transfer of power is opaque or impaired, and there is significant risk that any succession will be disorderly and will damage the sovereign's credit profile. Highly contentious geopolitical relationships, which could include engagement in armed conflict, severely impair or disrupt economic activity, the ability to obtain financing, or the orderly operation of institutions.

Factor: Susceptibility to Event Risk

Sub-factor	Sub-sub-factor	aaa	aa	a	baa	ba	b	caa	ca
Government Liquidity Risk	Ease of Access to Funding	The government has a strong track record of reliable access to extremely deep domestic capital markets with a broad and diverse base of investors, including a wide range of types of institutional investors. The government has unquestioned access to an extremely broad range of non-resident investors in local-currency debt, generally reflecting the reserve currency status of its currency. The government has a strong track record of reliable access to foreign currency financing from a broad and diverse range of investors.	The government has a strong track record of reliable access to extremely deep domestic capital markets with a broad and diverse base of investors, including a wide range of types of institutional investors. The government has a strong track record of reliable access to a broad range of non-resident investors in local-currency debt. Non-resident participation in domestic capital and credit markets is extremely stable. The government has a strong track record of reliable access to foreign currency financing from a broad and diverse range of investors.	Experience suggests that the government has generally reliable access to deep domestic capital markets with a reasonably broad and diverse base of investors, including a range of institutional investors. The government has a strong track record of reliable access to a broad range of non-resident investors in local-currency debt. Non-resident participation in domestic capital and credit markets is extremely stable. The government has generally reliable access to foreign currency financing from a reasonably broad and diverse range of investors.	Experience suggests that the government has generally reliable access to deep domestic capital markets with a reasonably broad and diverse base of investors, including a range of institutional investors. Experience suggests that the government has generally reliable access to non-resident investors in local-currency debt. Non-resident participation in the domestic capital and credit markets can be volatile but is expected to remain quite stable over time. The government has generally reliable access to foreign currency financing from a reasonably broad and diverse range of investors.	The government has intermittent access to domestic capital markets which are relatively narrow and underdeveloped. Experience suggests that the government has generally reliable access to non-resident investors in local-currency debt. Non-resident participation in the domestic capital and credit markets can be volatile but is expected to remain quite stable over time. The government has intermittent access to foreign currency financing through a relatively narrow range of investors and a variety of official lenders.	The government has intermittent access to domestic capital markets which are relatively narrow and underdeveloped. The government has intermittent access to non-resident investors in local-currency debt. Non-resident participation in the domestic capital and credit markets is limited and can be volatile. The government has intermittent access to foreign currency financing through a relatively narrow range of investors and a variety of official lenders.	The government has very limited access to domestic capital markets which are narrow and underdeveloped. The government has intermittent access to non-resident investors in local-currency debt. Non-resident participation in the domestic capital and credit markets is limited and can be volatile. The government has no or virtually no access to market-based foreign currency financing, and relatively limited access to official lenders.	The government has very limited access to domestic capital markets which are narrow and underdeveloped. The government has no or very limited access to non-resident investors in local-currency debt. Non-resident participation in the domestic capital and credit markets is shallow, volatile and unreliable. The government has no or virtually no access to market-based foreign currency financing and relatively limited access to official lenders.

Adjustment to Government Liquidity Risk Sub-factor Score
High Refinancing Risk
0 to 2 scoring categories

Factor: Susceptibility to Event Risk									
Sub-factor	Sub-sub-factor	aaa	aa	a	baa	ba	b	caa	ca
Banking Sector Risk	Risk of Banking Sector Credit Event (BSCE)	See the "Discussion of the scorecard factors" section							
	Total Domestic Bank Assets / GDP	See the "Discussion of the scorecard factors" section							
Adjustment to Banking Sector Risk Sub-factor Score									
0 to 2 scoring categories									

Factor: Susceptibility to Event Risk

Sub-factor	Sub-sub-factor	aaa	aa	a	baa	ba	b	caa	ca
External Vulnerability Risk	External Vulnerability Risk	The country benefits from a structural external surplus, as demonstrated by consistent current account surpluses resulting from a well-diversified export base. The country has a low level of net external liabilities. Alternatively, very high economic resilience and general attractiveness to investors enable it to support a high external debt load, even during times of economic and financial shock. The country has unfettered access to international capital markets, for example through a reserve currency status.	The country benefits from a structural external surplus, as demonstrated by consistent current account surpluses resulting from a well-diversified export base. The country has a low level of net external liabilities. Alternatively, very high economic resilience and general attractiveness to investors enable it to support a high external debt load, even during times of economic and financial shock. The country is expected to have no difficulty in using immediately available foreign currency reserves to service external debt. Alternatively, the country has deep and stable access to foreign exchange markets or a strong external guarantor, limiting the need for large foreign currency buffers.	Current account deficits are expected to be small (typically less than 5% of GDP over three years) and are, for the most part, consistently financed by FDI inflows. The country has high or moderate economic resilience or a moderate level of economy-wide external liabilities (above 100% of current account receipts). The country is expected to have no difficulty in using immediately available foreign currency reserves to service external debt. Alternatively, the country has deep and stable access to foreign exchange markets or a credible external guarantor, limiting the need for large foreign currency buffers.	Current account deficits are expected to be small (typically less than 5% of GDP over three years) and are, for the most part, consistently financed by FDI inflows. The country has high or moderate economic resilience or a moderate level of economy-wide external liabilities (typically above 100% of current account receipts). The country displays relatively limited vulnerability in its capacity to service external debt. Foreign exchange reserves are expected to remain sufficient to prevent external liquidity pressures (typically EVI of around 100%).	Current account deficits are expected to be large and persistent (typically more than 5% of GDP over three years). Financing is partly dependent on portfolio and debt capital inflows that expose the economy to shifts in market sentiment. The country is a net debtor. It has a low economic resilience and high level of economy-wide external liabilities (typically above 200% of current account receipts) which makes it vulnerable to external shocks. The country displays relatively limited vulnerability in its capacity to service external debt. Foreign exchange reserves are expected to remain sufficient to prevent external liquidity pressures (typically EVI of around 100%).	Current account deficits are expected to be large and persistent (typically more than 5% of GDP over three years). Financing is partly dependent on portfolio and debt capital inflows that expose the economy to shifts in market sentiment. The country is a net debtor. It has a low economic resilience and high level of economy-wide external liabilities (typically above 200% of current account receipts) which makes it vulnerable to external shocks. The country displays increasing vulnerability in its capacity to service external debt. Foreign exchange reserves have fallen to low levels and external liquidity is increasingly constrained (typically EVI of around 200%).	Current account deficits are expected to be very large and persistent, indicative of a structural imbalance. Financing is highly dependent on portfolio and debt capital inflows that expose the economy to shifts in market sentiment. The export base is narrow or concentrated on commodities. The country is a net debtor. It shows very weak economic resilience and a very high level of economy-wide external liabilities (typically above 400% of current account receipts), or a large share composed of short-term debt resulting in very high external refinancing needs. The country displays increasing vulnerability in its capacity to service external debt. Foreign exchange reserves have fallen to low levels and external liquidity is increasingly constrained (typically EVI of around 200%).	Current account deficits are expected to be very large and persistent, indicative of a structural imbalance. Financing is highly dependent on portfolio and debt capital inflows that expose the economy to shifts in market sentiment. The export base is narrow or concentrated on commodities. The country is a net debtor. It shows very weak economic resilience and a very high level of economy-wide external liabilities (typically above 400% of current account receipts), or a large share composed of short-term debt resulting in very high external refinancing needs. The country displays significant vulnerability in its capacity to service external debt. Foreign exchange reserves have fallen to very low levels and external liquidity is materially constrained (typically EVI above 200%).

Adjustment to External Vulnerability Risk Sub-factor Score
0 to 2 scoring categories
Adjustment to Factor Score
0 to 2 scoring categories

[1] For the linear scoring scale, the aaa endpoint value is 15%. A value of 15% or better equates to a numeric score of 0.5. The ca endpoint value is 0%. A value of 0% or worse equates to a numeric score of 20.5.
[2] For the linear scoring scale, the aaa endpoint value is 0%. A value of 0% equates to a numeric score of 0.5. The ca endpoint value is 10%. A value of 10% or worse equates to a numeric score of 20.5.
[3] For the linear scoring scale, the aaa endpoint value is $25,000 billion. A value of $25,000 billion or better equates to a numeric score of 0.5. The ca endpoint value is $1 billion. A value of $1 billion or worse equates to a numeric score of 20.5.
[4] For the linear scoring scale, the aaa endpoint value is $100,000. A value of $100,000 or better equates to a numeric score of 0.5. The ca endpoint value is $1,000. A value of $1,000 or worse equates to a numeric score of 20.5.
[5] For the linear scoring scale, the aaa endpoint value is 0%. A value of 0% equates to a numeric score of 0.5. The ca endpoint value is 700%. A value of 700% or worse equates to a numeric score of 20.5.
[6] For the linear scoring scale, the aaa endpoint value is 0%. A value of 0% equates to a numeric score of 0.5. The ca endpoint value is 700%. A value of 700% or worse equates to a numeric score of 20.5.
[7] For the linear scoring scale, the aaa endpoint value is 0%. A value of 0% equates to a numeric score of 0.5. The ca endpoint value is 35%. A value of 35% or worse equates to a numeric score of 20.5.
[8] For the linear scoring scale, the aaa endpoint value is 0%. A value of 0% equates to a numeric score of 0.5. The ca endpoint value is 35%. A value of 35% or worse equates to a numeric score of 20.5.
[9] For more details about how these weights may vary, please refer to our discussion on the Treatment of Reserve Currency Countries and HIPC/IDA Countries within the Fiscal Strength section of the methodology.
Source: Moody's Investors Service

Discussion of the scorecard factors

In this section, we explain our general approach for scoring each scorecard factor or sub-factor,[4] and we describe why the sub-factors we use are meaningful credit indicators.

The sections below describe how we calculate or estimate quantitative sub-sub-factors. For sub-sub-factors that are scored qualitatively, we generally do not expect each of the attributes listed for a given scoring category to exactly match those of a given sovereign. We typically assign each sub-sub-factor score based on the alpha category for which the sovereign has the greatest number of characteristics. However, there may be cases in which one characteristic is sufficiently important to a particular sovereign's credit profile that it has a large influence on the sub-sub-factor score.

Factor: Economic Strength

Why it matters

A sovereign's economic strength provides critical indications of its resilience to shocks and long-term structural shifts, which could include those related to climate and demographic change. A sovereign's ability to generate sufficient revenue to service debt over the medium term relies on sustained economic growth and prosperity.

Economic weakness, either sudden and severe or milder but long-lasting, has been a decisive factor in past sovereign defaults. An erosion of external competitiveness, caused either by a major terms-of-trade shock or by a gradual erosion that leads to a loss of export revenue, is also an indicator of default risk. Past sovereign defaults have typically occurred in the context of severe and sustained economic stress, underscoring the importance of a sovereign's economic strength in reducing the likelihood of default in the event of adverse shocks or severe or prolonged economic downturns. Large, diversified and flexible economies are much more resilient to economic shocks or downturns than smaller, concentrated and inflexible economies.

The factor comprises three sub-factors:

Growth Dynamics

Low or volatile levels of economic growth can, if sustained over a number of years, amplify debt serviceability challenges and can render a heavy debt burden unsustainable. A low level of growth over a long period typically indicates challenges in addressing structural constraints to growth. In turn, prolonged low growth may reduce the latitude for economic and fiscal reforms, which often involve short-term economic costs for longer-term economic and fiscal gains. In addition, high growth volatility, if sustained over several years, undermines wealth creation and competitiveness, reducing an economy's ability to withstand shocks and the government's capacity to pursue stable, predictable policies. Meanwhile, sovereigns experiencing robust, sustained growth are typically better able to implement socially challenging, credit-positive reforms, maintain strong budgetary performance and manage relatively large debt burdens or reverse increases in debt ratios caused by domestic or external shocks.

Environmental conditions, demographic change and a country's governance are key determinants of an economy's growth dynamics. For instance, environmental shocks, such as frequent natural disasters, can lead to heightened volatility in growth, which in turn may hinder investment and growth potential. Changes in the population structure, such as aging, can also lead to lower growth as the labor force shrinks. Strong governance can support long-term growth by fostering a more stable and predictable economic environment.

Scale of the Economy

Scale is an important indicator of an economy's diversity and complexity, which greatly influences its ability to withstand shocks and hence a sovereign's capacity to generate stable revenue streams to service its debt. For example, a very small country with a competitive economy but concentrated exposure to a few sectors can be subject to abrupt economic shifts, which can undermine a sovereign's ability to raise revenue from within the economy. As another example, governments with larger, stronger and more diverse economies typically have a higher level of economic and fiscal flexibility to mitigate a wide range of risks, including environmental threats or cyber and geopolitical risks.

National Income

National Income provides important indications of an economy's output in relation to the size of the population and is a further proxy for the revenue-generating potential of a sovereign. We use per capita income in purchasing power parity (PPP) terms as a measure of national income because it provides comparability of the level of buying power associated with that per capita income across different countries and currencies. High national income is generally closely correlated with a low risk of default, because higher national income is associated with a greater capacity on the part of the population to absorb economic or fiscal shocks. Conversely, low income levels and pervasive poverty, a source of social risks, undermine a population's ability to face shocks. National Income can also be a proxy for other characteristics that inform a sovereign's economic strength, including the underlying degree of competitiveness within an economy such as the availability and quality of labor and capital.

How we assess it for the scorecard – Growth Dynamics sub-factor

AVERAGE REAL GROSS DOMESTIC PRODUCT GROWTH:

We calculate or estimate the average of real gross domestic product (GDP) growth levels based on a 10-year average, including the average of the five most recently reported annual periods and our estimate of growth for the following five years. Where environmental or social risks point to significant change in growth trends over the long term, we reflect this in our qualitative assessment of economic strength (see "Other" in the "Adjustments to the Economic Strength factor score" section). For instance, we typically incorporate information derived from climate models to assess the share of a sovereign's economy, population and agricultural production that is exposed to extreme weather events. The most exposed sovereigns may experience structurally lower growth in the long term as a result of climate change. We would also typically consider how changes in governance and institutions may affect economic performance over time.

MAD VOLATILITY IN REAL GDP GROWTH:

We calculate or estimate the volatility in real GDP growth based on the median absolute deviation (MAD) of real GDP growth over the 10 most recently reported years. The MAD provides a measure of variability of growth around the median over the time period considered.

To arrive at the MAD, we first calculate the median GDP growth rate for the most recent 10 years. Then, we calculate the absolute values of the differences between the GDP growth rate for each year and that median. The median of the absolute value of those differences is the value for the MAD.

How we assess it for the scorecard — Scale of the Economy sub-factor

NOMINAL GDP:

We use the most recently reported annual nominal GDP, denominated in billions of US dollars at market exchange rates.

How we assess it for the scorecard — National Income sub-factor

GROSS DOMESTIC PRODUCT PER CAPITA:

We use the most recently estimated GDP per capita in purchasing power parity (PPP) terms, in international dollars.[5] For countries where we do not have estimates of relative price levels, we use GDP per capita, unadjusted for price level, as a proxy.

This measure of average income levels informs our assessment of social risks to economic strength, and we use that assessment in our forward-looking view of economic strength, which may lead to adjustments to the factor score, as described below.

Adjustments to the Economic Strength factor score

We may apply a notching adjustment[6] to the Economic Strength factor score where we conclude that the core scorecard metrics do not adequately reflect relative strengths or weaknesses.

Adjustments to the Economic Strength factor score most often reflect our judgment regarding the economy's (i) adaptability; (ii) diversity; (iii) productivity; and (iv) labor supply challenges, which we consider to be key factors influencing the level and volatility of medium-term growth. They may also reflect other considerations relevant in our assessment of the Economic Strength factor score, including environmental and social considerations. Adjustments can be upward or downward and are limited to nine notches in aggregate. While there may be several considerations, there is one overall notching adjustment.

Adjustments are generally more likely for either extremely large or small, extremely wealthy or poor countries. For example, we may adjust the Economic Strength factor score upward where we consider an economy to be unusually diverse for its scale, and where economic size therefore understates the economy's resilience.

In assessing whether to apply notching adjustments related to flexibility, diversity, productivity, labor supply challenges or other economic or ESG considerations, we use a set of globally relevant indicators to inform our analysis, examples of which are provided below. However, indicators that are relevant and globally available may vary over time. Peer comparisons also inform our assessment. For example, we may differentiate between two sovereigns whose core metrics signal similar economic strength but where other indicators and analytical judgment indicate material differences in economic fundamentals.

ADAPTABILITY:

Countries that have efficient markets for labor, goods and services and deep financial markets are generally more adaptable to changing market conditions and shocks, which in turn support sustained growth and ultimately boost long-term economic prosperity.

For example, labor markets that facilitate a broad equilibrium between demand and supply are better able to withstand downturns by redeploying labor toward the most efficient sectors or helping employees retrain to adjust their skills to changes within their sector. Legislation or regulatory changes that aim to facilitate an adequate match between demand and supply of labor, without exacerbating wealth and income inequality, may weigh positively in our assessment.

Flexibility in a country's production structure and resource allocation, reflected in conditions that support a competitive product market, helps ensure that goods and services are traded efficiently and also drives an economy's capacity to adapt to changes. Well-developed and deep financial markets can support the reallocation of resources between sectors, and thereby support an economy's flexibility.

In assessing flexibility, we typically consider indicators such as the World Economic Forum (WEF)'s Global Competitiveness Index (GCI), including components that measure labor and goods market efficiency, and the WEF Financial Market Development Index.

DIVERSITY:

We may apply upward notching to the Economic Strength factor score where we consider an economy to be unusually diverse for its scale, and where economic size therefore understates the economy's resilience.

Conversely, high economic dependence on a single or a few products or services as a percentage of GDP may result in a downward notching adjustment. For example, a country that shows a particularly large concentration of exports of a few products is vulnerable to a shock hitting demand for these products. This can be the case for countries whose growth or revenue is highly dependent on the production and export of a commodity (or a group of highly correlated commodities). Sudden shocks or long-term changes in the demand and prices of particular commodities, such as hydrocarbons, affect sovereigns that rely on them as a source of economic activity. The risk associated with an economy that has a large concentration in commodities diminishes when a country produces a diverse set of commodities whose price movements and international demand trends exhibit weak correlation with one another.

We generally consider a sovereign to be highly dependent on commodities where they account for more than half of all exports, and exports account for more than a quarter of GDP. We typically do not apply a downward notching adjustment on the basis of high concentration where the Economic Strength factor score before adjustments is already very low, because we generally expect concentration to be reflected in the core indicators.

In assessing diversity, we typically consider broad measures of export structure diversification, such as the United Nations Conference on Trade and Development (UNCTAD) Export Product Concentration Index, and indicators of the value-added nature or price sensitivity of the country's exports, such as the World Development Indicator (WDI) for goods exports to high-income countries and the Economic Complexity Index produced by the Observatory of Economic Complexity.

In limited cases, we may apply an upward notching adjustment, or offset the downward adjustment for concentration, where a sovereign benefits from exceptionally large, untapped natural resources that can be accessed readily and cheaply. Such resources typically allow a sovereign to adjust output to mitigate a price shock, and help to sustain economic growth over the long term. We typically limit this upward notching to two notches. However, we may fully offset the downward notching adjustment otherwise suggested by excessive economic concentration in commodities in rare cases where proven oil or gas reserves are projected to last more than 50 years or, on a sustained, forward-looking basis, proven reserves of other commodities are in approximately the top 15th percentile among global producers and the cost of production is in or very near the lowest decile among global producers.

For services, we typically assess the contribution to GDP of major service categories produced in an economy as well as their relationships with other sectors of the economy. For example, a country whose economy is heavily dependent on a service sector (e.g., tourism or financial services) would typically score lower for this factor. Conversely, countries that produce diverse types of services typically show greater resilience to adverse shocks and would typically score higher.

PRODUCTIVITY:

An economy's productivity is a key source of its competitiveness and helps drive wealth creation. Productivity reflects how efficiently the inputs into production, such as labor and capital, are used to produce a given level of output. Countries that have low or declining productivity levels generate less wealth and typically face diminishing long-term growth prospects. Where we consider the underlying productivity potential is understated or overstated by the scorecard metrics, we may apply an upward or downward notching adjustment to the Economic Strength factor score.

Sustained productivity growth has many drivers, including innovation, adequate infrastructure, and a mix of favorable economic and social policies and trends. The capacity to adopt new technologies supports productivity by increasing the country's level of output for a given labor force. Poor infrastructure can hinder the effective functioning of the economy by impeding the provision of goods and services, the free flow of information through communication networks and the reliability of electricity and energy supplies. Economic or social policies, such as investment in workforce skills and education, can sustain or improve a country's productivity.

In assessing productivity, we typically consider the WEF Infrastructure, Innovation and Higher Education and Training Indexes. We also typically consider estimates of longer-term changes in productivity based on a country's average growth of real GDP per capita over 10 years.

LABOR SUPPLY CHALLENGES:

In many countries, changing demographics and labor supply developments can weigh on the size and composition of a country's workforce. For example, slowing labor force growth, a decline in working-age populations or pervasive social unrest raise labor input challenges that can weigh on long-term growth. Similarly, an aging workforce may affect labor productivity if it is not supported by technological solutions or skills development. Conversely, positive trends in the labor force, such as through net inward migration or increases in female labor force participation can, over time, support the growth of the workforce and its productivity.

These social considerations, while longer-term in nature, are typically an important part of our assessment of a sovereign's ability to expand its economy sustainably and to foster economic prosperity.

Where labor market challenges are expected to become acute, we may reflect these in a downward notching adjustment to the Economic Strength factor score to recognize that these longer-term considerations may not be adequately reflected in the scorecard metrics.

In assessing labor supply challenges, we may consider estimates of a country's working age population growth over the next decade compared with the previous 10 years. We may also consider indicators for the extent of aging within a population.

OTHER:

In limited cases, we may also apply upward or downward notching adjustments to the Economic Strength factor score based on other considerations. Following are examples of other notching considerations:

- » We may consider applying a downward notching adjustment to the factor score where excessive credit growth suggests that apparently strong core scorecard metrics will not be sustained. We typically consider the absolute levels of credit growth, whether credit growth has deviated materially from estimates of its long-term trend or the extent to which it exceeds nominal GDP growth for a sustained period. We also typically assess the severity of a potential credit boom-bust cycle based on the size of the domestic credit stock relative to GDP, because generally, the larger the size of domestic credit as a proportion of GDP, the greater the potential severity of a credit boom-bust cycle. We also may consider whether there is evidence of excessive asset price growth, which might lead to an unsustainable buildup of credit. Furthermore, we may look beyond aggregate credit growth and consider the sectors that have borrowed heavily to inform our assessment of the extent to which credit growth is excessive. We typically consider whether macroprudential frameworks are in place that may curb excessive credit growth or mitigate the impact.
- » We may apply a notching adjustment to the factor score where an economy is undergoing a structural break, positive or negative, that the scorecard metrics fail to capture. This notching adjustment may be particularly relevant where a sovereign's growth prospects or volatility of growth are likely to change beyond the five-year period captured in the scorecard metrics. For example, a commodity-based economy may undergo deep structural change resulting from a depletion of natural resources, or an increasing risk in the future of an inability to exploit a resource to the same extent as in the past. As a counter-example, policies aimed at supporting economic diversification may point to more balanced and sustained growth in the future.
- » Where there are extremes of high national income or poverty, we may consider that core metrics understate or overstate a sovereign's economic strength relative to its peers, and that these social risks indicate a materially higher or lower buffer to absorb internal and external shocks. For example, small jurisdictions that act as offshore centers may report income per capita levels above those which would in reality be available to absorb shocks. In such circumstances, we may apply upward or downward notching to the Economic Strength factor score to the extent this consideration is not already captured in metrics or other adjustments.

Factor: Institutions and Governance Strength

Why it matters

The strength of institutions and governance is an important determinant of a sovereign's creditworthiness because it influences the predictability and stability of the legal and regulatory environment, which is of importance to investors. Institutions and governance provide a strong indication of a government's willingness to repay its debt. They influence the sovereign's capacity and willingness to formulate and implement economic, fiscal and monetary policies that support growth, socioeconomic stability and fiscal sustainability, which in turn protect the interests of creditors over the long term.

We define a country's institutional and governance framework broadly, to include all the actors, i.e., broadly speaking, state and non-state actors, that participate in the formation and enforcement of rules and norms and in the policymaking process. Checks and balances that allow policy and other public actions to be scrutinized and to be informed by feedback are also part of a country's institutional and governance framework.

There has been a clear linkage between institutional weaknesses and sovereign defaults, arising in part from an erosion in governments' willingness to pay, but also because institutional weaknesses amplify other credit weaknesses, such as structural growth challenges, which influence the sovereign's capacity to pay.

This factor comprises two qualitative sub-factors.

Quality of Institutions

Core aspects of the quality of a sovereign's institutions are (i) the quality of its legislative and executive institutions; and (ii) the strength of civil society and the judiciary.

Transparent, predictable and robust legislative and executive institutions are important drivers of the strength of a sovereign's credit profile. Where legislative and enforcement institutions are weak and the development and enforcement of laws, rules and societal norms are unpredictable, opaque and unreliable, the position of investors in sovereign debt is correspondingly more uncertain and credit risk higher. In such environments, administrative and legislative capacity tends to be weaker, with negative long-run implications for growth, debt and investor confidence.

Social risk can undermine the quality of institutions. For instance, actual or perceived income or wealth inequality can undermine trust in legislative, executive and judicial institutions and hamper their effectiveness.

The strength of the judiciary and, more broadly, civil society is also important because these institutions can act as a check on a country's lawmakers or executive. They enforce the rule of law, control corruption and reinforce norms in a way that typically protects the interests of creditors and supports effective policymaking.

When the general enforcement environment is weak, governance mechanisms are typically less effective and adherence to the rule of law and to norms of society is more uncertain, thus undermining the overall strength of the business environment, including the repayment culture that prevails in a given country.

Policy Effectiveness

The willingness and capacity of a country's institutions to design and implement policies that foster economic and fiscal strength are important aspects of a sovereign's credit profile.

Sovereigns that exhibit a lack of policy stability or a weak capacity to legislate policies typically exhibit greater economic inertia and find it more difficult to adapt to changes or shocks. For example, emerging economies that have not sufficiently built up the quality of their legislative and executive institutions may face difficulty in designing and implementing multiyear economic and social plans and, more generally, in unlocking the country's growth potential or building resilience to shocks.

In developed economies, a lack of reforms may diminish the ability to adapt to eroding competitiveness and to other structural challenges. This inaction may result from a lack of consensus, instability around the design of socioeconomic policies or from the complexity and rigidity of the legislative process. Social risks can reduce policy effectiveness. For instance, poor access to high-quality education can prevent workers from securing jobs in the formal economy and prevent the government from collecting tax revenue.

Our assessment of policy effectiveness focuses on two core aspects, namely (i) fiscal policy effectiveness; and (ii) monetary and macroeconomic policy effectiveness.

Effective fiscal policies support debt sustainability over the medium term. Such policies create fiscal capacity during periods of economic expansion that allows a country to weather inevitable cyclical downturns, the crystallization of contingent liabilities or other foreseeable fiscal challenges without permanently impairing the government's credit quality. The capacity to sustain credit-positive fiscal policy over time can also support investor confidence, which improves debt affordability. Investors typically place a great deal of importance on public debt sustainability, because signals that a government does not have the sufficient fiscal firepower to pursue its socioeconomic role or to protect the economy from shocks may erode business confidence and investment. For example, measures taken to address social considerations such as adverse demographics, including reducing pension benefits and extending working lives, or encouraging immigration, can have in some cases political consequences that discourage their implementation and undermine the credibility — and hence the effectiveness — of policies.

Preventing and correcting macroeconomic imbalances through robust monetary and macroeconomic policies is key to supporting sustained economic growth over the longer term. Macroeconomic imbalances may erode competitiveness and impair social cohesion over time. Such imbalances can take many forms, depending on the stage of development of an economy and the fundamental characteristics of a country's economic model. These include elevated inflation, volatile currency and investment inflows, high current account deficits, unsustainable external indebtedness and asset price bubbles.

How we assess it for the scorecard — Quality of Institutions sub-factor

QUALITY OF LEGISLATIVE AND EXECUTIVE INSTITUTIONS:

We assess this sub-factor qualitatively, based on the quality of public actions we observe, both at the legislative and executive levels. However, our qualitative assessment is informed by a range of quantitative indicators. The Worldwide Governance Indicators (WGI) for regulatory quality and government effectiveness are typically primary considerations in our assessment. Beyond those inputs, our assessment incorporates our forward-looking views of certain other considerations, including the efficiency of the government and public administration, institutional capacity constraints (typically more prevalent in very small countries), the reporting of data, the capacity to translate policy into law and whether independent bodies have a voice in policymaking.

Among other aspects, the WGI for government effectiveness captures an element of social risk, including perceptions of the quality of public services. Our view of the effectiveness of government action is also driven by the quality of the public administration, because its role is key in the formulation and implementation of government policy. Understaffing or a poorly skilled public sector workforce typically constrains government effectiveness. Similarly, infrequent and limited data reporting and major revisions may indicate a weaker institutional setting.

Due to their more limited human and financial resources, very small countries are typically constrained in their capacity to plan and execute policy at the legislative and executive levels. As a result, we typically do not assign the highest score for this sub-factor to very small sovereigns.

How we assess it for the scorecard — Quality of Institutions sub-factor

STRENGTH OF CIVIL SOCIETY AND THE JUDICIARY:

We focus on institutional outcomes, not on the form of government, namely, the ability and willingness of sovereigns to observe and enforce laws and norms in a way that supports the government's overall creditworthiness and the interests of creditors.

