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Financing the unpredictable:

What role could sovereign catastrophe bonds play in disaster risk management?

Lea Reitmeier, Denyse S. Dookie and Viktor Rözer

Policy report

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Summary

Extreme weather events can cause significant loss of life and damage to economies and livelihoods. While in the past governments have often relied on budget reallocations and increased borrowing to respond to such events, their rising frequency and severity, related to climate change, is causing significant fiscal challenges that mean other responses must be considered. In the context of understanding the range of avenues of financial risk transfer in light of these consequences, and the need to improve financial resilience, catastrophe bonds are attracting mounting attention. Since publicly available information about 'sovereign catastrophe bonds' is limited, this report assesses some of the challenges and opportunities presented by these bonds.

An increasing focus on disaster risk reduction strategies, including catastrophe bonds

Droughts, heatwaves, tropical cyclones and floods pose serious risks to humanity, infrastructure and the natural environment. The significant and growing economic, fiscal and human impacts of these climate-related hazards have prompted policymakers in various capacities, including finance ministries, central banks and financial supervisors, to better understand risk exposures and identify strategies to adapt. Within the remit of finance ministries, this would include the formulation of plans that consider the potential financial impacts of natural hazards.

Definitions

In this report we refer to the following:

Catastrophe bonds from private entities – where private entities such as insurance or reinsurance companies are the sponsor.

Sovereign catastrophe bonds – where governments are the sponsor.

An array of instruments can be used in anticipation of such events, such as countercyclical fiscal policies, reserve funds or insurance products. Diversifying risk across different financial instruments is key but should be approached in a sensible and well-coordinated manner. Disaster risk reduction strategies should be improved to incorporate complementary financial instruments.

Catastrophe bonds are a type of insurance-linked security that transfers specific risk exposures to the global capital markets. They represent a niche financial instrument, albeit one whose coverage is rapidly expanding. Sovereign catastrophe bonds provide ex-ante financial protection for governments and are gaining interest as a risk management instrument, particularly in developing countries, to provide coverage to specific high severity, low frequency events. In emerging markets and developing countries, issuances through multilateral development banks and the coverage of secondary perils such as floods and droughts is expected to grow. This is particularly the case given the World Bank's aim to expand its catastrophe bond support, with sovereign issuance intended to increase by 400% through to 2028.

However, catastrophe bonds are not a silver bullet. Furthermore, despite the building interest, information about the detailed structures of catastrophe bonds in the public space is limited. There is a significant lack of transparency about the challenges and trade-offs between bond characteristics, as well as operational aspects.

Balancing government needs with investor objectives

The offering circular of a bond contains all the information that potential investors need to understand the bond's risk and coverage, including the perils, region, trigger structure and temporal aspects. In cases where a catastrophe occurs that fulfils the predetermined trigger criteria, some or all of the investors' money is paid out to the government. If the trigger criteria are not fulfilled over the lifetime of the bond, the investors get their entire investment (principal) back.

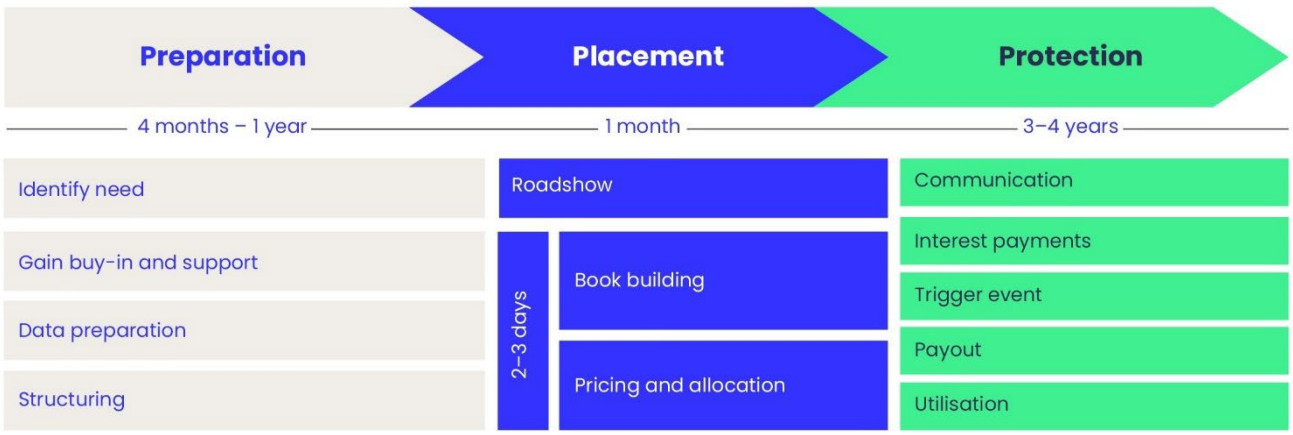
While sovereign catastrophe bonds have been recognised for their provision of financial protection without increasing a country's debt, such transactions do not come 'cost-free'. The investor receives the coupon payment for their investment quarterly, which includes a risk premium that is determined based on the estimated risk exposure to natural catastrophes. The issuance of a catastrophe bond necessitates the involvement of stakeholders including legal counsel, risk modelling agents and debt capital market agents, whose service fees can be around US$3 million per transaction.

In the past, sovereign catastrophe bonds have used parametric trigger structures, where a predetermined amount is paid based on the magnitude of the event rather than the magnitude of the losses caused by the event. The discrepancy between the actual losses experienced and the bond payout size has been criticised, a phenomenon referred to as 'basis risk'. While the parametric trigger is intended to facilitate rapid disbursement of the principal following the occurrence of a triggering event, the bond sponsor (the government in this case) is subject to a greater degree of uncertainty than the investor. For investors, the potential loss of their initial investment represents the worst-case scenario. The sponsor, on the other hand, is faced with the prospect of potential losses from an event that may exceed the principal by a significant margin.

Initial insights to inform phases in issuance

Based on the issuance of sovereign catastrophe bonds to date and available documentation, we can start to identify key phases and steps in issuing such bonds. These start with a preparation phase, through bond structuring and placement, to the live phase, i.e. when the bond provides protection (see Figure S1). Governments must clearly communicate the structure, role and limits of the catastrophe bond and its place within their wider disaster risk reduction strategy.

Figure S1. Phases in issuing a catastrophe bond



Source: Authors

Catastrophe bonds as a facilitator of collaboration and disaster risk reduction tool

The process of designing a catastrophe bond has the potential to bring together the agency responsible for disaster management with other government ministries, such as environment and finance, and public institutions, through the necessary knowledge- and data-sharing. There is even the potential to foster cooperation across multiple countries through the need to pool resources and share risks, promoting regional collaboration in disaster preparedness.

If a catastrophe bond is identified as a valuable addition to a disaster risk reduction toolbox, it is essential to ensure that the investments made and knowledge gained are used for future issuances. Appropriate supporting structures must be put in place to guarantee the effective utilisation of potential payouts. The sponsor should make as many documents available to the public as possible, including details about the transaction structure, event definitions and calculations, payout information and risk analysis. In this regard, insights could be drawn from other sustainable debt instruments, such as green bonds, where principles and frameworks exist. Such frameworks provide a valuable source of guidance, outlining best-market practices, optimising issuance processes, and, ultimately, fostering transparency.

Increased transparency in the sovereign catastrophe bond market would help to further position them within the sustainable finance market, facilitate increased academic research and build up knowledge across governments and institutions. These actions would also contribute to building public trust and awareness about the opportunities and limitations of these instruments. This is necessary if the share of sovereign catastrophe bonds is to increase from its current level of 2.55% of the total market volume.

1. Introduction

Extreme weather events, including droughts, heatwaves, tropical cyclones and heavy rainfall, are becoming more frequent and intense due to climate change, exacerbating physical risk, vulnerability and damaging impacts for people, infrastructure and nature. This is increasing the need for capital while also impacting borrowing costs for developing countries. Policymakers in affected countries are needing to increase their focus on how to ensure stability and climate resilience in their fiscal and economic policies and risk management practices.

This report aims to enhance understanding of sovereign catastrophe bonds, a type of insurance-linked security, as a tool in comprehensive disaster risk reduction. Traditional disaster risk finance tools, such as insurance and reserve funds, remain important, but catastrophe bonds are gaining attention as a specialised option. Interest in their use is particularly strong in developing countries, where multilateral development banks are expanding support for catastrophe bonds.

The impacts of extreme weather events are posing mounting losses to the global economy due to the interaction with factors such as population growth, inflation, asset accumulation and urban expansion. The destruction of infrastructure and housing, along with disruption to production and supply chains, are among the most conspicuous consequences of natural hazard-based disasters. These direct damages to households and businesses can be quantified through catastrophe risk models. However, the extent to which indirect damages propagate across time and space is contingent upon the source of shock and such effects are often not considered in models due to modelling challenges. Even for policy decision-makers, these second-order effects, such as impacts on social and economic systems, are not always fully comprehended.

As the burning of fossil fuels continues and global temperature rises further, the difficulty of predicting and responding to these effects will only increase. Localised shocks such as flooding cascade through the economy, public finances and the financial sector in a manner that differs from problems like water scarcity or heat stress, which tend to affect larger areas. Governments therefore need a diversified disaster risk management approach within sovereign debt strategies that ensures fiscal resilience and financial stability are maintained as different types of extreme events escalate.

Purpose and structure of the report

This report aims to enhance understanding of sovereign catastrophe bonds in countries with different levels of climate risk exposure. It is targeted primarily at governments, particularly finance ministries in emerging markets and developing countries that are highly affected by extreme weather events, including Small Island Developing States (SIDS) that are particularly exposed to fast-onset climate-related events like hurricanes. It can also inform national and international policymakers or donor agencies interested in increasing their understanding of the role of these bonds for disaster risk management practices.

The report explores the role of these instruments, while addressing the complexities and challenges involved in their design and implementation. To better contextualise this, we utilise case studies to offer insight into specific factors that influence the issuance and utilisation of catastrophe bonds. The report thus contributes to the ongoing discussion and literature on the potential role of

catastrophe bonds, including as a risk management tool, by assessing its financial mechanism to deal with disaster risk.

Section 2 explores the links between physical climate risks and their impacts on lives, livelihoods and economic activity. It also provides an overview of various financial instruments that can contribute to enhancing resilience to disaster risks.

Section 3 first introduces catastrophe bonds and then examines their use by governments in emerging markets and developing countries, detailing their financial structure, geographical distribution and key stakeholders required for a transaction and associated costs.

Section 4 addresses key aspects and challenges of structuring and issuing a catastrophe bond.

Section 5 presents case studies, focusing on three identified phases of catastrophe bond issuance: preparation, placement and protection. Jamaican and Mexican bond examples are analysed to illustrate the different steps and considerations involved in issuing these bonds.

Section 6 delineates the fundamental contributions of catastrophe bonds, contextualises their function within the disaster risk reduction toolbox and highlights some emerging trends.

Section 7 concludes the report, summarising key insights.

Flooding following Typhoon Goni in 2020, Santa Maria, Macabebe, Philippines. Photo: Judgefloro, CC0, via Wikimedia Commons

2. Addressing the impacts of physical climate risk

Globally, the scale and speed at which adaptation to climate change is happening is inadequate relative to the extent of the risk. Twenty-six countries still lack a national planning instrument for adaptation. The challenge is particularly severe for Small Island Developing States, whose adaptation finance needs far exceed those of other developing countries. Ranging from risk reduction to risk transfer and also risk retention, a diverse set of financial instruments should be utilised to enable governments to effectively address both immediate disaster relief and long-term resilience-building, as this section introduces.

Physical climate risk and the impact on people and economies

The annual global costs of extreme weather attributable to climate change amounted to US$143 billion over the period 2000–2019 (Newman and Noy, 2023). A considerable proportion of economic losses used to be more associated with events such as hurricanes, which are commonly referred to as primary perils due to their destructive power. However, losses caused by so-called secondary perils such as floods, droughts and wildfires are rapidly increasing. (See Box 2.1 below on terminology.)

Interest has grown in the potential for physical risks to affect economic outcomes (Batten, 2018) or fuel persistent inflationary pressures (Barmes et al., 2024), and the implications for financial stability (ECB, 2021; BCBS, 2021), and as such, financial supervisors and central banks have conducted their own assessments to understand the impact of climate change (NGFS, 2024; ECB, 2022). The occurrence of physical risks has both microeconomic and macroeconomic impacts. At the micro level, impacts include a loss of cash flow and reduced labour productivity, as well as the destruction of physical capital, which can hinder production capacity and slow down recovery, ultimately impacting credit default rates and collateral value (de Bandt et al., 2024). Additionally, beyond reduced productivity, there may be a lasting negative impact on labour supply due to injury, mortality and displacement of workers, further constraining economic activity. The macroeconomic impacts include changes to trade and capital flows, and to price stability. These impacts then affect the economy, including through employment and food security concerns, the public finances through a decline in tax revenues and increased public expenditure and imports, and the financial sector, through risk to credit or insurance underwriting, for example.

Box 2.1. Variations in terminology related to physical climate risks	
The terminology to describe physical climate risks varies across sectors and areas. In the (re)insurance industry the historic economic costs of events have been the key determinant for categorisation, while for central banks and supervisors, risks are often categorised based on the speed of their impact. However, the fundamental distinction between slow-evolving and sudden risks remains the same.	
UNFCCC	Extreme natural events that lead to physical risks are often split into two categories. The Cancun Adaption framework (UNFCCC, 2011) differentiates between **'slow-onset'** events (e.g. sea level rise, salinisation, loss of biodiversity and desertification) and **'rapid-onset'** events such as a hurricane, which are characterised by their discrete and singular occurrence. Historically, slow-onset events have received less attention from various stakeholder groups.
(Re)insurance	In the financial sector, and particularly the (re)insurance sector, the source of physical risk is differentiated according to its destructive potential. Tropical cyclones and earthquakes are described as **'primary perils'** and events like severe thunderstorms, flooding and droughts as **'secondary perils'** (Tomassetti et al., 2023; Sinai, 2019). This reflects the – historically – significantly higher economic losses caused by primary perils. With the destruction and disruption caused by secondary perils already outpacing losses caused by primary perils in more recent years, this distinction could be misleading.
Central bank and supervisors	In a financial regulatory context, a differentiation is made between acute and chronic risks (NGFS, 2022). **'Acute'** physical climate risks arise from shifts in the climate pattern, causing the severity and frequency of, for example, floods, drought, wildfires and hurricanes to increase. **'Chronic'** physical climate risks evolve slowly, such as sea-level rise and changes to global precipitation patterns.
Note: It is important to clarify the term **'climate risk'**. Even without the impacts of climate change, extreme weather events would take place, making a case for the use of instruments to increase financial resilience against those. However, as the global average surface temperature rises, climate change is intensifying pre-existing climate risks. Institutions like World Weather Attribution aim to assess how climate change alters the intensity and frequency of extreme weather events.	

