5 CLIMATE CHANGE

APRIL 2020—GLOBAL FINANCIAL STABILITY REPORT

PHYSICAL RISK AND EQUITY PRICES—ONLINE BOXES 5.1–5.3

The following three Online Boxes provide additional analyses that complement Chapter 5 of the April 2020 Global Financial Stability Report:

- **Online Box 5.1. Insuring against Climate Change Physical Risk: The Role of Catastrophe Bond Markets**

  CAT bonds are an important risk sharing mechanism for issuers such as insurers or sovereigns. Online Box 5.1 describes the development of the market for CAT bonds over the past two decades.

- **Online Box 5.2. Assessing the Impact of Climate Change Physical Risk on the Equity Risk Premium with a Long-Run Risk Model**

  Online Box 5.2 complements the analysis of the chapter by comparing the equity risk premiums implied by a stylized asset pricing model (that takes climate change physical risk into account) with the market implied equity risk premiums.

- **Online Box 5.3. The Pricing of Climate Change Physical Risk into Sovereign Bonds**

  While the Chapter does not find evidence for climate change physical risk being priced in equities, it may be priced in other asset classes. Online Box 5.3 looks at the sensitivity of sovereign bond issuance costs to climate change physical risk by comparing long- and short-term sovereign bond spreads at the time of issuance.

Online Box 5.1. Insuring against Climate Change Physical Risk: The Role of Catastrophe Bond Markets

Catastrophe (CAT) bonds are specialized securities that allow issuers to transfer natural disaster risk to capital markets. They are usually short- to medium-term, high-yield instruments with low turnover, issued primarily by insurance and reinsurance companies. CAT bonds come with specified triggers attached to them, most often related to the size of insurance claims following a particular natural disaster. If the bond is triggered, the principal is either partially or fully forgiven. Demand for CAT bonds has increased over the past 10 years, driven by the search for high-yield assets uncorrelated with other types of financial risk.[1] CAT bonds are a major component of so-called "alternative reinsurance capital," which accounted for 16 percent of the total amount insured by global reinsurance capital in 2019 (Aon 2019).

The most important single peril covered by CAT bonds is hurricanes and other storms (such as cyclones, typhoons, and windstorms), followed by earthquakes (Online Box Figure 5.1.1, panel 1). More than one-quarter of CAT bonds insure against multiple perils, most of which also cover hurricane risk. By volume, almost 75 percent of CAT bonds issued between 2009 and 2018 were exposed to hurricane risk.

The CAT bond market has grown from an annual issuance of about $3 billion in 2008 to a peak of nearly $12 billion in March 2018 (Online Box Figure 5.1.1, panel 2). As of February 2020, more than $41 billion in CAT bonds were outstanding (Artemis 2020). Most CAT bonds offer only short-term protection from catastrophe risks, with maturities between two to four years (Online Box Figure 5.1.1, panel 3). Consistent with search-for-yield behavior, CAT bond primary market spreads have been declining since the global financial crisis, even though the expected losses from CAT bonds have been increasing on average over the past 20 years (Online Box Figure 5.1.1, panel 4).

In light of increasing uncertainty due to climate change, investors might demand a greater risk premium for taking on exposure to climatic disasters relative to other forms of disasters. Regression analysis shows that in a sample of 656 CAT bonds, controlling for expected losses and other factors, exposure to hurricane disasters was associated with around a 90 basis points higher premium on average, relative to CAT bonds with no exposure to hurricanes.[2] Part of this premium might be due to additional uncertainty about future climatic conditions.[3] Going forward, understanding the way climate change affects the pricing of CAT bonds will be crucial for the market to grow.

Given the high costs of insuring against natural disasters, and particularly disasters related to climate change, greater use of CAT bonds could benefit the most vulnerable countries. In developing countries, where the protection gap is largest and a substantial fraction of the population and economy is exposed to climatic disaster risk, government insurance could help reduce this gap (Cebatori and Youseff 2020). CAT bonds can offer an effective avenue for sovereigns to insure against disasters, as seen in the case of Colombia, Chile, and Peru, which issued sovereign CAT bonds equivalent to $1.1 billion in 2018 alone.

This box was prepared by Manuel Perez Archila in collaboration with Alan Feng and Peter Windsor.

[1] CAT funds and institutional investors now comprise 75 percent of total buyers in the CAT bond market (Aon 2019).