We assess this sub-factor qualitatively, principally based on the strength of the sovereign's rule of law, including the judiciary system and role of civil society institutions. Again, however, we typically inform our qualitative assessment using quantitative measures, namely the WGI for voice and accountability, rule of law and control of corruption. Beyond those metrics, our assessment incorporates our forward-looking views of certain considerations, including the enforcement of laws, the balance and separation of power between the judiciary and the government, the prevalence of corruption, the effectiveness of judicial and legal processes and civil society's capacity to act as a check on the exercise of government power.

In our overall assessment of this sub-factor, we also consider the consistency and predictability of the enforcement of laws, including as they apply to the government itself and public officials. We generally view effective public enforcement as a pre-condition to enforcement of private mechanisms such as contract rights, which require public laws to function predictably. A track record of delayed, partial or absent enforcement of laws typically signals limited predictability of enforcement in the public and private sectors and may weigh negatively on our assessment of this sub-factor score.

The existence of judicial institutions that have meaningful influence on and independence from the government is also an important determinant of the strength of an enforcement environment. Legal obligations or contractual arrangements between private and public stakeholders are not likely to be easily enforceable in an environment where judicial institutions are subject to a large degree of government interference or where they have by law or due to capacity constraints little control over the government's compliance with the law.

Corruption negatively affects our view of the quality of sovereign institutions and governance. The presence of corruption may reflect the absence of enforceability of the law or incentives to abide by it. It may also influence other credit features, such as the government's ability to collect revenues effectively or, more broadly, growth levels in the economy. We typically assign lower scores to this sub-factor in cases where corruption is widespread or undermines policy formation, the business environment or social cohesion.

Our view of the quality of the judiciary is also influenced by an assessment of its impartiality and effectiveness in enforcing the law and resolving disputes. For example, we consider whether the judicial power operates with laws that facilitate the enforcement of contracts and whether it benefits from sufficient human and financial resources to be effective. A track record of bias in judicial decisions, for example in favor of a specific socioeconomic, ethnic or religious group or a particular sector (e.g., large government-owned corporations) typically does not reflect strong enforcement foundations and practice.

Civil society can play an important role in shaping the enforcement of laws and norms and can act as a check on the exercise of government power. Capacity to voice concerns about the rule of law and exert influence on government policy to promote good governance are viewed positively in our assessment of this sub-factor score.

In assessing the strength of civil society and the judiciary for a sovereign, we may also consider other indicators, such as the World Justice Project's (WJP) index of regulatory enforcement, index of constraints on government power, index of civil justice and index of criminal justice, or similar information from other established international organizations with sufficiently broad coverage.

How we assess it for the scorecard — Policy Effectiveness sub-factor

FISCAL POLICY EFFECTIVENESS:

We assess this sub-factor qualitatively, based on the trajectory of public debt through cycles, fiscal balances and fiscal performance against budgetary plans, medium-term planning, transparency in reporting of government accounts as well as debt management. In our assessment of this sub-factor, we consider fiscal policy effectiveness over a sustained period.

In assessing the trajectory of public debt throughout cycles, we consider historical and anticipated government debt[7] levels as a percentage of GDP through several economic cycles. Stronger fiscal effectiveness is typically associated with stable or decreasing debt levels over time. In times of downturn or crisis, government debt levels may increase, typically because of reduced revenue levels and budget expansion to support recovery. However, the ability of a government to contain increases and rebuild shock absorption capacity thereafter through a reduction in debt loads is a key indication of its fiscal effectiveness. Conversely, sovereigns that exhibit large debt burdens or consistent increases in debt levels over several economic cycles typically score lower for this sub-factor.

The trajectory of budget balances is also an important indicator in our assessment of fiscal policy effectiveness. Governments that have stronger budget planning capacities typically build in flexibility to accommodate larger fiscal deficits than planned during an economic downturn and tighten the fiscal stance during an economic expansion. Examples of flexibility built into a budget include options to levy progressive income taxes that boost government revenue during economic expansions or introduce spending during downturns in a counter-cyclical way. Flexibility in the design of the budget is key to mitigating economic gyrations and one-off events. Sovereigns with weaker fiscal effectiveness typically have more rigid budgets that make it more difficult to adjust to changed economic circumstances. Similarly, challenges in tax collection are typically indicative of developing administrative capacities, or as can be the case for tax evasion, a lack of effective tax enforcement from the fiscal institutions. These characteristics are typically commensurate with a low score for this sub-factor. In assessing a sovereign's trajectory of budget balances, we may also consider structural fiscal balances[8] that are produced by the International Monetary Fund (IMF) or similar information from other established international organizations with sufficiently broad coverage, where available.

The existence of fiscal targets, such as expenditure ceilings, and consistent compliance with those targets over a number of political cycles generally signal stronger fiscal policymaking and implementation. Fiscal targets or expenditure ceilings are useful budgetary tools to foster fiscal discipline and expenditure efficiency. A track record of adherence to the targets or limits is typically viewed positively in our assessment, to the extent that they are designed to maintain a good fiscal performance or to improve the fiscal trajectory. However, the absence of stated fiscal rules does not necessarily signal weaker policy effectiveness. Our main analytical focus is on the track record of fiscal prudence and our expectations regarding budgetary performance and debt management over the medium term.

While flexibility to adjust revenue and expenses to mitigate unplanned circumstances is an important driver of our assessment, medium-term fiscal policy planning is also key. Robust multiyear planning is typically accompanied by better fiscal performance over the long term. In particular, frequent changes in the policy mix as a reaction to unforeseen or unplanned events, such as large and sudden discrete spending items (e.g., capital expenditures), may support the fiscal trajectory in the short run but undermine the effectiveness of the longer-term fiscal policy objectives. The existence of nonpartisan bodies that form part of the budget-making process through a consultative or review role is typically viewed positively in our assessment of the quality of budgetary planning practices.

Transparency and quality of government accounts, for all levels of government, are important determinants of effective budget planning. The availability of comprehensive, accurate and recent data on government accounts supports budgetary authorities and related stakeholders (including external non-partisan bodies) in the design of robust fiscal policies. Sovereigns with higher quality of disclosures typically report monthly budget accounts (on a cash basis) and annual or quarterly accrual budget accounts as well as government balance sheets, including contingent liabilities and other off-balance-sheet items. The perimeter of accounts is also typically clearly defined. Our primarily qualitative assessment is also informed by various indices assessing transparency of fiscal reporting (for example, the Open Budget Index and certain dimensions of the World Bank's Country Policy and Institutional Assessment) as well as the IMF assessment on the adequacy of data for surveillance. While accounting standards can be complex and evolve over time, leading to ex-post revisions of fiscal performance and debt levels, a track record of frequent and large revisions in past budget accounts would typically weigh negatively on our assessment of a sovereign's fiscal policy effectiveness.

Our view of fiscal policy effectiveness also relies on the quality of government debt management. Sovereigns with a higher score for this sub-factor typically have a generally professional and capable public administration. Well-structured debt management policies typically aim at ensuring reliable access to financing, for example through frequent issuances across maturities and by diversification of funding sources, while limiting the service cost and refinancing risk. Mitigation strategies are typically well-articulated. Stronger debt management practices also typically include regular public reporting of key financial information, planning and policies. Indications of weaker debt management practices typically include the absence, or the understaffing, of dedicated professionals; poor or nonexistent formal debt management plan and policies, for example characterized by the absence of a multiyear strategy (which considers, for example, investor type, maturities and currencies); or practices that are informed by insufficient data, for example on future financing needs.

We may also consider any material benefit a country may derive from its participation in an external assistance program, such as from the IMF or the European Stability Mechanism (ESM), or cooperation with other institutions such as the EU or the World Bank, where we see lasting positive credit impact. The measures policymakers may implement under the auspices of these institutions can have a positive impact on all dimensions captured in our Institutions and Governance Strength factor, but the largest impact would typically be within the fiscal policy effectiveness and monetary and macroeconomic policy effectiveness sub-factors. In assessing the institutional benefits governments may derive from these programs, we also consider the capacity of governments to sustain the benefits after their participation in the program.

How we assess it for the scorecard — Policy Effectiveness sub-factor

MONETARY AND MACROECONOMIC POLICY EFFECTIVENESS:

We assess this sub-factor qualitatively, based on the effectiveness of monetary and macroeconomic policies. Considerations include the implied effectiveness of monetary policy in maintaining price stability, including through low, stable and predictable inflation and the level of inflation relative to any targets set for or by policymakers. We also consider a sovereign's rate of inflation relative to that of peers and the capacity of the authorities to adjust inflation targets in response to macroeconomic imbalances. In addition, we assess the role and effectiveness of the central bank, the strength of macroprudential tools and banking system regulation. In our assessment of this sub-factor, we consider monetary and macroeconomic policy effectiveness over a sustained period. The effectiveness of the public policy response to shocks and trends, including adverse economic, social or financial changes, is another important consideration. Sovereigns whose institutions swiftly mitigate the impact of shocks or formulate effective plans to address slowly unfolding trends without threatening macroeconomic stability typically score higher for this sub-factor. Delays in responding to changing circumstances can weigh negatively on our assessment, in particular if these institutions' response or inaction jeopardizes macroeconomic stability.

Sustained economic growth and prosperity are best achieved with price stability. Inflation is also a determinant of an economy's competitiveness. Inflationary episodes are often a precursor to economic, social and political instability given that inflation effectively acts as a tax, particularly on the more vulnerable members of a society. High inflation also typically erodes confidence in the function of a domestic currency as a store of value and can contribute to capital flight and to currency and balance-of-payments crises. The ability of the monetary authorities to contain inflation provides meaningful insight into the broader capacity of a country's institutions to articulate and achieve creditor-friendly policies. We typically assign lower scores for this sub-factor to sovereigns whose economies exhibit high and volatile inflation, reflecting our view that the policy objectives or tools of the monetary authorities are insufficient to deliver price stability and ensure macroeconomic stability.

While the inflation level relative to any targets typically offers a good proxy for the effectiveness of monetary and macroeconomic policies, we also consider more holistically the sovereign's capacity and willingness to address macroeconomic imbalances and structural challenges. Sovereigns whose institutions proactively prevent the buildup of macroeconomic imbalances or address them swiftly through structural reforms typically receive higher scores for this sub-factor. Where sovereigns address imbalances as a result of external incentives — for example, because it is a prerequisite to regain investor confidence or to secure financing from a supranational, or because the sovereign would otherwise be subject to any form of penalty — scores for this sub-factor are typically lower. Sovereigns whose policies do not address macroeconomic imbalances or are ineffective in doing so typically have scores in the lowest categories.

The role of identifying and addressing macroeconomic and structural imbalances can belong to different authorities in a given country depending on the institutional framework. Our assessment of the capacity to prevent and address those imbalances typically considers the tools relevant authorities have at hand to perform a comprehensive and effective diagnostic assessment and implement effectual corrective actions.

The central bank generally plays an essential role in ensuring monetary and macroeconomic stability. The role and mandate of a central bank can be different across jurisdictions. In our assessment, we consider the central bank's objectives, whether they are clearly delineated and whether the central bank has sufficient capacity and independence from the government to fulfill its role. A lack of clearly established goals or a central bank's track record of falling short of meeting its objectives, for example, illustrated by high or volatile inflation, a deflationary environment,[9] large currency fluctuations, or buildup of unsustainable private indebtedness, typically weigh negatively on the sub-factor score. Where the emergence of central bank digital currencies (CBDC) is accelerating, we may also incorporate into our assessment the ways in which a central bank is planning for the adoption of related policies and the ways in which the adoption of CBDC can impact the sovereign. The central bank's de jure and de facto insulation from government interference is typically also an important input to our assessment of this sub-factor. We may also consider the availability and credibility of the tools the central bank can use to address any future economic or financial shock.

We may also assess how imbalances that may exist in the financial system are addressed. Because of its intermediary role in the economy, its increasingly interlinked nature, and, typically, its large size relative to the economy, the financial system can be a key source of macroeconomic risk. Financial or banking crises have often translated into economic downturns, with rising unemployment, costly bailouts for governments and social discontent. The existence of effective macroprudential tools[10] that are reviewed on a regular basis and informed by relevant data is viewed positively in our assessment. The very strongest macroprudential tools are expected to increase the resilience of the financial sector, contain the buildup of systemic vulnerabilities by managing procyclicality in the financial system, and control structural vulnerabilities that can arise due to interlinkages in the financial system and the broader economy.

Similarly, effectively balancing the need for the banking sector to support economic growth against the need to avoid excessive risk-taking is one of the key objectives of banking regulation. Weaker regulations fail to achieve these goals, typically as a result of a lack of effective tools or difficulty in keeping pace with the complexity of the financial system. Sovereigns that have experienced a systemic banking crisis in the recent past would typically score lower for this sub-factor as a reflection of their past inability to contain systemic risks. In these cases, we typically also consider any regulatory or restructuring reforms the sovereign may have undertaken in its banking sector to respond to weaknesses highlighted by the crisis, where we think those reforms will have a lasting effect in reducing credit risk.

Adjustments to the Institutions and Governance Strength factor score

GOVERNMENT DEFAULT HISTORY AND TRACK RECORD OF ARREARS:

We may apply a downward notching adjustment to the Institutions and Governance Strength factor score in cases where there is a track record of government default or significant arrears. Our assessment typically focuses on defaults on debt owed to the private sector. The adjustment can only be downward and is limited to three notches.

The number of downward notches applied typically depends on our expectations for the risk of re-default, how recent the default was and the size of the loss for investors. The larger the losses, the greater the downward notching to this factor score. Moreover, we typically apply a greater downward adjustment for a government that has defaulted several times in the past 20 years, regardless of the recovery rate observed. If there have been no new defaults in the past 10 to 15 years, we may reduce the downward adjustment if it is clear that the underlying economic, financial or political problems that gave rise to the default event have been resolved in an enduring way. If there have been no new defaults in 20 years, we generally do not make a downward adjustment due to default.

Similarly, we may also make a downward adjustment to the factor score if the government has a frequent history of accumulating significant arrears to creditors, including suppliers or government employees. Frequent and large arrears can point to weak fiscal management, a poor culture of repayment and ultimately, a fragile rule of law and contract enforcement.

OTHER:

In limited cases, we may apply a notching adjustment to the Institutions and Governance Strength factor score based on our view that the combination of the sub-sub-factor weights and the government's default history and track record of arrears adjustment do not fully reflect our overall view of a sovereign's institutions and governance strength. The adjustment can be upward or downward and is limited to three notches. For example, where one sub-factor is very important to a particular sovereign's institutions and governance strength, the impact it has on the factor score may be much greater than the standard scorecard weight would imply.

Determining the Economic Resiliency Outcome

We combine the final scores of the factors Economic Strength and Institutions and Governance Strength to arrive at the Economic Resiliency score using equal weights.

Factor: Fiscal Strength

Why it matters

A sovereign's fiscal strength is an important indicator of the sustainability of the sovereign's debt burden. Persistent fiscal deficits often result in elevated leverage and deteriorating debt affordability, ultimately making the sovereign more vulnerable to financial shocks and the risk of not being able to meet its obligations.

This factor comprises two quantitative sub-factors, each of which comprises two metrics.

Debt Burden

This sub-factor provides indications of a sovereign's debt level relative to GDP, i.e., relative to the size of the economy, as well as relative to overall government revenue, i.e., the sovereign's repayment capacity based on its actual revenue base.

High debt burdens often result from the buildup of persistent financial imbalances. Apart from reflecting such legacy fiscal weaknesses, high debt levels may also be the result of the assumption of contingent liabilities (e.g., from the recapitalization of financial institutions or state-owned enterprises), or stock-flow adjustments, driven, for example, by a depreciation of the local currency and its effect on foreign-currency-denominated debt relative to GDP.

An elevated debt level relative to GDP also constrains the sovereign's capacity to provide fiscal support to the economy, particularly in times of economic or financial stress, dampening the growth prospects for an economy.

Environmental and social risks can place pressure on fiscal accounts. For example, climate-related trends such as more frequent and severe natural disasters or sea level rise can raise borrowing needs. The effect of social pressures, such as high unemployment, income inequality or an aging population can result in higher demands for spending and over time can erode fiscal strength if not matched by an increase in revenue or a decrease in expenditures in other areas.

Debt Affordability

This sub-factor provides indications of a sovereign's capacity to service its debt. The ratio of interest payments to revenue indicates the extent to which a government's debt service burden is within its revenue-generation capacity. Drivers of debt affordability are the debt burden itself (the larger the stock of debt relative to GDP or revenue, the weaker the debt affordability); the interest rate (which reflects the willingness of creditors to finance government deficits with smaller or larger risk premia); and revenues generated by the sovereign (the lower the value of revenues, the less that is available for interest payments).

A high ratio of interest payments to revenue means that a large share of revenue needs to be diverted to interest payments, crowding out other types of government spending, including on the provision of basic services, education, and health and safety. The lower the sovereign's debt affordability, the higher the social costs of servicing debt. Unsustainably high social costs of servicing debt may over time undermine a sovereign's ability, and eventually its willingness, to service debt.

The ratio of interest payments to GDP expands our analysis to the broader capacity of the economy to provide a revenue base to meet government debt service requirements.

Social risks such as heightened income inequality can reduce the revenue base and worsen debt affordability. Conversely, strong governance contributing to high policy credibility is likely to lower debt costs and support debt affordability.

How we assess it for the scorecard

In assessing the Debt Burden and Debt Affordability sub-factors, we use debt and fiscal metrics at the general government level. The typical perimeter for our definition of general government debt includes the debt of the central government and the regional and local governments, and, when separate from the central government, the social security system We generally draw the perimeter at that level to reflect both the high mutual reliance between central and lower government levels that we typically observe and the overlap in sources and uses of revenue. Our calculation or estimation includes government debt owned by a central bank but typically excludes the central bank's liabilities.

In cases where there are insufficient reported data to calculate or estimate the general government debt perimeter, we typically calculate or estimate the metrics for this factor using a perimeter based on available data and assess any credit impact on fiscal strength related to the fiscal position outside of the factor core metrics (see the "Adjustments to the Fiscal Strength factor score" section).

We may in some cases calculate or estimate the metrics for this factor at the central government level where there is no or very limited risk that the central government will assume the debt obligations of lower tiers of government. For example, in a few cases of federal systems with a very clear and credible division of fiscal responsibilities, we may focus our assessment only on the finances of the central or federal government.

On the other hand, we may include the debt of other entities in the metrics for this factor where we consider there to be a high likelihood that this debt would be serviced by the central government or by other entities in our defined general government perimeter on an ongoing basis. For example, we may include the debt of loss-making state-owned enterprises that are unable to service their debt if we consider that the government is, in effect, responsible for this liability on an ongoing basis.

How we assess it for the scorecard — Debt Burden sub-factor

GENERAL GOVERNMENT DEBT / GDP:

The numerator is general government gross debt, and the denominator is GDP in nominal terms.

GENERAL GOVERNMENT DEBT / REVENUE:

The numerator is general government gross debt, and the denominator is general government revenue.

How we assess it for the scorecard — Debt Affordability sub-factor

GENERAL GOVERNMENT INTEREST PAYMENTS / REVENUE:

The numerator is general government interest payments, and the denominator is general government revenue.

GENERAL GOVERNMENT INTEREST PAYMENTS / GDP:

The numerator is general government interest payments, and the denominator is GDP in nominal terms.

Our assessment of environmental, social and governance considerations may affect our view of a sovereign's debt trend and contingent liabilities, which may lead to adjustments to the factor score, as described below.

Treatment of reserve currency countries and HIPC/IDA countries

For reserve currency countries and countries that are eligible for funding from the World Bank or the IMF as part of the Heavily Indebted Poor Countries (HIPC), International Development Association (IDA) or similar programs, the scorecard weights for the debt burden and debt affordability ratios may be different from the weights shown in the scorecard above, reflecting our view of the varying importance of these considerations in assessing the fiscal strength of these countries.

A reserve currency is a currency held by central banks as part of their foreign currency reserves and is widely used in international trade and in pricing international contracts. We consider sovereigns that issue reserve currencies as their legal tender as reserve currency countries. We typically consider that these countries benefit from an exceptional capacity to attract investors and as such, our assessment largely focuses on debt affordability rather than on debt burden. Accordingly, for reserve currency countries, the weights of the Debt Burden and Debt Affordability sub-factors are 10% and 90%, respectively.[11] We consider that Australia, Canada, Japan, Switzerland, the UK and the US are currently reserve currency countries. While the euro is considered a reserve currency, we consider only the two largest member states, Germany and France, to benefit from reserve currency status.

For countries in HIPC, IDA or similar programs, apparently strong debt affordability ratios typically reflect the largely concessional terms of their debt but do not denote high fiscal strength. If these countries were to shift toward greater issuance of marketable debt, the cost of debt would typically be higher and debt affordability correspondingly lower. Accordingly, the weights of the Debt Burden and Debt Affordability sub-factors are typically 100% and 0%, respectively,[12] reflecting our view that for these countries, debt burden metrics generally provide a more relevant indication of debt sustainability than do the debt affordability metrics. However, where the application of standard scorecard weights results in weaker debt metrics, we apply the weaker of the two scores to reflect our view that debt affordability may be weighing on the sovereign's fiscal strength.

Participation in official sector debt relief

Where a sovereign participates as a recipient in official sector debt relief, we consider a number of key elements in order to assess if such participation constitutes meaningful credit support that results in improved fiscal strength. Official sector debt relief has the potential to lower the sovereign's debt burden and improve debt affordability (as well as reducing government liquidity risk and alleviating balance of payments pressures). However, in our assessment, we also take into account the extent to which the sovereign's participation in debt relief is indicative of credit pressures (please also see the "Other considerations" section).

Adjustments to the Fiscal Strength factor score

We may apply notching adjustments to the factor score based on a sovereign's debt trend. The debt trend incorporates a sovereign's historical change in its debt burden and can result in downward notching. The debt trend also incorporates an assessment of the expected change in the debt burden and can result in upward or downward notching.

We may also apply downward notching adjustments to the factor score based on the government's exposure to a sudden exchange rate depreciation or a crystallization of its contingent liabilities. Where there are sizable government financial assets, we may apply upward notching. In aggregate, the notching can result in an upward or downward adjustment to the factor score of up to six notches.

FISCAL STRENGTH FACTOR SCORE ADJUSTMENT — DEBT TREND:

We may apply notching adjustments to the Fiscal Strength factor score based on two forms of credit-relevant information captured by a sovereign's debt trend. The first is an assessment of the accumulation of debt over the past economic cycle, which provides information about the vulnerability of a sovereign's debt-carrying capacity to changes over the period and of its ability to unwind the effects of such changes. The second is based on our expectations for an increase or decrease in the government's debt burden and how this change is likely to affect the sovereign's fiscal strength in the future.

Historical Change in Debt Burden

A sovereign's debt accumulation over the past economic cycle provides important information about the challenges a sovereign may confront in stabilizing or reducing its debt burden and maintaining its debt affordability following a potential shock.

This adjustment is qualitative but is informed by quantitative data, in particular the changes in the government's debt burden over the last eight years. This adjustment can only be downward and is limited to two notches.

In limited cases, we may apply a notching adjustment that is different from that indicated by the data over the look-back period to reflect a recent structural change that materially reduces a sovereign's fiscal vulnerability to stress or shocks relative to the previous cycle.

Exhibit 5
Historical change in debt burden

Indicative notching adjustment	0	-1	-2
Change in General Government Debt / GDP (percentage points) t-8 to t	< 25	25 - 50	≥ 50

Source: Moody's Investors Service

Expected Change in Debt Burden

The notching adjustment for the forward-looking debt trend is qualitative and based primarily our near-term baseline projections of a sovereign's debt burden. Our projections incorporate our baseline macroeconomic assumptions, including for commodity prices, and take into account the government's stated policy plans and its track record of implementing such plans, as well as budget pressures that may arise from social issues.

We assess the percentage point change in the debt-to-GDP ratio between the base year for our scorecard (t) and our baseline projection for the subsequent two years (t+2). The number of downward notches depends on the magnitude of the projected increase in the debt burden. Conversely, we may apply an upward notch to the factor score in cases where we expect the government's debt burden to decline (please see Exhibit 6).

We may apply a notching adjustment that is different from the adjustment resulting from our debt-to-GDP projections where there is exceptionally high uncertainty around our forecasts, where our longer-term expectation for the debt trend is substantially different from the two-year projection or where we view that the expected change in the debt burden would not imply a material change in a sovereign's fiscal strength. As an example of the latter, for reserve-currency sovereigns, an increasing debt burden may not be indicative of deteriorating fiscal strength.[13] In our assessment, we may also consider forward-looking scenario analyses with respect to nominal growth, fiscal trajectories and the government's ability to manage budgets, interest rate developments and other risk factors of a sovereign's debt trend that could cause meaningful variations in the direction of fiscal strength relative to our baseline scenario. Exposure to physical climate risk, such as that arising from a dependence on weather-exposed economic sectors, i.e., agriculture or tourism, can result in increases in debt and challenge debt affordability under some scenarios. Similarly, an aging population can raise some sovereigns' debt burdens sharply unless governments take measures to mitigate this rise.

In cases where our baseline projection for the debt burden incorporates contingent liabilities that would crystallize on the government's balance sheet or changes in the debt burden that would result from a change in the government's financial assets, we do not include them in the other notching adjustments described below.

The upper bound of notching for the fiscal direction adjustment is more constrained than the lower bound because governments are less likely to attain large debt reductions. Governments typically enact economic stimulus measures, which increase debt, more often and more effectively than they impose fiscal austerity. Debt-reduction programs are typically short-lived, and declining debt trends are more likely to plateau or reverse than increasing debt trends.

Exhibit 6
Expected change in debt burden

Indicative notching adjustment	+1	0	-1	-2	-3
Change in General Government Debt / GDP (percentage points) t to t+2	< (5)	(5) - 5	5 - 10	10 - 15	≥ 15

Source: Moody's Investors Service

FISCAL STRENGTH FACTOR SCORE ADJUSTMENT — GENERAL GOVERNMENT FOREIGN CURRENCY DEBT / GDP:

We may apply a notching adjustment to the Fiscal Strength factor score based on the amount of the government's debt denominated in or linked to foreign currencies. The adjustment can only be downward and is limited to six notches.

Our assessment of the adjustment for foreign currency government debt is qualitative but is informed by quantitative data, in particular the amount of government debt denominated in foreign currency relative to its GDP. A sovereign's stock of foreign currency debt in relation to its GDP provides an indication of the susceptibility of a sovereign's fiscal strength to a currency depreciation, i.e., the higher the stock of foreign currency debt, the higher the potential impact of a currency depreciation on the debt burden and debt affordability. The number of downward notches we apply is informed by the potential for added debt-servicing costs and debt stock in the case of a currency depreciation.

We may consider meaningful mitigants to foreign exchange risk, such as financial hedges or natural hedges. For example, a natural hedge could occur where a sovereign receives a large share of its revenue in foreign currency, as may be the case for oil-and gas-exporting sovereigns.

Where a sovereign has adopted another sovereign's currency as an official legal tender, for example, where an economy is entirely dollarized, we typically do not consider the potentially negative credit impact of debt issuances denominated in the adopted currency, considering that the adopted foreign currency is the de facto local currency. However, we may still apply some downward notching adjustment if the value of the local currency is fixed to another sovereign's currency through a fixed exchange regime or peg, because sovereigns operating under these regimes are susceptible to a risk of devaluation should external imbalances destabilize the pegs. Where currency pegs have been maintained over many decades and where we have no reasonable expectation that these pegs could be destabilized over the foreseeable future, we typically would apply limited or no downward notching. In limited cases, a more negative notching could be applied for sovereigns with highly concentrated or rigid economic and fiscal structures, which expose them to significantly larger debt sustainability risks from a potential currency depreciation than implied by their stock of foreign-currency-denominated debt relative to GDP.

Exhibit 7

General government foreign currency debt / GDP

Indicative notching adjustment	0	-1	-2	-3	-4	-5	-6
General Government Foreign Currency Debt / GDP (%)	< 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	≥ 60

Source: Moody's Investors Service

FISCAL STRENGTH FACTOR SCORE ADJUSTMENT — OTHER NON-FINANCIAL PUBLIC SECTOR DEBT:

We may apply a notching adjustment to the Fiscal Strength factor score based on the presence of sizable debt from the non-financial public sector and our view of the related risk of the direct or indirect assumption of this debt by the government. The adjustment can only be downward and is limited to three notches.

Weak public sector companies can drain fiscal resources from the government, which can eventually lead to the government directly or indirectly assuming debt that was previously a contingent claim. The assumption of debt can take different forms, such as recapitalizations, subsidies or transfers of the debt obligation.

The adjustment to the factor score is primarily qualitative but is typically informed by quantitative data, in particular by the debt level of non-financial public entities relative to GDP. The number of downward notches is based on both the size of the non-financial public sector debt and the likelihood that there will be a partial assumption of this debt by the government. Considerations that may indicate a material likelihood of the assumption of this debt by the government over time typically include weak stand-alone financial profiles with low or negative profitability levels and a history of financial support. For example, gradual but persistent changes in a state-owned enterprise (SOE)'s environment may also point to a likelihood of financial support from the government in the future. This may be the case for an SOE exposed to carbon transition risk.

The likelihood of the government's assumption of public sector debt also depends on the government's willingness to provide financial support. Entities that carry an economic or social mandate that is viewed as being strategically important for the country, such as a public utility company, are typically more likely to receive some form of support in times of stress.

Because there can be myriad public companies in a country, we generally restrict the perimeter of our assessment to non-financial corporates that are material relative to domestic GDP or whose debt makes up a material portion of the government's debt, i.e., typically where they represent more than a few percentage points. We exclude from the perimeter of our assessment entities whose financial obligations are already consolidated within the general government debt perimeter used for core metrics in the Fiscal Strength factor. Guarantees that are not already directly included in the general government debt perimeter are typically considered in our assessment of this adjustment.

Our assessment is typically based on reliable and comprehensive data on public companies, including audited financial statements. Where there is insufficient data on public companies or the size of public companies appears individually very small but may collectively represent a sizable risk for the sovereign's fiscal strength, we may apply a downward adjustment, although it would typically be limited to one notch.