Physical climate risk and adaptation – gaps and challenges

Adaptation to climate change can be defined as the process of adjusting to the anticipated negative effects of climate change, including disasters, in order to reduce the potential harm caused (Seneviratne et al., 2021). This can be achieved through methods including the construction and strengthening of infrastructure, incentivising behavioural shifts and enhancement of adaptive capacity risk and risk management. The UN *Adaptation Gap Report 2024* found that 87% of countries (171 countries) now have one national adaptation planning instrument in place, 51% a second, and 20% a third, demonstrating a growing commitment to put continuous work into adaptation plans and strategies (UNEP, 2024). However, development challenges such as internal fragility, conflict and geopolitical tensions impede the progression of countries. Twenty-six countries still lack any national planning instrument for adaptation. Further, even for countries with a national adaptation plan (NAP), the scale and speed at which adaptation is happening is inadequate relative to the extent of climatic risks (ibid.).

Investors need to understand how countries are planning to manage future impacts of climate change due to the implications for the long-term risk profile and debt sustainability of sovereign issuers. The Assessing Sovereign Climate-related Opportunities and Risks (ASCOR) project assessed

70 countries in 2024 on how they are managing their transition, physical and social risks, including whether they have published a NAP and disclose reports on implementation progress (Scheer et al., 2024). Only one-third of the assessed countries disclose such reports, pointing to significant gaps in global knowledge about the effectiveness of NAPs and different adaptation instruments. ASCOR also found that among 26 of the assessed middle- and low-income countries, only five are members of sovereign catastrophe risk pools that can support access to financial support as part of emergency responses following a climate disaster.

Developing countries that have historically been the most vulnerable to climate change are confronted with considerable obstacles that impede the implementation of effective measures (Omolere, 2024). In addition to the impact of heightened climate vulnerability on debt costs (Bernhofen et al., 2024), a significant challenge is the scarcity of adequate and predictable financial resources for adaptation (Omolere, 2024). Even a decade after major hurricane events, declines in tax revenues, public expenditure and debt financing are observed (Jerch et al., 2023). Subsequently, credit ratings deteriorate, which in turn increases the cost of debt for governments (Klusak et al., 2023). Sustained out-migration, which frequently ensues after severe disasters (Boustan et al., 2020), further complicates the recovery process.

Relevance to Small Island Developing States

These issues present a significant challenge for SIDS, as they are particularly susceptible to climate-related hazards due to a combination of factors, including their small size, geographical remoteness, vulnerability to rising sea levels and other natural hazards, highly dispersed and relatively small populations, and often highly concentrated economies (UN Secretariat, 2024; Dookie and Osgood, 2021). Other unique combined issues they face include high transport costs, limited natural resources, lack of updated infrastructure, skills gaps and labour shortages. How to increase financial resilience in these countries has been discussed on the global stage, for example through the 'Bridgetown Initiative'[1] and the 4th International Conference on SIDS (UNEP, 2023). However, challenges persist, with strategic, anticipatory and transformational measures for adaptation still significantly underfinanced (UNEP, 2023). Further, the inability of UN COP29 discussions to adequately increase financial flows to vulnerable nations to deal with the consequences of climate change was particularly devastating for SIDS (Reitmeier and Dookie, 2024).

With nearly half of SIDS in or nearing debt distress, they often need to channel money towards servicing debt rather than investments in social services or resilience-building. At the same time, access to grants, concessional loans and other innovative finance instruments is becoming more challenging for many SIDS. The qualification of a country to receive official development assistance (ODA) depends on its Gross National Income (GNI). Countries that exceed the threshold of US$13,845 GNI per capita for three consecutive years move into the 'high-income' category and thus lose access to concessional funding sources. Currently, there are 12 SIDS that might exceed this threshold by 2030 (OECD, 2024). Of these, Palau, Nauru, St. Lucia and Montserrat, for example, are still significantly dependent on ODA but are expected to graduate into the high-income category as early as 2026 (ibid.). Given their ineligibility for ODA, indebtedness and the host of other unique factors described above, SIDS have significant adaptation finance needs.

The gap between the adaptation finance needed and the reality of international public finance flows globally is already significant and widening, estimated to be US$194–366 billion per year (UNEP, 2023). The adaptation finance needs for SIDS are even higher compared with other nations. On average, SIDS require 3.4% of GDP annually, far exceeding the 1.4% required to adapt to climate change by other developing countries (UNEP, 2024). To strengthen financial resilience, SIDS require both ex-ante financing — such as funds for adaptation planning and preventive infrastructure — and contingencies for ex-post financing to cover immediate catastrophe-related costs. Currently, there are shortfalls in both kinds of finance.

[1] Among the Initiative's calls is for the inclusion of disaster risk clauses in debt issued by multilateral development banks to poorer countries affected by shocks including climate shocks (UN Climate Summit, 2023; Harvey, 2023; Mooney et al., 2023).

Financial instruments available to respond to physical climate risks

Some financial instruments are better suited for certain risk characteristics than others, therefore their role to enhance financial resilience varies. Some instruments, such as grants or resilience bonds, are designed to achieve a reduction in risk exposure, for example through financing adaptation infrastructure. Others, such as dedicated reserve funds, are intended to expand fiscal headroom. Insurance products in particular are aimed at transferring risk exposure to other stakeholders. Employing a diverse range of financial instruments should enable governments to effectively address both immediate disaster relief and long-term resilience-building. This should help to strike a balance between the unpredictability of disaster occurrences and the necessity for a rapid and sustained financial response.

More generally, there is a need for reliable data on risk exposures for making choices about financial instruments. For coastal regions and SIDS, where climate information on impending physical risks is still limited in terms of availability, accessibility and dissemination, and not readily utilised for decision-making (Dookie, 2024), this can be supported by resources such as 'ocean accounts'. These accounts help to measure the economic value of coastal and ocean-based activities as well as the health of these ecosystems. Ocean accounts can help measure the potential economic impact of natural-hazard related disasters on infrastructure, guiding land-use planning decisions and policy prioritisation to reduce risk exposure (UN ESCAP, 2018).

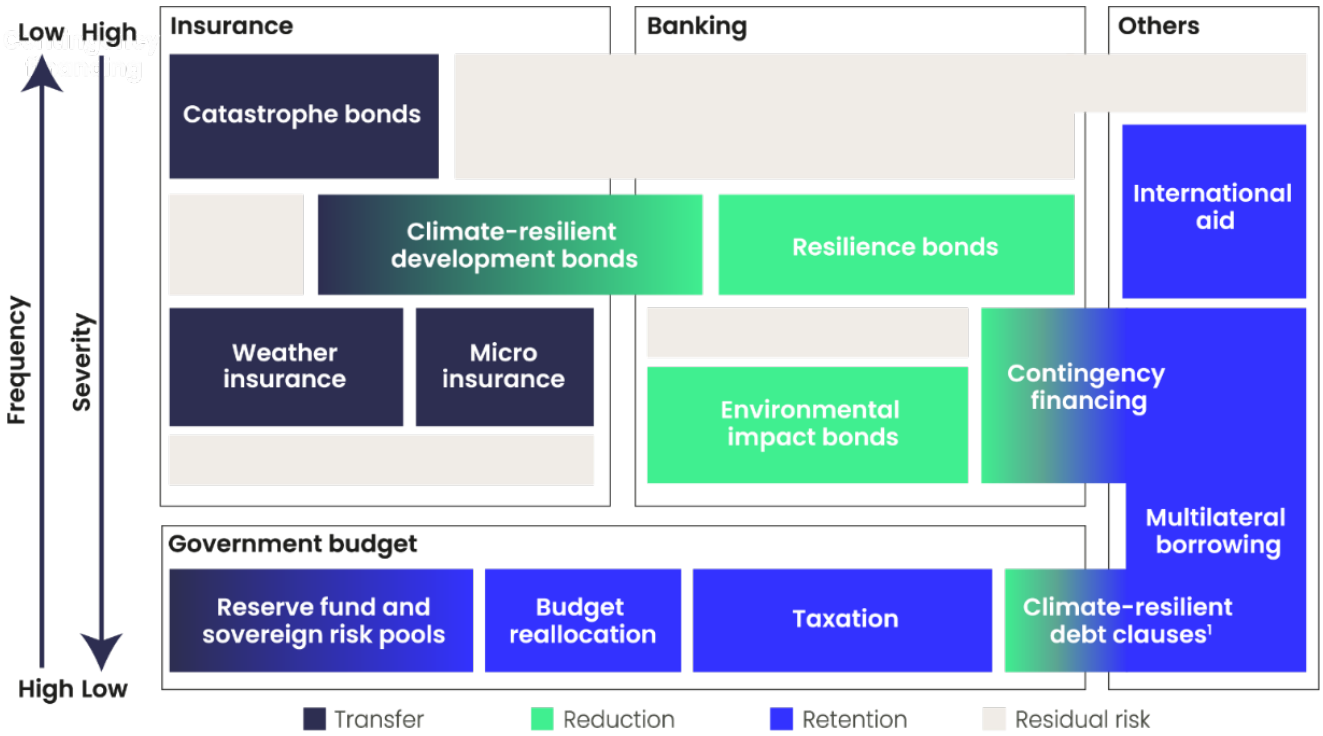
Figure 2.1 provides an overview of different instruments. They are broadly categorised into insurance, banking, government budget, and others, based on the source of financial protection and instrument characteristics and by key objective, ranging from transferring risk to reducing risk or retention of risk:

- Instruments in the **insurance** bucket are broadly aimed at covering unforeseen events and will lead to a payout after such an event takes place.
- **Banking** instruments provide finance for actions whose need is not unforeseen and are planned in advance, like the construction of a seawall.
- **Government budget** instruments include some that can be set up and used from government budgets directly.
- The **'other'** category goes beyond financial instruments and provides an overview of common other ways to ease financial pressures after a catastrophe event, ranging from international aid to the inclusion of specific terms in lending obligations, particularly from multilateral development banks.

There are instruments that are challenging to put into one risk category as their structure incorporates aspects that transfer risk as well as incentivise risk reduction, such as climate-resilient development bonds (see below). Some instruments are also harder to put into one bucket, such as climate-resilient debt clauses. While these clauses are relevant to government budgets, they rely on finding an agreement with external stakeholders such as the World Bank for such terms to be added to new or existing loans.

Figure 2.1 also shows that while a government budget can be used to tackle events with lower severity but higher frequency, as the severity increases, the reliance on additional financial instruments also increases. While banking products provide debt to invest in adaptation-related assets and projects, insurance provides financial support after an event takes place. However, there are likely to be risks that are not covered by instruments or are covered only partially. So-called 'residual risk' can exist at all levels of event frequency and severity but is particularly evident for very severe events (see the grey boxes in Figure 2.1).

Figure 2.1. Financial instruments to reduce disaster risk and increase financial resilience



Notes: 1. Including catastrophe-deferred drawdown options in loans.
Bonds can be issued at sovereign or corporate level, but here the focus is on sovereign issuances. We also note the general nature and discussion of *anticipatory action,* which refers to acting ahead of predicted hazardous events to prevent or reduce impacts. This may include 'forecast-based financing', which is a strategy to enable anticipatory humanitarian action by releasing a pool of funds triggered by scientific forecasts of extreme weather events, such as droughts or floods. See UNDRR (2024). Source: Authors

The use of bonds

By implementing countercyclical fiscal policy, establishing fiscal buffers or introducing insurance products, governments seek to safeguard their budgets and maintain essential services, even amid exposure to natural catastrophes. The catastrophe bond – introduced in more detail in the next section – is rapidly gaining attention in this context, as an instrument to transfer disaster-related financial risks to the private capital markets.

The following provides a high-level comparison of how catastrophe bonds differ from other bonds:

- **Resilience bonds:** In contrast to catastrophe bonds, which function in a similar way to life insurance policies and provide support after a claim event, resilience bonds can be viewed as similar to a progressive health insurance programme. Resilience bonds incentivise measures to bolster infrastructure resilience, much like how a health programme encourages healthier choices (Vaijhala and Rhodes, 2018). The funding of adaptation projects is made possible by the reduction of insurance premiums, which is justified by the expectation that such projects will result in a reduction of expected losses from a catastrophic event. However, in 2019 the European Bank for Reconstruction and Development (EBRD) issued the first dedicated climate resilience bond. Similar to a green bond, it raises capital specifically for climate-resilient investments, such as the modernisation of a hydropower plant in Tajikistan, supporting it to cope with the expected impacts of climate change on its hydrological systems while also improving electricity supply.
- **Environmental impact bonds** (EIBs) are similar to sustainability-linked bonds, which are characterised by their inclusion of a step-up (increase) or a step-down (reduction) mechanism for the interest rate paid by the issuer based on whether a predetermined performance threshold has been met. The first EIB was issued in 2016 in the United States by the District of Columbia Water and Sewer Authority (US EPA, 2017). If the utility company

performs well and significantly reduces its stormwater runoff, investors receive a one-time additional outcome payment. If the performance is below a specific level, investors make a one-time risk share payment to the company.

- EIBs differ from **green bonds** (which fund projects or specific assets) as they incorporate a pay-for-performance (or pay-by-results) structure (Trotta, 2024). Therefore, they can be directly linked to climate change adaptation interventions, contributing to overall risk reduction (coloured green in Figure 2.1).
- **Climate-resilient development bonds** emerged as a concept in 2023, merging characteristics of insurance and banking instruments. It is proposed that they combine climate risk insurance with resilience and mitigation efforts (Arnold-Dwyer, 2023). Like insurance instruments, they transfer risk away from the sponsor, and like banking instruments, they set aside some investment to fund preventive projects like flood defences. While this lowers the risk of a payout, it reduces the principal returned to investors at bond maturity. Thus, diverse investor participation is crucial, to include more than only traditional commercial investors, as some, such as ESG (environmental, social and governance) or philanthropic investors, prioritise positive impact over returns (ibid.). To date, this structure remains a conceptual idea, without any transactions being observed in the market.

3. Functioning and distribution of catastrophe bonds

Catastrophe bonds represent a niche, albeit expanding, financial instrument with the purpose of spreading the financial risk from disasters. They are a type of insurance-linked security that transfers specific risk exposures to global capital markets. This section explains how they work and describes their distribution.

Catastrophe bond structures

Catastrophe bonds were created in an attempt to increase the available insurance capacity beyond traditional reinsurance.[2] They were first introduced after the unexpectedly high damages caused by Hurricane Andrew in the southern United States in 1992, which bankrupted eight insurance companies (McChristian, 2012). There was substantial market growth in these bonds from 2005 onwards, driven by insurance and reinsurance issuances in North America, Europe and Japan.

