PHYSICAL RISK AND EQUITY PRICES

Chapter 5 at a Glance

- The impact of large climatic disasters on equity prices has been modest in the past.
- Climate change physical risk does not appear to be reflected in global equity valuations.
- Beyond climate change mitigation and adaptation, sovereign financial strength and higher insurance penetration help to preserve financial stability.
- Stress testing and climate risk disclosure are essential to better assess physical risk.

The projected increase in the frequency and severity of disasters due to climate change is a potential threat to financial stability. Equity markets are a key segment of the global financial system, provide a data-rich environment, and are sensitive to long-term risks, making them fertile ground for investigating how projected future physical risk affects financial markets and institutions. Looking back over the past 50 years shows a generally modest impact of large disasters on equity markets, bank stocks, and non–life insurance stocks, although country characteristics matter. Higher insurance penetration and greater sovereign financial strength have helped dampen the adverse effects of large disasters on equity markets and financial institutions. While projections of climatic variables and their economic impact are subject to a high degree of uncertainty, aggregate equity valuations as of 2019 do not appear to reflect the predicted changes in physical risk under various climate change scenarios. This suggests that equity investors may not be paying sufficient attention to climate change risks. Beyond policy measures to mitigate and adapt to climate change, actions to enhance insurance penetration and strengthen sovereign financial health will be instrumental in reducing the adverse effects of climatic disasters on financial stability. Moreover, better measurement and disclosure of exposures to climatic disasters are needed to facilitate the pricing of climate-change-related physical risks.

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Introduction

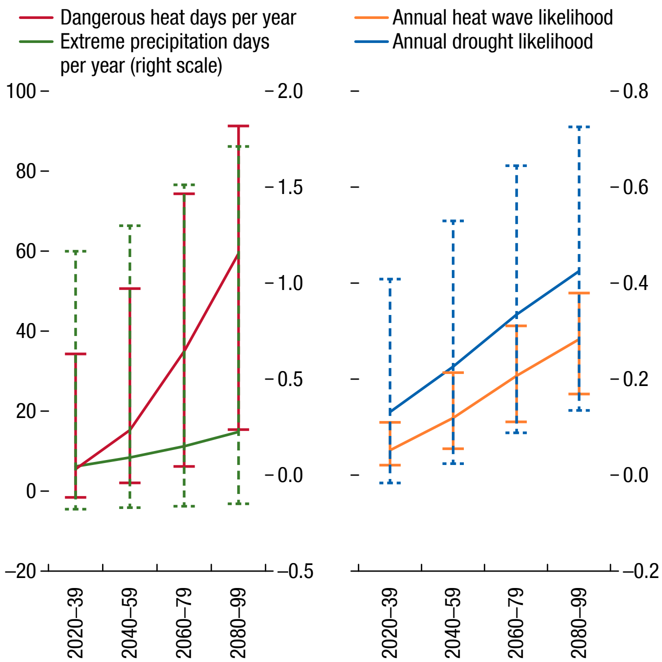
Global temperatures have increased by 1.1 degrees Celsius relative to preindustrial levels, and climate scientists have almost unanimously attributed this change to man-made (anthropogenic) greenhouse gas emissions. The path of global temperatures over the next several decades will depend in large part on mitigation actions that help reduce the amount of emissions. Based on currently stated mitigation policies, future anthropogenic greenhouse gas emissions are predicted to lead to warming of about 3 degrees Celsius by the end of the century (IPCC 2018). Climate change induced by this level of warming is, in turn, expected to adversely impact the world's stock of natural assets, lead to a significant rise in sea level, and increase the frequency and severity of extreme weather events (IPCC 2014 and Online Annex Table 5.1.3). The impact is subject to a significant degree of model uncertainty (Figure 5.1), is likely to vary considerably across economies, and may be nonlinear as a result of thresholds in the climate system beyond which the effects accelerate or become irreversible (DeFries and others 2019).