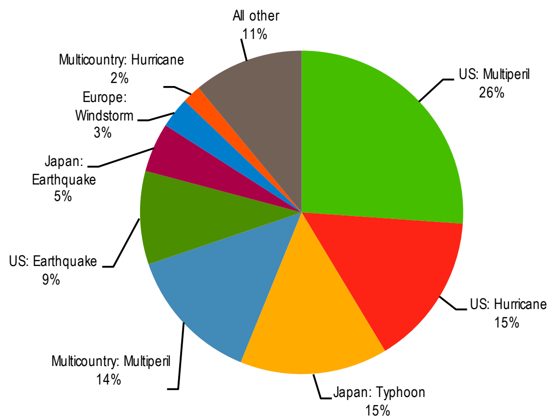
[2] The literature also finds that premiums increase in the immediate aftermath of natural disasters, even though the magnitude of this effect has decreased over time (Froot and O'Connell 1999; Tomunen 2019). A recent study points toward market segmentation and the relatively limited availability of capital in the market as a driver of premiums (Tomunen 2019).

[3] See Online Annex 5.5 for a detailed description of the empirical methodology.

Online Box Figure 5.1.1. Developments in the Global Catastrophe Bond Market

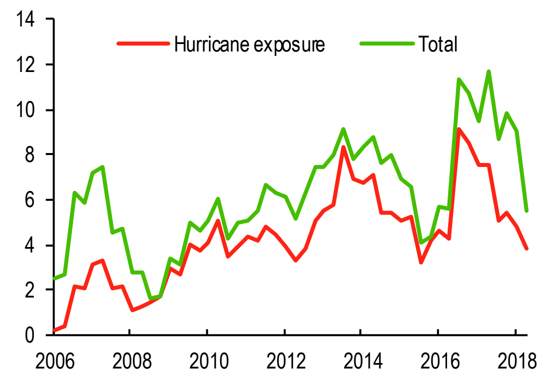
A large proportion of CAT bonds cover hurricanes and other storms

1. CAT Bond Exposure
(Percent of volume issued, 2009–18)



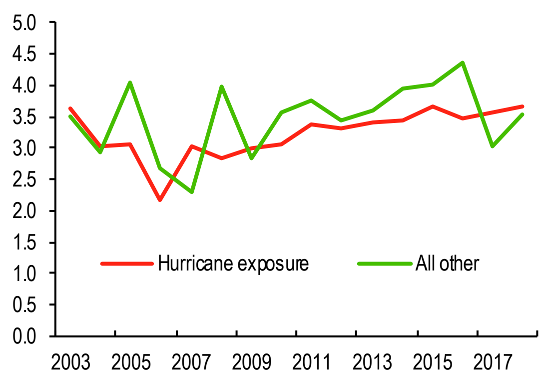
Issuance of CAT bonds has grown since the mid-2000s…

2. CAT Bond Annual Issuance Volume
(Billions of US dollars, past 12 months, 2006–18)



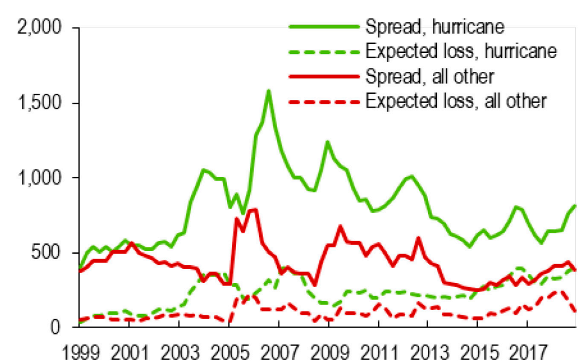
…but most CAT bonds offer only short-to-medium term protection from catastrophe risks

3. CAT Bond Maturity at Issuance
(Years, annual average, 2003–17)



While expected losses have been increasing, spreads have been declining since the global financial crisis.