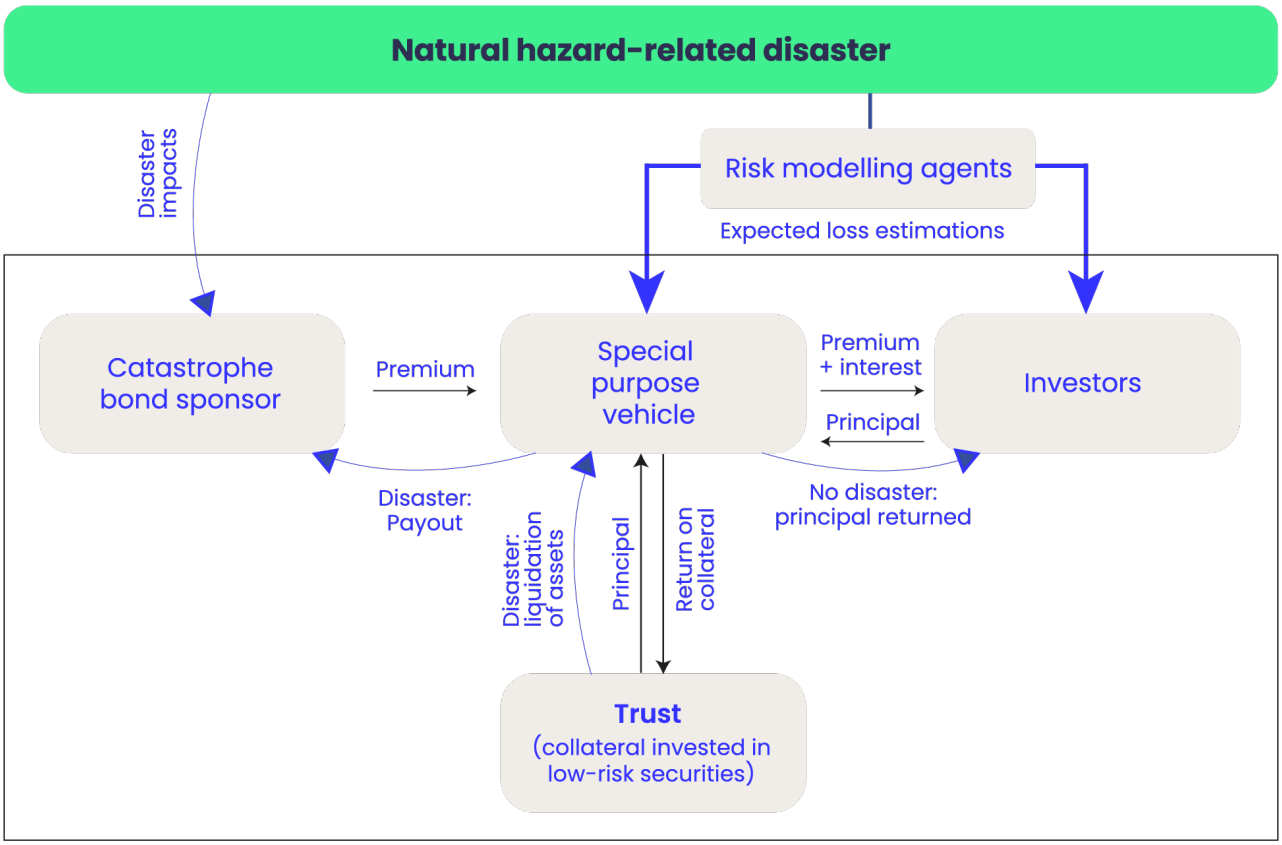
Catastrophe bonds work as follows: commonly, the sponsor (also known as the cedent) enters an agreement with a special purpose vehicle (SPV) that is used for the transaction. The SPV issues the catastrophe bonds; the SPV is a legal entity created to hold the capital (or principal) raised from investors in the form of highly liquid, low-risk instruments such as money market funds. The yield received from investing the principal in such funds, which in turn can be invested in securities such as US treasuries, is then transferred back to the investor. The investor receives their interest payments, which are adjusted quarterly to the market rate; therefore, the exposure to interest rate risks is not a concern. The investor also receives a risk premium, which is paid by the sponsor and determined based on the bond's exposure to natural-catastrophe risk. The coupon payments distributed to investors consists of the risk premium plus interest payments.

The SPV structure reduces uncertainty for all sides. The sponsor does not need to worry that the investor could default (the sponsor is not exposed to credit risk),[3] since the nominal of the bond is held in a trust account, while the investor faces no counterparty risk, as the invested capital reverts to the investor in case of default by the sponsor (since the SPV rather than the issuer is the sponsor).

The bond's offering circular contains all the information required by potential investors to understand the risk and coverage of the bond: including the perils covered (e.g. the peril of hurricane), the region covered, the trigger structure (e.g. a parametric trigger) and temporal aspects (e.g. bond duration relevant for factors in climate-related variation such as El Niño). In cases where a catastrophe occurs that fulfils the trigger criteria, some or all of the investors' money is paid out to the sponsor. In this case the investors receive neither part nor all of their investment back at the maturity of the bond. If the trigger criteria are not fulfilled over the lifetime of the bond, the investors get their entire principal back plus the annual coupon payment (usually paid quarterly) for their investment, when the bond matures (see Figure 3.1).

[2] Insurance-linked securities (ILS), the category catastrophe bonds fall into, are financial instruments whose value is affected by the costs that arise when an event that has been insured manifests itself. As well as catastrophe bonds, they include collateralised reinsurance instruments and other forms of risk-linked securitisation which are generally not deemed to be correlated with the wider financial markets as their value is linked to insurance-related, non-financial risks.
[3] This stands in contrast to a traditional reinsurance contract, where in the aftermath of a severe loss event the counterparty (e.g. a reinsurance company) could fail to meet their financial obligations due to financial constraints.

Figure 3.1. Example of a catastrophe bond structure



Source: Authors, adapted from Braun and Kousky (2021)

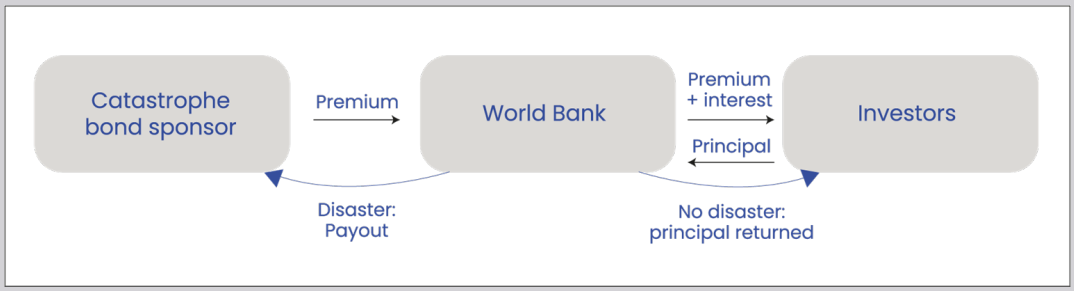
Box 3.1. Types of catastrophe bond sponsors	
Catastrophe bonds from private entities	In the past, catastrophe bonds were predominantly utilised by private entities, with insurance or reinsurance companies dominating the space. Over time other companies, such as North American rail transport provider Amtrak, tech company Alphabet and several financial institutions (e.g. Nephila Capital) have also issued catastrophe bonds, but they remain less common than those from insurance and reinsurance sponsors.
Catastrophe bonds from public entities	In some economies there are state-owned entities (e.g. Toka Tū Ake EQC in New Zealand) or insurers of last resort (e.g. Louisiana Citizens Property Insurance Corporation in the US) that issue catastrophe bonds.
Sovereign catastrophe bonds	Here, the sponsor is a government (e.g. Chile, Jamaica) or a government agency (such as Mexico's erstwhile fund for hazard-based disasters, FONDEN), which issues catastrophe bonds with the aim to support governmental budgets.
Note: The terminology describing the sponsor should not be confused with the type of bond issuance. A transaction can take place in a public or private manner. A bond placed through a public transaction, for example, can be traded on a stock exchange and is shown to the whole market, while a private transaction is arranged directly between different entities and is shown to a smaller group of investors. The costs involved in structuring a bond for a private transaction are typically lower than for a public one, therefore enabling entities with a smaller capital base to sponsor a catastrophe bond.	

Catastrophe bond sponsors (see Box 3.1) and investors have different motivations to engage in the catastrophe bond market. A sponsor typically uses this instrument to cover exposures to events with a low probability of occurrence but high loss impact (a so-called 'low frequency, high severity' event).[4] For both private and sovereign sponsors, catastrophe bonds allow them to transfer some of their risk to the capital markets and therefore they do not have to cover that exposure with their own capital, making equity available for other investments. To the investor, one of the most prominent benefits of catastrophe bonds is their low correlation with conventional capital market risks. While in traditional markets a financial crisis can propagate quickly between asset classes, regions and even stock market exchanges, it does not change the likelihood or intensity of a natural catastrophic event. Catastrophe bonds are therefore marketed as instruments that can be part of an appealing diversification strategy, which is particularly attractive during periods of high volatility in traditional markets (Demers-Bélanger and Lai, 2020).

Box 3.2. Sovereign catastrophe bond structure via the World Bank

Sovereign issuances that are issued with support of the World Bank have a few differences compared with the structure outlined in Figure 3.1.

First, they do not need a SPV or collateral trusts, as the World Bank provides countries access to the capital markets. Setting up both is associated with high costs, due to complex structuring requirements and involvement of other stakeholders such as legal teams. Through the World Bank's Capital at Risk Notes programme and facilitated by the Bank's triple-A credit rating (the highest possible rating), the World Bank can provide sovereign issuers with an alternative structure (see figure below). Instead of an SPV and trust, the World Bank issues the bonds, manages payments and invests the collateral into its developmental projects.



Second, countries have flexible payment options for catastrophe bond costs, including using World Bank financing proceeds, adding to existing loan interest rates, or periodic payments. In addition, the World Bank facilitates collaboration with donors to access grant funds. Third, having helped several sovereigns, the World Bank can support governments with the process, such as the preparation, structuring, marketing, execution and post-issuance communication and operations support. Particularly for the structuring and marketing aspects, reinsurance brokers such as Aon or Swiss Re have also taken up this task for sovereign issuances.

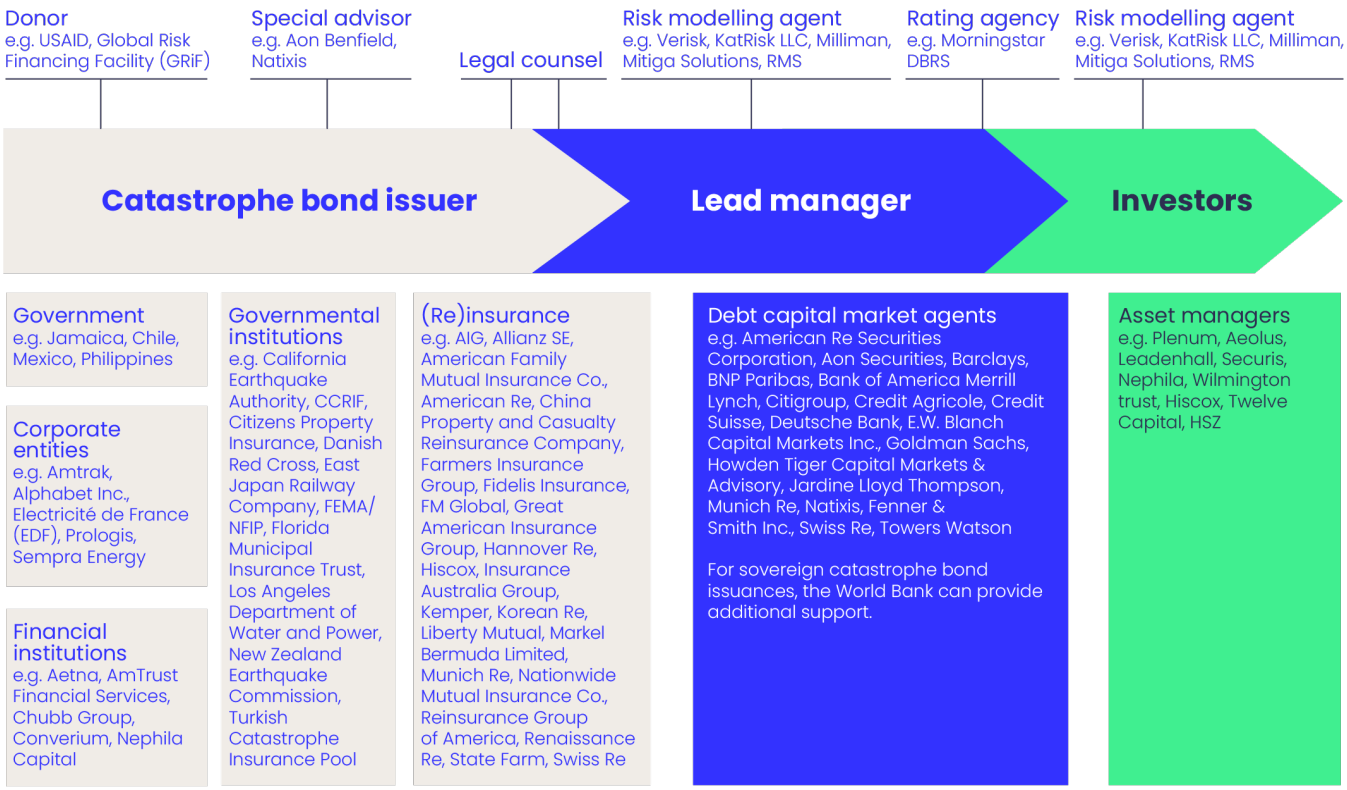
The support of the World Bank and other capital market agents is particularly beneficial, as through their market presence and existing networks with a wide range of investors they can provide insights into current investor preferences and access to a larger potential investor base, which is important during the book building process.[5]

[4] Catastrophe bonds can be designed as single-peril or multi-peril bonds, with the latter covering multiple risks.
[5] The key steps to issue a catastrophe bond are described in further detail in Section 4.

Key stakeholders and associated costs

The issuance of a catastrophe bond necessitates the involvement of several stakeholder groups. Figure 3.3 illustrates the key stakeholders involved in the three phases of catastrophe bonds described in this report: preparation, placement and protection (see Section 4). The figure includes an illustrative selection of companies that have been active in each phase in the past few years.

Figure 3.3. Stakeholders and example companies involved in catastrophe bond issuance



Source: Authors

Catastrophe bond sponsors can be governments, governmental institutions, corporate entities, financial institutions or, most commonly, insurance or reinsurance companies (see Box 3.1 above and Figure 3.3 for examples). They can be supported by a special advisor and receive legal advice during the process. The function of legal counsel can be assumed by multiple parties. For example, one party may specialise in drafting the deal-related documents, while another may specialise in legal issues pertaining to local specificities. Often the bonds are listed in Bermuda, Singapore or Hong Kong, requiring the 'local counsel' to have knowledge about the specific rules governing the listing of catastrophe bonds on the respective stock exchanges. For sovereign catastrophe bonds, sometimes donors provide financial aid.

The role of the lead manager (or broker or placement agent) is provided by so-called debt capital market agents, and they have overall responsibility for the transaction. The lead manager can collaborate with other institutions, which act as co-leads, to focus on different aspects of the transaction process. For sovereign issuances, the World Bank can also take over or contribute to some of the tasks. Sometimes various tasks are covered by the same entity, while for other transactions they are distributed across different entities.