Exhibit 8

Other non-financial public sector debt

Indicative notching adjustment	0	-1	-2	-3
Other Non-Financial Public Sector Debt / GDP (%)	< 20	20 - 40	40 - 55	≥ 55

Source: Moody's Investors Service

FISCAL STRENGTH FACTOR SCORE ADJUSTMENT — GOVERNMENT FINANCIAL ASSETS INCLUDING SOVEREIGN WEALTH FUNDS (SWF) / GDP:

We may apply notching adjustments to the factor score based on the presence of sizable government financial assets (GFA), including sovereign wealth funds and certain assets held by the ministry of finance or treasury, because these government financial assets are a partial mitigant to the government debt burden. We consider these assets to support debt sustainability if, in principle, they could be converted to cash, typically within a year and at a generally predictable value. For example, very large government financial assets can buffer the fiscal effects of environmental shocks and provide resources that could help a sovereign manage fiscal risks associated with longer-term environmental and social considerations. The adjustment can only be upward and is limited to four notches.

Our assessment of the adjustment to the factor score is primarily qualitative but is typically informed by quantitative data, in particular the level of financial assets held by sovereign wealth funds or other materially large financial assets that are owned by and available to the government, relative to GDP. Examples of these assets include government-owned domestic cash funds, including government deposits with the central bank and government contingency reserve funds and sinking funds earmarked for government debt repayments. We also typically include government-owned foreign currency funds other than central bank foreign-currency reserves or those already included in sovereign wealth fund assets, and on an exceptional basis we may include domestic funds that hold bonds issued by the government, unless those holdings have already been netted out in our calculation of consolidated general government gross debt.

We typically do not place meaningful weight on assets owned by social security or public pension systems, because using these assets to reduce government debt generally has the effect of replacing one liability with another. We also typically do not include financial assets of state-owned enterprises or the government's equity stakes in state-owned enterprises other than shares that are publicly traded.

We typically assign less uplift for government financial assets managed by sovereign wealth funds that have limited transparency. If the level of transparency is extremely poor, e.g., where the total size of sovereign wealth fund assets is unavailable or there is meaningful uncertainty around the size of the funds, we haircut the size estimate, typically by up to 50%. We also typically deduct from total government financial assets the sovereign wealth fund's or the government's equity shares in state-owned enterprises, if those shares are not publicly traded on a stock exchange. We also typically exclude government and sovereign-wealth-fund loans to third parties or the value of government-owned real estate and infrastructure. Where the sovereign wealth fund issues debt, we typically subtract borrowings from assets.

Our assessment of government financial assets is forward-looking, and the extent of any notching adjustment is case-specific, taking into consideration other information relevant to how these assets may mitigate the sovereign's debt burden. The amount of uplift provided by government financial assets rises according to their size in relation to GDP. However, if for example, we expect that the sovereign will liquidate a portion of its financial assets to pay down debt, we may apply notching that is lower than the adjustment resulting from the calculation of government financial assets to GDP.

Exhibit 9

Government financial assets including sovereign wealth funds

Indicative notching adjustment	0	+1	+2	+3	+4
Government Financial Assets including Sovereign Wealth Funds / GDP (%)	< 10	10 - 25	25 - 50	50 - 100	≥ 100

Source: Moody's Investors Service

FISCAL STRENGTH FACTOR SCORE ADJUSTMENT — OTHER:

In limited cases, we may apply additional notching adjustments to the factor score based on our view that the sub-factors and the previously described fiscal strength factor score adjustments do not fully reflect our overall view of a sovereign's fiscal strength. The adjustment can be upward or downward and is limited to three notches.

Determining the Government Financial Strength outcome

We combine the final score of the factor Fiscal Strength with the Economic Resiliency Outcome using dynamic weights according to the table below to arrive at the Government Financial Strength outcome. The weight of Fiscal Strength is highest for sovereigns with Economic Resiliency scores between baa2 and ba2, reflecting our view that the creditworthiness of countries with a high score for Economic Resiliency is less susceptible to changes in their fiscal strength whereas the creditworthiness of countries with mid scores for Economic Resiliency is more sensitive to changes in their Fiscal Strength. In contrast, the creditworthiness of countries with low Economic Resiliency scores tends to be weak irrespective of debt metrics.

Exhibit 10

Government financial strength

Economic Resiliency \ Fiscal Strength	aaa	aa1	aa2	aa3	a1	a2	a3	baa1	baa2	baa3	ba1	ba2	ba3	b1	b2	b3	caa1	caa2	caa3	ca
aaa	aaa	aaa	aaa	aaa	aaa	aa1	aa1	aa1	aa1	aa1	aa1	aa1	aa2	aa2	aa2	aa2	aa2	aa2	aa3	aa3
aa1	aa1	aa1	aa1	aa1	aa1	aa1	aa1	aa2	aa2	aa2	aa2	aa2	aa2	aa2	aa3	aa3	aa3	aa3	aa3	aa3
aa2	aa1	aa1	aa2	aa2	aa2	aa2	aa2	aa2	aa2	aa3	aa3	aa3	aa3	aa3	aa3	aa3	a1	a1	a1	a1
aa3	aa2	aa2	aa2	aa2	aa3	aa3	aa3	aa3	aa3	aa3	aa3	a1	a1	a1	a1	a1	a1	a1	a2	a2
a1	aa2	aa2	aa3	aa3	aa3	aa3	a1	a1	a1	a1	a2	a2	a2	a2	a3	a3	a3	a3	baa1	baa1
a2	aa3	aa3	aa3	a1	a1	a1	a1	a2	a2	a2	a2	a3	a3	a3	a3	baa1	baa1	baa1	baa1	baa2
a3	aa3	a1	a1	a1	a1	a2	a2	a2	a2	a3	a3	a3	a3	baa1	baa1	baa1	baa1	baa2	baa2	baa2
baa1	a1	a1	a2	a2	a2	a2	a3	a3	a3	a3	baa1	baa1	baa1	baa1	baa2	baa2	baa2	baa2	baa3	baa3
baa2	a1	a1	a2	a2	a2	a3	a3	a3	baa1	baa1	baa1	baa2	baa2	baa2	baa3	baa3	baa3	ba1	ba1	ba1
baa3	a1	a2	a2	a2	a3	a3	a3	baa1	baa1	baa1	baa2	baa2	baa3	baa3	baa3	ba1	ba1	ba1	ba2	ba2
ba1	a2	a2	a3	a3	a3	baa1	baa1	baa1	baa2	baa2	baa2	baa3	baa3	baa3	ba1	ba1	ba1	ba2	ba2	ba2
ba2	a2	a3	a3	a3	baa1	baa1	baa1	baa2	baa2	baa2	baa3	baa3	ba1	ba1	ba1	ba2	ba2	ba2	ba3	ba3
ba3	baa1	baa1	baa2	baa2	baa2	baa2	baa3	baa3	baa3	baa3	ba1	ba1	ba1	ba1	ba2	ba2	ba2	ba2	ba3	ba3
b1	baa2	baa2	baa2	baa2	baa3	baa3	baa3	baa3	ba1	ba1	ba1	ba1	ba2	ba2	ba2	ba2	ba3	ba3	ba3	ba3
b2	baa2	baa2	baa3	baa3	baa3	baa3	ba1	ba1	ba1	ba1	ba2	ba2	ba2	ba2	ba3	ba3	ba3	ba3	b1	b1
b3	baa3	baa3	baa3	ba1	ba1	ba1	ba1	ba2	ba2	ba2	ba2	ba3	ba3	ba3	ba3	b1	b1	b1	b1	b2
caa1	ba2	ba2	ba2	ba2	ba3	ba3	ba3	ba3	ba3	ba3	b1	b1	b1	b1	b1	b1	b1	b2	b2	b2
caa2	ba3	ba3	ba3	ba3	ba3	ba3	b1	b1	b1	b1	b1	b1	b2	b2	b2	b2	b2	b2	b2	b3
caa3	ba3	b1	b1	b1	b1	b1	b1	b1	b2	b2	b2	b2	b2	b2	b3	b3	b3	b3	b3	b3
ca	b1	b1	b1	b2	b2	b2	b2	b2	b2	b2	b3	b3	b3	b3	b3	b3	caa1	caa1	caa1	caa1

Source: Moody's Investors Service

Factor: Susceptibility to Event Risk

After arriving at the Government Financial Strength, we consider a sovereign's susceptibility to event risk. This factor may only lower the Government Financial Strength outcome. Exhibit 11 shows the midpoint of the overall scorecard-indicated range outcome resulting from the combination of the Government Financial Strength outcome and the Susceptibility to Event Risk factor score. The overall scorecard-indicated outcome is expressed as a three-notch range on our alphanumeric scale except for scores of Caa3 and Ca, for which the range is Caa2-C.

Exhibit 11

Combining government financial strength and susceptibility to event risk

Susceptibility to Event Risk \ Government Financial Strength	aaa	aa1	aa2	aa3	a1	a2	a3	baa1	baa2	baa3	ba1	ba2	ba3	b1	b2	b3	caa1
aaa	Aaa	Aa1	Aa2	Aa3	A1	A2	A3	Baa1	Baa2	Baa3	Ba1	Ba2	Ba3	B1	B2	B3	Caa1
aa	Aaa	Aa1	Aa2	Aa3	A1	A2	A3	Baa1	Baa2	Baa3	Ba1	Ba2	Ba3	B1	B2	B3	Caa1
a	Aaa	Aa1	Aa2	Aa3	A1	A2	A3	Baa2	Baa3	Ba1	Ba2	Ba3	B2	B3	Caa1	Caa2	Caa3
baa	Aaa	Aa1	Aa2	Aa3	A2	A3	Baa1	Baa2	Ba1	Ba2	Ba3	B1	B3	Caa1	Caa2	Caa3	Ca
ba	Aa1	Aa2	Aa3	A1	A2	Baa1	Baa2	Baa3	Ba2	Ba3	B1	B2	B3	Caa1	Caa2	Caa3	Ca
b	Aa2	Aa3	A1	A2	A3	Baa2	Ba1	Ba2	Ba3	B1	B2	B3	Caa1	Caa2	Caa3	Caa3	Ca
caa	Aa3	A1	A2	A3	Baa1	Baa3	Ba1	Ba2	B1	B2	B3	Caa1	Caa2	Caa3	Caa3	Caa3	Ca
ca	A1	A2	A3	Baa1	Baa2	Ba1	Ba2	Ba3	B1	B2	B3	Caa1	Caa2	Caa3	Caa3	Caa3	Ca

Source: Moody's Investors Service

Why it matters

Susceptibility to sudden, extreme events that could severely impact the country's economy or its institutions, or strain fiscal stability is an important indicator of a sovereign's creditworthiness. Event risks are varied and typically include domestic political and geopolitical risks, government liquidity risk, banking sector risk and external vulnerability risk.

This factor comprises four sub-factors.

Political Risk

Political risks, stemming from domestic politics or from geopolitics, may increase a sovereign's probability of default. A challenging domestic political environment characterized by political instability, elevated or rising social discontent, or religious, ethnic or social divisions, can challenge stability and predictability of policymaking. Limited employment opportunities, income disparities or unequal access to education, affordable housing and basic services, as well as environmental risks such as climate change, can also be sources of political risk. Political risk can also rise where a government seeks to generally reduce the quality of services, which can weaken the social safety net. In more extreme cases, a challenging domestic political environment can lead to civil wars and economic dislocation. Geopolitical risks can also threaten economic, institutional and fiscal stability. For example, a sovereign's credit standing may be influenced by unresolved political or military issues with a neighboring country, especially one with a bellicose foreign policy. An escalation of tensions between countries or the potential for a loss of sovereignty due to interference from another state can weigh on the creditworthiness of a sovereign.

Government Liquidity Risk

A government's liquidity risk is an important indicator of its ability to meet all its payment obligations, especially those related to debt service.

A core aspect of government liquidity risk is ease of access to funding. Most sovereigns operate with negative cash flows, run annual fiscal deficits and typically have maturing debt to repay or refinance each year. And they usually have a limited amount of highly liquid, high-quality assets relative to their refinancing needs. Their capacity to obtain fresh funding on a consistent and reliable basis is thus core to our assessment of government liquidity. Even for sovereigns with a track record of securing financing when needed, access to funding can be very sensitive to internal or external developments. For example, lenders may be less willing to provide funding where governance is weak.

Sovereigns typically borrow from varying types of creditors. Government borrowings most often entail the issuance of debt instruments on domestic or international markets. Many governments also tap loan markets or borrow directly from commercial banks.

Official sector lending, including from bilateral lenders (countries) and supranational institutions, is another common source of financing for emerging economies and frontier markets, generally at interest rates below the level offered by the other types of borrowing. Exceptionally, when governments have accumulated a very large reserve of financial assets such as sovereign wealth funds, they will also be able to rely on asset drawdowns.

Banking Sector Risk

Because of the essential role of banks in the economy, systemic banking crises are often accompanied by a material buildup of public debt typically issued to counter revenue losses due to deep recessions, bank bailouts or economically costly debt restructurings. Weak governance may contribute to weak regulation and supervision of banks in the country, raising banking sector risks for the sovereign.

Systemic banking crises often cause or exacerbate economic dislocation by impeding or sometimes halting the supply of credit and hampering policy effectiveness. An accompanying economic crisis would in turn weigh negatively on the government's revenue generation. Recovery from this type of economic crisis is often very lengthy, due in part to high levels of debt in the economy as a whole.

External Vulnerability Risk

External vulnerability risk is an important indicator of a sovereign's capacity to access or repay financing denominated in a foreign currency.

Economies rely on capital inflows to meet import payments and repay external debt. When risk appetite weakens, investors tend to rebalance their portfolios away from the economies most reliant on such capital inflows, in particular those with low reserve buffers. In turn, a reduction in capital inflows may erode official foreign exchange reserves, which may further discourage inflows, and contribute to a depreciation of the currency, ultimately challenging the sovereign's capacity to meet foreign currency debt payments.

Physical climate risk, water risk or risks related to natural capital can all impair a country's ability to rely on its natural resources for exports and foreign-currency generation. Over time, these negative environmental trends can hamper a sovereign's external position.

How we assess it for the scorecard

The aggregation of the four sub-factors of event risk uses a minimum function (in other words the factor score is the worst score of the four sub-factors), because the materialization of even one of these risks can lead to a severe deterioration of a sovereign's credit profile. The use of a minimum function also reflects that these risks are typically correlated, with the manifestation of one of these risks likely to accelerate the occurrence of other risks.

However, a score that is worse than indicated by the minimum of sub-factor scores may be assigned where weak scores are observed across more than one sub-factor, and where the risks driving those scores are considered to be largely uncorrelated.

How we assess it for the scorecard — Political Risk sub-factor

DOMESTIC POLITICAL AND GEOPOLITICAL RISK:

We assess this sub-factor qualitatively, based on our view of domestic political and geopolitical risks, typically using quantitative indicators to inform our analysis. Our assessment includes our expectation of the forward-looking scenario.

Our assessment of domestic political risk considers the existence of socioeconomic characteristics that could lead to discontent or divisions in a society, such as high levels of income inequality, ethnic or religious strife, or an absence of consensus around policy direction.

We generally consider people's ability to voice their preferences freely and to have an impact on policymaking, which typically support lower risk of tensions that could lead to disruptive political episodes and can have a credit positive impact on policy outcomes. To inform our assessment regarding freedom of expression, we typically use the WGI Voice and Accountability indicator.

Social risks such as high or rising unemployment and wealth and income inequality typically pose risks of social unrest and hence political disruption, in particular where most of an economy's resources are concentrated within a region or specific group, or where a government is seen as reducing programs or policies that provide economic security. We may use the Gini index[14] or other established indicators of wealth and income distribution to inform our assessment.

Tensions within society can also result from ethnic, religious or social divisions. Where we consider deep-rooted or rising divisions are likely to threaten political stability, we typically assign a lower score for this sub-factor.

Political stability is another important determinant of political risk. Sovereigns that achieve a high degree of policy continuity, possibly despite frequent government transitions, typically receive higher scores for this sub-factor. Conversely, countries where executive transitions are disorderly or typically translate into low policy predictability owing to their frequency, negative impact on the continuity of public administration work or the lack of effective succession plans and mechanisms typically receive lower scores for this sub-factor. We typically use the WGI political stability indicator to inform our assessment.

The above challenges can be magnified where there is an absence of consensus on policy outcomes that we view as credit positive. Heightened political or social divisions, which can arise from unequal access to education, affordable housing or basic services, may undermine the enactment of credit-positive policies.

In our assessment of the sub-factor, we also consider the existence of geopolitical tensions that have already materialized or that can escalate into events or policies that may weigh negatively on a sovereign's creditworthiness. Geopolitical tensions can include latent conflicts and armed conflicts on the one hand, and also instances of nonviolent state-to-state tension or tension between a state and a bloc of nations, including trade wars, cyberattacks or sanctions.

Over time, climate change, including heat and water stress, flooding, hurricanes and typhoons, and rising seas may contribute to forced displacement of large populations, raising credit risks both in the countries or regions that migrants leave and those in which they ultimately settle. For example, increasing competition for land and water resources may raise frictions between new migrants and the more established population.

In arriving at an overall assessment, we typically develop a qualitative view of the probability of political risk events and the impact on the economy, institutions and fiscal strength if these were to materialize.

We typically score to our view of the greater of the domestic political and geopolitical risks. However, in some cases, the two risks reinforce each other, leading to a score that is weaker than otherwise assessed for the individual risks.

How we assess it for the scorecard — Government Liquidity Risk sub-factor

EASE OF ACCESS TO FUNDING:

We assess this sub-factor qualitatively, based primarily on the government's ease of access to three main categories of borrowing: (i) local currency borrowing from domestic creditors; (ii) local currency borrowing from external creditors; and (iii) foreign currency borrowing. Considerations include the government's track record of having access to these types of funding, their cost and maturity relative to peers, the diversity of each sovereign's investor base for different types of debt instruments, the reliance on borrowing from official lenders and the existence of material government reserve assets. Our assessment of government liquidity risk is based on a forward-looking view and, to the extent we have visibility, includes an assessment of events that could impede a sovereign's access to funding. We may use scenario analysis to inform our assessment of this sub-factor.

In assessing a government's future capacity to access funding, we complement the assessment of a government's track record with an assessment of the robustness of a government's financing strategy, i.e., the priorities it has set in terms of price, maturity and currency, among other things, and not only based on its funding constraints. Whereas a government's funding mix may be skewed toward one specific source, this funding would not necessarily be indicative of the potential for access to other funding sources. In assessing a sovereign's ease of access to funding, we also may consider the willingness of lenders to provide funding where governance strength is weak or weakening.

Sovereigns that have low or no debt on a sustained basis or access to large reserve assets for the foreseeable future typically receive high scores for this sub-factor, reflecting our view of their very low liquidity risk.

- **Local currency borrowing from domestic creditors.** The presence of deep domestic capital markets on which the government can rely to borrow in local currency is a credit strength. A large, broad and diverse base of domestic investors fosters a deep local market, providing the sovereign with consistent ability to issue various types of debt instruments across a wide range of maturities. Conversely, where domestic capital markets are narrow, the government typically has fewer options and largely relies on banks, which carries a heightened risk that the capacity of the prime source of demand for government debt becomes saturated. A government's capacity to rely on banks for funding depends on a variety of considerations, including the size of the banking system, the dynamic of deposit inflows or the share of assets already invested in government securities. A high share typically denotes a track record of capacity, although it could also point to saturation risks. Regulations that incentivize government debt holdings by banks may indicate good access to bank financing. Conversely, regulatory frameworks that deter banks from holding government debt typically weigh negatively on our assessment of ease of access to funding.

- **Local currency borrowing from external creditors.** Access to foreign investors in local currency government debt broadens the government's borrowing base, which is positive in our assessment of the government's ease of access to funding. The larger, broader and more diversified the base, the lower the liquidity risk for the government. A track record of stable and reliable access to foreign investors for local currency debt issuance is an important credit differentiator, because foreign investors who typically have a wider array of investment choices generally represent a more volatile source of funding than domestic investors, which we view as being more captive. As a result, there is a greater risk of a sudden stop to foreign investment in local currency debt or a net disinvestment (i.e., capital outflows) over time.

  Indications that suggest a sovereign's strong and reliable capacity to attract foreign investors include a reserve status of the currency in which a government issues debt. Governments with a local currency benefiting from a reserve status, which is often reflected in a high share of government debt in local currency held by central banks of other countries as reserve assets, typically receive higher scores for this sub-factor. For governments with no track record, we typically assess their potential ability to borrow from foreign investors in local currency but would typically not expect the sovereign to score in the top scoring categories for the government liquidity risk sub-factor, unless the sovereign has no or very low debt or has very large reserve assets.

- **Foreign currency borrowing.** A government's capacity to borrow in foreign currency, typically from external creditors, further broadens the government's scope of funding sources and weighs positively in our assessment. Foreign currency borrowing primarily comes in the forms of international bond issuances and loans, including from the official sector. The larger, broader and deeper the available sources of foreign currency borrowing, the lower the liquidity risk for the government. Governments with a track record of stable and reliable foreign currency issuance in international markets typically receive higher scores for this sub-factor.

  The absence of any track record of stable access to international markets in foreign currency typically implies higher liquidity risk. Only if the government benefits from the best access to external borrowing in its own currency (i.e., is compatible with a aaa score for that consideration) we would consider that the government could benefit from the strongest access to foreign currency borrowing (i.e., would be compatible with a aaa score for this consideration). In such a case, it is likely that the government's financing strategy focuses on issuing only in local currency to avoid foreign exchange risk or the related hedging cost.[15]

  Indications that access to foreign currency borrowing may be limited typically include a strong reliance on official sector lending. Some governments rely on a broad range of official lenders, in which case the sovereign would typically score ba or lower for this sub-factor. The reliance on a broad range of official lenders is often associated with constrained access to other sources of funding. Official sector lending also may be less flexible because it is often earmarked for specific uses, such as infrastructure projects or social programs. A reliance on IMF financing programs, which are often a funding source of last resort, is generally a sign of significant fundamental credit weakness and heightened default risk.

» **Large reserve assets held by the government, including sovereign wealth funds.** The presence of large liquid assets also informs our assessment of liquidity risk. Where governments have large reserve assets, typically managed through sovereign wealth funds, we also consider in our assessment the size of these reserves relative to the stock of debt, the coverage these provide to the government's gross financing needs, their liquidity and the sovereign's ease of access to these reserves. We only include reserves that are readily available to support the government's budget and debt repayment and typically exclude the central bank's foreign exchange reserves from our assessment of government liquidity risk. Where we consider a sovereign wealth fund to be a source of liquidity, we incorporate our view of the longevity of these reserves and the risk that they may be depleted over a relatively short time frame. We also incorporate our view that domestic financial assets do not provide the same level of liquidity buffer as foreign assets, because domestically held and local-currency denominated assets are more likely to lose value or become illiquid in times of sovereign stress.

Adjustment to the Government Liquidity Risk sub-factor score

HIGH REFINANCING RISK:

We may apply an adjustment to the Government Liquidity Risk sub-factor score based on our forward-looking view of a government's funding needs and refinancing risks. The adjustment can only be downward and is limited to two broad alpha scoring categories.

In our assessment, we typically consider the size of a government's funding needs relative to GDP over the next two years in conjunction with its ease of access to funding. The stronger the access, the higher the tolerance for large government funding needs. In assessing refinancing risk, we typically consider the size of future principal debt payments in the context of the government's ease of access to funding. Large principal debt payments coming due in foreign currency typically expose governments to greater risk, including a more skittish investor base, resultant pressure on exchange rates if foreign currency maturities are refinanced through local currency debt issuance and the potential for depleting foreign currency reserves.

How we assess it for the scorecard — Banking Sector Risk sub-factor

We assess this sub-factor qualitatively, based on our view of the risk of a systemic crisis and the impact it may have on a country's economic strength and public finances, including through the crystallization of contingent liabilities in the banking system on the government's balance sheet.

There are two main considerations that underpin our assessment of banking sector risk for the sovereign: the stand-alone credit profile of the domestic banking system, i.e., absent any support from the government, which informs our assessment of the risk of a Banking Sector Credit Event (BSCE); and the size of the domestic banking system, measured or estimated by total domestic bank assets relative to GDP. The weaker and the larger the banking system, the greater the potential for contingent liabilities to crystallize on the government's balance sheet and for a banking crisis to spill over and affect the functioning of the economy.

For the purposes of our assessment of both the size and strength of the banking system, we define domestic banks as banks that have a strong footprint in the domestic market, as lenders, investors or deposit takers. We typically include the bank subsidiaries of foreign financial institutions as domestic banks but typically exclude the branches of foreign banks unless they have established significant lending or deposit activities in the domestic market.

As a result, our assessment of the size and strength of the domestic banking system may be markedly different from that of the total banking system for countries that house large offshore financial centers. Similarly, we would include the offshore operations of domestic banks within the perimeter of our assessment where we have a reasonable expectation, based on past actions, legislation or pronouncements, that these offshore operations would be considered part of the domestic bank's core business in a resolution, leading to higher contingent liability risks for the sovereign.

RISK OF BANKING SECTOR CREDIT EVENT (BSCE):

The BSCE is our assessment of the underlying credit strength of the domestic banking system. To inform our assessment, we use the average of Baseline Credit Assessments (BCAs), weighted by bank assets, for rated domestic banks (as described above). BCAs are our opinions of issuers' stand-alone intrinsic strength, absent any extraordinary support from an affiliate or a government.[16] BCAs incorporate a sovereign's governance, including the strength of banking regulation and supervision.

The underlying credit strength of the domestic system may not be fully reflected by the asset weighted-average BCA for countries in which our ratings cover only part of the overall banking sector. In these cases, we may consider the risk of a banking sector credit event to be higher than the weighted average BCA if the average for the system as a whole obscures credit concerns in a discrete but material part of the system. For example, where the weighted average BCA is uplifted by the BCAs of a small number of strong banks and understates the risk posed to the sovereign by a larger number of small banks with weaker credit quality, scoring for this sub-factor typically would reflect the higher risk.

Conversely, a banking system that is predominantly foreign-owned and whose parent banks have the capacity and a high propensity to support the branches or subsidiaries in other jurisdictions would typically lessen the need for sovereign support or its costs. In these cases, we may consider banking sector credit risk to be lower than what is implied by the weighted average BCA of the domestic system, because such support lowers contingent liabilities to the government and can lessen the impact of a banking sector credit event for the host country. In our assessment, we may consider the share of domestic assets under foreign ownership as well as the potential for parent support to reduce a domestic bank's credit risk, which may include reference to the subsidiaries' adjusted BCA (incorporating affiliate support).

Where we have no or very small rating coverage in a system, we estimate the risk of a banking sector credit event based on available data for the aggregate banking system and analytical judgment. Our assessment includes our understanding of the system's funding profile, capitalization, liquidity, industry structure, profitability and asset performance, and takes into account the strength of banking sector regulation and supervision. We typically compare this information with that of other banking systems that have similar characteristics. In our assessment, we also consider the existing sovereign rating. In these instances, we typically use the corresponding reference point provided in the table below. The BSCE score is not typically higher than the sovereign rating and would generally be lower, which recognizes the relationship between the sovereign rating and the risk of a banking sector credit event.

Exhibit 12
Risk of banking sector credit event

Sovereign Rating Category	Indicative Score for Risk of Banking Sector Credit Event
Aaa	a3
Aa	baa2
A	baa3
Baa	ba1
Ba	ba3
B	b2
Caa	caa2

Source: Moody's Investors Service

TOTAL DOMESTIC BANK ASSETS / GDP:

We calculate or estimate the size of the domestic banking system using the ratio of total assets of the domestic banking sector (as described above) relative to GDP. All else being equal, the larger the relative size of the domestic banking system, the larger the contingent liability risks and the risks of negative spillovers to the economy. In instances where our assessment of the risk of a banking sector credit event is based on a subset of the domestic system, we adjust the size perimeter accordingly.

Combining the BSCE and the Total Domestic Bank Assets / GDP Metric to Arrive at the Banking Sector Risk Score

Using the matrix shown in Exhibit 13 below, we combine the BSCE score and the total domestic bank assets to GDP ratio to estimate the overall banking sector risk for the sovereign.

Exhibit 13
Banking sector risk for the sovereign

	Risk of Banking Sector Credit Event						
Total Domestic Bank Assets / GDP	aaa-a3	baa1	baa2	baa3	ba1-ba2	ba3-b3	caa-c
≥ 400%	a	a	baa	ba	b	b	ca
230 - 400%	a	a	baa	baa	ba	b	ca
180 - 230%	a	a	a	baa	ba	ba	b
80 - 180%	a	a	a	a	baa	ba	ba
< 80%	aaa	aa	aa	a	a	baa	ba

Source: Moody's Investors Service

Adjustments to the Banking Sector Risk sub-factor score

We may adjust the Banking Sector Risk sub-factor score based on considerations that are not fully captured by the BSCE and the ratio of total assets of the domestic banking sector relative to GDP. The adjustments can be upward or downward and are limited to two scoring categories.

Examples of other considerations that may result in downward or upward notching adjustments may include:

» Where the domestic banking system, irrespective of its overall size, is highly concentrated in a few banks, we consider whether there is a higher risk that distress in a single institution would give rise to a systemic crisis. We may conclude that the risks to the sovereign from a highly concentrated banking system warrant a lower Banking Sector Risk score than indicated by the initial score. In such cases, we may apply a downward notching adjustment.

» We typically do not consider the existence of an Operational Resolution Regime (ORR) a mitigating factor in assessing banking sector risk for the sovereign. This is because an ORR, which entails specific legislation enabling the orderly resolution of a failed bank, may be effective in eliminating risks for the sovereign in case of an individual bank failing, but is less likely to prove effective in mitigating or eliminating the contingent liability risks for the sovereign in the event of a systemic banking crisis, which is the focus of our assessment of banking sector risk for sovereigns. In rare instances where we consider an ORR to be effective in the event of a systemic crisis, we may consider that the contingent liability risks from the banking sector are lower than suggested by the initial score and apply an upward notching adjustment. Such effectiveness would likely entail clear, recent and objective evidence that the sovereign is willing to not provide financial support to multiple entities within the banking system.