Extreme weather events—or climatic hazards—can turn into disasters that cause loss of life and capital stock, as well as disruptions to economic activity. As a result, they are a source of so-called physical risk for economic agents. Some climatic hazards have wrecked cities and even entire economies. New Orleans was devastated by Hurricane Katrina in 2005, while Dominica suffered damage amounting to more than twice its GDP when Hurricane Maria struck in 2017. As the frequency and severity of climatic hazards rise,

Figure 5.1. Projected Changes in Climatic Hazards

The size of the future increase in climatic hazard occurrence is large and uncertain.

Sample Economies: Latest Projected Changes in Extreme Weather Events, Relative to 1985–2005 (Various horizons)



Sources: World Bank Group, Climate Change Knowledge Portal; and IMF staff calculations.
Note: The figure shows the equal-weighted average across all sample countries of the median projection—from up to 35 models included in the fifth phase of the Coupled Model Intercomparison Project (CMIP5)—of four climate variables, defined as anomalies relative to historical simulations over the period 1986–2005. The extremities of the vertical bars show the equal-weighted average of the 90th and the 10th percentiles of the projections. Projections are based on the high-emissions scenario Representative Concentration Pathway (RCP) 8.5. See Online Annex 5.1 for the list of sample economies, as well as a definition of the RCP scenarios and the future climate variables.

the resultant socioeconomic losses could be significantly higher than in recent history.

The magnitude of the change in physical risk will depend not only on how future emissions (and therefore mitigation policies) translate into global warming, and on how this warming, in turn, translates into more frequent and more severe climatic hazards, but also on nonclimatic factors—that is, the reactions of economic agents (including governments) to these changes, in particular through adaptation.[1] For example, a study of predicted flood losses in the world's 136 largest coastal cities concluded that global annual average losses would exceed $1 trillion in 2050 in a scenario without adaptation versus only $60 billion in a scenario with adaptation investments that maintain constant flood probabilities despite a higher sea level (Hallegatte and others 2013).

Given the climatic trends, financial stability authorities have become concerned that the financial system may be underprepared to cope with this potentially large increase in physical risk, as well as with the so-called transition risk resulting from policy, technology, legal, and market changes that occur during the move to a low-carbon economy. Transition risks include assets becoming stranded, reputational damage, and financial distress of polluters. The Network for Greening the Financial System, a group of central banks and financial supervisors, has expressed concern that financial risks related to climate change are not fully reflected in asset valuations and has called for integrating these risks into financial stability monitoring (NGFS 2019). In its Financial Sector Assessment Program, the IMF is paying increasing attention to financial stability risks related to climate change and aims to push forward efforts around climate change stress testing across economies (see Box 5.1).

From the perspective of physical risk, climate change can affect financial stability through two main channels (Figure 5.2). First, a climatic hazard can turn into a disaster if it happens in an area where the exposure is large and vulnerability is high.[2] Such a disaster affects households, nonfinancial firms, and the government sector through the loss of physical and human capital, thereby causing economic disruptions that can possibly be significant. Financial sector firms are exposed to these shocks through their underwriting activity (insurers), lending activity (mostly banks), and the portfolio holdings of affected securities (all financial firms). Financial institutions could also be exposed to operational risk (such as in cases in which their structures, systems, and personnel are directly affected by an event) or to liquidity risk (such as if a disaster triggers sizable withdrawal of customer deposits). Insurers play a special role in absorbing shocks. The provision