Tasks include:

- The structuring agent works closely with the risk modelling agent to develop the trigger criteria and determine key metrics, such as the expected loss. This role involves managing and facilitating the engagement between the sponsor and the risk modelling agent.
- Sometimes engaging a rating agency to provide an analysis of the transaction.
- Collaboration with legal and regulatory teams during the structuring phase of the bond to ensure compliance with applicable laws.
- Developing the finance-related aspects of a transaction, such as initial price guidance, or timing of when to bring the transaction to market.
- Marketing the bonds, which involves the development of the offering strategy and marketing materials to attract potential investors.
- Managing the order book for the bond offering and selling the bonds. This includes collecting and organising investor orders, setting the final price for the offering, and allocating the bonds when demand exceeds supply. Often referred to as the 'bookrunner', the entity covering this task serves as the main point of contact throughout the placement, communicating with both investors and the sponsor.

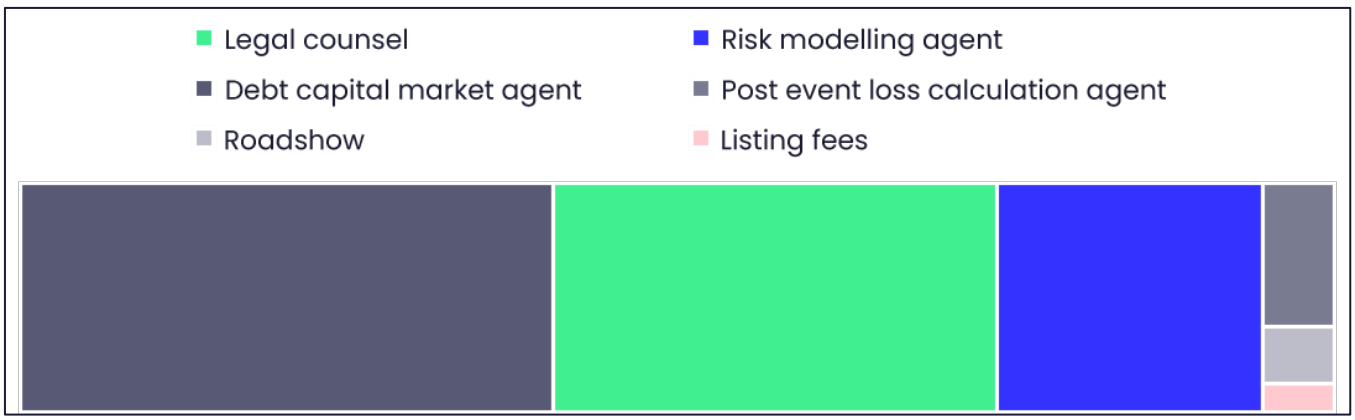
Cost structure of catastrophe bonds

Table 3.1 lists the costs paid to key stakeholder groups involved in issuing a catastrophe bond, along with a short description of their primary roles. Each stakeholder provides specialised services essential to the bond issuance process, from initial structuring and legal compliance to risk assessment, rating and investor engagement.

The largest share of costs goes to investors through coupon payments. For example, in Mexico's catastrophe bond coverage of four years to Atlantic storms (CAR 134), the total estimated premium costs exceeded US$65 million, and for earthquake risks (CAR 132) nearly US$25 million (see further Table 4.1). Coupon rates can vary widely, with key drivers discussed in Section 6 and the Appendix.

Issuing a catastrophe bond involves multiple stakeholders; Figure 3.4 presents an overview of the magnitude of the expenses associated with each. The total cost of issuance depends on several factors, particularly the issuer's experience in structuring and issuing bonds. The costs illustrated in Figure 3.4 amount to nearly US$3 million, providing a general indication of the cost magnitudes for an issuance size of about US$200 million. Additionally, staff costs from the sponsor side must be considered, in terms of both direct expenditure and opportunity cost as personnel working on catastrophe bonds are diverted from other projects.

Figure 3.4. Indicative distribution of costs across the stakeholder groups



Source: Authors

Table 3.1. Overview of costs to different stakeholders in the catastrophe bond issuance process

Costs	Payment to	Description
Fixed costs	Legal counsel	Manages the legal aspects of issuing the bond, charging for document preparation and regulatory compliance.
	Investor	Receives the annual coupon payment (usually paid quarterly) for their investment.
Variable costs	Risk modelling agent	Analyses and models potential catastrophic risks, charging for detailed risk assessment reports that will be used for the bond documentation. Most of the fee will arise upfront, during the structuring of the bond. For indemnity or industry loss trigger bonds a significantly smaller fee arises once per year for the annual reset.
	Debt capital market agent	Capital market agents can take on different roles such as structuring agent, bookrunner, lead manager or syndicate coordinator. Tasks and costs vary depending on the exact role, such as designing the financial structure and terms, managing investor orders and selling the bond. Payment varies based on the number of agents involved. Having joint brokers can sometimes be more expensive overall than a sole structuring agent and bookrunner. However, in some cases, joint brokers accept lower fees, resulting in total costs similar to having a single agent. Fees are calculated in basis points of the issuance volume.
	World Bank	Provides additional guidance and support to sovereign issuers, for example on structuring and placing the bond.
	Post-event loss calculation agent	Calculates if the specified conditions for a payout have been met after an event, charging a fee for the verification of trigger events, up to a cap. For parametric triggers this requires a risk modelling agent to assess the event.
Miscellaneous		Costs for data services, listing fees, roadshows (e.g. accommodation and travel expenses) and so on.

Global distribution of catastrophe bond issuances and investors

The United States represents the world's leading market in terms of catastrophe bond issuance and the number of perils covered. The majority of issuers in the US are private entities, particularly insurance and reinsurance companies. However, there are also some entities, known as 'insurers of last resort', such as the Louisiana Citizens Property Insurance Corporation, that issue catastrophe bonds frequently. In several other developed countries, including New Zealand, Italy and Canada, private entities also frequently issue catastrophe bonds.

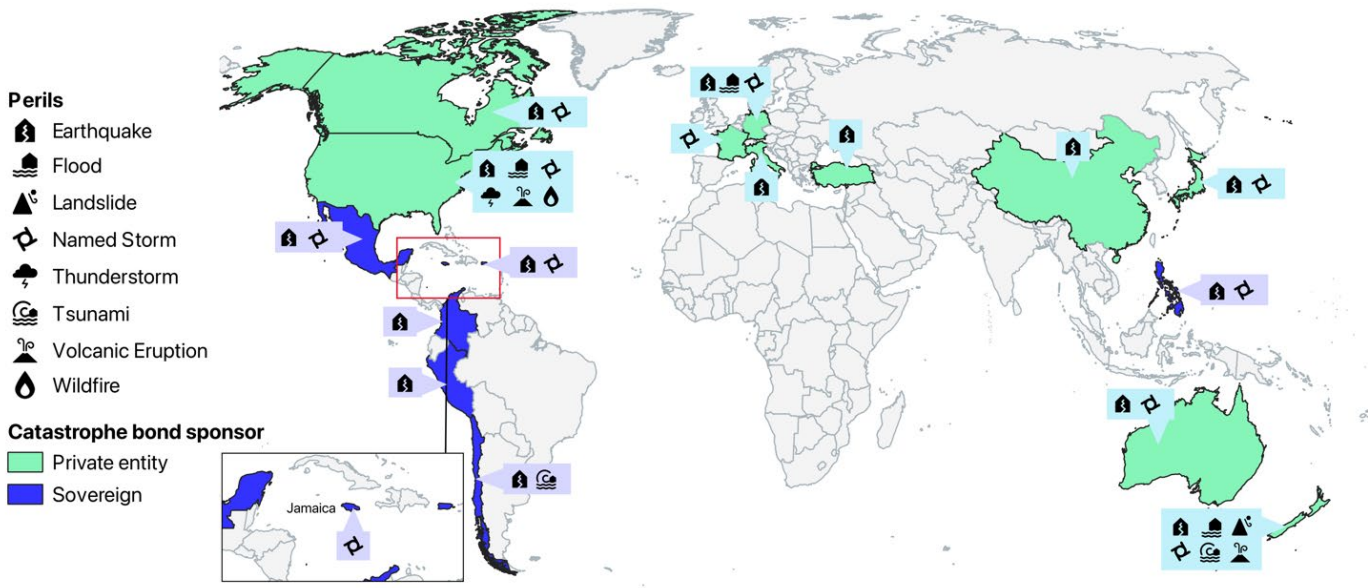
In developing countries, in contrast, issuances are used to support government budgets in the face of a disaster, rather than to reduce the risk exposure of a private institution. Consequently, the number of issuances is significantly lower than in developed countries, with one issuance per country every few years. Currently, sovereign catastrophe bonds make up only about 2.55% of overall

market volume.[6] The World Bank has supported sovereign catastrophe bonds since 2017. So far, no other multilateral development bank has been observed to provide this type of support and issue catastrophe bonds on behalf of governments.

Figure 3.5 illustrates this distribution and the thematic coverage of typical issuances within countries. The sponsor categories have been allocated based on the predominant type of issuer in a country. In the United States, for example, both private entities and public entities such as the Los Angeles Department of Water and Power issue catastrophe bonds, but private sponsors dominate.

The challenges in modelling and estimating risk exposures from primary perils are significant, but not as great as the challenges related to secondary perils.[7] Secondary perils have received little attention from the securitisation market in the past and the monitoring and developing of models to measure such risks is not as robust as for primary perils. The associated risk drivers are manyfold and arguably even more complex than for primary perils. While primary perils, such as earthquakes and tropical cyclones, typically impact only a few regions, secondary perils (e.g. droughts) affect a much larger number. In the future, as models improve, the coverage shown in Figure 3.5 may change significantly. Rather than being limited to a few jurisdictions prone to primary perils, there is growing recognition that severe secondary perils will become more frequent worldwide.

Figure 3.5. Distribution of catastrophe bond issuances



Note: Indicative overview of catastrophe bond issuances from private entities and sovereign sponsors to highlight countries and perils that are typically observed within the Artemis Deal Directory. In the United States some bonds only cover specific states (such as Texas, Florida or California). The map excludes perils that are not directly related to the natural environment, such as cyber risks or terrorism. Table 4.1 below lists all sovereign catastrophe bonds since 2017 that have been included on this map.
Source: Compiled by authors in August 2024 using data from Artemis Deal Directory.

Catastrophe bond investors

Investors in the catastrophe bond market are predominantly based in the Global North, with Europe and the US leading the market (see Figure 3.6). However, due to the niche nature of these products, certain financial hubs have developed specialised expertise, attracting insurance-linked securities funds. As a result, during roadshows, the bond sponsor — along with the lead agent team facilitating the transaction — typically visits key financial centres such as New York,

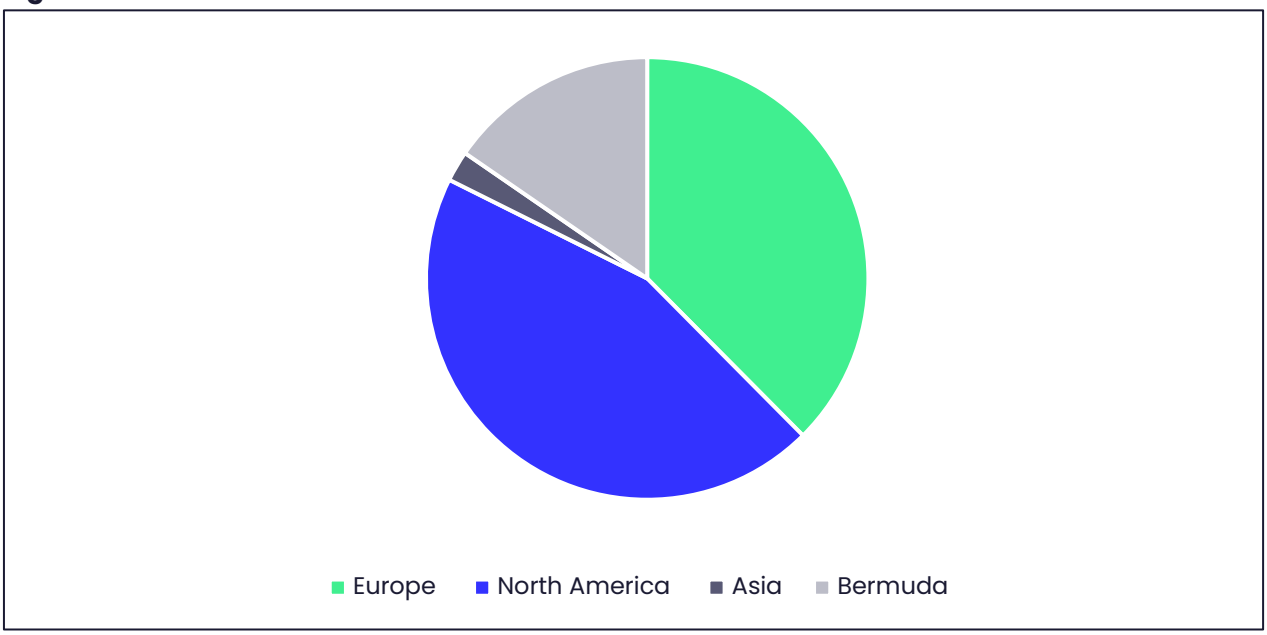
[6] Based on the AON Benfield 'Risk Linked Securities Indicative Pricing' sheet from 17 January 2025.

[7] See Box 2.1 for definitions.

London and Zurich, and also Bermuda, to engage with investors in person. The Bermuda focus is because with a regulatory framework focused on insurance-linked securities (ILS), supportive structures (e.g. a three-day registration for SPVs) and the specialised Bermuda Monetary Authority, the island provides an attractive environment for catastrophe bond issuances. The Bermuda Stock Exchange is the leading exchange for the listing of ILS instruments globally, with about 92% of outstanding catastrophe bond issuances listed in 2024 (Evans, 2025). Its dominant position in the global ILS market attracts investors, legal and financial professionals working in the ILS space to locate in Bermuda.

On average, approximately 20 investors have invested in a sovereign catastrophe bond in previous instances, which is indicative of the niche status of the product.[8]

Figure 3.6. Investor distribution



Note: Based on available information about the investor distribution for Mexico's issuance in March 2020, April 2024 and May 2024, and Jamaica's in July 2021 and May 2024.
Source: Compiled by authors in January 2025 using data from Artemis Deal Directory and World Bank press releases.

[8] Based on estimates from Mexico's April 2024 issuance (27 investors), Mexico's May 2024 issuance (15 investors), and Jamaica's May 2024 issuance (22 investors).

4. Bond structuring and challenges in detail

This section examines certain aspects of catastrophe bonds in more detail, including risk exposure, trigger mechanisms, payout structures and consideration of adaptation measures.

Identifying risk exposure

In contrast to many financial products where the default risk of the issuing entity represents a key factor influencing the return of the product, in the case of catastrophe bonds the natural catastrophe risk is the main risk to which a bond is exposed and the interest paid by the bond therefore depends on the level of the natural catastrophe risk.