» We may consider applying a downward notching adjustment to the sub-factor score where there is a significant presence of or dominance by state-owned banks in the domestic banking system. For example, we may notch down if we view that state-owned banks' dominance increases the risk of materialization of contingent liabilities for the sovereign, in particular in cases where the banking sector is weak.

» We may consider whether repeated capital injections to different banks from the government over time suggest a broader risk of financial distress at a systemic level and pose a contingent liability risk to the sovereign. In such cases, we apply a downward notching adjustment.

» We may consider adjusting the sub-factor score downward in the event of a significant and sustained shift in sentiment that poses acute financing pressures for the banking sector, including through a sharp rise in funding costs, and increases the potential risk of a systemic banking crisis.

» We may consider, in rare instances, adjusting the Banking Sector Risk sub-factor score downward to reflect risks to the sovereign from the wider financial sector in terms of contingent liabilities and possible disruption to the wider economy. For example, we may adjust our assessment downward to reflect the risks to the sovereign from non-bank systemically important financial institutions. A downward adjustment could also reflect the risks posed by the possible need for the sovereign to step in to support policy banks, to honor a contractual obligation or for another reason.

» In cases where we consider the risk of a banking crisis to be magnified and imminent, the Banking Sector Risk sub-factor score may also incorporate scenario analysis of sovereign contingent liabilities arising from the banking sector that could crystallize onto the sovereign's balance sheet. For this scenario analysis, we consider the aggregate potential capital needs of all rated banks and extrapolate proportionally to the entire banking system as needed for countries with sizable unrated banks. This assessment may result in a downward notching adjustment.

How we assess it for the scorecard — External Vulnerability Risk sub-factor

While we incorporate multiple quantitative elements into our analysis of external vulnerability, our assessment of this sub-factor is primarily qualitative, based on the descriptions below, incorporating multiple dimensions into a single assessment. The country's current account position and its financing structure, the level and sustainability of its external liabilities, the presence of foreign exchange reserves and the overall capacity to access hard currency are the main considerations. For some sovereigns, environmental risk may also be a consideration, for instance, where the transition to a low-carbon economy increases external vulnerability risk. For a particular issuer, the interplay among these risks and mitigants is often very specific, and we consider them holistically to arrive at an overall assessment.

Current Account Balance and How It Is Financed

We consider the current account position and the financing structure of any current account deficit. Considerations include the size and track record of current account surpluses or deficits relative to GDP, the composition of external financing and the level of diversification of the economy's export base.

» **Current account balance.** Our forward-looking expectation for the current account balance (CAB), based on the track record and our assessment of change drivers, often serves as the primary anchor in assessing external vulnerability. The CAB records all cross-border transactions between residents and non-residents, including exports and imports of goods and services, unilateral transfers (such as official grants and worker remittances), and flows of dividend and interest payments on foreign assets and liabilities. The CAB is positive if receipts from abroad exceed payments, and it is negative if the reverse is the case. Hence, the CAB (when in deficit) gives an approximate indication of the external position — how much net import of capital from the rest of the world a country requires to close the gap between domestic savings and investments. During times of weaker risk appetite, large current-account deficits can increase a country's vulnerability to sudden stops in foreign financing, with disruptive consequences for the overall economy.
We consider a structurally strong external position, demonstrated by a current account that is consistently balanced or in surplus, a credit strength. Conversely, large and persistent current-account deficits indicate a credit-negative structural imbalance — for example, structural features of the economy that constrain saving or competitiveness — and would typically lead us to consider assigning a low score for this sub-factor.

» **Financing of the external position.** How a current account deficit is financed is very meaningful to assessing the risk to the sovereign posed by a current account deficit. Financing a current account deficit through portfolio or similar flows, which are typically short-term and can be volatile, exposes the economy to shifts in international investor sentiment. Foreign Direct Investment (FDI) is generally a more stable source of external financing and less prone to sudden stops, and reliance on FDI to finance a current account deficit may indicate that the country has a combination of growth, stability and returns that are attractive to investors. Where current-account deficits are, for the most part, consistently financed by FDI inflows, the sub-factor score is typically higher than it would be if the sovereign's deficits were financed with debt.

» **Export base structure.** The diversification of the export base can be a distinguishing element in our assessment. A sovereign with an economy where a high share (typically about half) of total goods and services exports is driven by a single commodity, or by multiple commodities whose prices are largely correlated, has higher vulnerability to terms of trade shocks and significant fluctuations in the current-account balance and would typically receive a lower score for this sub-factor. Conversely, a high degree of export diversification can provide shock absorption, and would typically provide some uplift to our assessment of this sub-factor.

External Debt Sustainability

We consider the economy's stock of external liabilities and its ability to sustain them. Metrics informing this aspect of our assessment may include the ratio of gross external debt to current account receipts, the net international investment position (NIIP),[17] and the composition of overall foreign liabilities.

In our assessment, we consider both the ratio of gross external debt to current account receipts as well as the NIIP relative to GDP. Both are indicators of the sustainability of the country's current account balance and the potential for balance-of-payments stresses to emerge. We typically assign a lower score to sovereigns with a high level of external liabilities, particularly if a large share is composed of short-term debt obligations that result in very high external refinancing needs.

However, we also consider the level of economic resilience — the intrinsic strength of the economy and institutions — as a key mitigant. Economies with very high levels of economic resilience are typically able to support a higher external debt load, even during times of economic or financial shock. This resilience may reflect a general attractiveness to investors, strong institutions and policy frameworks, positive demographic trends and an educated workforce, deep and liquid financial markets, and sustained economic potential. As a result, these countries typically receive the highest score for this sub-factor. Conversely, countries with moderate or low economic resilience are typically more susceptible to external shocks and the risks associated with a higher level of external debt, and typically receive lower scores for this sub-factor.

Foreign Exchange Reserves and Other Resources

We consider the economy's ability to repay external debt and its ease of access to hard currency. Countries hold foreign-exchange reserves in part as a buffer against current and capital account shortfalls. In general, countries with high external debt obligations relative to foreign reserves are particularly at risk of an external crisis.

In our external vulnerability assessment, we primarily consider reserve adequacy through the external vulnerability indicator (EVI) ratio, which provides an important indication of a sovereign's capacity to use immediately available international reserves to make debt payments, even if there is a complete refusal of creditors to roll over debt that is due within a given year. The ratio is defined as the stock of official foreign exchange reserves at the end of year t-1 as the denominator, and the residual maturity short-term debt (including original maturity short-term debt and principal payments on long-term debt) falling due in year t in the numerator. Also included in the numerator are deposits in domestic banks by non-residents with a maturity greater than one year (those below one year are already included as part of short-term debt). This is included because, in a general run on the currency, depositors may attempt to withdraw longer-term deposits even if they have to pay a penalty to do so. The EVI thus measures the capacity to withstand a (temporary) loss of investor confidence resulting from heightened risk perception or a general liquidity squeeze.

A high ratio, particularly one exceeding 100%, can be a signal of vulnerability, resulting either from excessive short-term debt, large upcoming repayments on long-term debt, or insufficient reserves. A country with a high EVI or one where we assess that strains on the ability of the government or private sector to service external debt are otherwise evident would typically receive a low score for this sub-factor. Membership in a currency union in which the convertibility of the union's currency is guaranteed by a strong external guarantor can limit external vulnerability. In such cases, the EVI would typically be calculated at the level of the monetary union — if all member countries' foreign exchange reserves are pooled — instead of the country level. We also consider other mitigants to external debt repayment risk such as currency composition or presence of large intercompany debt. A large share of external debt in local currency typically weighs positively in our scoring of the sub-factor, and we typically consider that intercompany debt and trade credits carry less repayment risk because they can be more easily rolled over. As an additional mitigant, in scoring this sub-factor, we also take into account the availability of highly liquid foreign-currency denominated government financial assets that could be deployed to support the country's balance of payments in a stress scenario.

Our assessment of external vulnerability typically focuses on the economy as a whole. However, where external debt composition varies significantly across sectors, we may also focus on external risk for sectors that are important to the economy. We may also consider import coverage, i.e., the number of months of imports that can be covered with immediately available foreign-exchange reserves.

Not all countries need to hold reserves to the same extent. For advanced economies, we may consider the country's ability to draw on resources beyond reserve buffers to repay external debt, including reliable access to foreign exchange markets. The availability and adequacy of other means of access to hard foreign currency, and the country's role in the global financial system, may also be important considerations in our assessment. A track record of deep and resilient access to funding markets, including the foreign-exchange swap market, is credit positive and can lead to higher scores for this sub-factor. Countries with a local currency benefiting from a reserve status typically receive the highest score.

Adjustment to the External Vulnerability Risk sub-factor score

OTHER:

We may adjust the sub-factor score based on considerations that are not fully captured by the considerations listed above. The adjustment can be upward or downward and is limited to two scoring categories.

Other considerations

Ratings may reflect consideration of additional factors that are not in the scorecard, usually because the factor's credit importance varies widely among the issuers in the sector or because the factor may be important only under certain circumstances or for a subset of issuers. Such factors include our assessment of regulatory, litigation, liquidity, technology and reputational risk.

Following are some examples of additional considerations that may be reflected in our ratings and that may cause ratings to be different from scorecard-indicated outcomes.

Partial Guarantees

The credit quality of sovereign debt may benefit from partial guarantees extended by another entity, often by another sovereign or multilateral development bank. This entity may partially guarantee debt instruments issued by the sovereign in order to lower the interest rate or otherwise improve the terms and conditions. The guarantee is partial if it covers a portion of the debt issuance rather than the full amount. We consider that such guarantees materially reduce credit risk only in cases where the guarantor has a higher rating than the sovereign.

Where a higher-rated entity provides a direct partial guarantee[18] for a sovereign's bond issuance, the difference in the expected loss on the enhanced instrument relative to the expected loss on an unsupported instrument informs our assessment of the extent, if any, to which the rating of the enhanced instrument may be notched up from the sovereign's unenhanced debt rating. For the purposes of considering partial guarantees for sovereigns, and on the basis of broad historical average loss experience at various horizons, a one-notch downward movement on the alphanumeric rating scale can be thought of as generally implying an average 60% increase in expected losses for investment-grade ratings (Aaa – Baa3) and generally implying an average 40% increase in expected losses for non-investment-grade ratings (Ba1 and lower). The impact of the partial guarantee on expected loss depends on the coverage it provides of future debt payments (the percentage of principal or interest or both) and the rating of the entity providing the partial guarantee. The impact of the partial guarantee is typically informed by the 10-year Moody's Idealized Cumulative Loss Rates associated with the rating level of the guarantor, for the guaranteed portion, and the unenhanced rating or equivalent of the sovereign for the unguaranteed portion. Where the coverage is high and the credit profile of the guarantor is substantially stronger than the unenhanced credit profile of the sovereign, the uplift could be material because it would reflect the reduced expected loss on the relevant instrument.

Official Sector Debt Relief with Private Sector Involvement

In the Fiscal Strength factor section, we discuss some of the considerations that may arise from a sovereign's participation in official sector debt relief. We also assess the risk of private-sector involvement, e.g., that private sector creditors such as bondholders and banks may effectively be required to offer similar terms of debt relief to the sovereign, which typically constitutes a distressed exchange or other type of default (see *Rating Symbols and Definitions*).[19] In these cases, the sovereign's issuer rating incorporates our assessment of the risk of private-sector participation in debt relief and the likely extent of loss in the event of inclusion. For clarity, these considerations typically do not apply where debt relief is exclusively offered by the official sector with no risk of private-sector involvement.

Special Considerations for Central Banks

Because a central bank's credit profile is typically inextricably intertwined with that of the government and therefore influenced by the same credit fundamentals, issuer-level and instrument-level ratings assigned to a central bank typically correspond to those of the central government. In assigning a central bank rating, we consider the central bank's institutional setup, as well as relationship between the sovereign and the central bank and their overall alignment.

In evaluating a regional central bank, we consider the credit strength of each sovereign that is a member. Our analysis of a regional central bank is also informed by its institutional setup, which includes the ownership percentage of the central bank's shareholders or members. We often focus on the central bank's strongest shareholders and their ability to support, typically indicated by their rating or credit profile; however, the relative importance, or weighting, of each shareholder's credit profile depends upon the individual circumstances of the regional central bank. For example, we typically consider the central bank's economic importance in the region, the financial resources available to it and any specific institutional arrangements with supporting members and non-members.

A regional central bank's rating is typically constrained by the relevant currency ceiling of the strongest shareholder.

Additional Metrics

The metrics included in the scorecard are those that are generally most important in assigning ratings to sovereigns; however, we may use additional metrics to inform our analysis of specific sovereigns. These additional metrics may be important to our forward view of metrics that are in the scorecard or other rating factors.

Using the scorecard to arrive at a scorecard-indicated outcome range

1. Measurement or estimation of factors in the scorecard

In the "Discussion of the scorecard factors" section, we explain our analytical approach for scoring each scorecard sub-factor, sub-sub-factor or metric,[20] and we describe why they are meaningful as credit indicators. We explain how we generally calculate or estimate each metric for use in the scorecard and the weighting for each individual sub-factor, sub-sub-factor indicator or metric.

The information used in assessing the sub-factors is generally drawn from a number of international sources, including the International Monetary Fund, the Organisation for Economic Co-operation and Development, the European Commission, the World Bank, and the Bank for International Settlements. Some indicators, however, particularly in the area of government and external debt, may be estimated by Moody's analysts using data provided by national statistical sources. We may also incorporate non-public information.

Our ratings are forward-looking and reflect our expectations for future financial performance. However, historical results are helpful in understanding patterns and trends of a sovereign issuer's performance as well as for peer comparisons. Financial metrics, unless otherwise indicated, are typically calculated based on a historical period (an annual period unless otherwise specified in the "Discussion of the scorecard factors" section). However, the factors in the scorecard can be assessed using various time periods. For example, rating committees may find it analytically useful to examine both historical and expected future performance for periods of several years or more. We also incorporate our views on the future trend of key financial metrics. These trends can lead to adjustments to the sub-factors; upward if we expect a sovereign issuer's financial indicators to materially improve from their historic trend in the coming years or downward if the reverse holds true. We also explain other adjustments we may make in assigning scores.

2. Assigning sub-factor and factor scores and mapping to a numeric score

Qualitative sub-factors are scored based on the description in the scorecard and are mapped to a broad Moody's rating category (aaa, aa, a, baa, ba, b, caa or ca) and to a numeric score based on the scale below.

Exhibit 14

Assigning sub-factor and factor scores

aaa	aa	a	baa	ba	b	caa	ca
1	3	6	9	12	15	18	20

Source: Moody's Investors Service

Quantitative factors are scored on a linear continuum. For each metric, the scorecard shows the range by alphanumeric category. We use the scale below and linear interpolation to convert the metric, based on its placement within the scorecard range, to a numeric score, which may be a fraction. As a purely theoretical example, if there were a ratio of revenue to short-term debt for which the baa1 range was 5x to 5.5x, then the numeric score for an issuer with revenue/short-term debt of 5.4x, relatively strong within this range, would score closer to 7.5, and an issuer with revenue/short-term debt of 5.1x, relatively weak within this range, would score closer to 8.5. In the text or table footnotes, we define the endpoints of the line (i.e., the value of the metric that constitutes the lowest possible numeric score, and the value that constitutes the highest possible numeric score).

Exhibit 15
Scoring scale

Alphanumeric score	Numeric score
aaa	$x \leq 1.5$
aa1	$1.5 < x \leq 2.5$
aa2	$2.5 < x \leq 3.5$
aa3	$3.5 < x \leq 4.5$
a1	$4.5 < x \leq 5.5$
a2	$5.5 < x \leq 6.5$
a3	$6.5 < x \leq 7.5$
baa1	$7.5 < x \leq 8.5$
baa2	$8.5 < x \leq 9.5$
baa3	$9.5 < x \leq 10.5$
ba1	$10.5 < x \leq 11.5$
ba2	$11.5 < x \leq 12.5$
ba3	$12.5 < x \leq 13.5$
b1	$13.5 < x \leq 14.5$
b2	$14.5 < x \leq 15.5$
b3	$15.5 < x \leq 16.5$
caa1	$16.5 < x \leq 17.5$
caa2	$17.5 < x \leq 18.5$
caa3	$18.5 < x \leq 19.5$
ca	$19.5 < x \leq 20.5$
c	> 20.5

Source: Moody's Investors Service

Each numeric score for quantitative metrics and qualitative sub-factors or sub-sub-factors within the first three factors of the scorecard (Economic Strength, Institutions and Governance Strength, Fiscal Strength) is multiplied by the weight for that sub-factor (or sub-sub-factor), and the products are summed and rounded to the nearest integer to arrive at the initial numeric factor score, which can be mapped to an alphanumeric score using the table in Exhibit 15. The initial factor score may be adjusted upward or downward by a defined number of scoring categories, based on the "other" adjustments to factor score described in the "Discussion of the scorecard factors" section, to arrive at a final factor score.[21] For these first three factors, an adjustment of one in the scorecard corresponds to an adjustment by one alphanumeric scoring category (e.g., from baa2 to baa3 or from a2 to a1).

For the last factor, Susceptibility to Event Risk, the initial sub-factor scores may be adjusted. For these sub-factors, an adjustment of one corresponds to an adjustment by one alpha scoring category (e.g., from aa to a or from ba to baa). The combination of adjusted sub-factor scores in the Susceptibility to Event Risk factor is based on a minimum function, i.e., the initial factor score corresponds to the lowest alpha score (highest risk) of the four sub-factors within the factor. The initial factor score may be adjusted upward or downward by a defined number of alpha scoring categories.

3. Combining factors and determining the overall scorecard-indicated outcome

We combine, using equal weights, the Economic Strength and Institutions and Governance Strength factors to arrive at the Economic Resiliency score, which is rounded to the nearest integer, and the resulting numeric score can be mapped to an alphanumeric based on the scoring scale in Exhibit 15 We then combine the numeric Economic Resiliency with the numeric Fiscal Strength factor score using variable weights (see Exhibit 10) to arrive at a numeric Government Financial Strength value, which can be mapped to an alphanumeric based on the scoring scale in Exhibit 15.

The final step combines the Susceptibility to Event Risk factor with Government Financial Strength as detailed in Exhibit 11 to arrive at an alphanumeric that is the midpoint of the scorecard-indicated outcome, which is expressed as a three-notch range on our alphanumeric scale.

Assigning issuer-level and instrument-level ratings and distinguishing between local and foreign currency ratings

After considering the scorecard-indicated outcome, other rating considerations and relevant cross-sector methodologies, we may assign a senior unsecured debt rating, an issuer rating that usually corresponds to the senior unsecured debt rating, or both. In cases where a sovereign issues debt instruments other than senior unsecured debt, individual debt instrument ratings may be notched upward or downward from the senior unsecured rating to reflect our assessment of any differences in expected loss arising from an instrument's seniority and any collateral. Collateral is considered only where it would meaningfully lower creditors' loss upon default. Given sovereigns' broad powers, such collateral would typically need to be held offshore.

We may also assign issuer-level and instrument-level ratings to the central bank.

We also use this methodology to rate asset-based sukuk instruments where we conclude, based on the terms and conditions of the financing documents, that a sukuk instrument represents an obligation equivalent to a senior unsecured obligation of the sovereign.

We may also assign short-term ratings based on our methodology for assigning short-term ratings.[22]

Our rating approach typically does not differentiate between obligations in local currency and foreign currency. In rare cases, we may differentiate ratings of those obligations where there is (i) limited capital mobility; and (ii) the government faces constraints in terms of external liquidity, or, in exceptional cases, shows a material and observable distinction between its ability and willingness to repay creditors in local currency versus foreign currency (which could lead to lower ratings for foreign currency obligations), or vice versa (i.e., in very exceptional cases the foreign currency obligations could be rated higher than the rating of local currency obligations). The magnitude of any notching in favor of local currency obligations depends on the severity of the external liquidity constraint. Any difference of more than two notches would be very rare.

Even if these two necessary conditions are met, we would differentiate ratings only where we consider that these conditions will persist. If in our view these conditions could evolve over the foreseeable future we may not differentiate ratings, for instance if the government were likely to open up the capital account of the balance of payments, or if the country's external position were likely to improve considerably.

Key rating assumptions

For information about key rating assumptions that apply to methodologies generally, please see *Rating Symbols and Definitions*.[23]

Limitations

In the preceding sections, we have discussed the scorecard factors and many of the other considerations that may be important in assigning ratings. In this section, we discuss limitations that pertain to the scorecard and to the overall rating methodology.

Limitations of the scorecard

There are various reasons why scorecard-indicated outcomes may not map closely to actual ratings.

The scorecard in this rating methodology is a relatively simple reference tool focused on indicators for relative credit strength. Credit loss and recovery considerations, which are typically more important as an issuer gets closer to default, may not be fully captured in the scorecard. The scorecard is also limited by its upper and lower bounds, causing scorecard-indicated outcomes to be less likely to align with ratings for issuers at the upper and lower ends of the rating scale.

The weights for each sub-factor and factor in the scorecard represent an approximation of their importance for rating decisions across the sector, but the actual importance of a particular factor may vary substantially based on an individual issuer's circumstances.

Factors that are outside the scorecard, including those discussed above in the "Other considerations" section, may be important for ratings, and their relative importance may also vary from issuer to issuer. In addition, certain broad methodological considerations described in one or more cross-sector rating methodologies may be relevant to ratings in this sector.[24] Examples of such considerations include the following: the relative ranking of different classes of debt and hybrid securities, and the assignment of short-term ratings.

We may use the scorecard over various historical or forward-looking time periods. Furthermore, in our ratings we often incorporate directional views of risks and mitigants in a qualitative way.

General limitations of the methodology

This methodology document does not include an exhaustive description of all factors that we may consider in assigning ratings in this sector. Institutions in the sector may face new risks or new combinations of risks, and they may develop new strategies to mitigate risk. We seek to incorporate all material credit considerations in ratings and to take the most forward-looking perspective that visibility into these risks and mitigants permits.

Ratings reflect our expectations for an issuer's future performance; however, as the forward horizon lengthens, uncertainty increases and the utility of precise estimates, as scorecard inputs or in other rating considerations, typically diminishes. Our forward-looking opinions are based on assumptions that may prove, in hindsight, to have been incorrect. Reasons for this could include unanticipated changes in any of the following: the macroeconomic environment, general financial market conditions, sector competition, disruptive technology or regulatory and legal actions. In any case, predicting the future is subject to substantial uncertainty.

Moody's related publications

Credit ratings are primarily determined through the application of sector credit rating methodologies. Certain broad methodological considerations (described in one or more cross-sector rating methodologies) may also be relevant to the determination of credit ratings of issuers and instruments. A list of sector and cross-sector credit rating methodologies can be found here.

For data summarizing the historical robustness and predictive power of credit ratings, please click here.

For further information, please refer to *Rating Symbols and Definitions*, which is available here.

Authors:

Dietmar Hornung

Matt Robinson

Daniel Marty

Laura Barrientos

Endnotes

1 We may also assign local and foreign currency country ceilings for bonds and other obligations in order to facilitate the assignment of ratings to issuers domiciled in the country or structured finance transactions whose cash flows are primarily generated from domestic assets or residents. For more information on ceilings, please see the cross-sector methodology that describes our approach for assigning local and foreign currency country ceilings for bonds and other obligations. A link to a list of our cross-sector methodologies and a link to *Rating Symbols and Definitions* can be found in the "Moody's related publications" section.

2 In our methodologies and research, the terms "scorecard" and "grid" are used interchangeably.

3 For more information on issuer profile scores, see our cross-sector methodology that discusses ESG considerations and *Rating Symbols and Definitions*. A link to *Rating Symbols and Definitions* and to a list of our sector and cross-sector methodologies can be found in the "Moody's related publications" section.

4 For simplicity, we may use the terms *factor* or *sub-factor scoring* interchangeably in this methodology to refer to scoring at the factor, sub-factor, metric or sub-sub-factor level.

5 An international dollar is a hypothetical unit of currency that has the same purchasing power in a given country as the US dollar has in the US in a given year.

6 A downward notching adjustment decreases the Economic Strength alphanumeric equivalent factor score (e.g., from baa1 to baa2) and increases the corresponding numeric score. An upward notching adjustment increases the Economic Strength alphanumeric equivalent factor score (e.g., from baa2 to baa1) and decreases the corresponding numeric score.

7 For more details on the perimeter of government debt, please see the "Factor: Fiscal Strength" section.

8 The structural budget is an estimate of the nominal budget balance adjusted by the cyclical component, excluding one-off and temporary policy measures.

9 A deflationary environment also reflects adversely on a central bank's capabilities. Deflationary developments typically coincide with subdued or negative real growth and an increase in the debt-to-GDP ratio.

10 Macroprudential tools are used to regulate and mitigate risk to the financial or banking system as a whole rather than to its individual components and are thereby designed to reduce the risk and the macroeconomic costs of financial instability. Examples of such tools include leverage limits for lending to households, or minimum capitalization levels. Macroprudential tools are by nature preventative rather than resolution or crisis tools.

11 Metrics within the Debt Burden and Debt Affordability sub-factors are equally weighted.

12 Metrics within the Debt Burden sub-factor are equally weighted.

13 For more details, please refer to the "Treatment of reserve currency countries and HIPC/IDA countries" section.

14 The Gini index is a statistical measure of distribution of a value (here, income) within a population.

15 With a few exceptions, including some commodity exporter governments, the bulk of government revenues are in local currency.

16 Affiliate includes a parent, cooperative groups and significant investors (typically with a greater than 20% voting interest). Government includes local, regional and national governments. For more information about Baseline Credit Assessments, please see our methodology that discusses banks and *Rating Symbols and Definitions*; a link to this publication and to a list of sector and cross-sector methodologies can be found in the "Moody's related publications" section.

17 The difference between the market value of a country's foreign financial assets and that of its liabilities.

18 Where a higher-rated entity provides a full guarantee for another entity's bond issuance, the security is typically rated using our cross-sector methodology that discusses credit substitution. A link to a list of our sector and cross-sector methodologies can be found in the "Moody's related publications" section.

19 A link to *Rating Symbols and Definitions* can be found in the "Moody's related publications" section.

20 When a factor comprises sub-factors, we score at the sub-factor level, or, in cases where the sub-factor comprises sub-factor indicators, at the sub-factor indicator level.

21 In Fiscal Strength, for the Debt Trend, General Government Foreign Currency Debt, Other Non-Financial Public Sector Debt, and Government Financial Assets including Sovereign Wealth Funds adjustments, the indicated adjustments are based on quantitative indicators as described in the "Discussion of the scorecard factors" section and are included in the initial score. Qualitative judgment applied to these adjustments as well as any "other" adjustment applied to the initial Fiscal Strength factor score results in the final Fiscal Strength factor score.

22 A link to a list of our sector and cross-sector rating methodologies can be found in the "Moody's related publications" section.

23 A link to *Rating Symbols and Definitions* can be found in the "Moody's related publications" section.

24 A link to a list of our sector and cross-sector methodologies can be found in the "Moody's related publications" section.

This publication does not announce a credit rating action. For any credit ratings referenced in this publication, please see the issuer/deal page on https://ratings.moodys.com for the most updated credit rating action information and rating history.

REPORT NUMBER 1346995

Annex 594

“The role of insurers in tackling climate change: challenges and opportunities”, *The Eurofi Magazine*, 2023, page 176

CLIMATE CHANGE INSURANCE NEEDS

PETRA HIELKEMA
Chairperson - European Insurance and Occupational Pensions Authority (EIOPA)

The role of insurers in tackling climate change: challenges and opportunities

Climate change is a global challenge posing material risks to society and the economy. Its consequences are becoming more and more apparent particularly on physical risk exposures, for instance in terms of increasing frequency and severity of natural disasters, such as floods, droughts or wildfires. Regarding Europe, EIOPA's dashboard on the insurance protection gap for natural catastrophes shows that currently only around a quarter of the total economic losses caused by extreme weather and climate-related events are insured, leading to a substantial insurance protection gap. The insurability and pricing of climate-related risks become increasingly critical concerns for insurers and policymakers, and if no countermeasures are taken, the protection gap is expected to widen.

The expected growth in physical risk exposures and insurance claims due to climate change will increase risk-based premium levels over time, potentially impairing the mid- to long-term affordability and availability of insurance products with coverage against climate-related hazards. Moreover, the increased frequency and severity of natural disasters associated with climate change can make it more difficult for insurers to predict the likelihood of future losses accurately and to price insurance products appropriately. In this context, EIOPA will regularly re-assess the appropriateness of the requirements of the standard formula regarding natural catastrophe risk, and if necessary, provide suggestions for potential changes in Solvency II.

The insurance industry has a unique role to play in addressing climate change by making society and the economy more climate resilient. Insurers can develop innovative insurance products that incentivize climate-related risk prevention, for instance through offering lower premiums to policyholders implementing climate-related adaptation measures. Such measures, like anti-flood doors or early warning systems, can reduce the policyholder's physical risk exposures and insured losses. Adaptation measures can therefore be a key tool to maintain the future supply of insurance products with coverage against climate-related hazards and help reduce the climate-related insurance protection gap in Europe.

Insurers play a critical role through innovative products incentivising climate risk prevention.

With its concept of impact underwriting, EIOPA aims to foster the development and discussion about insurance products implementing climate-related adaptation measures in Europe. To better understand the industry's current underwriting practices regarding climate change adaptation, EIOPA conducted a pilot exercise with volunteering insurance undertakings in 2022. EIOPA found that progress is being made to increase policyholder resilience against climate change by implementing dedicated adaptation measures in insurance products and offering premium-related incentives, but the overall EU insurance market still appears to be at a relatively early stage.