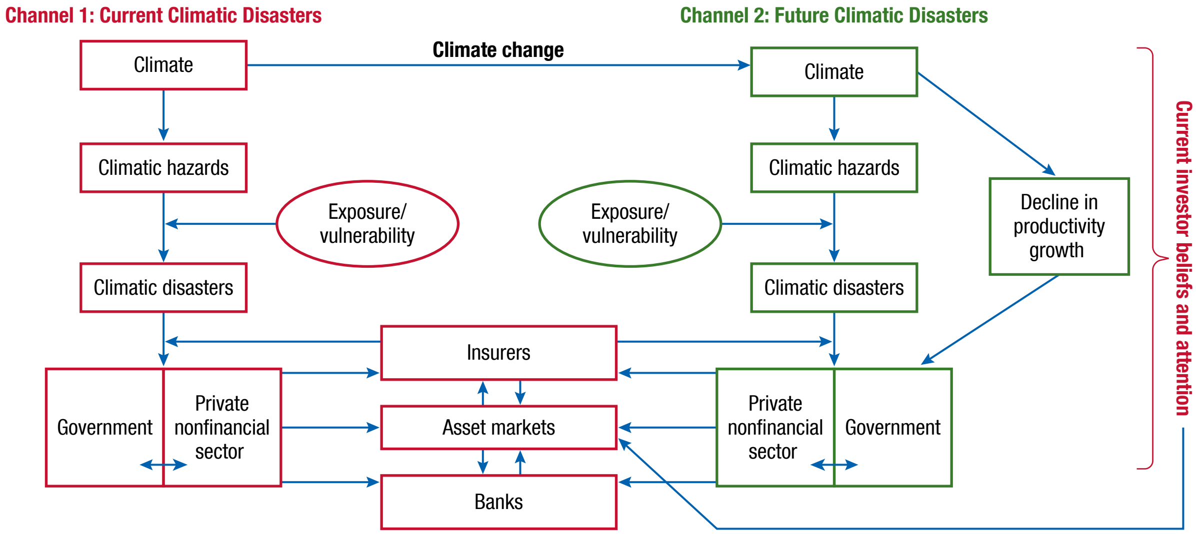
[1]Mitigation addresses the causes of climate change, whereas adaptation addresses the impacts of climate change.

[2]This chapter uses the same terminology as climate change research: exposure is defined as "the presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected." Vulnerability is defined as "the propensity or predisposition to be adversely affected" (IPCC 2012). Resilience is the opposite of vulnerability.

Figure 5.2. Climate Change Physical Risk and Financial Stability

The financial sector is exposed to climatic disasters through two channels. First, current climatic disasters affect credit, underwriting, market, operational, and liquidity risks.

Second, the shifts in expectations and attention about future climatic disasters can affect asset values today.



Source: IMF staff.

of insurance concentrates the impact of the shock on the insurance sector and reduces the impact on other economic agents.[3] Governments also generally play an important cushioning role by providing some forms of insurance, as well as relief and support in the aftermath of a disaster. The strain on government balance sheets after a disaster could potentially have financial stability implications given the strong sovereign-bank nexus in many economies.

Second, investors form beliefs about physical risk—the result of a combination of climatic hazards, exposures, and vulnerabilities—as well as insurance coverage (and risk sharing more broadly, including through the government) at various time horizons in the future. Standard asset pricing theory suggests that investors should demand a premium for holding assets exposed to a future increase in physical risk induced by climate change. In other words, these assets should have a lower price compared with assets with similar characteristics but not exposed to this change in physical risk. However, because the nature of the risk is long term, and depends on complex interactions between climate variables and socioeconomic developments that are difficult to model, markets may not price future physical risk correctly, potentially leading to capital misallocation and economic inefficiency. Perhaps more important from a financial stability perspective, a sudden shift in investors' perception of this future risk could lead to a drop in asset values, generating a ripple effect on investor portfolios and financial institutions' balance sheets.[4]

Against this backdrop, this chapter analyzes the financial stability implications of the anticipated increase in the frequency and severity of climatic hazards over the next several decades.[5] To do so, it

[3]Insurers can transfer portions of their risk portfolios to reinsurers. Yet anecdotal evidence suggests that some large disasters had a sizable impact on insurers' solvency. For example, Hurricane Andrew led to the failure of at least 16 US insurers in 1992–93 (III 2020).

[4]As shown in Figure 5.2, the climate economics literature suggests that climate change could lead to a decline in productivity growth, which may also not be reflected adequately in asset prices. Under a scenario of no further mitigation action on climate change, most estimates suggest a loss of global economic output of less than 5 percent in 2050 and 10 percent in 2100 (Kahn and others 2019). While this implies that the average productivity growth decline due to climate change would be small, the historical relationship between temperature and GDP growth may not be an accurate guide to the future in the presence of tipping points in the climate system.