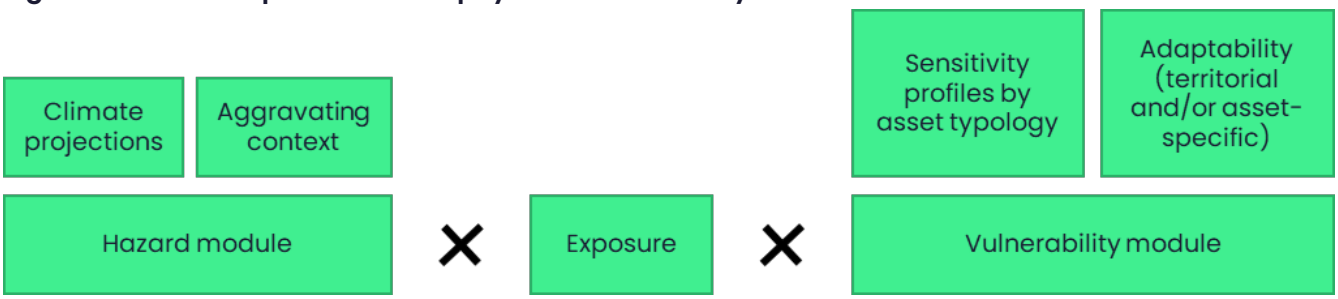
The main risk metric used to quantify the natural catastrophe risk for catastrophe bonds is known as the 'expected loss value'. The structuring agent of the bond works together with a risk modelling agency to determine the expected loss for the peril, the region covered and financial structure of the bond. The expected loss indicates the average annual loss to be expected when investing in the bond. In turn, the expected loss serves as a basis for pricing the bond; the higher the expected loss, the higher the interest paid on the bond. This is shown in Figure 3.1 above, which indicates that investors also use their own risk models and can separately collaborate with risk modelling agents to get their own expected loss estimations. For the issuance of bonds, the market has been dominated by one risk modelling agent – Verisk (formerly AIR Worldwide) – for the last decade.

Many specialised catastrophe bond investors have established internal expertise, models and adjustments to analyse the expected loss value. However, mostly they also rely on the information and data provided by risk modelling agencies to determine the riskiness of a transaction.

All catastrophe models contain the following three parts (as illustrated in Figure 4.1):

- **Hazard module:** The basic building block of a natural catastrophe model is the generation of a stochastic event set (hypothetical events) for the peril and region under consideration. For high-severity, low-frequency events such as hurricanes or earthquakes, the historical set available is not sufficiently large to calculate reliable statistics. A stochastic event set is therefore produced to complement the historical set with a comprehensive set of possible scenarios. The hazard module will produce those stochastic events along with all their physical properties (for example for hurricanes, the direction of the wind field, the radius of maximum windspeed, central pressure, etc.) and will also compute the local intensity for each location within the affected area. Scientific models such as climate projections are employed to estimate the annual frequency of occurrence of these scenarios and historical data are used to determine their physical properties.
- **Vulnerability module:** This aims to calculate the damage on a given building of a given construction type from a particular hazard intensity. The module quantifies the sensitivity of underlying assets, such as infrastructure and regional-specific adaptation measures to different hazard intensities.
- **Financial module:** Both modules are combined with the exposure underlying the bond. The financial module takes into account the financial structure of the bond (attachment point, exhaustion point, additional stated reinsurance, occurrence or annual aggregate) in order to compute the net loss to the bond.

Figure 4.1. Catastrophe model for physical risks – analytical framework



Source: Authors

The industry's sensitivity to major and poorly implemented updates to risk models has been demonstrated in the past. Following an update in 2011 of the main risk modelling firms' risk model (including adoption of a new storm surge model and changes to vulnerability curves),[9] the risk metrics for catastrophe bonds produced by this modelling firm increased by a factor of three, prompting nearly all catastrophe bond sponsors to issue bonds using the model of the competing modelling agency. This example emphasises the importance of users' trust in the underlying models, but also highlights their aversion to wide-ranging model updates. In particular, at a time when climate change, in conjunction with factors such as population growth, inflation, asset accumulation and urban expansion, could lead to non-linear increases in risk, having modelling firms that are reluctant to implement wide-ranging updates could lead to a mispricing of risk at a macro-level. Due to the widespread use of these models, if they systematically misprice risk exposure, this can have far-reaching systemic implications for the market and for financial stability. Some example aspects that could lead to an underappreciation of risk are listed below.

Challenges associated with historical data

To update catastrophe models, it is not sufficient only to adjust the probability of an extreme event occurring based on historical data. Firstly, it is imperative to understand and account for the nature of extreme weather events within historical data in the context of the presented impacts, noting that severe impacts may happen despite comparatively low intensities, or due to short forecast timeframes (see Dookie and Spence-Hemmings, 2022). In addition, in light of a changing climate, models require adjustments and the inclusion of highly probable events in terms of location, severity and timing, since past weather and climate conditions may not accurately represent current or future scenarios. Further, as well as incorporating the ongoing effects of climate change on extreme weather events, 'climate conditioning' of the model is required, to include a forward-looking view of risk. More broadly, as climate science develops, so too should catastrophe models to remain relevant. Taking a wider view, consideration should also be offered to the role of adaptation measures that have been taken or that are in the pipeline and would affect climate impact and resilience.

For example, the shifting of paths of tropical cyclones is leading to new coastal communities being affected (Wang and Toumi, 2021), that often have historically lower levels of adaptation. This poses challenges for vulnerability modelling, as merely adjusting likelihood or intensity is not enough: new regions (along with their respective vulnerability characteristics) must be integrated into the catastrophe models. Thermodynamic environments surrounding tropical cyclones have become increasingly likely to experience rapid intensification (RI) in light of global warming, which is particularly relevant to the hazard module. RI events not only result in considerable and unexpected damage but also present a significant challenge for forecasting, with forecasting errors for RI events being about two to three times larger than for non-RI events (Bhatia et al., 2022). The timing of events is also changing. For example, when Hurricane Beryl hit parts of the Caribbean in early July

[9] Before this, the last major upgrade RMS did of its U.S. hurricane hazard was in 2003.

2024, it became the earliest category-five Atlantic hurricane on record (with records stretching back around 100 years).

Changing socioeconomic factors

As well as climate change fuelling the intensity and frequency of natural catastrophes, economic growth, growing asset values (e.g. higher property prices) and an increasing number of assets being located in exposed areas, driven by urbanisation and population growth, are contributing to the increase in economic losses (Swiss Re, 2023). Further, vulnerabilities associated with ageing infrastructure, labour shortages and inflationary pressures are driving up reconstruction costs and therefore economic losses, too. However, policy interventions could reduce loss estimations, for example by increasing the implementation of adaptation measures. These socioeconomic factors impact the accuracy of calculations significantly, with many changing rapidly.

Policy changes that influence the way we live can give rise to new types of risks. For example, flooding could damage electric vehicle infrastructure, including chargers and parking areas (Raman et al., 2022). Policies that incentivise the large-scale uptake of solar panels on rooves could create additional vulnerability for homes during a natural catastrophe.

Data limitations

Data and information needed to calculate asset exposures are often missing or existing data sets are not of good enough quality. Locations that have had historically low risk exposure or low insurance coverage have likely not implemented sufficient structures to gather the required information. Rapidly changing socioeconomic factors require shorter update cycles for data sources used to model risk exposures. Differentiating between the levels of resilience of physical assets is currently not possible in the models and as a result they do not reflect the sensitivity of an individual property or infrastructure to natural catastrophe events. The adaptive capacity of assets to adjust and respond to shocks also varies depending on the type of natural catastrophe and their level of resilience.

An example of another aspect that is often overlooked due to data limitations, is highlighted in the insured losses of US$1.5 billion caused by floods in South Africa in 2022. Swiss Re (2023) concluded that the risk assessment in this case had significant shortcomings, as damages to assets that were part of global supply chains had not been included in assessments beforehand and their damage caused significant disruption to economic production abroad.

Compounding shocks

Catastrophe models are not designed to consider compounding shocks. A shock to a system through a natural catastrophe event could lead to non-linear amplification through other shocks that occur during a similar time horizon. Disregarding interlinkages between different crises such as hazard-based disasters, an energy crisis or public health emergency can lead to an underestimation of potential negative impacts.

Sovereign risk exposure

It is important to understand the vulnerability of a country despite most sovereign catastrophe bonds using a parametric trigger type that does not rely on figures for actual damage caused by a specific event to determine a payout. The risk modelling agent AIR Worldwide (now Verisk) prepared multiple catastrophe bond prototypes between 2020 and 2021 for Jamaica. One of those prototypes consisted of a grid with 21 boxes, each containing a minimum central atmospheric pressure measurement in millibars (see World Bank, 2021a). A payout could be triggered if a tropical cyclone passes through the box and meets the minimum central pressure specified for that box. For the box that includes Jamaica's capital, Kingston, there would be:

- A payout of 30–70% if central pressure is between 969mb and 900mb
- A payout of 70–100% if central pressure is less than 900mb.

For areas where less economic damage from a tropical cyclone is expected, the threshold for a payout is higher than for Kingston (indicated by a lower minimum central pressure figure, and thus a stronger storm). In structuring a catastrophe bond for a sovereign issuer that uses parametric triggers it is thus also important to understand the vulnerabilities to specific perils and risk levels as the trigger parameters are dependent on that information. For example, identifying critical infrastructure and its respective adaptation levels is key to ensuring these areas are sufficiently covered by the parametric grid.

Links to sovereign credit rating

Sovereign credit ratings play a crucial role in determining a country's borrowing costs and access to capital. This subsection explores what is known about the relationship between sovereign credit ratings and catastrophe bonds; credit rating agencies have begun to incorporate catastrophe bonds in their sovereign assessment practices, though in an inconsistent way.

A credit risk assessment is an evaluation of a borrower's ability to repay debt, taking into account their financial health, the likelihood of default and the willingness to honour their debt. This is provided by an external party: a credit rating agency. These ratings have a significant impact on several issuer financial metrics, including borrowing costs and access to capital. As government indebtedness increases, the impact of such ratings on the budget becomes more significant, as lower ratings increase the interest cost of outstanding debt. The budget required to meet interest payments reduces the money available to meet other political, social and economic objectives. Rating downgrades have been associated with reductions in spending on social services and transfers (Johnston and Barta, 2023). Investors use such ratings as an important input to inform their investment decisions. Three credit rating agencies cover most of the financial market: Moody's, Standard and Poor's (S&P) and Fitch Ratings. However, the assessment methodologies differ by type of debt and across rating agencies. While there is no consistent methodology on how catastrophe bonds are considered and assessed, they have not gone unnoticed by the agencies.

For example, Fitch Ratings has considered the benefit of providing "a new layer of protection against hurricanes" via the catastrophe bond to strengthen Jamaica's disaster risk-mitigation strategy. Fitch incorporates disaster risk in its Long-Term Foreign-Currency Issuer Default Rating assessment, through the so-called Qualitative Overlay in the external finances pillar. In this context it has positively recognised Jamaica's catastrophe bond issuance, saying it "significantly strengthens its disaster risk-mitigation strategy" while not adding to the national debt (Fitch, 2021). Jamaica's 2024 issuance has also been recognised by Fitch, but it noted that in comparison to its first issuance, where the risk margin was paid for by donor countries, this transaction was "not cost-free", as Jamaica has to cover the bond's risk margin, priced at 7.0% of par (US$10.5 million) per annum. Additionally, Fitch deemed its issuance size of US$150 million to "not provide sufficient funds to cover the likely costs of a large hurricane, which might require additional debt issuance at a future date to address storm damage, as well as potential economic and fiscal impacts" (Fitch, 2024).

This dedicated treatment of catastrophe bonds should be seen in the context of debt sustainability analysis in climate change-vulnerable countries more broadly. The increasing frequency and severity of climate-related extreme events such as hurricanes, and the growing costs of adaptation measures, have a significant impact on the economy and fiscal stability of a country, which is relevant for credit ratings. Rating agencies therefore consider climate change-related aspects in their sovereign credit ratings. For example, in the aftermath of a hurricane, rating agencies may downgrade a rating, as a deterioration in economic conditions caused by the disaster reduces creditworthiness. Such downgrades increase the perceived risk of default, leading to an increase in borrowing costs and a reduction in the availability of debt for affected regions (Jerch et al., 2023; Klusak et al., 2023). The financial strain can persist for years, impeding recovery efforts and making it challenging for sovereigns to access the necessary funds for rebuilding or the provision of social services. It is therefore in the interest of finance ministries to improve their rating. Economic or fiscal reforms, GDP growth and improvements in credit profile – as measured by debt/GDP ratio, for example – are factors that can uplift ratings.

Trigger mechanisms

Box 4.1. Common trigger types for catastrophe bonds
In the case of an **indemnity trigger**, a payout is triggered based on the actual loss experienced by the issuer. It works similarly to traditional reinsurance in this respect.
Industry loss triggers are based on the losses to the entire insurance industry and can be structured as 'occurrence' or 'annual aggregate' triggers. In the US, for example, the insurance industry loss following a natural catastrophe is reported by Property Claims Services (PCS). A third-party modeller is needed to provide an independent computation of risk metrics for such cover.
A **parametric trigger** pays a predetermined amount based on the magnitude of the event — such as an earthquake's magnitude or a hurricane's wind speed and air pressure — rather than the magnitude of the losses caused by the event.

Arguably one of the most complex aspects of structuring a catastrophe bond is the definition of what triggers a payout. Catastrophe bonds, like other insurance products, rely on the probability of such a trigger event to determine the risk level of the financial instrument. Since 2012, indemnity triggers have been the most frequently used type among issuances from private entities. Box 4.1 above outlines three common trigger types for catastrophe bonds, while Table 4.1 below lists all sovereign catastrophe bonds that have been issued since 2017 and their trigger mechanisms.

For sovereign catastrophe bonds the parametric trigger is used the most because:

- There is a quicker payout time than would be the case with an indemnity trigger. This is particularly important in the context of providing cash flow in the short term following a catastrophic event.
- The parametric trigger determines the payout based on an independent third-party event parameter, ensuring transparency for involved parties, including the sovereign, the catastrophe bond investors and the modelling agent. Parametric triggers are designed to offer greater transparency than indemnity structures,[10] eliminating disputes over the 'actual loss' figure that can often arise with indemnity triggers and in traditional insurance.
- Using parametric triggers, where payouts are based on transparent and measurable parameters, can help to reduce uncertainty and build trust with investors who might be less familiar with the perils in developing regions.

One disadvantage of these trigger structures is that the actual loss experienced can differ significantly from the actual payout (which is known as 'basis risk'), as outlined in Section 5 in the case of Hurricane Beryl's destruction in Jamaica. This has the potential to impact both parties involved in the transaction. In some cases, the payout could exceed actual damages, resulting in investors losing a greater portion of their principal investment than anticipated. In others, the payout may be insufficient to cover the actual damages, leaving the bond issuer without the necessary funds to address the associated damage costs. Investors face a clearly defined worst-case scenario, limited to the loss of their principal whereas the bond sponsor bears greater uncertainty, as their potential losses from an event may greatly exceed the principal. This marks a significant difference from indemnity triggers, which transfer the burden of uncertainty to the investor.