EIOPA sees further room for improvement especially regarding standardising the implementation of climate-related adaptation measures in insurance contracts, for instance through dedicated risk-based certificates and programs. In its discussion paper on the prudential treatment of sustainability risks, EIOPA outlines regarding underwriting activities the framework to analyse the potential for a dedicated prudential treatment of climate-related adaptation measures in the solvency capital requirements for non-life underwriting risk.

While climate change is a growing risk for the insurance industry, it also creates opportunities. By taking a proactive approach to risk management, insurers can not only protect policyholders from losses but also ensure the long-term availability of insurance products and reduce the overall cost of insurance. It is however important to highlight that reaching the objective of adapting the society and economy appropriately to climate change requires further accompanying actions beyond the scope of the insurance industry, for instance in terms of developing and enforcing public building codes reflecting the dynamics of climate change appropriately. Besides considering Public-Private-Partnerships, public actors can also engage in improving the collection and sharing of climate-related loss data and raising awareness about climate change, thereby encouraging insurers and policyholders to adapt to climate change.

By working together, public and private actors can improve the overall understanding of climate-related risks and promote a more sustainable and resilient future. To foster climate change adaptation in the EU, EIOPA will continue its work on impact underwriting, including to raise the public awareness about climate risks and related prevention measures as well as promoting the use of open-source modelling and data.

Annex 595

"Natural catastrophes and inflation in 2022: a perfect storm", *Swiss Re Institute*, 2023

Swiss Re Institute

No 1/2023

sigma

Natural catastrophes and inflation in 2022: a perfect storm

Executive summary

In 2022, insurance covered about 45% of the USD 275 billion in global economic losses resulting from natural catastrophes.

Property catastrophe re/insurance rates rose to close to 20-year highs in the January 2023 renewals, continuing a trajectory that began in 2018. Demand for covers has grown as natural disasters continue to wreak property damage across the world. Natural disasters resulted in global economic losses of USD 275 billion in 2022, of which USD 125 billion were covered by insurance, the fourth highest one-year total on *sigma* records. Beyond the natural catastrophes themselves, other factors such as the impacts of economic inflation and financial market losses have also fed into market hardening. An additional contributing factor has been the need for more discipline in the modelling and underwriting of secondary perils in particular. This has led to mismatches of risk assessment and actual exposures and, in turn, insufficient market capacity.

Last year's outcome reaffirms the long-term growth trend of 5–7% in annual insured losses.

The re/insurance rate gains of recent years coincide with a trend period of heightened natural catastrophe activity and elevated losses that started in 2017. The 2022 insured loss outcome reaffirms a 5–7% annual growth trend in place since 1992, this based mostly on rising severity of losses resulting from primary and secondary peril events. Today average annual insured losses of more than USD 100 billion are standard. The biggest loss event in 2022 was Hurricane Ian (estimated insured loss of USD 50–65 billion). Other large-loss events were floods in Australia and South Africa, hail in France, winter storms in Europe, and heatwaves in Europe, China and the Americas.

Economic factors remain the main driver of rising losses. In 2021–22, high inflation rates increased the value of insured assets.

Rather than the physical destructive force of natural catastrophes themselves, the main driver of resulting high losses are economic growth, accumulation of asset values in exposed areas, urbanisation and rising populations, often in regions susceptible to natural perils. We expect that these and the evolution of a range of present-day risk factors like climate change effects and, of late, inflation, will continue to drive losses higher. Economic inflation has surged over the last two years, averaging 7% in the advanced markets and 9% in the emerging economies in 2022. Initially sparked by pandemic-induced supply chain disruptions and large monetary and fiscal stimuli, soaring food and energy prices due to the war in Ukraine have compounded inflation pressures. The effect of high prices has been to increase the nominal value of buildings, vehicles and other insurable assets, in turn pushing up insurance claims for damage caused by mother nature. The impact has been most immediate in the construction sector. Increases in the costs for materials and labour because of shortages thereof have led to higher claims to cover the costs of building repairs. In the US, for example, the aggregate replacement cost of buildings in 2022 had risen by an estimated 40% since the start of 2020.

The 2022 catastrophes were driven by known risk factors, yet losses high.

Rising natural catastrophe losses and shortfalls in industry estimates of those losses point to the need for better understanding of all the risk drivers at play. The re/insurance industry has long monitored primary perils but this has not always been the case for secondary perils, the associated losses of which have been rising for many years. There is a need for greater discipline in the monitoring of the loss-driving secondary peril exposures and industry sharing of related findings. Lack of granular exposure data can also hinder understanding of all present-day risks. For instance, the increase in built-up land area and changes to the vulnerability of homes to hazards (eg, more solar panels on roof tops) are difficult to keep track of. The fast rate of change of such variables necessitates shorter update cycles of data sets and models, to mitigate risk accumulation and underestimation of loss trends.

Uncertainties around risk trends are constraining industry capacity. This will underpin continuation of hard re/insurance market conditions.

We expect the hard market in re/insurance to continue, based on increased demand for coverage and because of inflation-driven higher values of insured assets. Current supply-side stresses also underpin the hard market. For one, industry capital has fallen in response to rising interest rates. Adding to capacity shortages, six years of weak results in property underwriting have reduced risk appetite. In the face of higher financing costs given interest rate rises, some capacity providers have become more cautious with respect to the potential for misalignment of risk assessment and loss experience. In our view, as higher exposures encounter shrinking risk appetite, momentum for rising prices, higher retentions and tighter terms and conditions will likely continue.

Key takeaways

2022 in a nutshell: insured losses well above the 10-year average

Economic losses

Total
USD 284 billion*

2021: USD 303 bn
10-year average: USD 220 bn

Natural catastophes
USD 275 bn

Man-made
USD 9 bn

0.27%
of global GDP

10-year average: 0.23%

*Ranks 16th in terms of GDP -normalised economic losses from natural catastrophes since 1970

Insured losses

Total
USD 132 billion

2021: USD 130 bn
10-year average: USD 91 bn

Natural catastophes
USD 125 bn

Man-made
USD 7 bn

6% of global property direct premiums written

10-year average: 4.6%

Natural catastrophe insured losses

Total
USD 125 billion

2021: USD 121 bn
10-year average: USD 81 bn

Secondary perils
USD 54 bn (43%)

2021: USD 77 bn

Primary perils
USD 71 bn (57%)

2021: USD 44 bn

Global protection gap

2021
USD 173 bn

2022
USD 151 bn

10-year average
USD 130 bn

Victims

>35 000

Catastrophe events

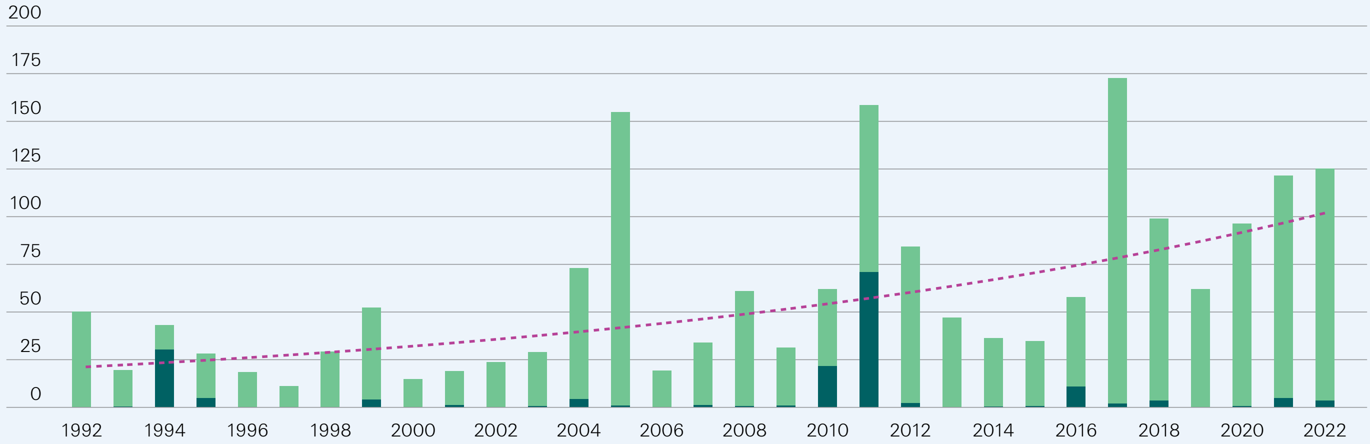
285

Source: Swiss Re Institute

Average annual growth trend of 5–7% in insured losses from natural catastrophes affirmed

Since 1992, insured losses have grown by 5–7% on an average annual basis. This includes the period 2012–16 when losses were at a lower annual mean. Irrespective of yearly volatility, insured losses will likely continue to grow at trend, even when real-time amplifying factors such as current high levels of inflation recede.

Growth in global natural catastrophe insured losses in USD billion (2022 prices)



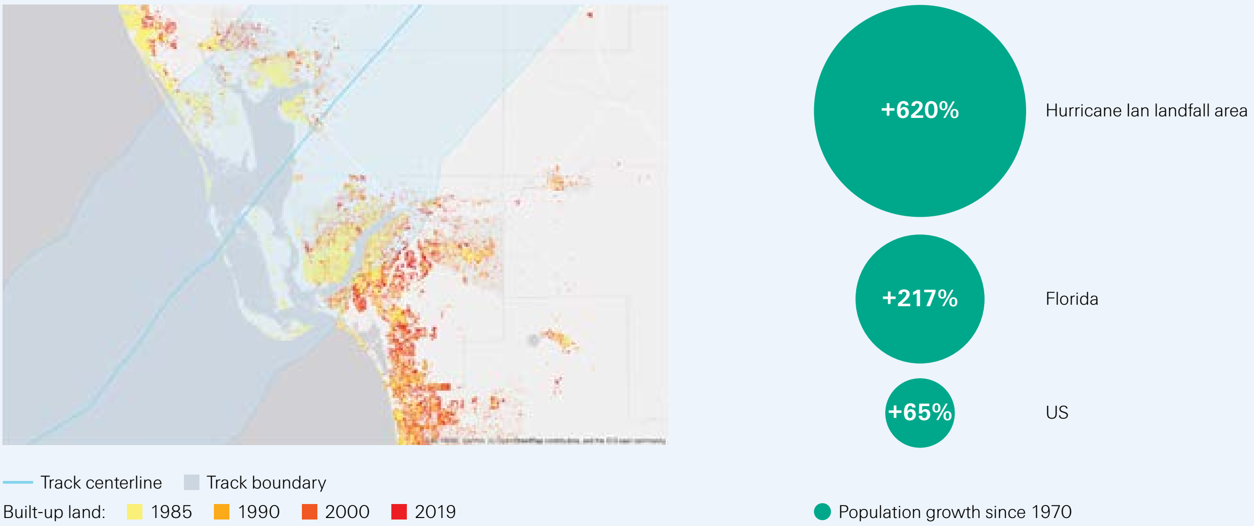
Earthquakes Weather-related Trend

Source: Swiss Re Institute

Location, location, location: one storm is all it takes

Last year was "average" in terms of hurricane activity in the North Atlantic. Even so, the 2022 hurricane season is third most costliest on *sigma* records. The reason is Hurricane Ian, which resulted in estimated insured losses of USD 50–65 billion. When Ian made landfall in western Florida as a category 4 storm, it hit an area that has seen rapid population growth, expansion of built areas and accumulation of physical assets. Since 1970, the population where the storm made landfall has increased by 620%, exceeding both the population increase in the state of Florida (+217%) and the entire US (+65%). Hurricane Ian demonstrates that location of landfall rather than number of storms, is the main driver of heavy loss burdens.

Changes in built-up land in the Ian landfall area (left) and population growth statistics (right)

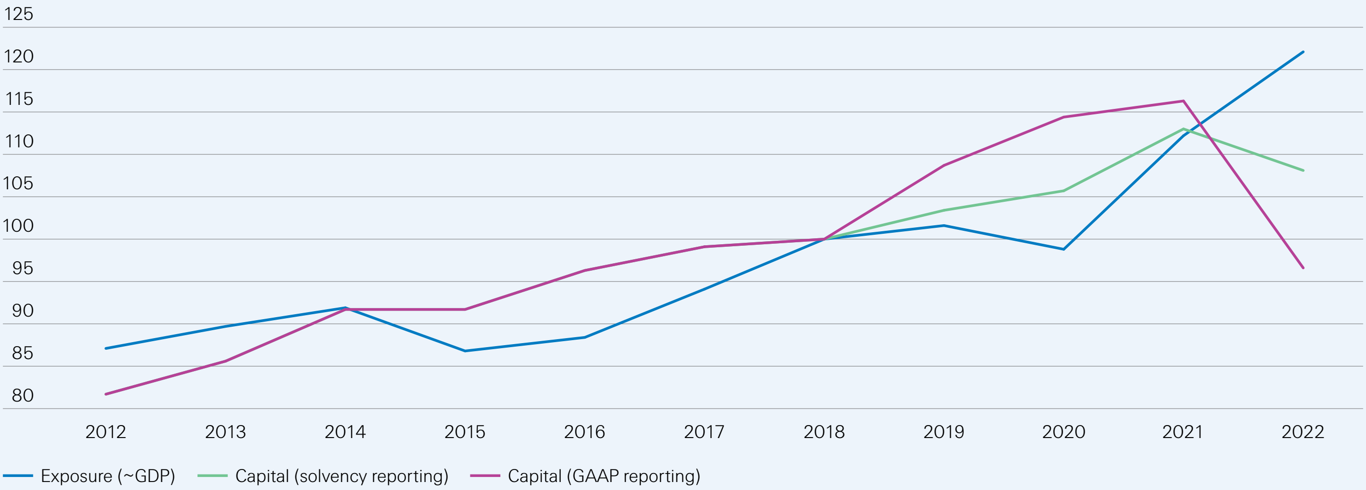


Source: German Aerospace Center, National Hurricane Center, US Census Bureau,Swiss Re Institute

Global reinsurance capital vs exposure growth: a mismatch that looks set to stay

Demand for coverage for natural disasters had risen on evidence of increased catastrophe activity, and because of higher insurable values of buildings and other fixed assets. At the same time, catastrophe claims pay outs have reduced the supply of re/insurance capital. Rising interest rates and lower financial asset values have also contributed to supply constraints. Risk appetite has further decreased due to poor property re/insurance underwriting results in recent years, and widely held perceptions that risk assessments are underestimating actual loss experience. This is leading to hesitation on the part of capital providers to commit new funds to re/insurance risks and replenish the industry capacity.

Global reinsurance capital vs exposure growth, 2018 = 100



Source: AM Best, Swiss Re Institute

In perspective: 2022 and longer-term trends

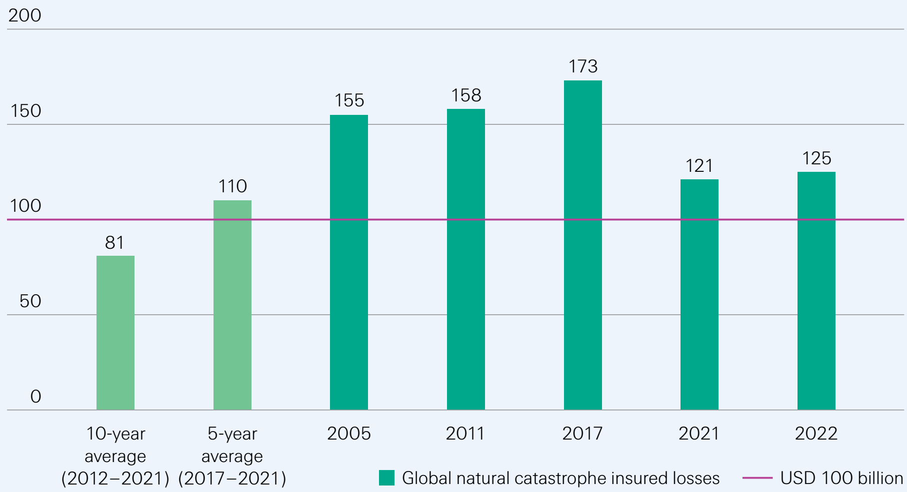
At USD 125 billion, global insured losses from natural catastrophes in 2022 are the fourth highest on *sigma* records. Each region of the world suffered a major event. Hurricane Ian was the year's biggest loss event, and ranks as the second-costliest insurance natural catastrophe loss ever on *sigma* records. Today, average annual industry losses from natural catastrophes of more than USD 100 billion are standard. Last year's outcome continued a run of seemingly elevated global insured losses since 2017 after a benign 2012–2016 period, reaffirming an average annual growth rate of 5–7% in losses in place since 1992. We expect this trend to continue, driven by growing loss severity on account of rising property and values-at-risk exposures, continued urban sprawl, economic growth and a backdrop of hazard intensification due to climate change effects.

Another year of above-average losses

Global insured losses from natural catastrophe events in 2022 were USD 125 billion.

Last year's natural catastrophe-related losses were, once again, high. Driven mostly by extreme weather events, global insured losses from natural disasters were USD 125 billion in 2022, well above the previous 5- and 10-year averages (USD 110 billion and USD 81 billion, respectively, inflation adjusted, see Figure 1). The losses were the fourth highest in any one year since 1970 (see Figure 21) and for first time ever, global insured losses exceeded USD 100 billion two years running (ie, in 2022 and 2021). The insured annual loss totals from natural catastrophes has surpassed the USD 100 billion-mark five times since 1970, and three times in the past six years (2017, 2021 and 2022). Economic losses of USD 275 billion point to a still large protection gap, with around 54% of the total losses uninsured. Though still large, this is less than the 61% average protection gap of the previous 10 years. Last year's main events hit areas of relatively higher insurance penetration, attesting to the fundamental value proposition of the industry to making households, businesses and institutions more resilient.

Figure 1
Global natural catastrophe insured losses, in USD billion at 2022 prices



Source: Swiss Re Institute

Hurricane Ian was the main loss event of the year.

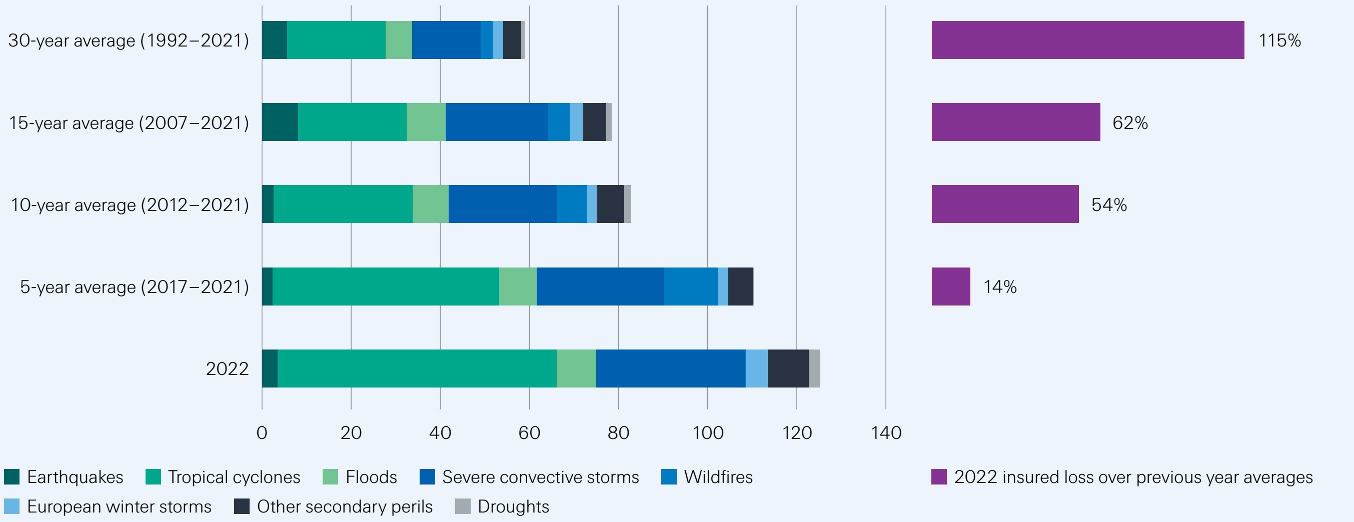
Hurricane Ian was the costliest event of 2022, resulting in estimated insured losses of USD 50 to 65 billion.[1] The category 4 hurricane made landfall in western Florida in September, bringing strong winds, torrential rain and storm surge. After Hurricane Katrina in 2005, Ian ranks as the second-costliest natural catastrophe insured loss event on *sigma* records. It pushed global insured losses from tropical cyclones above prior-period averages, making 2022 the third most expensive hurricane season on record after 2005 (Katrina, Wilma and Rita) and 2017 (Harvey, Irma and Maria).

[1] Includes National Flood Insurance Program (NFIP). The foregoing estimates are subject to uncertainty and may be subsequently adjusted as the claims notification and assessment process continues.

Flood and hailstorm events across the world also resulted in significant losses.

At over USD 33 billion, global insured losses from severe convective storms (SCS) were also above prior-period averages (see Figure 2), driven by thunderstorms with hail and tornadoes in the US. Another contributor was the highest-ever annual loss (USD 5 billion) from hailstorms in France. Global losses from floods were just above average, the main event being flooding in eastern Australia in February-March. The flooding resulted in insured losses of USD 4.3 billion, the biggest natural catastrophe claims event ever in Australia. Another national "costliest ever" event was flooding in Durban in South Africa in April, leading to estimated insured losses of USD 1.5 billion.

Figure 2
Global insured losses from natural catastrophes in 2022 by category, in USD billion at 2022 prices



Source: Swiss Re Institute

Losses from winter storms in Europe were above average.

After a few years with low loss-severity winter storms, in February 2022 a cluster of storms (Eunice, Dudley, Franklin) in northwestern Europe triggered combined claims of an estimated USD 4.1 billion, bringing the total for this category to almost double the previous 10-year average. Winds in winter storms are less severe than in tropical cyclones, but large parts of Europe can be impacted by a single storm, and damage in different locations can see combined losses accumulate to multi-billion levels.

Heatwaves and droughts led to crop yield losses in many regions.

At the opposite end of the temperature spectrum, weather variability and anomalous atmospheric circulation conditions caused severe drought and heatwaves across the world. Heat and drought impacted crop yields in many regions, adding to global food inflation pressures and elevated agriculture insurance losses. Table 1 shows the crop loss impacts in US dollar terms in select markets. In Europe, the summer of 2022 was the hottest on record.[2], [3] In Morocco, heat and dry conditions[4] coincided with a North Atlantic Oscillation phase of rainfall deficit.[5] In Brazil, monsoon rains were below average.[6] Crop yields, particularly for soybean and maize, suffered most.[7] Total precipitation across contiguous US in 2022 made the year the third driest on record,[8] and crops yield were lower than in 2021.[9] And in China, extreme heat and dry conditions in the Yangtze River and weak monsoon rains impacted summer crops.[10]

2 *Summer 2022 Europe's hottest on record*, Copernicus, 8 September 2022.
3 *Trockenheit in Europa 2022*, Deutscher Wetterdienst, July 2022
4 *Drought in western Mediterranean February 2022*, European Commission, 22 March 2022.
5 See *Climate Prediction Center*, National Weather Service.
6 See "Phases of the South American Monsoon System", *Climate Prediction Center*, Natl Weather Service
7 See *Crop Explorer – World Agricultural Production Briefs: Brazil*, Foreign Agriculture Service, USDA.
8 *Record drought gripped much of the US in 2022*, National Oceanic and Atmospheric Administration, 10 January 2023.
9 *Corn and soybean production down in 2022, USDA reports Corn stocks down, soybean stocks down from year earlier Winter Wheat Seedings up for 2023*, USDA, 10 January 2023.
10 "Scientific interpretation of severe drought in the Yangtze River Basin", *Journal of Arid Meteorology*, 2022.

Table 1
Insured crop losses due to drought in select markets, USD billion

Country	Economic losses	Insured losses
Brazil	13	1
Europe	6.2	0.6
China	4.7	0.8
Morocco	0.25	0.04

Source: CAN, PSR, Ministry of Emergency Management, Swiss Re

Wildfire-related losses were less than in recent years.

Waves of high temperatures in Europe also inflicted a heavy human toll: according to the WHO, a series heatwaves in Europe caused at least an estimated 15 000 excess deaths.[11] In spite of the heatwaves, one peril for which losses were below recent-year totals and historical averages were those for wildfire.

Longer-term loss trends

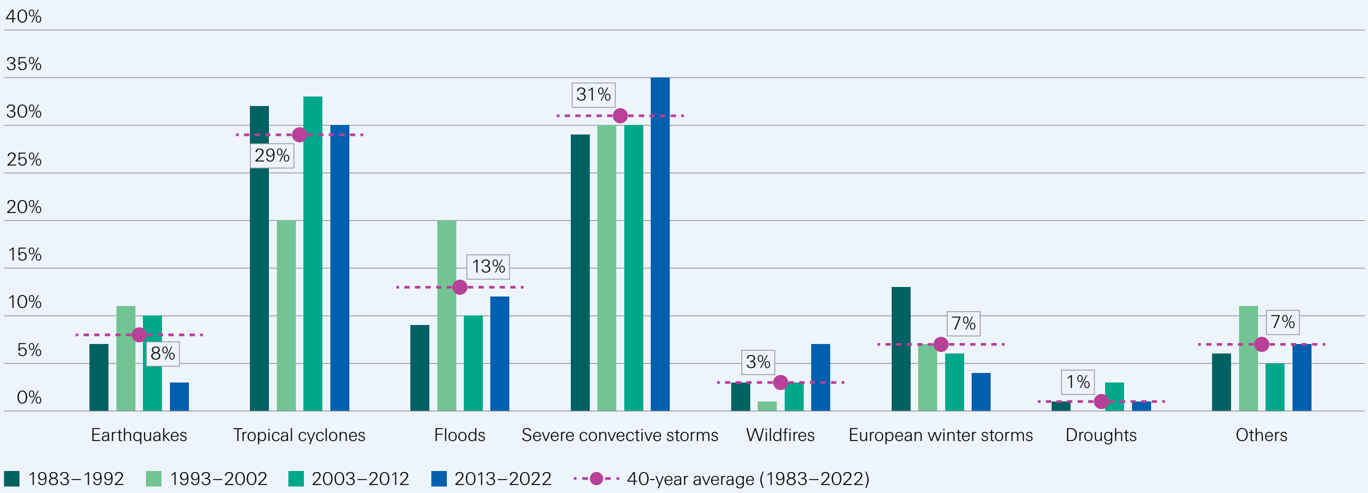
At 30% each, the contributions of tropical cyclones...

Losses from individual perils fluctuate year on year. That said, at on average 30% each, the contribution to global insured losses from the two biggest peril categories – tropical cyclones and SCS – have remained largely stable over the last 40 years (see Figure 3). On the east coast of the US, hurricanes (primary perils) originating in the North Atlantic are a main threat to residents and businesses.[12] Though rare, when a major hurricane strikes, the losses can be very severe. As in the case of Hurricane Ian, just one peak tropical cyclone event can wreak very large losses.

...and SCS to annual insured losses have remained largely stable.

SCS are categorised as secondary perils, occur more frequently and happen all over the world. Given the frequency, aggregated their annual loss amounts are less volatile.[13] Typically, losses resulting from SCS are lower than for primary perils, but there have been instances when a single SCS has resulted in insured losses of similar size to those coming in the wake of medium-sized hurricane. Noteworthy too is a marked step up in the share of all SCS to insured losses in the last decade.

Figure 3
Share of insured losses by peril type by decade



Source: Swiss Re Institute

[11] *Statement – Climate change is already killing us, but strong action now can prevent more deaths*, World Health Organization, 2 November 2022.
[12] Primary perils are natural catastrophes that tend to happen less frequently, but have high loss potential. They can include secondary effects. Examples include tropical cyclones, earthquakes and European winter storms.
[13] Secondary perils are independent natural catastrophe events that can happen frequently, typically generating low- to medium-sized losses. Examples include severe convective storms (thunderstorms, hail and tornadoes), drought, wildfire, snow, flash floods and landslides.

Heat-related perils like wildfires are contributing an increasing share of losses.

Another longer-term trend development has been a doubling of the share of natural catastrophe insured losses from wildfires over the last 30 years. Fire-related losses were low in 2022 itself but in recent years, large wildfires have wreaked huge damage and unprecedented losses, notably in North America (in Canada in 2016, and in California in 2017, 2018 and 2020). They reflect a rising risk due to ever-increasing populations in the wildland-urban interface, particularly in California. The trend may also signal hazard intensification as the planet warms, with extreme heat conditions adding fuel to wildfire formation. Projected changes in climate and prolonged periods of heatwaves in the next decades may well increase the frequency and loss severity of large wildfires and drought events.

European winter storms represent an ever-present primary peril loss-making threat.

Meanwhile, in the absence of major events, the share of European winter storms in annual natural catastrophe-related insured losses has been declining since the large storms of 1990 (winter storms Daria and Vivian) and 1999 (winter storms Lothar, Martin and Anatol). Nevertheless, winter storms are an ever-present hazard in Europe and, as the 2022 experience shows, just one event or cluster of storms can result in significant property damage. Equally, the comparably low level of earthquake losses over the last decade (ie, post the seismic events of 2010 and 2011 in Chile, Japan and New Zealand) should not lead to underestimation of this low frequency-high severity peril: earthquakes are rare but as with other primary perils, when a major quake strikes a heavily populated urban area, the resulting losses can be enormous.