[5]An in-depth exploration of the impact of transition risk is left for future issues of the *Global Financial Stability Report*. For a comprehensive discussion of financial stability risks related to climate change, including transition risk, see Carney (2015); Bank of England Prudential Regulatory Authority (2018); European Central Bank (2019); and NGFS (2019), among others. Chapter 6 of the October 2019 *Global Financial Stability Report* also discusses these risks as part of a broad analysis of sustainable finance.

focuses on equity markets, which play a central role in the financial system and provide a useful avenue to explore the two channels described. This is so because, relative to other financial markets, equity markets provide readily available high-frequency information on investors' perception of the impact of a shock on the future performance of a broad range of financial and nonfinancial firms. Equity markets are thus well suited for an event-study type of analysis to investigate the first channel. Moreover, because equities are perpetual claims on firms' cash flows, their price should reflect the long-term risks facing firms, including those associated with changes in physical risk, allowing an investigation of the second channel.

The chapter focuses on 68 economies with available aggregate stock market data[6] and asks the following key questions: (1) What has been the trend in frequency and severity of climatic disasters in these economies? (2) How have aggregate equity prices, bank equity prices, and insurance equity prices reacted to large climatic disasters in the past? (3) Can better insurance coverage and sovereign financial strength enhance the resilience of equity markets and financial institutions? (4) Acknowledging the informational challenges faced by investors, are climate change risks reflected in equity prices—that is, do equity valuations as of 2019 correlate negatively with the predicted changes in physical risk? (5) Are equity investors paying attention to temperature, a climate variable that—in contrast to future climatic hazards—is not predicted or model-dependent but can actually be observed at high frequency? The sample used in the analysis comprises 34 advanced and 34 emerging market and developing economies and covers the past 50 years. The data sources and econometric methodologies, as well as robustness tests of the key findings, are described in the online annexes.

The chapter's main findings are as follows: Climate change is a source of financial risk for investors that could lead to adverse consequences for financial stability. However, over the past several decades, the reactions of aggregate equity prices, bank equity prices, and insurance equity prices to large climatic disasters have generally been modest, in particular in economies with high rates of insurance penetration and sovereign financial strength. Pricing future climate risks is extremely challenging, given the large uncertainties around climate science projections and the economic cost of predicted hazards. However, current economy-level equity valuations as of 2019 are generally not statistically significantly associated with the currently available proxies of future changes in physical risk. Furthermore, equity investors do not seem to have paid full attention to temperature, which could suggest that they do not pay full attention to climate change either. The analysis implies that, in the current baseline scenario, in which climate change mitigation policies are projected to remain weak globally, domestic financial stability will be best protected if governments preserve or enhance their financial strength, reduce barriers to non–life insurance penetration while ensuring adequate capital in the insurance sector, and encourage adaptation. Soberingly, preserving or enhancing financial strength appears challenging as public debt ratios continue to increase (see Chapter 1). In addition, better measurement and increased disclosure of exposure and vulnerability to climatic hazards would help reduce investors' informational challenges and facilitate risk pricing.

Climatic Disasters—Some Stylized Facts

Climatic hazards range from acute (storms, floods, heat waves, cold waves, wildfires, landslides) to chronic (droughts). Hazards that result in large-scale damage to human life, physical assets, and economic activity are defined as disasters.[7] The transformation of a climatic hazard into a disaster depends not only on the physical magnitude of the hazard (for example, the wind speed during a storm event), but also on the economic exposure of the region where it strikes (especially the value of assets and the population size) and its vulnerability (for example, the quality of buildings and infrastructure and disaster preparedness). Given that disasters are more economically meaningful than hazards, the focus here

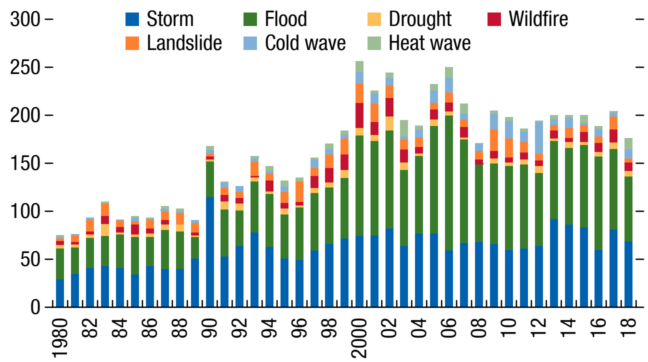
[6]All economies for which aggregate stock market data are available have been included in the sample. These represent about 95 percent of world GDP in 2018. See Online Annex 5.1 for the list of economies. All online annexes and online boxes are available at www.imf.org/en/Publications/GFSR.