4. CAT Bond Expected Loss and Spreads
(Basis points, four-quarter rolling average, 1999–2017)



Sources: Refinitiv Datastream; Dealogic; Artemis Deal Directory; Lane Financial; Bloomberg L.P.; Tomunen (2019); and IMF staff calculations.
Note: Panel 1 shows the percent of the volume of CAT bonds issued between 2009 and 2018 with the peril that triggers them. Multicountry bonds are exposed to risks from multiple countries, while multiperil bonds are triggered by multiple catastrophes. In panel 2, the volume of issuance is computed at the end of each quarter as the sum of the face value of all the tranches issued in the previous 12 months. Hurricane exposure bonds include all bonds that are triggered by hurricanes, windstorms, cyclones, or typhoons, although they might also protect against additional perils (multiperil bonds). In panel 3, the maturity is computed by taking the average of the difference in years between the maturity date and the issuance date for all bonds issued in the previous four quarters. "All other" refers to all bonds that are not exposed to any hurricane risk (including the risks of windstorms, cyclones, or typhoons). In panel 4, the expected loss from each bond is taken from a forecasting model and should be interpreted as the annualized expected loss expressed as a fraction of the bond's face value.

Online Box 5.2. Assessing the Impact of Climate Change Physical Risk on the Equity Risk Premium with a Long-Run Risk Model

As large climatic disasters adversely affect the economy and increase market tail risks, a future rise in the frequency and severity of such events should be reflected in equity valuations. Building on a stylized macrofinancial model with long-run risks (LRR), this box illustrates how future climatic disasters can affect the equity risk premium (ERP): that is, the return over the risk-free rate equity investors require for holding equity risk.

In the standard LRR model, time-varying uncertainty about long-run growth is a key factor driving equity prices.[1] To account for the potentially severe consequences of climate change, the model used in this box further incorporates temperature-induced climatic disasters. The model is calibrated using consumption, equity prices, and market dividends data, discount rates found in the literature, a future temperature scenario running until 2100, and a reduced-form mapping between temperature and disasters.[2] Based on data for the United States, a version of the model is estimated for each of four temperature scenarios. The four model-generated equity risk premiums are then compared to one another.

The four scenarios are the following: [3]

- A no warming scenario, in which climatic disasters remain at their current level.
- A low warming scenario corresponding to the RCP 2.6 scenario, in which climate change mitigation actions are implemented forcefully.
- A medium warming scenario corresponding to the RCP 6.0 scenario, in which some climate change mitigation actions are undertaken but emissions rise quickly up to 2060.
- A high warming scenario corresponding to the RCP 8.5 scenario, in which no mitigation action is implemented (see the Online Annex 5.1 for a description of the RCP scenarios).

Model simulations, based on mean temperature projections, deliver ERPs of 5.9 percent, 8 percent, and 11.6 percent, and 13.4 percent respectively, suggesting that a scenario with no mitigation would result in much higher risks for equity investors (Online Box Figure 5.2.1, panel 1).

Based on a similar model for a representative advanced economy, the climate-augmented ERP is then constructed for a sample of advanced economies. When comparing ERPs across economies the risk premiums in the high warming scenario are consistently higher than the current market implied risk premiums with no apparent relationship between the two—suggesting that equity markets may not currently price climate change risk (Online Box Figure 5.3.1, panel 2). Under the high future warming scenario, the model delivers equity risk premiums that are on average more than twice as large as what they are under the no warming scenario.

Overall, the analysis highlights that climatic disasters could be a key source of long-run economic risks and underscores the importance of timely policy action to mitigate climate change and avoid possible market dislocations.

This box was prepared by Andrea Deghi.

[1] See Bansal and Yaron (2004); Bansal and others (2016); and Beeler and Campbell (2012).

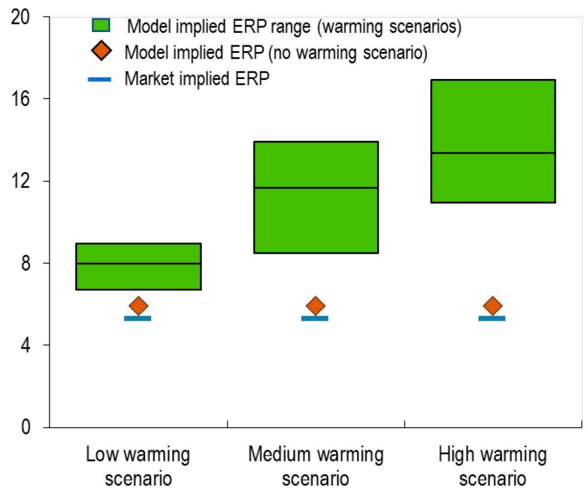
[2] Details on the estimation and calibration are provided in Online Annex 5.6.