[10] Here the distribution of payouts is contingent upon the extent of the losses incurred by the sponsor, which necessitates a variety of loss data and calculations to be made by the modelling agency after the event. This approach ensures that the basis risk for the sponsor is the lowest, as the losses and the recovered funds are perfectly aligned.

Therefore, parametric triggers have been subject to criticism regarding the determination of the trigger criteria and thresholds.

Catastrophe bond trigger structures need to be carefully balanced to meet investor demand while effectively addressing the needs of affected communities. Bonds backed by entities like the World Bank often attract significant investor interest but if a bond's trigger threshold is set too low — making a payout more likely — investors face higher expected losses, which drives up premiums and bond prices. This can even deter investors from participating in a specific transaction. Conversely, structuring bonds to appeal strongly to investors might compromise community support goals. Therefore, to reduce some of the trade-offs, catastrophe bond issuances are often divided into different tranches. This allows lower-risk tranches to be priced differently to higher-risk tranches.

Limited public information on trigger mechanisms currently complicates understanding of these structures and the roles of different tranches on disaster relief. Bond and tranche characteristics are outlined in bond offering circulars which are available to potential investors but not to the public. The World Bank often publishes case studies about recent transactions detailing the financial challenges, solutions and high-level terms of the bonds. However, they often lack sufficient detail to understand the trigger mechanism and design. Sovereign issuances without World Bank involvement usually provide even less information to the public. These factors can lead to public disapproval of such bonds, particularly when the payouts are perceived as inadequate.

To date, only a small number of sovereign catastrophe bonds have provided a payout, as shown in Table 4.1.

Table 4.1. Overview of sovereign catastrophe bond transactions and selected characteristics

Year	Sponsor	Peril	CAR identifier	Issuance size (principal) (US$ million)	Expected loss (%)	Risk multiple	Estimated premium costs (US$ million)	Payout thresholds (%)				2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
								25	50	75	100												
2017	Government of Mexico	Earthquake	CAR 113	150	3.43	1.31	1.06	X	X	X	X	Trigger event: 08.09.2017 Trigger breach calculated: 11.10.2017 Payout received: US$150m (100% of principal)											
2017	Government of Mexico	Named storm (Atlantic)	CAR 114	100	5.56	1.67	18.60	X	X		X	Trigger event: 22.10.2018 Trigger breach calculated: 23.10.2018 No payout received											
2017	Government of Mexico	Named storm (Pacific)	CAR 115	110	3.96	1.49	12.98	X	X		X												
2018	Republic of Chile	Earthquake	CAR 116	500	0.86	2.91	37.50	30		70	X												
2018	Republic of Colombia	Earthquake	CAR 117	400	1.56	1.92	36.00	X	X		X												
2018	Government of Mexico	Earthquake	CAR 118	160	0.79	3.16	8.00		X		X												
2018	Government of Mexico	Earthquake	CAR 119	100	6.54	1.26	16.50		X		X												
2018	Republic of Peru	Earthquake	CAR 120	200	5.00	1.20	29.89	30		70	X		Trigger event: 27.05.2019 Trigger breach calculated: 20.06.2019 Payout received: US$60m (30% of principal)										
2019	Republic of the Philippines	Earthquake	CAR 123	75	3.00	1.83	12.38	35		70	X												
2019	Republic of the Philippines	Named storm (Pacific)	CAR 124	150	3.00	1.88	22.73	35		70	X			Trigger event: 22.12.2021 Trigger breach calculated: 24.01.2022 Payout received: US$52.5m (35% of principal)									
														Trigger event: 19.04.2022 Trigger breach calculated: 23.05.2022 No payout received									
														Trigger event: 26.09.2022 Trigger breach calculated: February 2023 No payout received									
2020	Government of Mexico	Named storm (Atlantic) (riskier)	CAR 125	175	0.90	3.89	24.50	X	X	X	X												
2020	Government of Mexico	Named storm (Pacific)	CAR 126	60	5.78	1.56	21.60	X	X	X	X												
2020	Government of Mexico	Named storm (Atlantic)	CAR 127	125	5.61	1.78	50.00	X	X		X				Trigger event: 25.10.2024 Trigger breach calculated: April 2024 Payout received: US$60m (48% of principal)								
2020	Government of Mexico	Earthquake (incl. tsunami impacts)	CAR 128	125	4.06	1.60	32.50	X	X		X												
2021	Government of Jamaica	Earthquake	CAR 130	185	1.52	2.89	19.54	30*															
2023	Republic of Chile	Earthquake	CAR 131	350	1.00	4.75	49.88	30		70	X												
2024	Government of Mexico	Earthquake	CAR 132	225	0.90	4.44	36.00	X	X	X	X												
2024	Government of Mexico	Earthquake (riskier)	CAR 133	70	5.84	1.88	30.80	X	X	X	X												
2024	Government of Mexico	Named storm (Atlantic)	CAR 134	125	5.69	2.37	67.50				X												
2024	Government of Mexico	Named storm (Pacific)	CAR 135	175	4.09	2.93	84.00	X*															
2024	Government of Jamaica	Named storm (Atlantic)	CAR 136	150	1.50	4.67	37.63	30*															
2024	Government of Puerto Rico	Named storm (Atlantic) and earthquake	N/A	85	1.65	5.45	22.31	*															

*Transactions that use a linear sliding scale CAR = Capital-at-Risk issuance Estimated premium costs = Principal * coupon * bond duration Source: Artemis Deal Directory (2024) ■ Payout has been made ■ No payout

Source: Compiled by authors in August 2024 using data from Artemis Deal Directory and Plichta and Poole (2023).

Bond payout structures

Understanding of the bond trigger mechanism is inextricably linked to an understanding of the actual payout process. The process of making a payout on a catastrophe bond is contingent upon the occurrence of an event that meets the predetermined parameters of the bond. In the case of sovereign issuances, which mostly use parametric triggers, this process is of paramount importance.

Payout duration

For governments facing catastrophic situations, timely payouts are essential to rapidly mobilise resources for disaster relief, recovery and rebuilding. Delays in funding can exacerbate a crisis and hinder recovery efforts. Table 4.1 includes information about when specific catastrophe bonds have been affected by a disaster and the sponsor requested a calculation if a trigger point was reached. It is worth noting that the bond terms set out in the offering documents often determine that the modelling agency has up to five working days to deliver its report on whether the event has triggered the predefined thresholds.

Payout amount

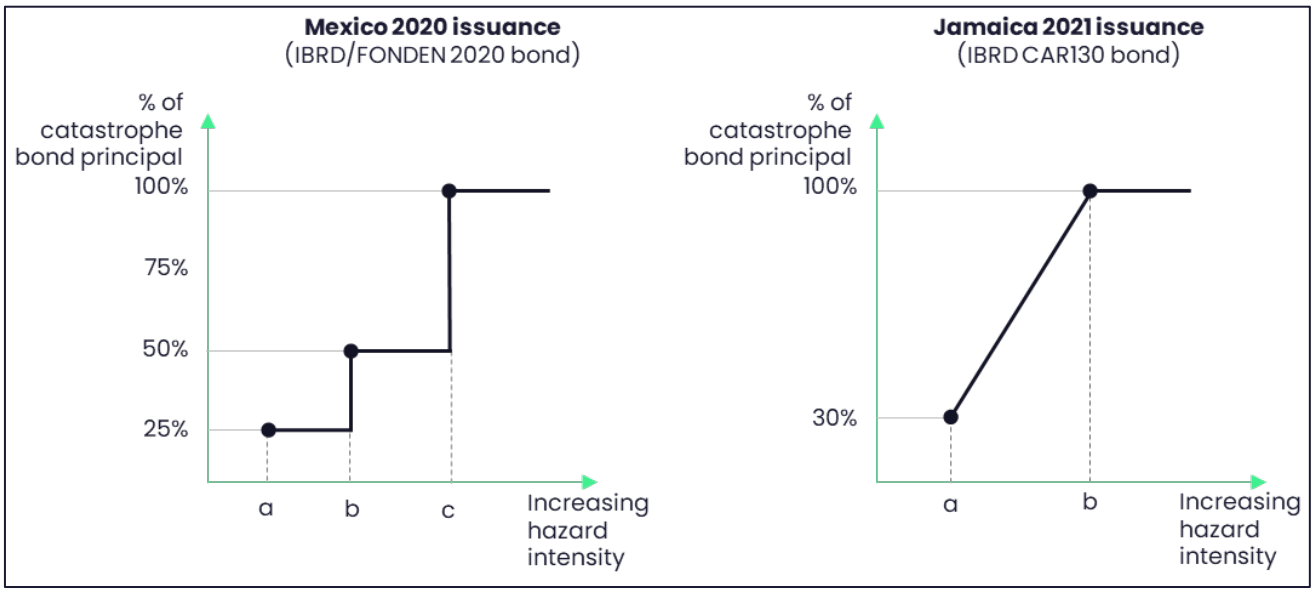
An external agency determines whether the severity of the disaster meets the thresholds set out in the bond's trigger mechanism, which includes factors such as earthquake intensity, minimum central pressure of a hurricane or storm wind speed. Besides information on the trigger mechanism, the bond documents will also outline which source for this information should be used, often relying on public databases, such as data from the National Hurricane Center from the US National Oceanic and Atmospheric Administration. This task can be provided by the same risk modeller (often referred to as modelling agency) that was involved in the transaction during the preparation phase although this is not essential. There are two key roles to be undertaken: the reporting agent determines the parameters of the event, and the calculation agent determines if these meet the trigger thresholds and therefore any payout.

Sovereign catastrophe bond structures with parametric triggers typically involve a structured payout function in accordance with the severity of the event. A simple 'linear' or 'stepped' payout of the outstanding principal are the most common types (see Figure 4.2), although it is important to note that the exact payout mechanism can often be more complex than the description and visualisation in the figure, as different structures or thresholds can apply to different parts of a country. However, in the absence of publicly available information about these mechanisms, this provides some context and illustrates some broad differences.

Figure 4.2 uses two examples related to Atlantic named storm risk. It shows firstly the 2020 issuance by Mexico, which featured payout intervals for different minimum central pressure values. In this system, once a trigger threshold is exceeded, the corresponding percentage determines the payout size. The most common payout percentages are 25%, 50% and 100% of the outstanding principal (see also Table 4.1). For example, if an event meets the trigger criteria of hazard intensity 'b', then 50% of the outstanding principal is paid out.

The structure used by Jamaica, as shown in the figure, uses a linear sliding scale to determine the amount of principal that is being paid out, rather than setting multiple thresholds. It does define a minimum and maximum threshold, but for any events exceeding 30%, the linear sliding scale allows more variation in the payout that is made.

Figure 4.2. Payout structures for two parametric triggers for Atlantic named storm risks – Mexico (2020) and Jamaica (2021)



Source: Authors based on Artemis Deal Directory, Artemis (2020) and World Bank (2021b)

5. Phases in issuing sovereign catastrophe bonds, informed by past issuances

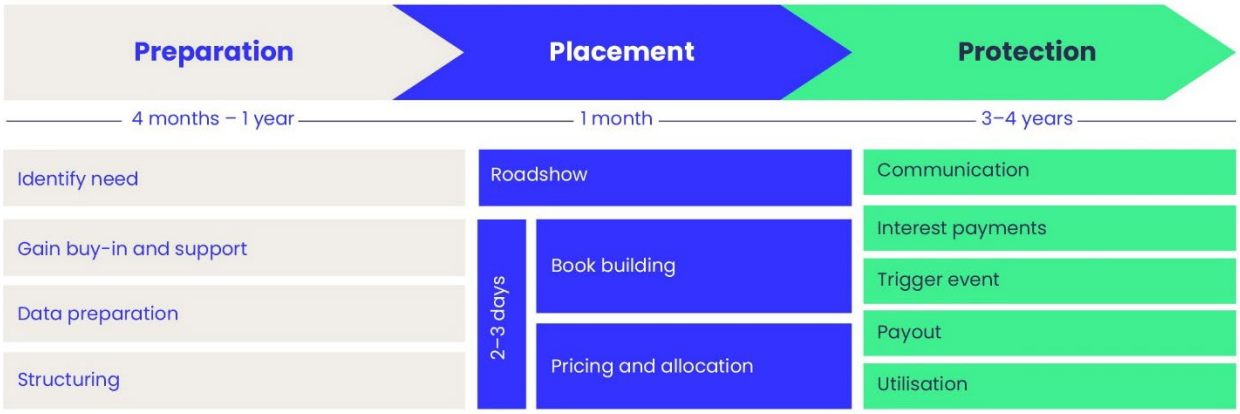
This section develops an outline of the main steps across three phases in issuing sovereign catastrophe bonds, and the stakeholders relevant to each, based on case studies of past issuances, mainly from Jamaica and Mexico.

Based on the issuance of sovereign catastrophe bonds and available documentation, we have identified several key steps in issuing these bonds. These start with the preparation phase, through bond structuring and placement, to the live phase, i.e. protection of the bond. The phases and steps are shown in Figure 5.1 below, which also illustrates which stakeholders are involved at different points.

Following Figure 5.1 we provide a closer examination of certain key aspects across the three phases based on the experience of selected issuances. Due to the limited public information available for many sovereign catastrophe bonds, the case studies are heavily reliant on insights from the Jamaican and Mexican issuances. (The Appendix then provides further detail about Jamaica's experience.)

Damage in Puerto Marqués, Mexico, following Hurricane Otis in 2023. Photo: ProtoplasmaKid via Wikimedia Commons

Figure 5.1. Key phases and steps in issuing a sovereign catastrophe bond, with relevant stakeholders



Step	Description	Government	Parliament	Community	Legal counsel	Donors	MDB	Lead manager	Investor	Modelling agent
Identify need	Identify residual disaster risk that is not covered by existing financial mechanisms. Identify knowledge and capacity gaps.	X	X	X						
Gain buy-in and support	Gain buy-in from key governmental decision-makers and identify sources for external support if necessary. External support can be in knowledge as well as financial terms.		X			X	X			
Data preparation	Work together with risk modelling firms and financial structuring agents to identify high-risk areas and translate this into trigger structure.	X			X		X	X		X
Structuring	Finalisation of legal bond documents, which includes detailed description of trigger mechanism.	X			X		X	X		X
Roadshow	Present the structure to potential investors, address any queries they may have and seek to generate interest in the transaction. Non-deal-related roadshows can take place anytime to engage with investors, usually over a longer time horizon. The decision to place a bond is influenced by several factors, including market appetite, market trends and a timetable that takes into account potential seasonal risks (e.g. hurricane season).	X					X	X	X	X
Book building	If there is sufficient interest during the roadshow, a suitable date for the placement is identified. When the day arrives and market conditions are favourable, the transaction is announced to investors with initial pricing thoughts and indicative bond size. The subsequent investment marketing phase involves bilateral and group meetings between the issuer and investors. The order book is opened and digital orders from investors are noted. After a few hours the issuer and bookrunners will assess the interest from the market and decide on additional guidance to narrow the spread for the bond pricing and bond.	X					X	X	X	
Pricing and allocation	Once the book is closed and the bond has been oversubscribed (investors would buy more than is available) a decision needs to be made on how much is sold to which investor. This is often based on the quality of the investor and their investment strategy.	X					X	X	X	
Communication	Government and/or multilateral development bank publishes information and details about the transaction to the public.	X				X				
Interest payment	Investors receive regular interest payments for their investment.	X				X	X		X	
Trigger event	A risk modelling agent is tasked with conducting its analysis in the event of a natural hazard-related disaster to determine whether the trigger thresholds have been met.	X					X	X		X
Payout	In the event of a payout, the Special Purpose Vehicle (or World Bank fund) where the capital was held would release some of the capital and transfer it to the issuer.						X		X	
Utilisation	The money is transferred to the issuer of the bond to be used e.g. for disaster relief and reconstruction.	X								

Source: Authors

Phase 1: Preparation

Jamaica: Identification of need for disaster risk reduction

The Caribbean island of Jamaica is exposed to several hydrometeorological hazards: tropical storms and hurricanes, flooding and landslides. The annual average economic loss from hurricanes is estimated at around US$67 million, representing 0.5% of GDP. Earthquakes are also common, causing around US$36 million of annual damage, or 0.3% of GDP (World Bank, 2016).