[7]Disaster data are sourced from the Emergency Events Database (EM-DAT). Disasters conform to at least one of the following three criteria: 10 or more deaths; 100 or more people affected; the declaration of a state of emergency and/or a call for international assistance. Reported damages from disasters are measured imperfectly and generally cover only direct costs from damages to physical assets, crops, and livestock.

Figure 5.3. Climatic Disasters and Related Damage

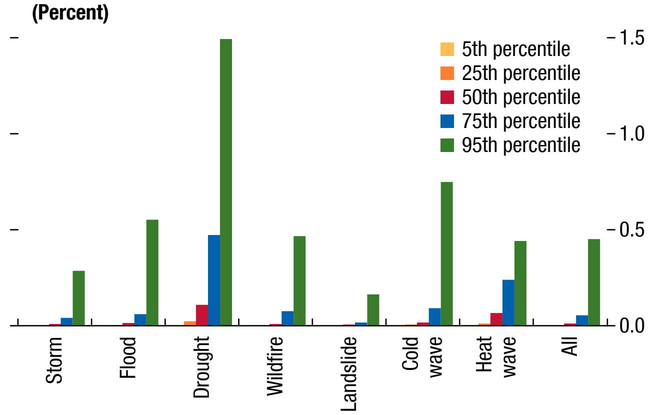
After rising until 2000 the number of climatic disasters has been stable over the past 20 years, with storms and floods accounting for most occurrences.

1. Sample Economies: Annual Number of Climatic Disasters, 1980–2018



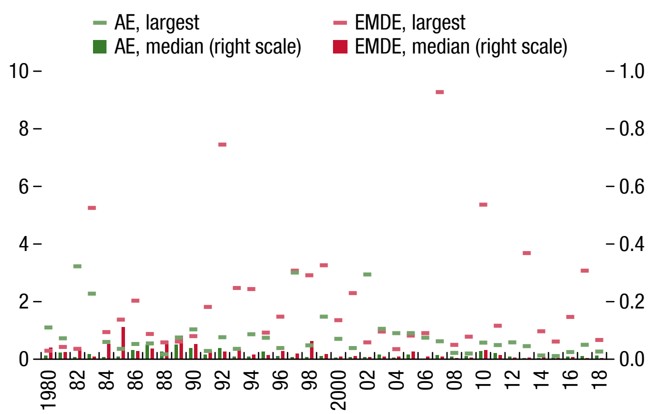
Only large disasters cause sizable damages relative to domestic GDP.

2. Sample Economies: Damages-to-GDP Ratio, by Disaster Type and Percentile of the Distribution, 1980–2018 (Percent)



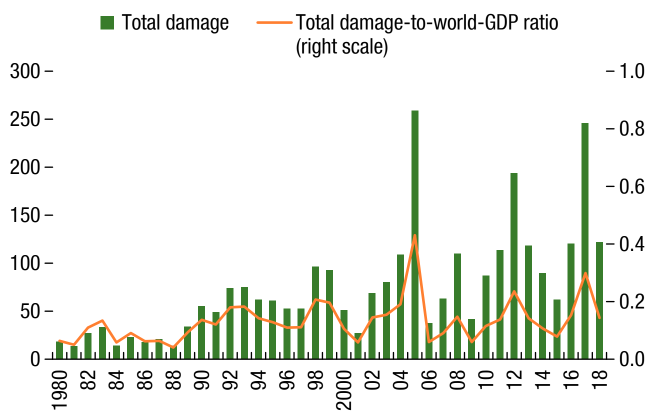
The damage from disasters has been stable over the past 30 years ...