Loss severity of individual primary and secondary peril events on the rise

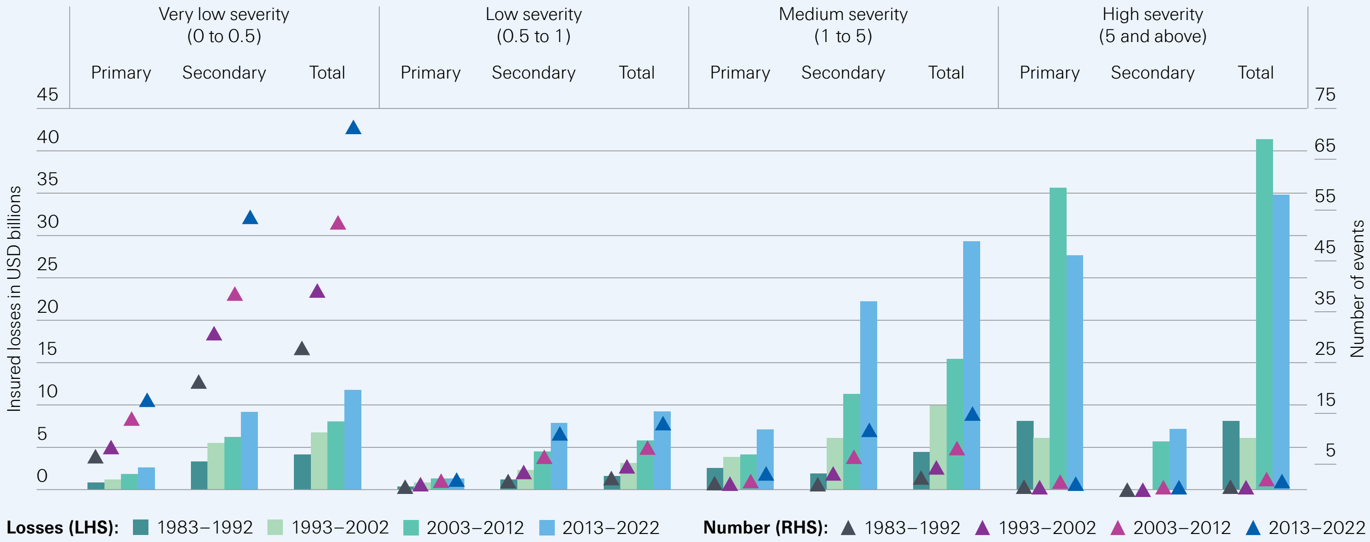
Growth in severity of losses resulting from primary and secondary perils is driving insured losses higher.

Across perils, there has been a shift in distributions to larger insurance loss amounts. Breaking down the losses by severity, medium (USD 1–5 billion of insured losses) and high severity (more than USD 5 billion) events contribute the majority of all insured losses (see Figure 4). Moreover, the associated losses are rising faster than those from very low severity events (less than USD 0.5 billion), even though the latter occur more frequently. From 2013–2022, there were on average 70 low severity events each year. Their contribution to total insured losses, however, was justUSD 11.7 billion. Over the same decade, an average of just two high-severity events each year contributed USD 34.4 billon cumulatively to total losses.

Tropical cyclones and SCS have consistently been the main contributors to global insured losses.

Thus, over the last 40 years, growth in annual losses has been primarily driven by rising severity of losses, these resulting from medium- to high-loss secondary and high-severity primary peril events. Tropical cyclones and SCS have consistently been the main contributors to global insured losses. High severity secondary peril events of the magnitude of the floods in Thailand (2011) and Germany (2021), and wildfires in North America were unheard of before 2011. The fact that these natural disasters have occurred more frequently in the last decade is indicative of the growing threat they present. Overall, this implies that the main physical driver of associated losses has been accumulation of value exposure as a result of economic development, urbanisation and rising population concentrations, often in regions susceptible to natural hazards (eg, coastal regions, river fronts, wildland urban interface).

Figure 4
10-year averages of insured losses (left) and number of events (right) by severity category in USD billion of insured loss per event, losses at 2022 prices

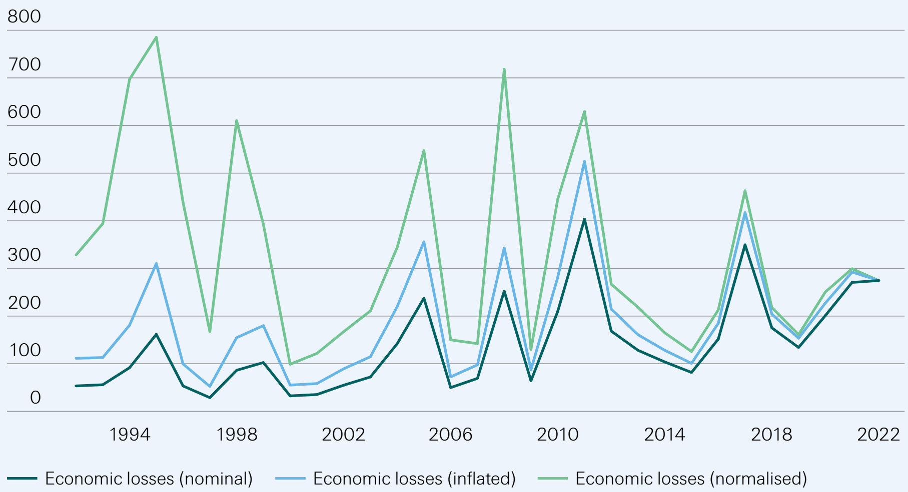


Source: Swiss Re Institute

Rising losses over the last 40 years have been mostly driven by economic growth and urbanisation.

Another way to demonstrate the impact of socio-economic factors on loss history is to "normalise" the economic losses triggered by natural catastrophes for nominal GDP growth effects. An event of the past, if it were to occur at equal magnitude today, would cause more economic damage than in the year of occurrence due to exposure value accumulation. A common approach is to apply real GDP and inflation factors to past economic losses (see Figure 5). We thereby estimate that the annual growth rate of global normalised (adjusted for inflation and real GDP growth) losses from natural catastrophes between 1992 and 2022 is around 1.2% on a 10-year moving average basis, still increasing but at much slower rate than shown by nominal losses (7%) and also real (adjusted for inflation) losses (4.5%) over the same time period.

Figure 5
Nominal, inflated (2022 prices) and normalised economic losses from natural catastrophes, USD billion



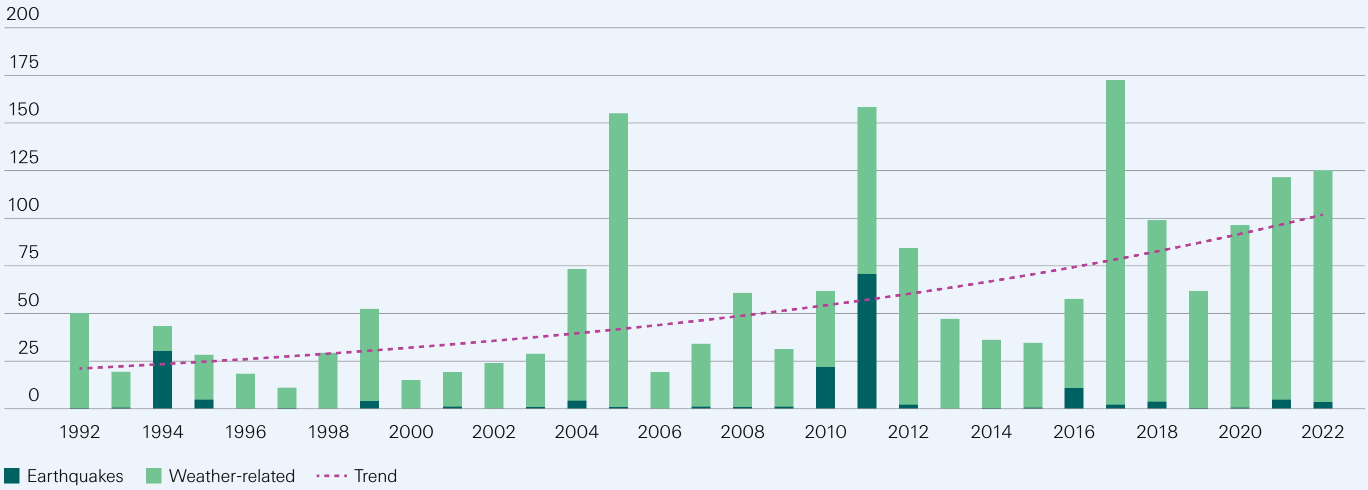
Source: Swiss Re Institute

Up-trend reaffirmed, and set to continue

We expect that average insured losses from natural catastrophes will continue to grow by 5–7% annually.

Insured losses from natural catastrophes have been on a long-term upward trajectory for much longer than the last six years. Since 1992, the average annual trend growth of losses has been 5–7% (see Figure 6). In the period 2012–2016, losses were at a lower annual mean, but there has been a return to said trend growth over the last six years and we expect this to continue. We project that irrespective of year-on-year volatility, insured losses will continue to grow at trend, even when real-time amplifying factors such as high inflation subdue.

Figure 6
Growth in global natural catastrophe insured losses in USD billion (2022 prices)



Source: Swiss Re Institute

Since 2017, average annual insured losses have exceeded USD 110 billion.

Starting from 2017, average annual insured losses from natural catastrophes have been above USD 110 billion, more than double the average of USD 52 billion over the previous 5-year period. This marks a notable step-up in the scale of losses after the 2012–2016 period of benign losses. Asset value accumulation in an area struck by an extreme weather or other natural catastrophe can spark heavy financial losses. Another factor has been changes in construction costs. Of late, aging infrastructure vulnerabilities and inflationary pressures have boosted repair costs. And, with demand-supply imbalances of materials and labour still in play in the post COVID-19 era, we expect construction costs to remain elevated into 2023, further inflating repair and reconstruction costs. This will impact attritional losses and further augment property losses over the next two years at least. Hazard intensification will likely play a bigger contributory role to rising losses in the coming decade also. With the world getting warmer, findings from scientific research infer that climate change effects on loss frequency and severity will intensify.

Losses of more that USD 100 billion annually are here to stay.

We also expect, irrespective of below-average loss years, that annual insured losses will average more than USD 100 billion from hereon. Our expectation is supported by other parties: for example, Verisk recently modeled the global insured average annual loss as USD 123 billion.[14] In any one year losses can be higher or lower depending on whether natural catastrophe events do or do not strike urban and more populated areas. A case in point, had Hurricane Ian last year made landfall in the Tampa Bay area as many predictions were showing, the resulting losses would have been much higher. There is no reason to anticipate that this, nor peak-loss disasters like Hurricane Katrina in 2005, will not happen again in the future. The takeaway is to not underestimate loss potential on account of a year or period of below trend growth.

[14] *Global Modelled Catastrophe Losses*, Verisk, 2022.

2022 natural catastrophes: lessons learned

The natural disasters of 2022 demonstrate that economic factors, in the last two years augmented by inflation, are the main driver of elevated insured losses from natural catastrophes. There were a number of high-loss events last year, including Hurricane Ian, floods in Australia and hailstorms in France. All of the events can be explained by known risk drivers, signalling need for continued discipline in property underwriting. The loss experience of the 2022 events offers several lessons for re/insurers including: better monitoring and sharing of granular exposure and claims data for secondary perils in particular; the importance of appropriate observation periods and a debiasing of historical losses; the need for models and underwriting decisions to more readily adjust to and take account of the rapidly changing risk landscape.

Loss drivers are manifold

The 2022 natural catastrophe year saw many loss drivers at play.

There were many large natural catastrophes in 2022 demonstrating the wide variety of risks across different perils around the world. The different events shed light on the underlying drivers of the long-term trend of rising catastrophe-related insured losses. Figure 7 highlights the notable loss drivers at play across the insurance value chain. Notwithstanding the severity of last year's catastrophes, none of the events were outliers from the perspective of resulting in unprecedented losses. Where there were record losses, these were the result of explainable, and known, risk drivers. The losses were not due to exceptional features of the physical events themselves, but the result of growing exposure values, inflation, insufficient exposure data and other factors. To this end, last year's catastrophe experience reaffirms the challenges the re/insurance industry faces in keeping up with a fast-evolving risk landscape.

Figure 7
Loss drivers at play in 2022

Hazard	Vulnerability	Exposure	Socio-economic effects
▪ Impact of the two large perils: tropical cyclones and severe convective storms ▪ Impact of La Niña (mode of ENSO) ▪ Climate change effects on weather perils	▪ Outdated and/or updated building codes ▪ Inadequate flood protection infrastructure ▪ New types of infrastructure (eg, roof-top solar panels)	▪ Development and capital accumulation in exposed areas ▪ Urbanisation and urban sprawl	▪ High inflation (especially high construction costs) ▪ Misuse of Assignment of Benefits (AOB) rules

Note: ENSO is the El Niño–Southern Oscillation, a recurring climate pattern.
Source: Swiss Re Institute

This chapter covers a selection of 2022 natural catastrophe events, each yielding unique outcomes.

Table 2
2022 events, and lessons learned

Event	Region	Estimated insured loss	Lesson learned
Hurricane Ian	North America	USD 50 to 65bn	All it takes is one storm
Australia floods	APAC	USD 4.3bn	Exposure growth and inflation drive losses higher
South Africa floods	EMEA	USD 1.5bn	Lack of data transparency compromises risk assessment
Severe convective storms	North America	USD 26bn	Rising property losses set to continue
Hailstorms France	EMEA	USD 5bn	A new market return period needed
Winter storms in Europe	EMEA	USD 4.1bn	Bigger storms will come

Source: Swiss Re Institute

North Atlantic hurricanes: all it takes is one storm

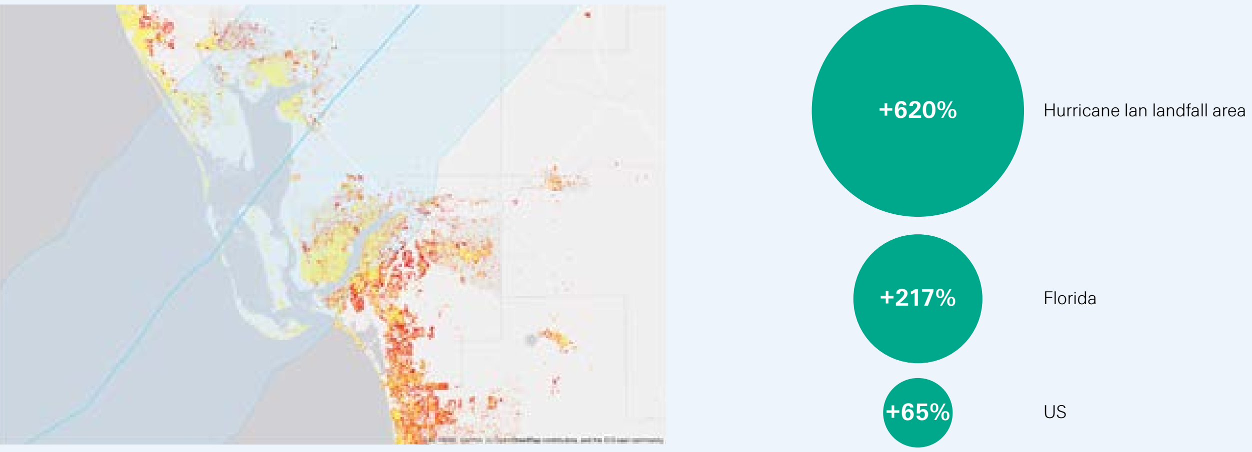
A benign North Atlantic hurricane season was still the third costliest ever.

By most measures, the 2022 North Atlantic hurricane season was "average". There were 14 named storms, in line with the average 14.4 annually in the period 1991–2020.[15] With only two major hurricanes (category 3 and higher), insurance-relevant storm activity was below forecast, and also below the historical annual average of 3.2 major storms. Even so, despite being relatively benign activity-wise, the 2022 season was the third most expensive on *sigma* records.

The reason was Hurricane Ian, and where it struck.

Why? Because of Hurricane Ian. Resulting in estimated insured losses of USD 50–65 billion, this one hurricane demonstrates that location of landfall (rather than number of storms) was the main driver of the heavy loss burden. When Ian made landfall in western Florida in late September as a category 4 storm, it hit an area that has seen a rapid population increase, growth in built areas and accumulation of physical assets (see Figure 8). Since 1970, the population where the storm made landfall, the Cape Coral-Fort Meyers metro area, has increased by 620%, exceeding both the population increase in the state of Florida (+217%) and the entire US (+65%). The storm demonstrated the loss potential of an individual major hurricane hitting a densely populated coastline, and the potential risks involved in people settling in regions more exposed to extreme weather events. As Hurricane Ian moved towards Florida, some predictions had put landfall in the Tampa Bay area. If this had happened, the losses would likely have been higher. To this end, the experience is reminiscent to Hurricane Andrew in 1992, which missed Miami by just 20 miles (as opposed to 100 miles for Ian). Had Miami been in Andrew's path, the 1992 losses would also have been up to three times higher than those that transpired.[16]

Figure 8
Changes in built-up land in the Ian landfall area (left) and population growth statistics (right)



Track centerline Track boundary
Built-up land: 1985 1990 2000 2019
Population growth since 1970

Sources: German Aerospace Center, National Hurricane Center, US Census Bureau, Swiss Re Institute

Updated Florida building codes helped newer homes withstand Hurricane Ian…

There was extensive wind damage to buildings in the path of Hurricane Ian. However, losses would have been much worse were it not for revisions to and enforcement of stricter building standards following hurricanes Charley in 2004 and Irma in 2017. In the past two decades, many buildings have been constructed according to the new building standards, and many roofs have been replaced and storm-proofed.

[15] "Atlantic Hurricane Outlook and Summary Archive," in *Background Information: North Atlantic Hurricane Season*, National Weather Service – Climate Prediction Center.
[16] *Hurricane Andrew: The 20 miles that saved Miami, Swiss Re, 10 August 2017.*

...but damages from storm surge were exacerbated by inadequate proofing against high water levels.

The immediate surroundings of Hurricane Ian's landfall location also suffered extensive storm surge. Water levels exceeded 4-5 metres in the Fort Myers Beach area and affected homes up to 0.5 km inland. While many buildings are wind-proofed, there is lack of "proofing" for high waters. The takeaway is that more investments in flood protection and existing infrastructure are needed. In addition, further improvements in flood protection will support adaption to climate change effects, one of which is the heightened risk of coastal flooding (see also Figure 13).

Further, In Florida social inflation has been a major driver of elevated claims in property insurance.

Florida's re/insurance market has been in focus since Hurricane Irma made landfall in 2017 as a category 4 storm, causing significant property damage and high losses. Loss severity in Florida is compounded by a factor other than damage caused by a hurricane: social inflation, driven by the state's litigation environment, particularly Assignment of Benefits (AOB) rules.[17] An AOB is an agreement that transfers insurance rights to a third party, enabling that party to file claims, make repair decisions and collect payments without the involvement of the original policyholder. In the case of Hurricane Irma, AOB rules pushed claims up by 10–20% (see Florida: hurricanes and litigation).[18] The rules have resulted in a stressed property insurance market: homeowner premiums in Florida are 3-times the national average.[19]

Florida: hurricanes and litigation

Assignment of Benefit agreements have ramped up insurance costs...

Social inflation – the increase in claims severity above what would be expected under usual conditions of economic inflation and loss trends – is mainly a feature of liability insurance. It is also a fundamental aspect of Florida's homeowners' insurance market. Primary drivers of social inflation in Florida include AOB, one-way attorney fees (the requirement that insurers pay plaintiffs' legal fees if the carrier loses in court), and a low threshold for roof repairs, which require a full update to the current building code if at least 25% of a non-compliant roof was damaged.[20] These rules allow the use of insurance payouts to fund roof replacements, contributing to higher insurance prices for all and resulting in market dysfunction. In 2021, Florida accounted for 7% of homeowners' claims in the US but 76% of homeowners' lawsuits against insurers.[21]

...and put six insurers in Florida out of business last year.

The fallout from this high level of litigiousness was evident in market dysfunction in Florida before Hurricane Ian. Six insurers declared insolvency in 2022[22] and the number of policies in force at Citizens Property Insurance Corp. – the state's insurer of last resort – more than doubled between year-end 2020 and 2022.[23] It is an indicator that the cost of insurance continues to increase for many policyholders in the state: Citizens' policies are only available if cover in the private market is unavailable or at least 20% more expensive.

AOB rules have been reformed, but proof of results will take some time to show.

The Florida legislature took action in 2019 to mitigate AOB abuse (House Bill 7065) and in 2021 to restructure litigation rules and limit excessive litigation, but additional measures were needed. As a result, the authorities in Florida held two special legislative sessions in 2022. Legislation passed in December 2022 is expected to significantly improve the re/insurance market and legal environment. Among other changes to disincentivise lawsuits, it eliminates AOB and the one-way attorney fee provision entirely in property insurance contracts. However, it will likely take 12–18 months for the full effects of the recent updates to take effect. The reforms will in all probability be challenged in court, and AOB elimination does not apply to policies issued before 1 January 2023.

17 *Hurricane Irma Dredged Up AOB Issues in Florida: Are Changes Ahead?*, Verisk, 2020.
18 Ibid.
19 *Extreme Fraud and Litigation Causing Florida's Homeowners Insurance Market's Demise*, Insurance Information Institute, 23 June 2022.
20 SB4 in 2022 loosened the requirement, avoiding the full-repair requirement for roofs built in compliance with the requirements of the 2007 Florida Building Code or subsequent versions.
21 *Property Insurance Stability Report*, Florida Office of Insurance Regulation, 1 January 2023.
22 "Florida Government Seeks to Repair Property Insurance Market", AM Best, 8 December 2022.
23 *Policies in Force*, Citizens Property Insurance Corporation

Australia floods: exposure growth and inflation drive losses higher

The February-March floods in Australia were the country's costliest insured loss events ever.

In Australia, three consecutive years of La Ninã weather patterns have increased the risk of flood events through elevated precipitation levels, dams that are full and saturated soils. In February and March 2022, heavy rainfalls on saturated soil led to a series of floods in eastern Australia, resulting in insured losses of USD 4.3 billion.

Flood risk in Australia is strongly driven by urbanisation

The flooding of Brisbane and Sydney are a reminder of the impacts, recurrence and drivers of urban floods. The share of Australia's population living in urbanised areas is among the highest in the world and also advanced economies.[24] Over the last 20 years, the increase in soil sealing in Australia's five biggest cities has been the main contributor to a 7% increase in annual expected losses from floods.[25] Ongoing urbanisation, population growth, inadequate flood protection infrastructure and increased soil sealing will add to an increase in flood-related insured losses.[26]

Inflation impacts drove up claims substantially.

The cost of rebuilding after the floods in February-March 2022 has been higher than expected. Last year's high economic inflation, driven by disruptions to global supply chains and lingering effects from pandemic-related border restrictions, meant that building replacement costs could have risen by more than 20%.[27] Shortages in skilled labour drove costs even higher. There are models to assess local flood risk, but these may not always capture all loss drivers. For instance, flood models in particular should reflect urbanisation and soil sealing effects, and also be forward-looking to account for potential La Niña or other conditions. Elevated inflationary factors, to the extent not captured in exposure data and temporary, should also be factored in.

South Africa floods: lack of data transparency can compromise risk assessment

The loss magnitude from the South Africa floods shows the importance of transparency in exposure data.

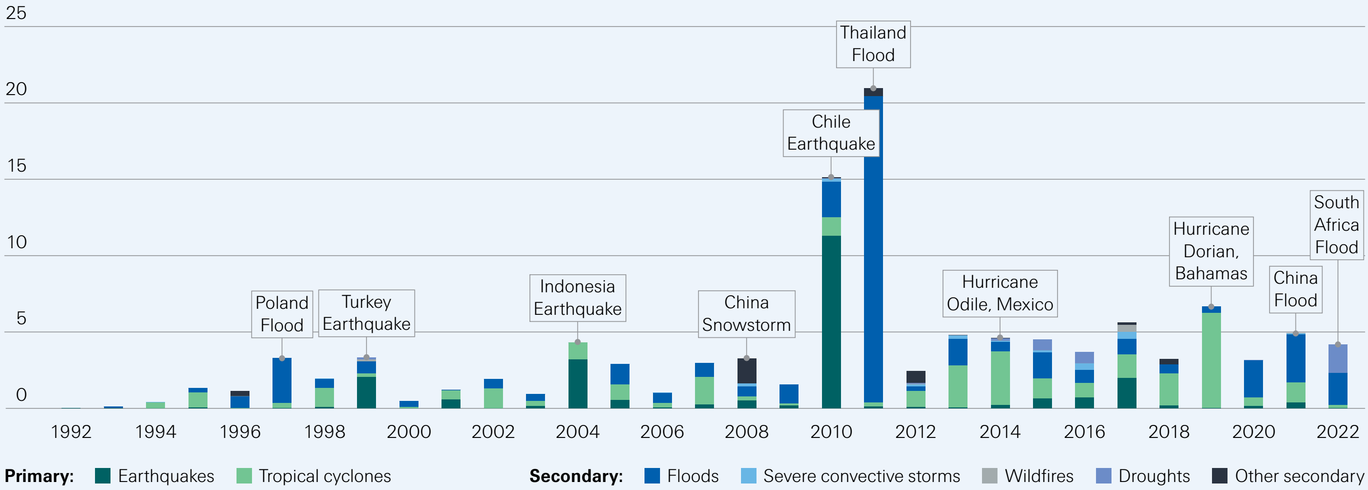
Last year, a storm bringing days of heavy precipitation in the Durban area of South Africa resulted in floods and landslides, and estimated insured losses of USD 1.5 billion. The losses included claims for damage at industrial locations that are part of international supply chains, exposures that had not been taken into consideration. The loss magnitude shows that lack of transparency in exposure data can lead to an underestimation of risks, and unanticipated losses.

Emerging economies are central to global supply chains. Risk assessment should factor in the exposures in these markets.

Insured losses from natural catastrophes in emerging markets can be very large. The biggest loss years on *sigma* records are 2010, when an earthquake in Chile resulting in insured losses of USD 10.7 billion, and 2011, when floods in Thailand caused insured losses of USD 19.5 billion. In both years emerging markets contributed more than 15% of the global insured losses. Today's commercial and industrial operations are global and complex. For accurate risk assessment, re/insurers need full transparency with respect to the assets and international connections within a firm's production sites and internal processes, wherever these may be based. Lack of awareness can lead to underestimation of the risks. Modelling capabilities need to be expanded to cover the growing number of regions involved in global supply chains, and also the different perils those regions are exposed to. Land-use changes also relevant for model updates.

[24] *Urbanization*, Our World in Data, November 2019.
[25] *sigma* 1/2022: Natural catastrophes in 2021: the floodgates are open, Swiss Re Institute.
[26] Ibid.
[27] *Costs of rebuilding a flooded home to climb 20pc – Australian Financial News (afndaily.com.au)*

Figure 9
Natural catastrophe insured losses in emerging markets, in USD billion at 2022 prices



Source: Swiss Re Institute

2022 saw substantial SCS-related losses in the US, again.

Severe convective storms in the US: rising losses set to continue

The cumulative losses from SCS in the US in 2022 were more than USD 25 billion, well above the average of the previous 10 years (inflation adjusted). We expect annual insured losses from SCS in the US to continue rising in line with the annual 5–7% increase in global losses from natural catastrophes.[28] We estimate average SCS losses will likely exceed USD 25 billion annually in the coming years, reaching USD 30 billion before the end of the decade, equivalent to around 7% of projected US property sector premiums.

We expect rising construction costs and vulnerabilities to push SCS-related property claims higher.

SCS in the US currently represent 20–30% of the global natural catastrophe insured losses. Economic growth and urbanisation will increase exposures in the coming years. In addition, building costs rising faster than the rate of overall inflation are expected to push reconstruction costs and claims even higher. Other loss drivers include an increase in the average claims amount due to gains in the insured values of assets vulnerable to SCS, such as roof-mounted solar panels.

There were record hailstorm-induced losses in France last year.

Large hailstorms in France: a new market return period assumption needed

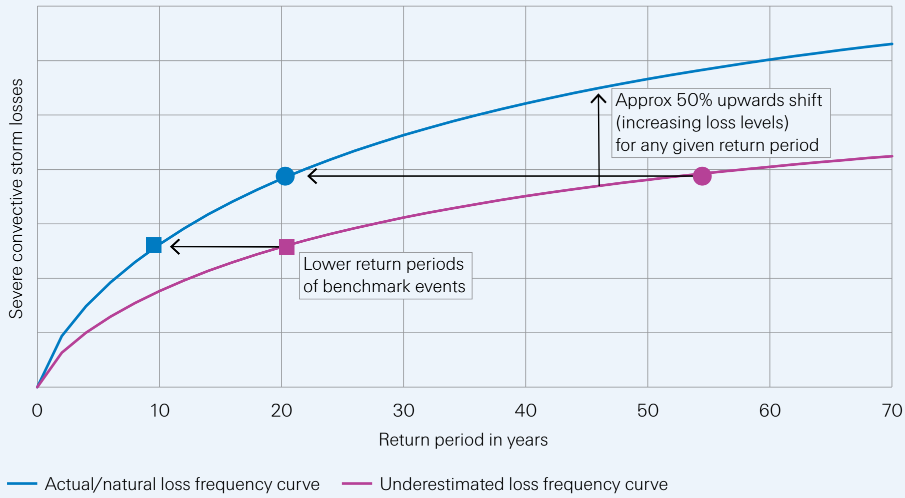
France too was hit by SCS last year, with storms in May and June resulting in insured losses of USD 4.8 billion. Those losses exceeded the previous record year 2014 by 3-4 times when Storm Ela resulted in insured losses of more than USD 1 billion. Since then, Ela is considered the industry benchmark for hailstorms in France, with an assumed market return period of 20 to 50 years. However, with the losses from storms Qiara and Maya in 2022 both exceeding the Ela loss, the benchmark USD 1 billion loss level has been surpassed three times in the past decade. In our view, this justifies a revision of the return period assumption, to below 10 years.

[28] *sigma* 1/2021 – Natural catastrophes in 2020: secondary perils in the spotlight, but don't forget primary-peril risks, Swiss Re Institute.

Hard-to-assess risk drivers and rare event occurrence can lead to underestimation of loss trends.