[3] See Online Annex Table 5.1.3 for the temperature projections under the different Representative Concentration Pathways (RCPs).

Online Box Figure 5.2.1. The Effect of Climate Change Physical Risk on the Equity Risk Premium

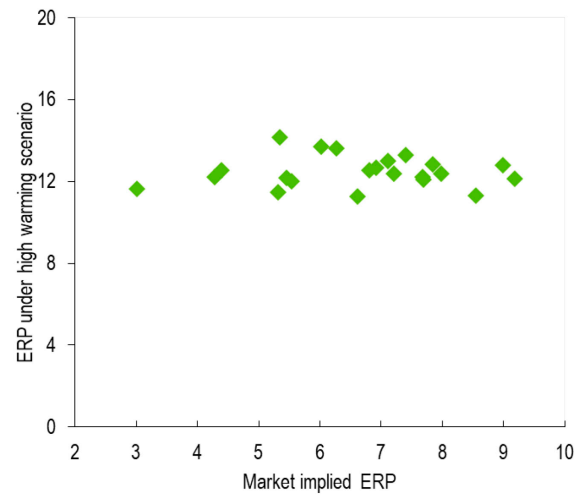
A climate change scenario with no mitigation would result in much higher risk for equity investors in the United States…

1. United Sates: Equity Risk Premiums under Different Climate Scenarios
(Percent)



… and in other advanced economies.

2.Advanced Economies: Market Implied Equity Risk Premiums and Equity Risk Premiums Under High Warming Scenario
(Percent)



Sources: EM-DAT disaster dataset; KNMI Climate Explorer; Haver Analytics; Refinitiv Datastream; and IMF staff calculations.
Note: Panel 1 shows risk premiums for different climate risk scenarios compared to a counterfactual scenario with no future climate risk and the market-implied risk premia based on a standard discounted cash-flow valuation model. Mid-line in the boxplots corresponds to the equity risk premium estimated using the average temperature projection in each scenario. The outer lines in the boxplots correspond to the equity risk premiums estimated at the 5th and 95th percentile of temperature projections in each scenario. Simulation and estimation of the long-run risk model is performed using bootstrapped simulated data until 2100. Disaster shock probability is mapped to the temperature level in each climate scenario. In panel 2, each dot represents an advanced economy and the ERP under the high warming scenario is estimated using model calibrations from a representative advanced economy and the average temperature projection in the RCP 8.5 scenario. ERP = equity risk premium.

Online Box 5.3. The Pricing of Climate Change Physical Risk into Sovereign Bonds

Sovereign risk can be directly affected by climatic disasters, such as through damages to government-owned infrastructure, an increase in expenditures related to the sovereign's role as the economy's ultimate insurer, or loss of fiscal revenue. Budget deficits tend to increase after climatic disasters, especially in countries with low levels of financial development and insurance penetration, often resulting in a higher level of public debt that can increase the cost of debt issuance for the sovereign (Melecky and Raddatz 2011).

Rating agencies have started to recognize that climate risk may affect the creditworthiness of sovereigns (Moody's 2017; Standard & Poor's 2014). In the United States, there is evidence that borrowing costs of municipal bond issuers have become sensitive to risks from rising sea levels (Painter 2020), a trend that is expected to continue (BlackRock 2019).

Based on a global sample of more than 40,000 sovereign bonds issued between 1990 and 2018, this box looks at the sensitivity of issuance costs to climate change risk by comparing long- and short-term sovereign bond spreads at the time of issuance.[1] Long-term bond prices would be expected to have a higher sensitivity to climate change risk than short-term bonds, given the long time frame over which these risks are expected to materialize.[2]

The main findings are as follows: Projected changes in the occurrence of individual climate hazards—extreme heat and precipitation, heat waves and droughts, and sea level rise—are not associated with higher issuance costs for long-term bonds compared to short-term bonds. However, a different picture emerges when focusing on broader, readily available composite measures of climate change hazard risk that take into account both current and future climate extremes. A rise of the Climate Change Hazard Index by 1 point increases spreads by about 8 basis points (Online Box Figure 5.3.1, panel 1).[3] More importantly, the effect is also significant when considering the effect of an index that captures not only hazard, but also exposure and vulnerability: namely, the Climate Change Physical Risk Index. A 1-point increase in this index, which can take values between 0 and 10, is associated with an increase in spreads by 11 basis points.