3. Sample Economies: Median and Largest Annual Damage-to-GDP Ratio, 1980–2018 (Percent)



... as have total damages relative to the world GDP.

4. Sample Economies: Total Annual Damages and Total Annual Damages-to-World-GDP Ratio, 1980–2018 (Left scale = 2018 billion US dollars; right scale = percent)



Sources: Emergency Events Database (EM-DAT); IMF, World Economic Outlook database; and IMF staff calculations.
Note: In panels 2–4, ratios are calculated based on nominal GDP in the starting year of the disaster. In panel 4, conversion to 2018 US dollars is based on the US GDP deflator. AE = advanced economy; EMDE = emerging market and developing economy.

is on disasters, especially on large disasters.[8] The sample includes more than 6,000 disasters, about 60 percent of which have occurred in emerging market and developing economies. The annual number of disasters has increased considerably in the past few decades, from slightly more than 50 in the early 1980s to about 200 since 2000, though it has remained stable over the past 20 years (Figure 5.3, panel 1). Floods and storms have been the most frequent climatic disasters, constituting about 80 percent of the sample. While part of the rise in the frequency of disasters may be related to better reporting over time, a large part of it is also due to increased frequency of the occurrence of hazards and increased exposure of assets and people to hazards (IPCC 2012).

In general, emerging market and developing economies have been hit much harder by climatic disasters

[8]The chapter defines a disaster as "large" if the rate of affected population is greater than 0.5 percent or the damage is greater than 0.05 percent of GDP.

than advanced economies, suffering almost twice as much average damage relative to the size of their economies (0.13 percent of GDP compared with 0.07 percent of GDP). The difference is even starker when looking at the 10 largest disasters over 1970–2018: emerging market and developing economies incurred damages in the range of 2.9 percent of GDP to 10.1 percent of GDP versus 1.0 percent of GDP to 3.2 percent of GDP in advanced economies (Online Annex Table 5.1.4). Moreover, the number of people affected by climatic disasters in emerging market and developing economies also tends to be much higher than in advanced economies.

The distribution of the damage-to-GDP ratio is asymmetric and strongly positively skewed (Figure 5.3, panel 2). While the median disaster damage amounts to only a small fraction of GDP (0.01 percent), the largest disasters tend to be costly, with the 95th percentile of the distribution corresponding to damage of about 0.5 percent of GDP.[9] Despite an increase in hazard strength and exposure, the average damage from disasters (including from the largest disasters) in terms of GDP has not increased much over time (Figure 5.3, panel 3). This is consistent with a concomitant reduction in vulnerabilities.[10]

In absolute terms, the total annual average damage from climatic disasters (measured in constant 2018 US dollars) has been increasing in the sample of economies considered here—rising nearly sixfold and surpassing $120 billion in 2010–18 compared with $22 billion in 1980–89. As a share of world GDP, however, it has remained broadly constant at about 0.2 percent over the past 30 years (Figure 5.3, panel 4).

Large Climatic Disasters and Equity Returns

The reported damages reflect the loss of physical capital stock and do not capture the disasters' full impact on economic activity. Overall, large climatic disasters can significantly adversely impact GDP for several quarters, especially in low-income countries, as discussed in the recent literature (Felbermayr and Gröschl 2014).

The adverse impact of large climatic disasters on economic growth prompts the question: Do such events trigger a response in equity markets that could lead to financial stability concerns? The impact on equity prices can inform financial stability assessments for at least two reasons. First, large disasters could expose financial institutions to market risk if they lead to a large drop in equity prices because of widespread destruction of firms' assets and productive capacity or a drop in demand for their products. To this end, the analysis focuses on aggregate stock market indices to capture the systemic impact of disasters on equity prices.[11] Second, the reaction of the stock prices of financial institutions provides a summary measure of the extent to which these institutions are affected by disasters. For banks, for example, disasters are a source of credit risk, market risk, operational risk, and liquidity risk. For insurers, disasters are a source of underwriting risk, market risk, credit risk, and operational risk. (They may also be an opportunity to increase underwriting volumes and premiums, as the demand for insurance is likely to rise following a disaster.)