The larger number of SCS in the US offer a reference point for analysis of the relatively few hail events in Europe. The impact of economic growth and inflation are well understood, but other factors like the increase in built-up land area, vulnerability changes (eg, from solar panels) and social inflation are more difficult to assess. Hidden or hard-to-quantify risk drivers combined with rare event occurrence mean that loss trends can be underestimated over a longer-term period. Data from the US suggest that risk drivers beyond economic growth add a few percentage points to annual losses.[29] A hypothetical example as in Figure 10 illustrates how just a 2% underestimation of annual loss increase over a period of two decades (on account of difficult-to-assess loss drivers) can lead to estimated larger return periods and lower loss levels. For example, an event with a return period of around 10 years can be mistaken as a once in 25-year event. The effect is more pronounced at higher return periods, where a one-in-20-year event is assumed to have a return period of 60-years or more.

Figure 10
Impact of increasing loss levels on loss frequency curve and event return periods



Source: Swiss Re Institute

Models need to reflect all factors relevant to hail exposures.

The 2022 experience illustrates a trend of increasing losses from hailstorms in France. Models need to be updated with the latest understanding of all relevant factors to avoid an underestimation of hail risk.[30] This includes the use of appropriate loss experience windows to determine suitable return periods, and consideration of factors beyond economic growth and urbanisation, such as, changes in land use, assets exposed to hail damage or claims behaviour.

Winter storms Europe: bigger storms will come

2022 European winter storms were a reminder …

In February last year, a cluster of three winter storms (Eunice, Dudley, Franklin) hit north-western Europe, resulting in combined insured losses of more than USD 4 billion, above the previous 10-year average of winter storms losses of US 2.5 billion. In the decades before, there were larger loss events. For instance, winter storm Kyrill in 2007 resulted in insured losses of USD 5.9 billion. Based on 2022 prices and exposure, we estimate that the same storm would have today resulted in losses of USD 10.6 billion.

… of an important peril that remains largely dormant, for now.

History shows that European winter storm activity is variable on a decadal time scale. Recent storm activity has been below-average. However, it is important that risk modellers and underwriters are not lulled into a false sense of security by assuming lower activity will remain indefinitely. The 2022 losses serve as a timely reminder of the ever-present risk of winter storms. To this end, we concur with the view that European winter storms are a "sleeping giant".[31] Given the natural variability, phases of higher storm activity and/or occurrence clusters of winter storms will re-occur.

[29] Ibid.
[30] *Severe 2022 hail damage in France sets new benchmarks, underscores shift of risk and calls for pricing adjustments*, Swiss Re, November 2022.
[31] *European Windstorm Risk in a Warming World*, SCOR, 23 January 2023.

Lessons for risk assessment and underwriting

Lessons learned.

There has been significant progress in natural catastrophe risk modelling capabilities over the last decade. That said, there is always room for further enhancements. The insurance loss experience of 2022 offers some pointers as to where and how.

- **Sharing of peril specific, granular exposure data is key:** Comprehensive data on existing exposures is the starting point for any underwriting process. There is room to improve the collection and transmission of exposure data of sufficient granularity, specifically for secondary perils (in particular for floods and hail storms). The re/insurance industry has long monitored primary perils and its modelling capabilities for these are strong. Secondary perils have not received the same attention in terms of peril-specific exposure and the sharing of model results. This has sometimes compromised efforts to underwrite those risks. Insured losses from secondary perils have been on the rise for many years, sometimes reaching the magnitude of losses resulting from medium-size primary peril events. For more complete risk assessment and to capture the large loss potential that secondary perils can inflict, as in the case of the flooding in Durban in South Africa in 2022, it is time the industry affords these exposures the same discipline around the monitoring, and sharing of exposure data and model results as primary peril risks.

- **Up-to-date exposure data matters in times of high inflation:** Another consideration is to ensure that exposure data is updated to capture latest inflation developments. For instance, in the last two years inflation has surged, and this has pushed up the costs of property rebuilds and reconstruction. Inflation effects contributed to the large losses from the floods in Australia in February-March last year. The cost of rebuilding were higher than anticipated by re/insurers because the inflation impacts of lingering disruptions to global supply chains and pandemic-related border restrictions had not been fully factored into risk assessment.

- **Risk assessment to more readily reflect rapidly changing risk landscapes:** Models and risk assessments need to reflect all loss drivers such as soil sealing, construction of new risk mitigation infrastructure assets, updates to building codes, climate change effects and social inflation. It is important to capture changes in all relevant risk drivers, and to do so in a forward-looking manner. When models results are adjusted for temporary effects like (expectations of) higher inflation, underwriting decisions ensure adequate risk assessment.

- **Selection of appropriate observation windows and debiasing of historical data is key:** Past loss experience is a key input for natural catastrophe risk assessment. The chosen observation window should be peril-specific appropriate, both limited to a more recent past and forward-looking to capture important developments such as changes in weather regimes. In addition, historical data points need to be translated to represent the current-day risk environment. A mere adjustment for inflation and economic growth trends can lead to underestimation of the risk levels. More holistic and representative trending/debiasing of historic losses should also take into account that reconstruction and repair costs typically increase faster than consumer price inflation, and that physical asset values increase faster than the rate of economic growth. Consideration of all relevant peril and region-specific loss drivers, including changes in urban development, migration to areas vulnerable to extreme weather events, and enhancements of risk mitigation infrastructure, make for effective debiasing of historical loss data.

- **Sometimes bold changes are necessary:** Regular model updates lead to a gradual shift of risk perspective. Updates across all model inputs and/or in underwriting decisions are of particular importance for fast evolving secondary perils such as wildfires and SCS. Most natural catastrophe events contain learnings , requiring the industry to incorporate these in its risk assessment practices. Ideally, these learning steps are small and digestible. Sometimes, however, more bold changes can be necessary and appropriate too. For instance, the 2022 loss experience from the hailstorms in France and flooding in Australia warrants a reassessment of the respective return period assumptions.

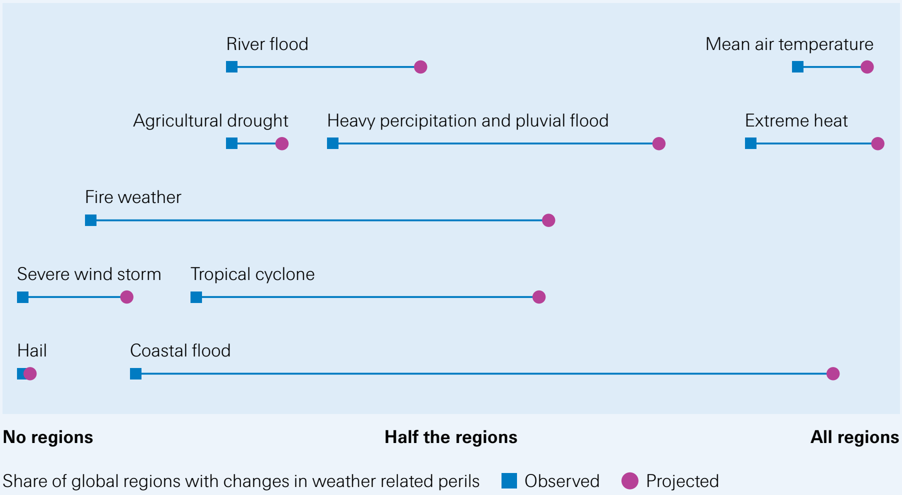
- **Loss severity of 2022 events driven by other than climate change effects:** The impact of climate change on the 2022 loss events was measured. The scientific attribution of extreme weather events like cyclones or hailstorms to climate change is muted, at best (see What about climate change?). Today, the dominant drivers of rising losses from natural catastrophes are exposure growth, urban concentration in exposed areas, and changing vulnerabilities exacerbated of late, by high levels of inflation. Natural variability of extreme weather is today more significant than an underlying climate change signal. Even so, property underwriters should remain vigilant with respect to climate change effects and to what extent those already manifest are captured in risk models.

The main drivers of rising losses from natural catastrophes are economic growth, urbanisation and populaiton expansion in exposed areas.

What about climate change?

The main drivers of rising losses from natural catastrophes are growth, urbanisation and rising populations in exposed areas, with factors such as social and economic inflation adding upward pressure in recent years. Climate change effects likely play a role also, but are not a primary driver increasing losses, at least not yet. This assertion is supported by observations of climate change effects, as reported by the Intergovermental Panel on Climate Change (IPCC).[32] Figure 11 summarises where, to date, climate change effects in different perils have already been observed (blue squares) across all regions of the world. For example, the figure demonstrates that already today, climate change effects on mean air temperatures and extreme heat have been observed in all regions on the world, putting these two "effects" to the right of the figure. With this context, the occurrence of heatwaves in China, Europe and the Americas last year is not a "surprise" per se.[33]

Figure 11
Extent of observed and projected changes due to climate change in weather related perils



Source: Swiss Re Institute, based on IPCC

[32] *IPCC Sixth Assessment Report*, 2022.
[33] *Provisional State of the Global Climate in 2022*, World Meteorological Organization, WMO, 2022.

There been observations, to varying degrees, of climate change effects in occurrence of different peril events.

Observations of an increase in heavy precipitation are less definite. Some regions (North America, northern Europe, central and eastern Asia) have seen more frequent heavy precipitation events. A case in point is Pakistan, which saw record breaking rainfalls and severe flooding in 2022.[34] In other regions, however, an observable trend is less clear cut. This is more so the case for other weather-related perils such as hail, river flood or tropical cyclone.

But not all weather-related perils show clear climate change effects – yet.

Lack of hard evidence of climate change effects can be the result of infrequent peril occurrence in monitored areas (eg, hailstorms), incomplete understanding of the physical processes of weather events (eg, storm tracks, hail formation), natural variability (tropical cyclones), or the complexity of interlinked physical process (eg, how changes in precipitation patterns translate into river discharges and flooding). That effects have not been widely observed, however, is not a signal of no change.[35] Progress in scientific understanding and observations may, in time, yield different conclusions. Figure 11 also shows the share of regions where changes in weather-related perils are projected for the scenario of a 2°C warming in global temperature by 2050 (purple circles). Hence, for instance, it is expected that sea-level rise and coastal flooding will, over time, affect all regions.

[34] *Pakistan's Monthly Climate Summary*, Pakistan Meteorological Department August 2022.
[35] For more, see *sigma* 2/2020: Natural catastrophes in times of economic accumulation and climate change, Swiss Re Institute.

Market dislocation: Hurricane Ian, inflation and interest rates

Property reinsurance rates rose significantly at the January 2023 renewals. The losses from Hurricane Ian last year were a contributory factor, but signals for a market correction had already been mounting. The industry has experienced poor underwriting results following the step-up in natural catastrophe loss severity since 2017, new risk drivers and fallouts from the pandemic and war in Ukraine, including inflation raising the value of insured property assets. Uncertainties around modeling discipline and the adequacy of premium levels to deal with increasing loss costs and emerging secondary perils have led to reduced risk appetite on the part of providers of capital. So too have the recent interest rate hikes, which have increased the cost of capital. When higher exposures encounter shrinking risk appetite, rising prices, higher retentions and tighter terms and conditions result. But even with the market reset in January, some reinsurers and investors in the sector will likely wait for signs of improved industry profits before materially replenishing capacity again.

The re/insurance underwriting cycle

Re/insurance rate increases gathered pace at the January 2023 renewals.

Reinsurance rates have been rising since 2018. The momentum picked up at the January 2023 renewals, with global risk-adjusted property catastrophe rates up 20–50% for loss-free portfolios and up to 100% for loss-hit.[36] The re/insurance underwriting cycle is characterised by periods of soft (falling/stable premium rates, coverage readily available) and hard (rising rates, cover less available) market conditions. The driver is re/insurer competition, affected by claims trends, interest rates, industry capital and catastrophe losses (see Figure 12). We attribute most of the current step up in prices to uncertainty around claims trends and the effect of inflation and interest rates on industry capital and demand. Risk appetite and alternative sources of capital affect overall capacity and the speed with which prices adjust to updated risk assessments. Recent underwriting experience affects the supply of existing industry capital and also influences expectations of future profits, both of which affect capacity decisions.

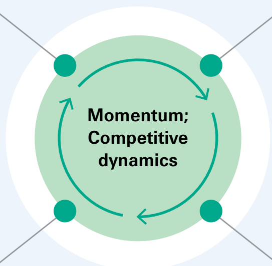
Figure 12
Main drivers of the underwriting cycle

Claims trends

- Changes in expected losses have the strongest impact on insurance prices.
- Inflation surge has lifted exposures and claims.
- Modelling uncertainty: economic inflation, social inflation, climate change, Ukraine war, pandemic, supply-chain risks, cyber.

Investment income

- Rising interest rates will improve portfolio yields with a lag but causes m-t-m losses in the short-term.
- Interest rates play a minor role in explaining short-term changes in underwriting dynamics.
- There is a long-term relationship between the combined ratio and nominal interest rates.



Cat losses

- Catastrophes have larger effects on supply and demand if they reveal un-modeled risks.
- The effect of catastrophes on price increases is smaller than often assumed.
- Lost industry capital can be replenished with fresh capital if market opportunities arise.

Industry capital

- Excess capital increases competitive pressures and can trigger falling rates. Capital constraints can lead to higher rates.
- Accounting capital can be inflated by low interest rates and deficient claims reserves.
- Influx of Alternative capital drove competitive dynamics 2012–18 but stalled recently.

Source: Swiss Re Institute

[36] *1st view: Market Turns*, Gallagher Re, January 2023. Guy Carpenter indicates a rate increase of 27.5% of its *global property CAT XL RoL index.*

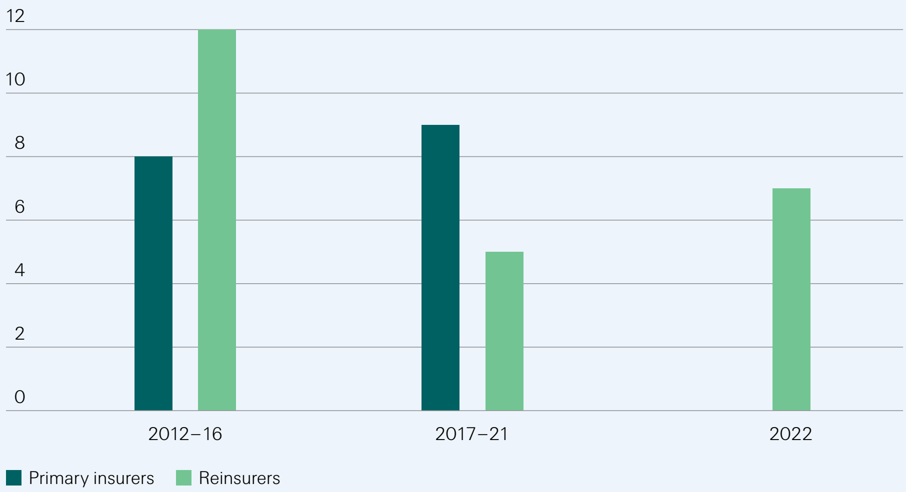
Demand for coverage is high, but in an environment of reduced risk appetite, capital supply is restrained.

The current hard market is a textbook case of shifting demand and supply, with the market seeking a new equilibrium. Demand for coverage had risen on evidence of increased natural catastrophe activity since 2017 and because of higher insurable values of buildings and other fixed assets. At the same time, natural catastrophe claims pay outs have reduced supply of capital. Supply has also fallen in response to rising interest rates and lower financial asset values. Lending further momentum to the supply-demand dynamic, risk appetite has decreased due to poor property re/insurance underwriting results in recent years, and widely held perceptions that risk assessments are underestimating actual loss experience. This is – apart from financial market uncertainty and rising interest rates – leading to hesitation on the part investors in insurance-linked securities (ILS) and traditional reinsurers to commit new funds to replenish industry capital. After six years of weak underwriting results, property re/insurance capacity providers have become more cautious. Some traditional players have reduced cat exposures, and alternative capital providers are waiting for evidence that pricing better aligns with loss experience.

Since 2017, premium income in property catastrophe has lagged exposure growth

Since 2017, the re/insurance industry has paid out USD 650 billion (in 2022 prices) for weather-related natural catastrophes claims. However, premium income has not kept pace with events or exposure growth – whether proxied by GDP or more targeted measures – the result being steadily declining profits (see Figure 13). Natural catastrophe losses affect industry capacity directly; while making societies financially more resilient, the payments to policyholders reduce profitability and capital supply. They also have indirect impact as re/insurers and investors update risk assessments. Perceptions about whether risks are priced adequately is key in determining the supply of capital and capacity available for underwriting. The historically elevated catastrophe and claims activity since 2017 has created doubts on the part of re/insurers and investors, and slowed the capital supply response.

Figure 13
Profitability (return on equity) of primary insurers vs reinsurers, 2012 – 2022



Source: S&P Capital IQ, Swiss Re Institute

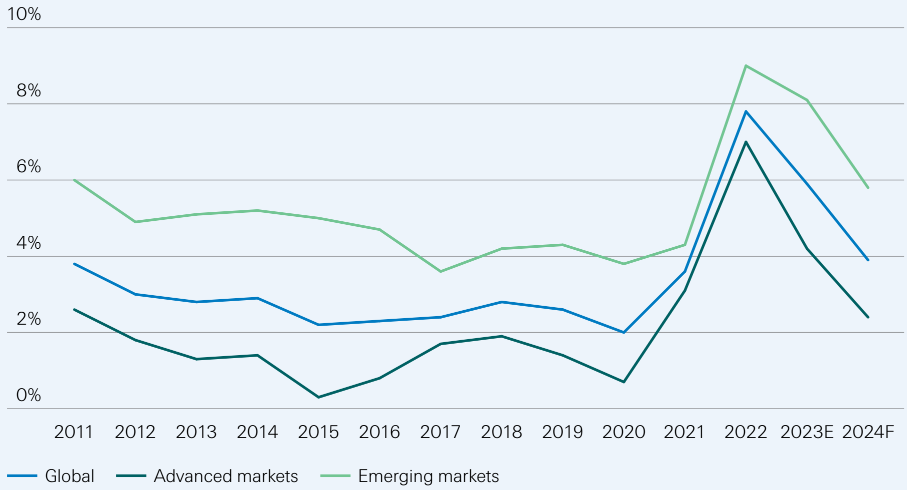
Gaps in exposure data have given rise to concerns as to the accuracy of risk assessment models.

The increases in loss severity in recent years and new risk drivers had a strong impact on the recent renewals. Accurately quantifying and pricing for shifts in the exposure landscape and underlying loss distributions is key to maintaining the insurability of natural catastrophe risks. After six years of elevated losses and with gaps in exposure data, however, there is scepticism that existing models fully capture the risks. The wide range of loss drivers, uncertainties and macroeconomic pressures described in Section 2 must be better understood if the re/insurance industry is to collect sufficient premiums for the risks it assumes. The re-pricing of property risks at the January 2023 renewals is a clear sign that past prices did not capture the recent loss dynamic.

New risk drivers, such as the highest inflation in 40 years in advanced economies, has materially affected exposure values.

The unanticipated surge in economic inflation over the last two year to levels not seen in four decades was a catalyst for the step-up in prices at the latest reinsurance renewals. Inflation has the effect of raising the value of insurable assets and in turn, also claims. After rarely passing the 2% threshold targeted by most monetary authorities in the previous decade, in 2021 inflation in advanced markets rose to 3.1%, driven by pandemic-related issues such as supply chain disruptions. In 2022, it averaged 7.1%, with the war in Ukraine driving food and energy prices to new highs. In emerging markets, inflation reached 9% last year, also driven by food and energy prices (see Figure 14).

Figure 14
Inflation, 2011–2024



Source: Swiss Re Institute

The value of insurable exposures have grown faster than headline inflation and economic growth.

Since the start of the pandemic, property insurance exposures – the nominal value of buildings, motor vehicles, and other fixed assets that insurers cover – have grown faster than headline inflation and real GDP growth. The fastest rising prices have been in sectors such as construction and vehicle sales, directly impacting claims costs in some of the largest lines of insurance. In the US, for instance, the replacement cost of all privately-owned structures increased by an estimated 40% between year-end 2019 and 2022, well above a near-20% increase in nominal GDP (for more on replacement values, see US property insurance exposure, claims and premiums). Increases in litigation-driven social inflation indicate the applicable inflation rate for claims costs could be even higher than the relevant economic indices.

Rising costs in the construction sector due to supply chain disruptions have led to rising property claims.

One of the first indications of surging inflation was in the construction sector when lumber prices rose in the summer of 2020 because of supply-chain disruptions and rising demand for new homes, renovations and do-it-yourself projects during lockdowns.[37] From May to September 2020, lumber prices in the US were up 57% and they remained volatile over the following two years. They settled at a level around one third higher than before the first price surge. The share of lumber and other materials in property claims varies significantly by line of business, geography and catastrophe exposure, but the overall cost of construction has risen significantly. For instance, today construction materials in the US are more than 40% higher since the beginning of 2020, and 20% higher in Europe.[38] The increase in the cost of materials, components and also labour is driving property replacement costs higher, which in turn feeds through into higher homeowner and commercial property claims.

We expect claims will continue to rise, pushing reinsurance rates higher.

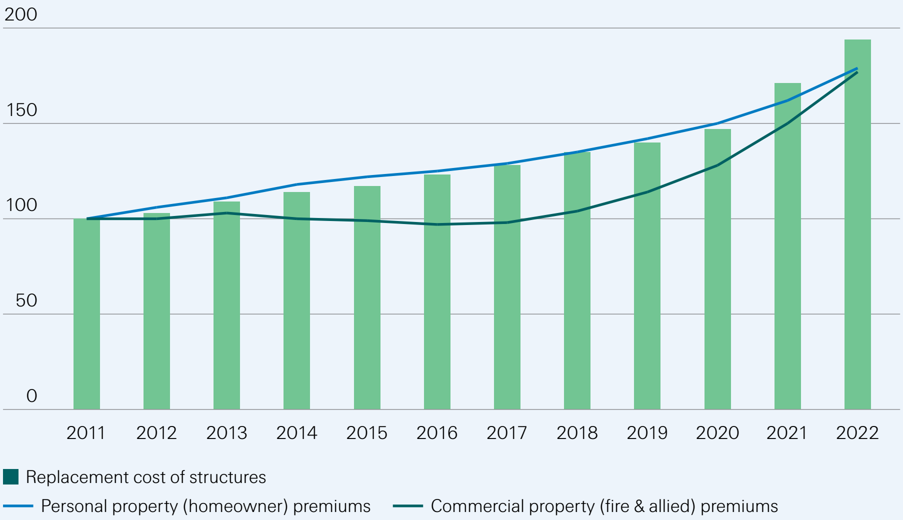
Price inflation in the construction market has caused difficulties for property underwriters, and the general surge in economic inflation of the last two years started by the pandemic has extended uncertainties around risk assessment to more lines of business. Swiss Re Institute forecasts ongoing elevated inflation in cost components relevant for property insurers, and that this could lead to a marked increase in claims in 2023 and, in turn, reinsurance rates. Even if inflation abates in 2024, cost levels will not go back to pre-pandemic times but remain at elevated levels.

[37] *"Wood Price Spike Caused By Pandemic Finally Starting To Drop"*, NPR, 21 June 2021.
[38] US Bureau of Labor Statistics, Producer Price Index; Eurostat, Construction producer prices

The pandemic-induced surge in inflation has increased replacement costs in US property.

US property insurance exposure, claims and premiums
US property insurance business is under earnings pressure. Annual natural catastrophe property claims averaged USD 83 billion in 2017–2022, a more-than-doubling of average annual pay outs in the previous six years. At the same time, the average share of natural catastrophe-related losses of all property claims rose from 20% to 35%,[39] mainly driven by a step-up in annual loss severity since 2017. Since 2019, so too has been an increase in the replacement value of buildings and equipment sparked by the pandemic-induced surge in inflation. The replacement value of the net stock of private structures in the US was an estimated USD 53.5 trillion in 2022,[40] up around 40% from 2019. Since 2011 the replacement cost of private structures has grown by 6% annually compared to 5% for property lines premiums (see Figure 15). The outcome is that even with market hardening in primary commercial property since 2019, premiums have lagged replacement cost increases.

Figure 15
Exposure and premium growth, US property, 2011 = 100



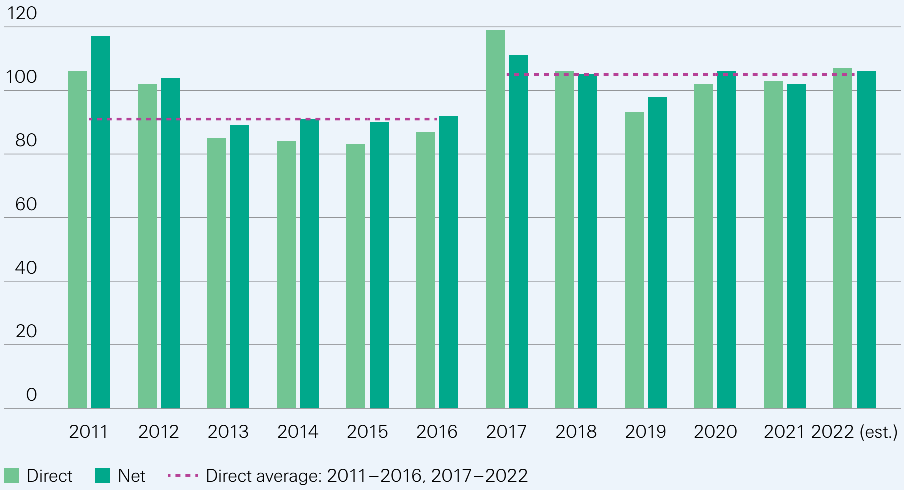
Source: US Bureau of Economic Analysis, S&P Global Capital IQ Pro, Swiss Re Institute

Re/insurance rate gains have lagged increases in insured losses and replacement costs.

Underwriting experience indicates that pricing has also lagged natural catastrophe losses and replacement values. Between 2011 and 2016, the combined ratios for US property lines averaged 91%, while from 2017–2022 they averaged 105% (see Figure 16). Based on 2022 US property premiums of USD 200 billion, the profitability gap amounts to extra annual losses of nearly USD 30 billion, or 3–5% of industry ROE. Returning to underwriting profitability in US property will require continued underwriting discipline alongside a reassessment of the underlying risks.

[39] We classify allied lines (including crop and flood), home- and farm-owners, commercial multi-peril (non-liability), ocean marine, inland marine, and motor physical damage as weather catastrophe-exposed lines.
[40] To estimate the replacement cost of structures at year-end 2022, we adjust the BEA current-cost net stock of private fixed assets at year-end 2021 (USD 47.2 trillion) by the YTD growth through 3Q22 of the current cost basis of residential and nonresidential structures owned by households and non-financial noncorporate business.

Figure 16
Combined ratios, US property lines (Fire, Allied, Homeowners), 2011–2022 (est.)

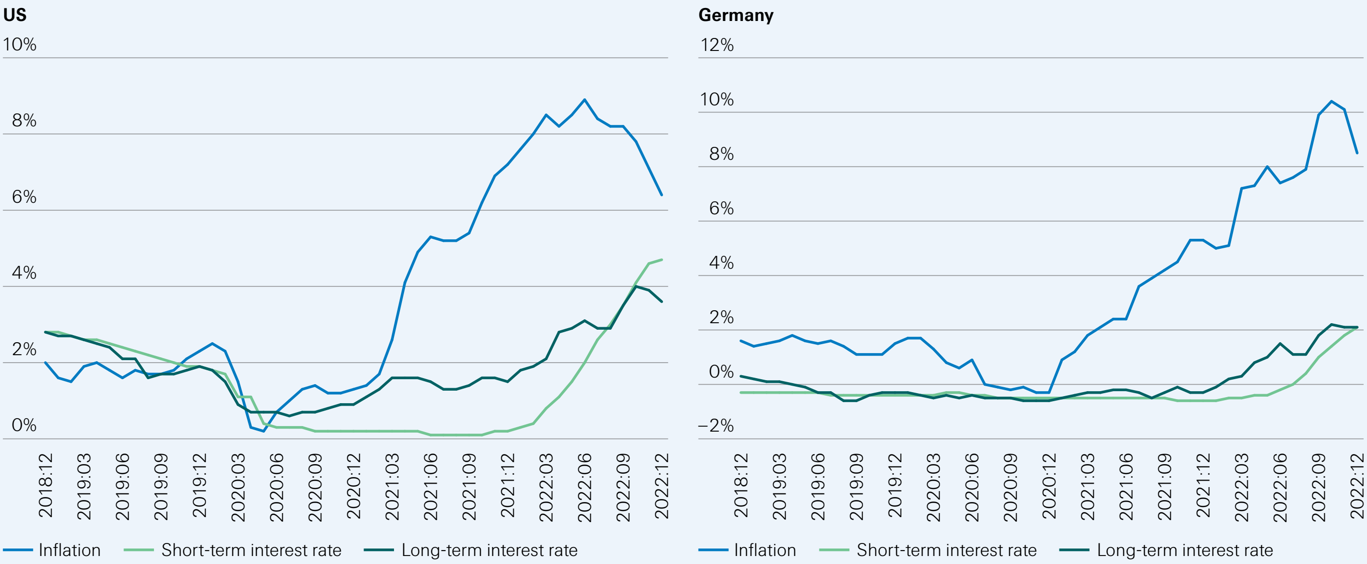


Source: S&P Global Capital IQ Pro, Swiss Re Institute

High inflation has sparked interest rates hikes...

High economic inflation has impacted exposures and demand for coverage directly. The supply-side impact has been indirect. Rising prices led to decisive monetary policy action by the US Federal Reserve (Fed) and many other central banks. In 2022, the Fed, Bank of England (BoE), European Central Bank (ECB) and other central banks raised short-term policy rates from zero (or near-zero) to 4.375% (Fed), 3.5% (BoE) and 2.5% (ECB). Long-term interest rates also moved up considerably.