When differentiating across bonds based on their maturity structure, the results show that both long-term bonds (that mature between 2025 and 2040) and very-long-term bonds (that mature after 2040) are cheaper when issued by countries with low climate change risk, and that the effect is larger for very-long-term bonds. This suggests that markets expect risks to materialize over the very long term (Online Box Figure 5.3.1, panel 2).

Overall, these findings suggest that investors demand a premium when purchasing sovereign bonds exposed to climate change physical risk. However, results are sensitive to the choice of climate change risk proxies. Further research is required to better understand the sensitivity of sovereign bonds to such risks.

This box was prepared by Felix Suntheim.

[1] The sample includes 41,211 bonds, issued in 121 economies from 1990 to 2019. The economies and the time period covered in this analysis do therefore not correspond to those in the main chapter. The sample is dominated by advanced economies, with more than half of the observations pertaining to the United States, though the results are robust to excluding the United States from the sample. See Online Annex 5.7 for methodological details.

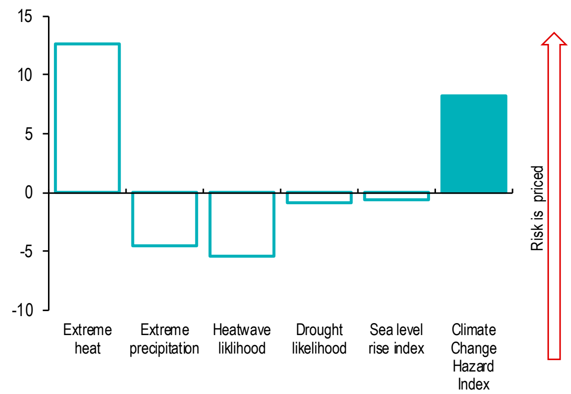
[2] Long-term bonds are defined as bonds that mature after 2040. The analysis is robust to different maturity thresholds.

[3] The indices are defined from 0 = low risk to 10 = high risk.

Online Box Figure 5.3.1. Climate Change Physical Risk and Sovereign Bond Spreads

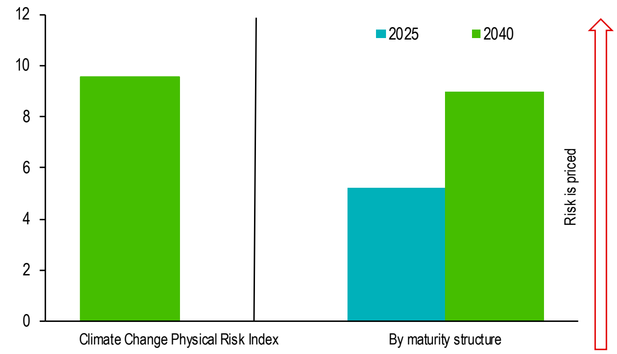
Sovereign bond spreads at issuance are generally not associated with single measures of projected changes in the occurrence of climate hazards.

1. Marginal Effect of an Increase in Climatic Hazard Occurrence on Long-Term Bond Spreads
(Basis points)



However, long-term and very long-term bonds of economies exposed to an increase in composite physical risk indices are issued at a discount.

2. Marginal Effect of an Increase in Physical Risk on Long-Term and Very Long-Term Bond Spreads
(Basis points)



Sources: Refinitiv Dealogic; World Bank; Verisk Maplecroft; and IMF staff calculations.
Note: Panels 1 and 2 show the coefficient of the interaction term of climate risk measures with a dummy for bonds with maturities longer than 2040. Climate hazards 1–4 are projected anomalies over the period 2020–39 under RCP 8.5 relative to historical simulations over the period 1986–2005. Coefficients 1–4 are multiplied by the standard deviation of the variable; The sea level rise index and the Climate Change Hazard Index range from 0 to 10. Panel 2 shows on the left-hand side the coefficient of the interaction term of the Climate Change Physical Risk Index with a dummy for bonds with maturities longer than 2040. The right-hand side the panel shows the coefficients from the interaction of the Climate Change Physical Risk Index with bonds that mature between 2025 and 2040, and from an additional interaction between the climate risk measures and a dummy for bonds that mature after 2040. All regressions include economy-year fixed effects. In both panels, solid bars indicate significance at the 10 percent level. See Online Annex 5.7 for variable definitions and methodological details.

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