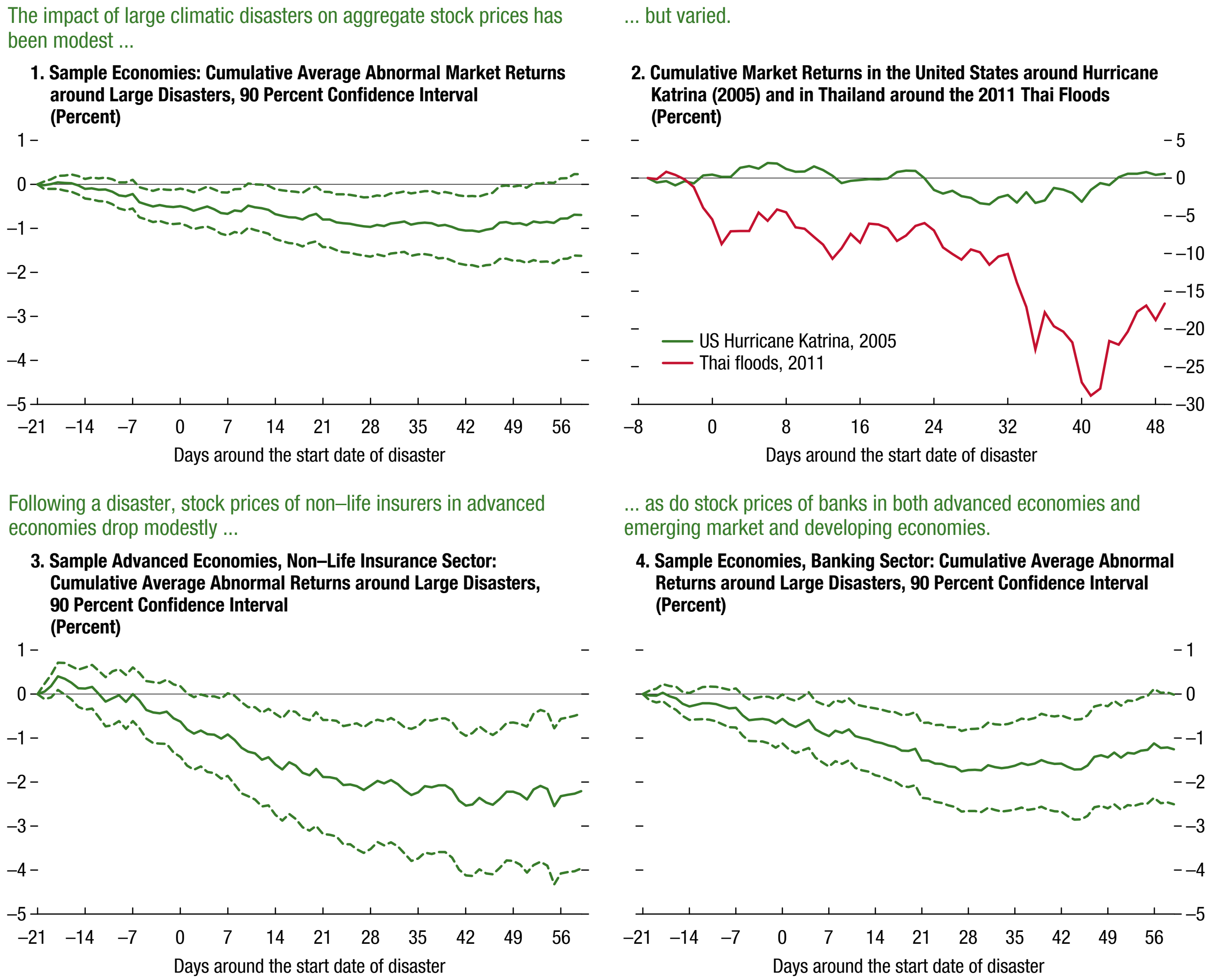
The analysis indicates that, on average, there has been only a modest response of stock prices to large climatic disasters. The cumulative average abnormal returns (defined as the actual returns minus the returns predicted by a pricing model with a global stock market factor, averaged over disasters) are about −1 percent from 21 trading days before the disaster (to incorporate possible anticipation effects) to 40 trading days after the disaster (Figure 5.4, panel 1). Results, however, vary considerably across disasters. For example, Hurricane Katrina, which resulted in the largest damage in the sample in absolute constant US dollar terms