Figure 17
Inflation and interest rates in the US and Germany, 2019 – 2022, monthly data

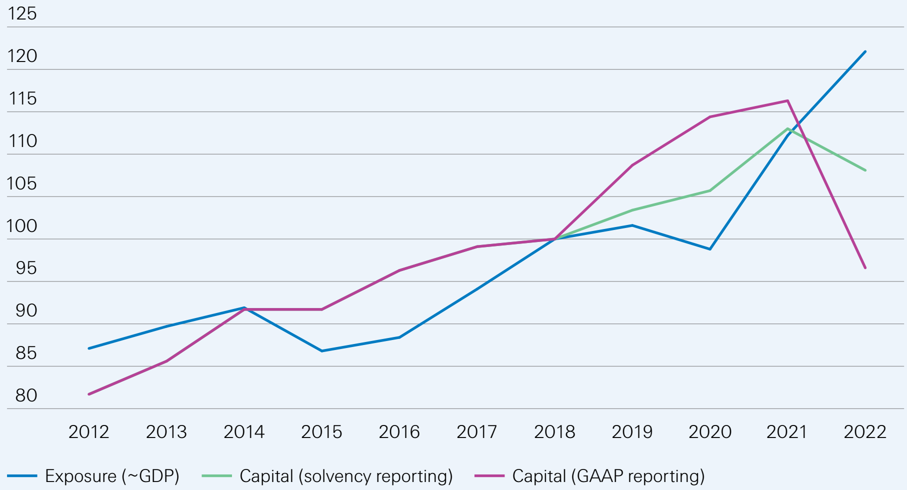


Source: Swiss Re Institute

...materially affecting re/insurance capital by decreasing asset valuations.

One effect of the higher interest rates has been a decline in financial asset values and more specifically shareholder equity. This has had immediate impact on re/insurers, whose fixed income portfolios have suffered significant mark-to-market losses. The global bond index was down 16% in 2022, and global equity markets also declined (the S&P Dow Jones Broad Market Index was down 18% year-on-year). The combined effect on reinsurer balance sheets – where invested assets are typically 3-4 times equity – was significant. By the end of 2022, reinsurance capital (traditional and alternative) had declined by around 20–25% from year-end 2021. After adjusting for the interest rate impact of mark-to-market losses for fixed income securities, we estimate a decline in capital of around 5%, partly as the result of catastrophe losses. However, exposures (here proxied by GDP) continued to rise fast, hence creating a gap between supply and demand (see Figure 18).

Figure 18
Global reinsurance capital vs exposure growth, 2018 = 100.



Source: AM Best, Swiss Re Institute

Hurricane Ian did not spark a significant influx of capital.

Historically, large catastrophe events have sparked a significant influx of fresh capital. But this did not happen after Hurricane Ian. As of January 2023 an estimated USD 3.3 billion (ie, less than 1% of current reinsurance capital of more than USD 400 billion) of capital had been raised after Hurricane Ian.[41] This is much lower than in 2020, when reinsurers and a few new players raised close to USD 15 billion of capital as prices rose, or the surge of alternative capital (AC) between 2012 and 2018 in the phase of benign natural catastrophe years. ILS and other forms of AC offer a quick supply response and now provide most of the retrocession market. However, growth in AC has stalled since 2018 after the high claims that hurricanes Harvey, Irma and Maria in 2017 sparked, and above-average catastrophe loss years since. ILS structures have become more exposed to loss creep and coverage disputes, and investors are hesitant to commit fresh capital to natural catastrophe risks ahead of what could be another heavy-loss year, with economic inflation adding to valuation and pricing uncertainty.

Reinsurers and investors will likely wait for signs of improved sector profitability before committing more capital.

When higher exposures encounter shrinking risk appetite, the expected outcome is rising prices, higher retentions and tighter terms and conditions. The pricing correction in January 2023 is a source of optimism for the re/insurance industry. However, the prospect of still-elevated catastrophe losses and constrained capacity come as geopolitical, economic and environmental uncertainties remain omnipresent. These include loss uncertainty in specialty lines related to the war in Ukraine, the threat of a systemic cyber event, and the prospect of a renewed surge in COVID-19. With risks still elevated and higher interest rates raising returns elsewhere, we expect some reinsurers and ILS investors will wait to see proof in re/insurance industry profits before materially increasing capacity.

[41] J. Alovisi et al., *The Great Realignment*, Howden, 3 January 2023.

Conclusion

Socio-economic factors will continue to inflate catastrophe loss severity.

The elevated natural catastrophe insured losses of the past six years reaffirm the 5–7% uptrend in average annual losses established over the last 30 years. We expect the trend to continue. The growth has been and will be largely driven by rising loss severity of individual catastrophes. This is the result of rising exposures that comes alongside economic development, urbanisation, and population growth, often in areas exposed to natural hazards.

World circumstances have become more uncertain, beyond evidence of heightened catastrophe activity.

Demand for catastrophe-related insurance has risen on evidence of more peril activity since 2017. This is one factor behind today's hard market in re/insurance. So too are the geopolitical and economic storms the world faces. In particular, fallout from the decade long zero-to-negative interest rate environment, the pandemic, and war in the Ukraine has included high inflation and rising costs in the construction sector in 2022. This has increased the value of insured property assets and associated claims for damage caused by weather and other events. High inflation rates have also had financial market impacts given the need for central banks' to hike policy rates rapidly.

Re/insurance industry assessment of secondary peril risks in particular can be strengthened…

Another factor is a mismatch between the assessment of the risks that natural catastrophes pose and actual exposures. Last year's loss experience indicates that in this regard, the re/insurance industry remains in catch-up mode. All of last year's primary and secondary peril events were driven by known risk factors, yet the industry's valuation of potential losses was below actual outcomes. The mismatch reflects in declining industry profitability over recent years. Since 2017, the re/insurance industry has paid out USD 650 billion for weather-related natural catastrophes claims. However, premium income has not kept pace, contributing to a decline in reinsurance sector profitability, with return on equity down from an annual average of 12% in 2012–2016 to 5% in 2017–2021 (see Figure 13 on page 21). This signals gaps in dealing with several aspects of secondary peril risk assessment in particular, the associated losses of which have been on long-established upward trend. Where the industry has traditionally focused risk assessment on tail exposures and capital threatening events, the recent-years' loss experience underpins the need for as much focus and discipline on the higher frequency end of loss distributions. Against this backdrop, it is time to think of ***all*** perils as primary. That is, rather than maintain a mindset of primary and secondary, for the purposes of risk assessment all perils should be given the same attention and resources as afforded primary hazard exposures.

…with a culture of systematic data collection, updating and sharing.

To this end, there is a need for more discipline around the monitoring of perils and the collection, updating and sharing of exposure and claims data, and also model outcomes. In similar spirit, the historical loss data used as a core benchmark in secondary peril risk assessment needs to be systematically debiased to represent current-day, location-specific loss drivers to capture their compounded and rapid growth. This means accounting for the many evolving variables shaping risk landscapes, such as the impact of inflation on local rebuild costs, social inflation, urbanisation and soil sealing, and migration to exposed areas among others.

And, underwriting discipline needs to be maintained to improve risk pricing.

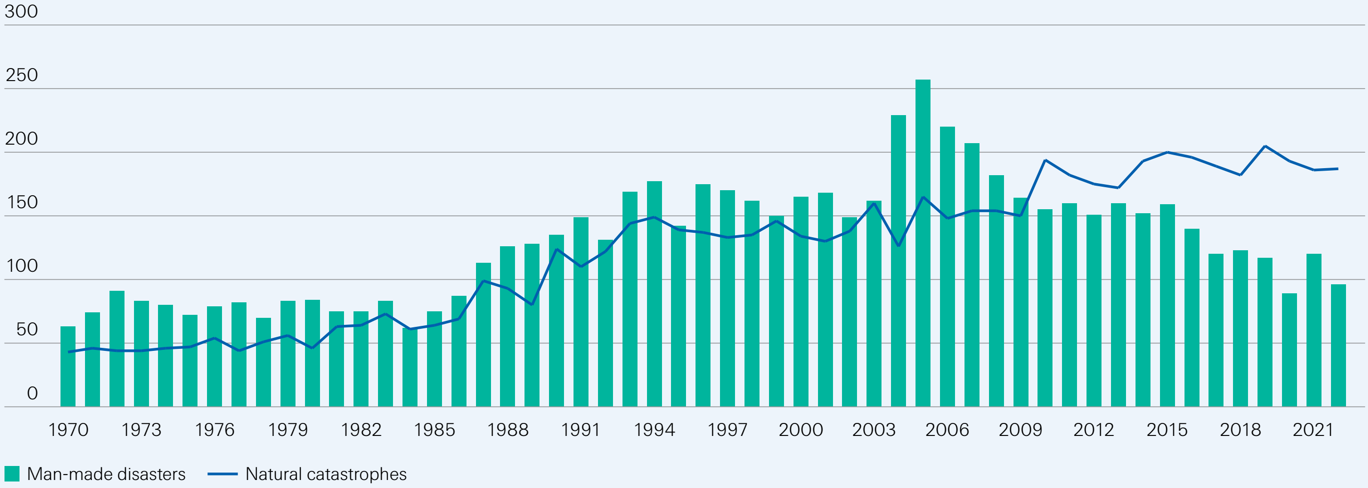
In addition to risk assessment, commensurate risk pricing is key for efficient market functioning, and sufficient capacity supply. Perceptions around risk assessment accuracy influence the supply of capital and capacity available for underwriting. The January 2023 renewals saw a long overdue re-pricing of risks before the background of increasing challenges to correctly capture the fast-moving risk landscape, capacity constraints and higher hurdle rates in a new interest rate environment. Market discipline is required for pricing to remain oriented to long-term exposure developments. With this, the insurance industry is best placed to fulfil its role as enabler of economic growth and financial resilience.

Appendix 1: 2022 – the year in review

Facts and figures

Number of catastrophic events: 285
Based on *sigma* criteria, there were 285 catastrophes worldwide in 2022, down from 306 in 2021. There were 187 natural catastrophes, up from the 186 in 2021, and 98 man-made disasters (down from 120 in 2021).

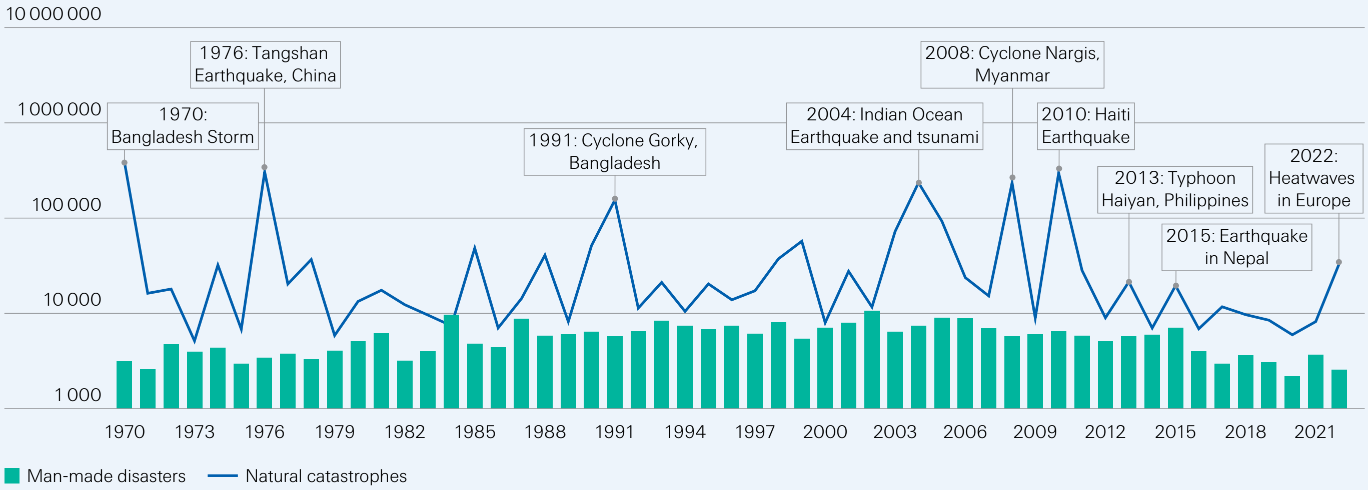
Figure 19
Number of catastrophic events, 1970–2022



Source: Swiss Re Institute

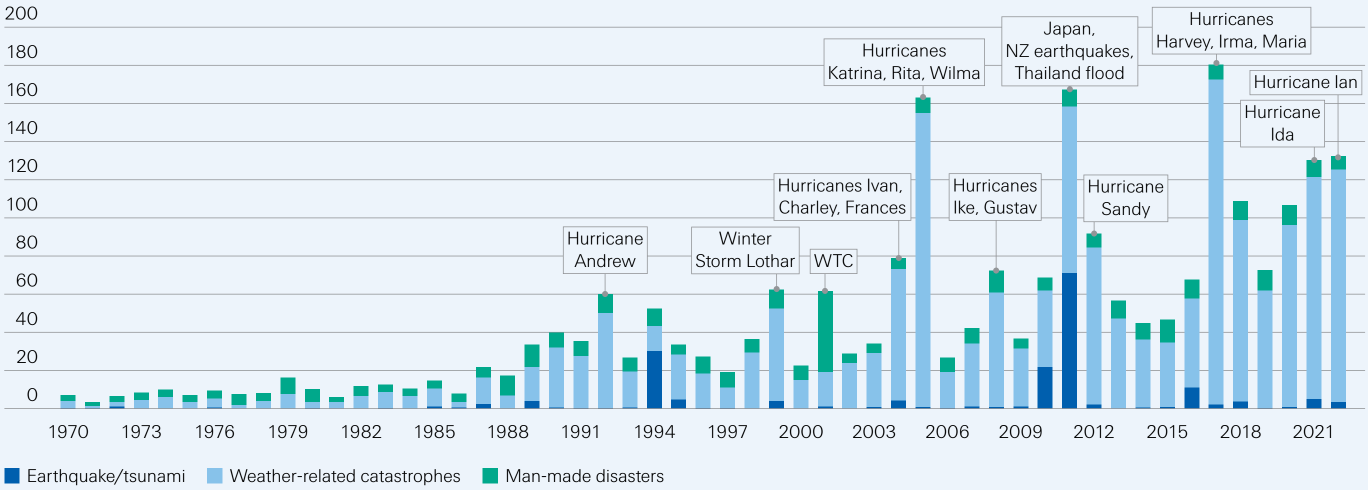
Number of victims: more than 35 000
Worldwide, 35 157 people are believed to have died or gone missing in disaster events in 2022. Natural catastrophes claimed over 32 600 victims, and man-made disasters over 2500.

Figure 20
Number of victims, 1970–2022



Note: Scale is logarithmic: the number of victims increases tenfold per band. Source: Swiss Re Institute

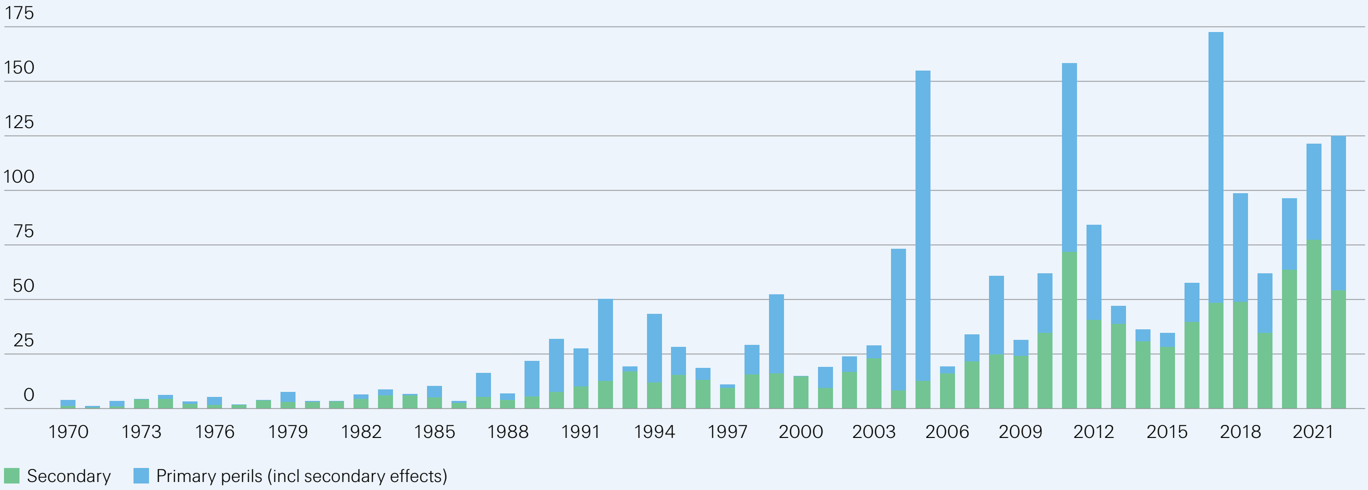
Figure 21
Insured catastrophe losses, 1970–2022, in USD billion at 2022 prices



Source: Swiss Re Institute

Primary and secondary perils
Hurricane Ian brought the share of insured losses from primary perils to 57% in 2022, from a previous 10-year average of 37%.

Figure 22
Global insured losses from primary and secondary perils in USD billion at 2022 prices



Source: Swiss Re Institute

Total economic losses: USD 284 billion

Total economic losses from disasters across the globe were an estimated USD 284 billion in 2022, down from USD 303 in 2021. Around USD 275 billion resulted from natural catastrophes and the remainder from man-made events.

Table 3
Economic losses, in USD billion and as a % of global GDP, 2022

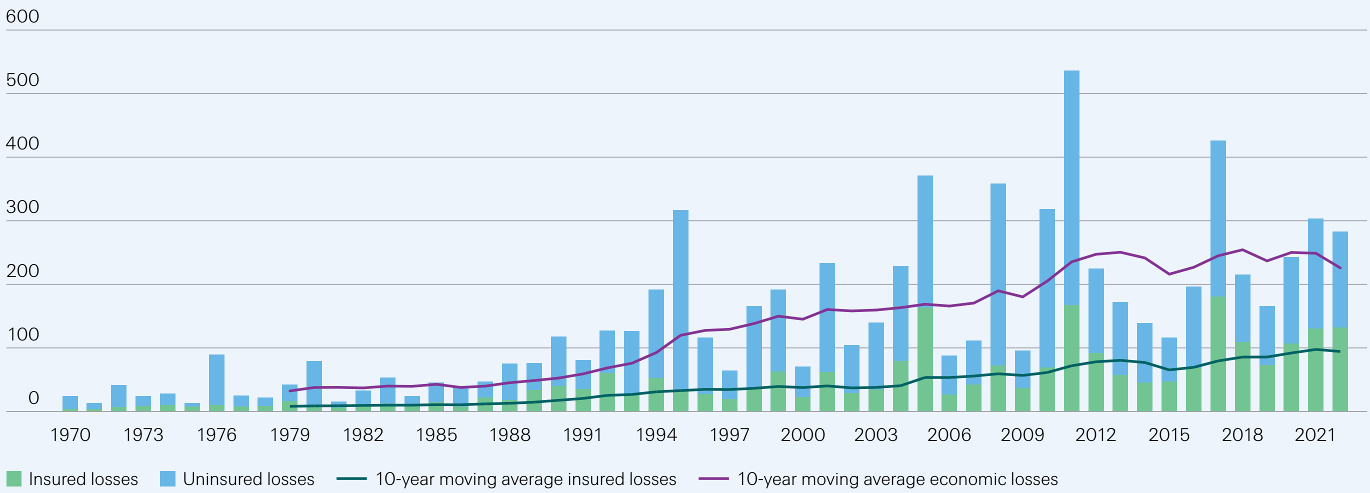
Regions	in USD bn*	in % of GDP
North America	176	0.64%
Latin America & Caribbean	17	0.31%
Europe	21	0.09%
Africa	8	0.27%
Asia	51	0.13%
Oceania/Australia	10	0.50%
Total	**284**	**0.27%**
World total		
10-year average**	220	0.27%

*rounded numbers
**inflation adjusted
Source: Swiss Re Institute

Global catastrophe protection gap: USD 151 billion

Figure 23 shows global economic and insured losses over time. This highlights the insurance protection gap, ie the financial loss generated by catastrophes not covered by insurance. In 2022, the global protection gap, uninsured losses, was around USD 151 billion, down from 173 in 2021 and up from the previous 10-year average of USD 130 billion. The protection gap was 53% of the total economic losses, down from the previous 10y average of 59%.

Figure 23
Insured vs uninsured losses, 1970 – 2022, in USD billion at 2022 prices



Economic losses = insured + uninsured losses. Source: Swiss Re Institute
Source: Swiss Re Institute

Regional loss overview

Insured and economic losses were highest in North America, driven by Hurricane Ian.

Table 4

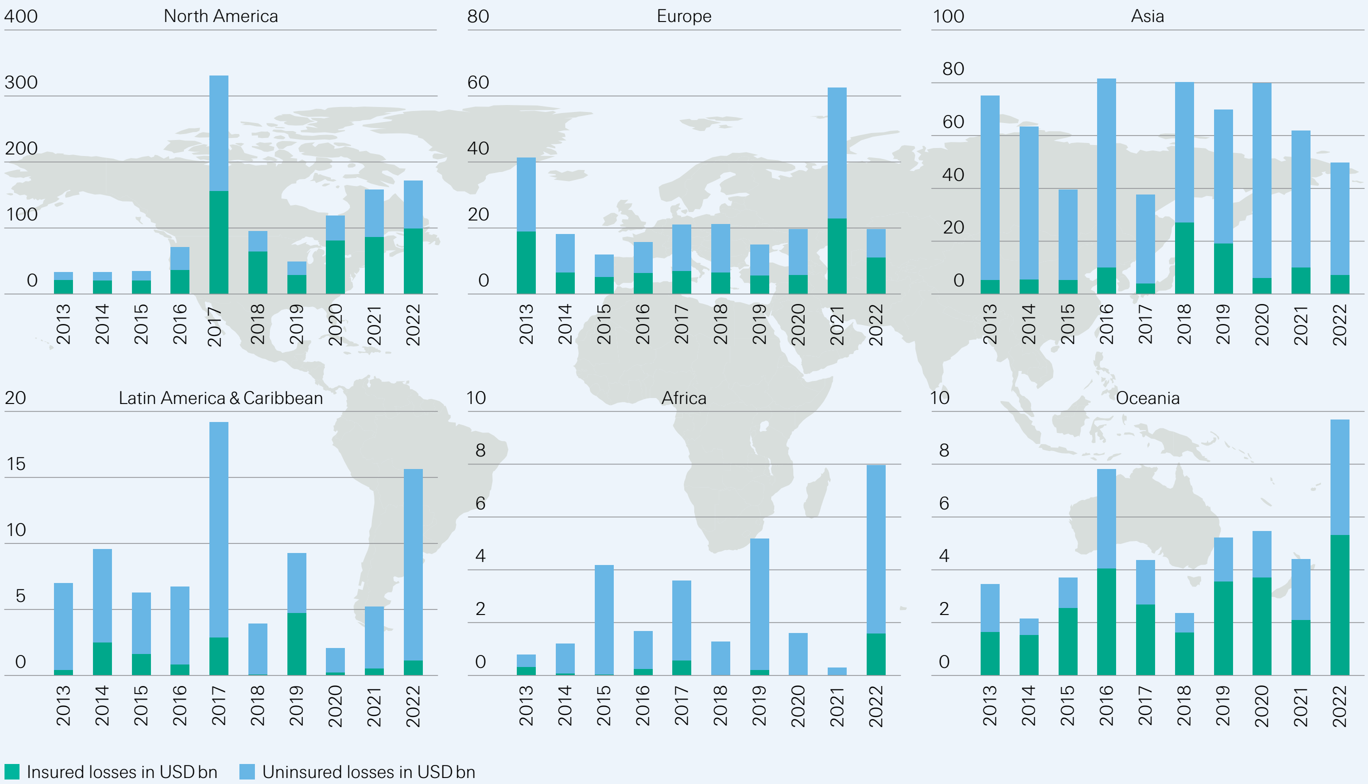
Number of events, victims, economic and insured losses by region, 2022

Regions	Number	Victims	in %	Insured losses (USD bn)	in %	Economic losses (USD bn)	in %
North America	84	510	1.5%	102.8	77.6%	176.0	62.1%
Latin America & Caribbean	20	906	2.6%	1.9	1.5%	17.4	6.1%
Europe	37	23 864	67.9%	12.2	9.2%	21.0	7.4%
Africa	43	3 044	8.7%	1.6	1.2%	8.0	2.8%
Asia	92	6 804	19.4%	8.4	6.3%	51.2	18.1%
Oceania/Australia	7	29	0.1%	5.3	4.0%	9.7	3.4%
Space	2			0.3	0.2%	0.3	0.1%
World total	**285**	**35 157**	**100.0%**	**132.5**	**100.0%**	**283.7**	**100.0%**

Note: some percentages may not add up to 100 due to rounding.
Source: Swiss Re Institute

Figure 24

Natural catastrophes protection gap by region 2013–2022, in USD billion at 2022 prices



Source: Swiss Re Institute

Appendix 2

Definition of terms

Natural catastrophes

The term "natural catastrophe" refers to an event caused by natural forces. Such an event generally results in a large number of individual losses involving many insurance policies. The scale of the losses resulting from a catastrophe depends not only on the severity of the natural forces concerned, but also on man-made factors, such as building design or the efficiency of disaster control in the afflicted region. In this *sigma* study, natural catastrophes are subdivided into the following categories: floods, storms, earthquakes, droughts/forest fires/heat waves, cold waves/frost, hail, tsunamis, and other natural catastrophes.

Man-made disasters

This study categorises major events associated with human activities as "man-made" or "technical" disasters. Generally, a large object in a very limited space is affected, which is covered by a small number of insurance policies. War, civil war, and war-like events are excluded. *sigma* subdivides man-made disasters into the following categories: major fires and explosions, aviation and space disasters, shipping disasters, rail disasters, mining accidents, collapse of buildings/bridges, and miscellaneous (including terrorism).

Primary and secondary perils

Swiss Re Institute categorises natural catastrophes as primary and secondary perils. A key differentiator is the sophistication of insurance industry modelling for different perils with respect to the rigour of data collection, submission and underwriting consideration. Table 5 shows the distinction.

Table 5
Swiss Re Institute classification of primary and secondary perils

	Event type	Re/insurance industry status	Examples
Primary perils	▪ Natural catastrophes that tend to happen less frequently, but which have high loss potential. ▪ Include secondary effects.	▪ Traditionally well-monitored and managed risks in developed re/insurance markets. ▪ **Secondary effects are** not always explicitly modelled alongside the originating primary peril, less rigorous monitoring.	▪ Tropical cyclones (including tropical cyclone-induced inland flooding and storm surge); earthquakes (including tsunamis, liquefaction and fires following earthquakes); European winter storms
Secondary perils	▪ Natural catastrophes that can happen relatively frequently, and typically generate low- to medium-sized losses. ▪ Refer to independent secondary perils only.	▪ Less rigour in the industry monitoring and modelling than for primary perils. Weaker exposure data capture and claims tracking.	▪ Severe convective storms (including thunderstorms, hail and tornadoes); floods, droughts, wildfires, landslides, snow, freeze.

Source: Swiss Re Institute

Economic losses
For the purposes of the present *sigma* study, economic losses are all the financial losses directly attributable to a major event, ie damage to buildings, infrastructure, vehicles etc. The term also includes losses due to business interruption as a direct consequence of the property damage. Insured losses are gross of any reinsurance, be it provided by commercial or government schemes. A figure identified as "total damage" or "economic loss" includes all damage, insured and uninsured. Total loss figures do not include indirect financial losses – ie loss of earnings by suppliers due to disabled businesses, estimated shortfalls in GDP and non-economic losses, such as loss of reputation or impaired quality of life.

Generally, total (or economic) losses are estimated and communicated in very different ways. As a result, they are not directly comparable and should be seen only as an indication of the general order of magnitude.

Insured losses
"Losses" refer to all insured losses except liability. Leaving aside liability losses, on one hand, allows a relatively swift assessment of the insurance year; on the other hand, however, it tends to understate the cost of man-made disasters. Life insurance losses are also not included.

Adjustment for inflation
sigma converts all losses for the occurrence year not given in USD into USD using the end-of-year exchange rate. To adjust for inflation, these USD values are extrapolated using the US consumer price index to give current (2022) values.

For the 2022 reporting year, the lower loss thresholds were set as follows:

***sigma* thresholds for 2022**	
Insured losses (threshold in USD m)	
Maritime disasters	25.2
Aviation	50.4
Other losses	62.5
or Total economic losses (threshold in USD m)	120.6
or Casualties	
Dead or missing	20
Injured	50
Homeless	2000

If changes to the loss amounts of previously published events become known, *sigma* takes these into account in its database, but Swiss Re is under no obligation to publicly revise or update this *sigma* study.

Sources
Information is collected from newspapers, direct insurance and reinsurance periodicals, specialist publications (in printed or electronic form) and reports from insurers and reinsurers. In no event shall Swiss Re be liable for any loss or damage arising in connection with the use of this information (see the copyright information on the inside back cover).

Published by:
Swiss Re Management Ltd
Swiss Re Institute
Mythenquai 50/60
P.O. Box
8022 Zurich
Switzerland

Telephone +41 43 285 2551
Email institute@swissre.com

Authors
Dr Chandan Banerjee
Lucia Bevere
Dr Thierry Corti
James Finucane
Roman Lechner

The authors thank Dr Stefanos Mystakidis and Yordanka Velichkova for their contributions to this report.

Editor
Paul Ronke

Managing editors
Martin Bertogg
Head of Cat Perils, Cyber and Geo

Dr Jerome Jean Haegeli
Group Chief Economist

Explore and visualise *sigma* data on natural catastrophes and the world insurance markets at *www.sigma-explorer.com*

The editorial deadline for this study was 22 February 2023.

sigma is available on Swiss Re' s website: *www.swissre.com/sigma*

The internet version may contain slightly updated information.

Graphic design and production:
Corporate Real Estate & Logistics / Media Production, Zurich

Printing: Multicolor Print AG, Baar

Swiss Re Management Ltd.
Swiss Re Institute
Mythenquai 50/60
P.O. Box
8022 Zurich
Switzerland

Telephone +41 43 285 3095
swissre.com/institute