Consequently, the Jamaican government has paid significant attention to the development of a comprehensive strategy to enhance the country's social and economic resilience, reducing where possible the negative effects of hazard-based disasters (MLGCD, 2020). For example, the National Natural Disaster Risk Financing (NNDRF) Policy that was established in June 2023 promotes a risk-layered approach that involves establishing adequate funds and reserves. For risk retention, financial tools have been set up, including a Contingencies Fund to specifically provide for the possibility of hazard-based disasters, and the Jamaica Social Investment Fund. Insurance schemes transfer the risk from individuals (e.g. private property insurance) to third parties. Additionally, Jamaica is part of the Caribbean Catastrophe Risk Insurance Facility (CCRIF), a regional fund that uses parametric insurance to provide its member governments with coverage against several different perils. Jamaica has also been the first of the Caribbean SIDS to sponsor a catastrophe bond independently.

Despite all of the above provision, an assessment conducted by the World Bank (2021a) identified a significant residual risk for tropical cyclones in Jamaica, particularly for low frequency and very severe events, highlighting "an important sized gap that may be managed by risk transfer instruments". To reduce the size of this gap, Jamaica created a catastrophe bond. The World Bank project appraisal document highlights the additionality as follows: "A CAT bond will provide important diversification benefits for Jamaica as it triggers in a different way than the CCRIF SPC [segregated portfolio company] or the IADB [Inter-American Development Bank] contingent credit line" (World Bank, 2021a).

Even with a very well-designed catastrophe bond in place, and coverage across other instruments, there will always be some residual risk, given the expense of ensuring 100% coverage of risk for all situations. Clearly communicating this residual risk to the public is vital.

Learning point: The role and limits of each financial instrument should be communicated clearly, including any gap in risk protection/residual risk exposure.

Mexico: Structuring different risk levels in one bond

While bonds backed by the World Bank often receive high investor demand, a transaction structure that is deemed too likely to pay out drives up premiums and can even deter investors. If a bond is structured with a lower threshold, the risk exposure (measured as expected loss) for investors would be greater, resulting in higher interest payments, and increasing the price of the bond for the sponsor. However, making bonds very appealing to investors may neglect the needs of affected communities. One way to reduce the possibility of this trade-off is to design different tranches for each bond issuance (see Section 3). The aspects of the trigger event of each tranche[11] that could differ include the structure, perils and threshold. For example, the 2024 issuances by the Mexican Government demonstrate how different bond tranches can provide coverage for different risk levels and even different perils. A total of US$420 million of catastrophe bond protection was distributed across three tranches with the same maturity:

[11] Several related bonds can be offered as part of the same collateralised debt obligation, where each bond is a slice of the deal's risk. These are then referred to as bond tranches and are usually identified by numbers or letters (e.g. CAR 130, CAR 131, Class A, Class B) and can differ along several terms, such as covered perils, riskiness, coupon rate and issuance size.

1. One tranche covered earthquake risk, with expected loss of 0.9%. The size of this tranche was US$225 million and priced at 4%.
2. Another tranche covered more severe earthquake risk, with an expected loss of 5.84%. The size of this tranche was US$70 million and priced at 11%.
3. The third tranche provided protection against Atlantic named storms with an expected loss of 5.69%. The size of this tranche was US$125 million and priced at 13.5%.

The division of the bond into distinct tranches allows the pricing of lower-risk tranches (such as the first) at a lower price than higher-risk tranches (such as the second and third). However, there might also be a different level of demand for the different risk levels, leading to different tranche sizes. In Mexico's case, the first tranche, comprising the lowest risk levels, was settled at a lower price and higher volume than the riskier tranches.

Learning point: The trade-off between risk coverage and costs is vital but challenging to navigate when structuring catastrophe bonds. Different tranches can help to bring nuances into the bond issuance and therefore attract investors with different risk-preference profiles.

Phase 2: Placement

Enabling investor access

As well as providing financial protection, catastrophe bonds open up access to a broader range of investors, including those who may not typically engage in such instruments. For example, the first catastrophe bond covering volcano-related disasters was brought to the market by structuring agents Replexus and Howden Capital Markets on behalf of the Danish Red Cross (the sponsor) in 2021 (Artemis, 2021). It raised US$3 million to support communities living in proximity to 10 high-risk volcanoes across three continents. As it was the first bond purely for volcanic eruption risk, significant attention was given to the risk modelling to ensure investors understood the structure.

One major benefit for the sponsor was that it enabled funders who would not otherwise consider funding humanitarian projects, for example dedicated ILS investors (e.g. Schroder Investment Management and Solidum Partners), to invest into the bond. With the growth in sustainable finance, funds that aim to align their investments with positive impacts have also become interested in catastrophe bonds. For example, Plenum Investments invested through its ESG fund into the volcano bond. Some institutions such as foundations are often not able to invest in insurance products, but might be able to invest in catastrophe bonds. The sponsor of the volcano bond has been able to expand the sources of funding from donations to different types of investors.

Learning point: A prerequisite for the successful marketing of a catastrophe bond to investors is a comprehensive understanding of the investment requirements and preferences of the various investor groups.

Jamaica: Changing conditions affecting issuance

The World Bank, via its Capital at Risk Notes programme, has issued two bonds on behalf of the Jamaican Government to date, to provide protection against hurricane-related losses for a period of three seasons, with coverage of US$185 million in 2021 and US$150 million in 2024.

The risk multiple is a measure used by investors to gauge the relative risk of a bond by showing how many times the expected loss is covered by the bond's coupon payment. In this example, the bond from 2021 had a risk multiple of 2.89 times, while the 2024 bond had a multiple of 4.67 times. While the expected loss for both was similar (1.52% and 1.5%), at 7% the coupon payment for the 2024 issuance was nearly 60% higher than the 2021 issuance. This translates to an expected payout of about 35¢ for every $1 paid in premiums for the first issuance, and 21¢/dollar for the second.

While the trigger mechanism structure of the two issuances appears similar,[12] it is important to highlight two differing external factors:

- Firstly, there were significantly different market conditions between the two issuances: the first bond was issued in July 2021, during a low-interest period following the COVID-19 pandemic, when the US federal funds rate was 0.25%. The second was issued in May 2024, after multiple Federal Reserve rate hikes to counter inflation, leading the rate to be 5.5%.
- Secondly, climate-related aspects might have also contributed to the higher coupon rate. The lingering effects of El Niño, or the increasing influence of climate change, could have contributed to investors' expectations for increased or elevated losses.

Other market conditions, such as investor risk appetite, broader economic conditions, market liquidity, and recent catastrophic events can also influence the bond issuance. Additionally, the regulatory environment can influence the demand for bonds against certain perils and locations. For example, UCITS[13] Article 52 of the European Securities and Markets Authority (ESMA) states that a maximum of 20% can be invested into the same body, while the maximum exposure to a single risk is set at 35%. Given the dominance of US hurricane risk in the market, funds regulated under UCITS must exercise caution to ensure they do not exceed the 35% risk exposure to that particular risk. This rule influences investor decisions, as they will need to ensure risk diversification in such a fund. In light of the increasing focus by financial supervisors on climate-related risks, and the growing uptake of policies to mitigate these risks, the maximum exposure threshold to a single risk may be reduced in the future. This would have implications for portfolio construction and investment allocation, compelling investors to evaluate alternative risks sources or regions.

Learning point: External factors including market conditions, regulation, inflation and investor sentiments have a significant influence on how well the transaction will be placed in the primary market, therefore determining the price of the bond. As catastrophe bonds to date have tended to be issued by sovereigns with comparatively lower financial strength, the sponsor needs to consider these external market conditions carefully.

Phase 3: Protection

Jamaica: Providing information to the public

Jamaica's catastrophe bond issuance, supported by the World Bank, offers some insights into its structure through publicly available documents, though details remain limited. The World Bank's Project Appraisal Document (PAD) outlines that seven modelling prototypes were evaluated before the final structure was selected. While the PAD describes a model with 21 boxes, the model that was chosen consists of 14 boxes and five triangles, colour-coded to represent different trigger thresholds (World Bank, 2021a). However, a World Bank blog post that includes the final trigger grid (Jaramillo and Hua, 2021) does not clarify the exact minimum central pressure threshold per box nor provide an accompanying description. This makes it challenging to grasp the mechanics of the bond and anticipating if a payout might be triggered from the outside becomes impossible. In contrast, sovereign issuers of sustainable debt instruments like green bonds provide much more detail, in a green finance framework, regular allocation reports and sometimes even impact reports to the public. Investor presentations are often published too, and the framework and reports are assessed by an external party.

Learning point: Preparation of information materials for the public, such as case studies, is important to improve knowledge and build trust. Wherever possible, there should also be disclosure of documents that provide details on the transaction, such as the trigger mechanism – e.g. investor presentations or the bond's offering circular.

[12] Based on the limited public information available.
[13] The Collective Investment in Transferable Securities (UCITS) is a European regulatory framework for investment schemes.

Mexico: Determining catastrophe bond payout

Mexico's experience in determining the catastrophe bond payout after Hurricane Otis in 2023 demonstrates the difficulties that might arise from the complexity of bond documentation and the various factors to consider when designing parametric triggers. The hurricane hit Mexico on 25 October and the damage it caused was estimated to result in a loss of 50% of the principal. This estimation was based on storm data that was available through initial reports shortly after the event. However, the bond documentation determined that the estimate for the principal loss had to be based on the final figures from the US National Hurricane Center (NHC). These figures only became available in early March 2024. The calculation agent calculated how much of the principal would be lost based on those figures and as such the payout amount (of US$60 million) was not determined until April 2024, five months after the hurricane made landfall.

This stands in stark contrast to one of the key benefits parametric triggers are meant to provide – the rapid release of funds after a disaster. To external stakeholders including the general public, a month-long delay in payout may create the perception that the catastrophe bond had failed. Given there have only been a handful of payouts from sovereign catastrophe bonds, people may conclude that catastrophe bonds in general are ineffective, rather than recognising case-specific delays. In the case of Hurricane Otis, referencing the final figures from the NHC report, which took months to prepare, was an unfortunate misstep but this should not be used to make claims that parametric catastrophe bond triggers are inherently incapable of ensuring prompt fund disbursement. Open and transparent communication about the bond structure and details about any case-specific issues are key to preventing this.

Learning point: The complexity of catastrophe bond structures and the unfamiliarity of the public with these means greater transparency and education are needed to avoid misunderstandings. Issues or mishaps should also be made known to external stakeholders, in order to facilitate learning and avoid allegations that a bond has not functioned as intended.

Jamaica: Catastrophe bond response to Hurricane Beryl

Hurricane Beryl hit Jamaica on 3 July 2024, causing significant economic damage. The disaster resulted in an immediate requirement for emergency shelter supplies and relocation assistance, with around 160,000 individuals, including 37,000 children, in need of humanitarian assistance (UNICEF, 2024). It was estimated that Beryl caused the destruction of over US$6.4 million-worth of food crops and supporting infrastructure, which resulted in food shortages in the following weeks. Crops of staple foods, including plantains, yams and cassava, were destroyed, as were fruits. Extensive damage was also reported in the fishing and livestock sectors (Myers, 2024).

The catastrophe bond documents of the Jamaican catastrophe bond indicate that the most up-to-date data from the National Hurricane Center's automated tropical cyclone forecasting system needs to be used to calculate payouts. A few days after Hurricane Beryl hit, it was confirmed that no payout would be made, as the minimum air pressure required for a payout agreed in the bond structure was not reached in any of the areas covered. Instead, payouts from Jamaica's own contingency fund and disaster fund of up to J$4.5 billion were expected (Evans, 2024a). This highlights the importance of employing a combination of financial instruments to develop a multi-layered disaster risk financing strategy, as different instruments are triggered at different risk levels.

Learning point: A holistic and complementary disaster risk strategy to effectively address the challenges posed by catastrophic events is needed, that clearly articulates technical details related to the role and limitations of different financial instruments.

6. Discussion and outlook

This section contextualises the contributions and function of catastrophe bonds within the disaster risk reduction toolbox and within discussions on Loss and Damage, also outlining future projections for the sovereign catastrophe bond market.

Benefits from including catastrophe bonds in disaster risk reduction

Catastrophe bonds can represent a valuable component of a comprehensive disaster risk reduction (DRR) strategy. In the case of low-frequency, high-severity events, catastrophe bonds can provide an effective ex-ante risk transfer solution. In addition to providing insurance protection, including catastrophe bonds in the strategy and plans of countries to manage disaster risk provides the following benefits:

- **Diversifying the investor base.** For instance, ESG or ILS investors that would not typically invest in a conventional sovereign debt bond or support humanitarian projects can invest in catastrophe bonds. Stakeholders such as foundations, that usually cannot invest in insurance products, might also be able to invest in catastrophe bonds.
- **Providing leverage.** Catastrophe bonds can provide leverage to the sponsor, as their capital investment can facilitate significantly higher payouts in case of a trigger event. For example, donor countries agreed to cover interest payments worth around US$20 million of the first Jamaican catastrophe bond, while the bond provided coverage of up to US$185 million, providing access to nine times as much capital in the case of a disaster as the amount donated.
- **Coverage without increasing debt.** Catastrophe bonds are insurance-linked securities, facilitating the transfer of risk that does not necessitate a country taking on more debt, contrary to the case with green bonds, for example. Catastrophe bonds have been positively recognised by credit rating agencies as an instrument to enhance ex-ante financial protection.
- **Unrestricted humanitarian aid.** While direct donor contributions are often earmarked for specific expenses in the aftermath of a catastrophic event, the payout from a catastrophe bond is typically unrestricted, making it easier to allocate based on needs of affected communities.

Due to catastrophe bonds' contribution to reducing fiscal risks associated with disasters and the other additional benefits mentioned above, credit rating agencies have begun to acknowledge these bonds in their sovereign credit ratings. However, for catastrophe bonds to become a truly effective part of a diversified disaster risk management approach within sovereign debt strategies, their impact on sovereign credit ratings must be firmly established. When credit agencies consistently account for catastrophe bonds in their evaluations, ultimately leading to improved sovereign ratings, these instruments can have a profound effect — helping governments to reduce borrowing costs and enhance access to capital.

Implications for governments' disaster risk reduction toolboxes

Catastrophe bonds are only suitable for providing coverage to specific, highly impactful but low-likelihood events. This requires the use of a combination of financial instruments to ensure the availability of sufficient fiscal headroom for events with a higher probability of occurrence. It is therefore important to ensure that other available risk management instruments have been utilised that offer better cost-return profiles from an impact perspective.

When embarking on a catastrophe bond issuance, it is vital to have a long-term plan in place. As with other financial instruments, it is essential to create the appropriate supporting governance structures and plans to facilitate continuous use of such instruments. The issuance process entails significant costs, time and resources, for example for identifying vulnerabilities, designing trigger mechanisms and conducting a roadshow. However, the experience gained can be used for future issuances and thus reduce some of the costs down the line. This investment for a single issuance appears to serve primarily the interests of the involved private institutions, which generate revenue through fees for their services. If a catastrophe bond is identified as a valuable addition to a DRR toolbox, it is essential to ensure that the investments made and knowledge gained are used continuously, rather than as a one-off.

Similarly to a green bond, a catastrophe bond holds the potential to bring together government ministries and public institutions. For example, to identify vulnerabilities, knowledge and data from ministries like transport, housing, environment and economy is needed. To enhance data availability for specific perils, partnerships with organisations such as meteorological offices, research institutions and academic bodies can be encouraged to strengthen and expand data collection and analysis efforts. Catastrophe bonds can further facilitate cooperation by pooling resources and sharing risks across multiple countries, promoting greater regional collaboration in disaster preparedness.

One area in which sovereign catastrophe bonds have struggled in the past is in incentivising ex-ante risk reduction. As these issuances usually use parametric triggers, the risk premium is determined based on metrics related to the event. This means that there is always a basis risk, as the mathematical fit is never perfect and there will be instances where actual damage is significant but a payout is not triggered. To reduce the basis risk it is common practice to use an indemnity trigger instead. As the determination of the size of the payout is linked to the actual damages caused, it is possible to also incorporate ex-ante risk reduction measures in an indemnity structure. However, besides the higher risk premium that would likely need to be paid, for such a trigger structure it will also take significantly longer to calculate the payout size after an event. It lies with the government to decide how to deal with this trade-off.

There are also several financial instruments that are similar to catastrophe bonds but have been modified to incorporate mechanisms that warrant greater long-term benefit to communities. This is particularly evident in the incentivisation of actions that enhance resilience and adaptation to climate change through these instruments. For example, the environmental impact bond, resilience bond and climate-resilient development bond aim to incentivise climate resilience through their financial structures. However, neither of these three bonds has gained significant traction in the market thus far. This may be indicative of the difficulties in designing a financial product that offers a favourable arrangement to communities as well as appealing to investors. Rather than making the bond structures more complex and exceptional by adding further requirements into the legal documents, enhanced disclosure before and after the transaction can help overcome some of these issues. One potential avenue to improve transparency could be to draw insights from other sustainable debt instruments, such as green bonds. In particular, these instruments are characterised by a higher level of public information, which is instrumental in establishing the necessary structures, including the establishment of a committee that oversees the allocation of funds. The International Capital Market Association's Green Bond Principles are used as guidance by issuers around the world, and also outline how the issuer should report the impact and allocation of funds.

For catastrophe bonds to be an effective part of a long-term DRR strategy, there is a requirement for transparency about the bond mechanisms and the creation of appropriate supporting governance structures before a catastrophic event takes place. This is essential to build up knowledge and public trust and ensure that the money is allocated to the areas that need it most. Further, it is imperative that different government ministries (including the Ministry of Finance as well as relevant ministries relating to climate-affected sectors) and agencies such as disaster management and national hydrological and meteorological services collaborate on comprehensive disaster risk management practices, including the potential for catastrophe bonds, to ensure broad appreciation of risk and impacts.

Future projections for sovereign catastrophe bonds

For decades, investors have been drawn to the catastrophe bond market due to its attractive yields and low correlation with conventional risks, particularly during periods of high market volatility (Demers-Bélanger and Son Lai, 2020). After a record-breaking 2023, when over US$17 billion of additional volume was added to the catastrophe bond market, its size in terms of outstanding risk capital grew to nearly US$50 billion, double what it was 10 years previously (Artemis, 2025). While this expansion was largely driven by issuances from the insurance and reinsurance industry, a similar upwards trend is anticipated for the sovereign space.

The World Bank plans to significantly expand its catastrophe bond support, aiming to increase issuance by 400% up to 2028 (Naik, 2023; Evans, 2023). Pooled insurance solutions such as the CCRIF have been in existence for some time and have used catastrophe bonds in the past, but there is growing interest in establishing similar structures in other regions. One such example is African Risk Capacity, which already has a parametric drought insurance scheme in place (Evans, 2024b). The World Bank has already started to work on creating a Caribbean catastrophe bond (including seven Caribbean countries) (World Bank, 2023). Catastrophe bonds have also been mentioned as a potential financial instrument to leverage and transfer capital from developed to developing countries in the context of a Loss and Damage Fund (Pandit Chhetri et al., 2021) (see Box 6.1).

However, concerns have been expressed about the broader trend of the ‘financialisation’ of disasters (Klein, 2018; Keucheyan, 2018; Perry, 2021) and the public scrutiny of catastrophe bonds that do not pay out after an event is increasing. This was particularly visible after Hurricane Beryl, when the Jamaican Finance Ministry had to explain why there was no payout.

In 2022, only about 2% of US$76 billion in crisis finance funding was attributed to pre-arranged instruments (Plichta and Poole, 2024). As the frequency and intensity of climate-related events increase, the importance of such tools grows rapidly. With this, catastrophe bonds are expected to become an increasingly used tool.

Box 6.1. Catastrophe bonds within the context of Loss and Damage

Following the establishment of the Warsaw International Mechanism (WIM) for Loss and Damage (L&D) during the United Nations Framework Convention on Climate Change (UNFCCC) negotiations in 2013, there remains a focus within this forum on identifying the appropriate financial mechanism to fund a Loss and Damage facility and provide payments to other countries.

However, issues of ‘moral hazard’ have been raised: for example, by a 2016 report commissioned by the UK government which investigated the use of grants for public premium subsidies for disaster insurance. That report found that when a third party (such as a donor country) covers the insurance premium, the insured party (i.e. the vulnerable country) may lose the incentive to reduce its risk exposure, as it does not bear the direct financial cost of its risk level (Vivid Economics et al., 2016).

There is also no universally accepted definition of L&D, which adds to the challenge of driving action. From a legal perspective, Broberg and Romera (2020) define L&D action as "measures that address the impacts of climate change which are residual to mitigation and adaptation". According to Mechler et al. (2020), financial support under L&D action is appropriate where adaptation is infeasible and therefore risks are unavoidable. As shown in Figure 2.1 above, catastrophe bonds are designed to cover low frequency but very severe events, often those where it is not possible to make efforts to adapt. Therefore, for some time, catastrophe bonds have been mentioned as a possible financial instrument that could be used by an L&D fund.

Particularly when backed by financial support from developed nations, as seen in the case of Jamaica, catastrophe bond issuances can become a financially attractive addition to the DRR toolbox of governments. External support, in terms of financial support and know-how, is a key enabling factor for a government to issue a catastrophe bond. The World Bank's support to date has focused on a select group of emerging markets (see also Figure 3.5 above).

This raises critical questions about the feasibility and equity of using catastrophe bonds as a tool within the L&D context, particularly for lower-middle- and low-income economies that are often the most vulnerable to climate change. The World Bank's support for issuing catastrophe bonds begins only upon a formal request from the respective country, meaning that access is contingent on a government's awareness of and capacity to navigate these financial instruments. This creates a risk of inequity, where only countries with prior knowledge and specific financial expertise may feel comfortable to leverage catastrophe bonds, while others remain excluded. To address this disparity and ensure a fair approach, significant efforts in awareness-raising and capacity-building are essential.

Additional hurdles to considering catastrophe bonds in the context of L&D exist in connection to data availability and investor preferences. While the US hurricane risk models can be used to develop parametric triggers for the Caribbean region, this is not a viable option for most other regions and perils. In many cases, the lack of sophisticated models and even data represents a significant obstacle that requires additional investments for the issuer and investor. This may even have a significant impact on investors' decisions to invest, due to the additional uncertainties involved when they lack familiarity with the regions, risks, data sources and models in question. As mentioned in Section 5, investor demand is influenced by various factors, all of which ultimately impact the pricing of catastrophe bonds. If investors are hesitant to invest in certain bond structures due to concerns about risk or regional coverage, it raises the question of whether catastrophe bonds represent an effective use of L&D funds in these cases.

Another important factor to consider in the context of an L&D fund is that catastrophe bonds are not subject to the same restrictions and requirements as other forms of donor funding. While direct donor contributions may be earmarked for specific humanitarian aid expenses, the payout from a catastrophe bond is typically unrestricted. This makes it easier to spend in the aftermath of an event, but might also not be preferred by governments or entities that pay into an L&D fund, as their contributions might not have a visible impact, especially when no payout takes place.

Given the lack of publicly available information about the trigger mechanism and the disbursement of funds after a payout in particular, it is challenging to assess the efficiency of financial aid allocation to catastrophe bond issuances and its potential to aid the most climate-vulnerable and low-income nations. The suitability of such instruments in an L&D context warrants further analysis.

7. Conclusion

The frequency and severity of physical climate risks are growing; more and more communities and assets are becoming exposed. These factors combined with the maturing of capital markets globally mean that financial instruments to deal with climate-related risks will likely continue to gain interest. Flexible, unconstrained use of capital, available quickly in the aftermath of a catastrophic event, could be required as a core feature of the toolbox to reduce the disaster finance gap, including through catastrophe bonds.

However, while more catastrophe bond transactions have emerged, only four have so far led to a payout, and information about their effectiveness is limited. To prevent public backlash and foster trust, transparency about the functioning and use of these bonds is crucial. Governments must publish detailed information about bond structures, payouts and usage, so that the public is as informed as investors.

Additionally, the capital markets are yet to accept innovative solutions that not only try to transfer risk but also incentivise risk reduction. Investors seem more reluctant to invest in transactions with overly complex structures or unknown models, particularly when the potential upside is limited. Effort needs to be made to address the high transaction costs, opaque calculation models and the current narrow investor base, to remove these as possible impediments to the expansion of catastrophe bond use.

Messages from survivors of Hurricane Marilyn, 1995, on the island of St Thomas. Photo: SRA Tana R. Hamilton/The U.S. National Archives

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Appendix: Preparation, placement and protection phases in Jamaica

Phase	Example catastrophe bond transaction
Preparation	
Identify need	Extreme risks were deemed insufficiently covered under the existing CCRIF SPC or the IADB contingent credit line.
Gain buy-in and support	Due to the government's 'fiscal consolidation efforts', the international donor community[14] decided to support the issuance of the bond by paying for the interest payments to investors.
Data preparation	The World Bank assumed the role of global coordinator for the duration of the process, collaborating with the risk modelling firm (AIR Worldwide) and bookrunners and supporting on the selection of the trigger mechanism and placement strategy. Costs for this according to the project appraisal document (PAD) amounted to US$16.52 million. Together with the risk modelling agent the government and the World Bank chose the trigger mechanism. Not much is known about the involvement of local stakeholders in this process.
Structuring	AIR Worldwide provided the estimations for the expected loss based on the parametric trigger thresholds. Aon Securities and Swiss Re Capital Markets are joint structuring agents and bookrunners.[15] Relevant documents have been shared with investors, but are not available publicly. The PAD and some case study documents include some high-level descriptions of the trigger mechanism.
Placement	
Roadshow	Not much is known about the interaction between investors and government. Given the bookrunners went ahead with the placement of the bond, the responses and market appetite for this transaction was clearly positive.
Book building	Books opened on 19 July 2021 to receive orders from investors.[16] The bond was offered as a US$175 million tranche with expected loss of 1.52% and a coupon price guidance ranging from 3.75–4.5%. The coupon guide price range is informed by the risk level, but also the interests of investors during the roadshow, as demand influences the price level too.
Pricing and allocation	Significant investor interest led to an increase in size to US$185 million. However, the price guidance was tightened towards the upper-end of the range at 4.4–4.5%. This was not surprising, as the bookrunners expected several investors would drop out and not buy the bond if it was priced on the lower end of 3.75%. The bond settled at 4.4%

[14] Financial donor support was received from the UK and Germany-funded Global Risk Financing Facility (GRiF) and the United States Agency for International Development.
[15] Entities, often also investment banks, which are responsible for coordinating the entire process of underwriting and managing the issuance of the bonds on behalf of the issuer.
[16] The bonds can only be sold to investors who "(i) are 'qualified institutional buyers' within the meaning of Rule 144A under the United States Securities Act of 1933, as amended, and (ii) are residents of and purchasing in, and will hold the bonds in, a permitted U.S. jurisdiction or a permitted non-U.S. jurisdiction (and meet the other requirements set forth under 'Notice to Investors' in the Prospectus Supplement)" (World Bank, 2021).

	The second government bond was issued in May 2024. Books were opened for US$150 million of bond notes with an expected loss of 1.5%. The risk margin guidance ranged from 6.25–7%. During the book building process, pricing settled on the upper end of the range and was priced at 7%. Some information on the investors for the first catastrophe bond has been shared via the Artemis Deal Directory: 66% investors are dedicated ILS funds, 17% (re)insurers, 14% asset managers and 3% pension funds. About 60% are domiciled in Europe, 24% in North America, 15% in Bermuda and 1% in Asia.
Protection	
Communication	The World Bank published a two-page case study for the first Jamaican catastrophe bond.
Interest payment	Investors received annually 4.4% on their investment into the first Jamaican catastrophe bond and 7% for the second until maturity. The premium payments to investors totalled approximately US$19.54m for the duration of the first bond.[17]
Trigger event	During the period covered by the first bond there was no trigger event. If there had been, a risk modelling agent would have been tasked to determine if the necessary minimum pressures in the parametric boxes were met and then determine the size of payout.
Payout	No payout from the first bond or second bond has been made, with Hurricane Beryl narrowly missing the trigger thresholds of the second bond.
Utilisation	A comprehensive account of the disbursements and utilisation of funds in the wake of a catastrophe bond payout could not be found. It is therefore not possible to make any meaningful assessments of the effectiveness or usefulness of such funds.

Source: Authors; Artemis Deal Directory; World Bank (2021b)

[17] The risk margin (here used as coupon equivalent) was priced at 4.4% annually and the bond had a duration of 2.4 years.