[9]Some of the largest disasters in the sample have unfolded over a relatively long period of time. An example is the drought in Australia—the costliest disaster in an advanced economy—that started in 1981 and lasted two years. However, most other disasters have been acute and have unfolded over a period of a month or less. In the subsequent analysis, the costs of a disaster are attributed to the year of onset.

[10]Controlling for hazard size and exposure, the number of deaths from disasters decreases with GDP per capita and institutional quality (Kahn 2005). Some studies find that hurricane damages in the United States have not increased in line with exposure (Estrada, Botzen, and Tol 2015).

[11]Clearly the impact of disasters is highly firm-specific, as it depends on whether a firm's production facilities, suppliers' production facilities, or customers are significantly hit by the disaster (see Barrot and Sauvagnat 2016). Thus, a disaster may have significant consequences for firms listed in an economy where the disaster did not hit. It is also possible that some firms might benefit from the disaster, such as firms in the construction sector. Evidence that climatic events affect individual firms' equity returns has been provided in the literature (see, for example, Griffin, Lont, and Lubberink 2019).

Figure 5.4. Equity Market Returns Immediately before and after Large Climatic Disasters



Sources: Emergency Events Database (EM-DAT); Refinitiv Datastream; and IMF staff calculations.
Note: In panels 1, 3, and 4, all large disasters with a precise start date are included in the analysis. The *x*-axis represents trading days surrounding the events. Time 0 is the start day of the events. Cumulative average abnormal returns are relative to 21 trading days before the start day to incorporate any potential anticipation effects of disasters. Dashed lines represent the 90 percent confidence intervals. Abnormal returns are computed based on estimates from a one-factor model (global factor) using daily returns of one year before the disaster. Panel 2 plots the cumulative returns of the aggregate stock market for the United States during the days before and after Hurricane Katrina in 2005 and for the floods in Thailand in 2011.

(about 1 percent of US GDP, nearly 2,000 lives lost, and half a million people affected), triggered only a modest stock market reaction, with no discernible drop in the US stock market index (Figure 5.4, panel 2). By contrast, the 2011 floods in Thailand, which resulted in the largest damage in the sample relative to the size of the economy (amounting to 10.1 percent of GDP, 813 deaths, and 9.5 million affected people), resulted in a drop in the Thai stock market index of more than 8 percent soon after the onset of the disaster and a cumulative drop of about 30 percent after 40 trading days (Figure 5.4, panel 2).[12]

Among financial sector firms, large disasters have a statistically significant effect on the returns of non–life

[12]It is worth noting that the floods in Thailand caused repercussions not only for firms listed in Thailand, but also for foreign firms with supply chains depending on businesses located in the affected areas.

insurers in advanced economies: the cumulative average abnormal returns trend down for about 50 trading days after a large disaster and reach a trough of about –2 percent (Figure 5.4, panel 3). In emerging market and developing economies, however, there is no significant reaction of insurers' stock prices. What can explain these different outcomes? Such a difference could arise for several potential reasons, such as if a large share of insurance in emerging market and developing economies is provided by subsidiaries of insurers listed abroad; if insurers listed domestically do not or barely cover climatic disasters; or if insurers reinsure a large share of their exposures to climatic disasters. In fact, the stocks of global reinsurance companies react negatively to disasters happening in both advanced economies and emerging market and developing economies (Online Annex 5.2). For banks in both groups of economies, there is a small negative contemporaneous stock market reaction. Cumulative average abnormal returns of banks reach a trough of about −1.5 percent 25 trading days after the onset of a disaster (Figure 5.4, panel 4).[13,14]

The Role of Insurance Penetration and Sovereign Financial Strength in Cushioning the Equity Market Effects of Climatic Disasters

The United Nations Sendai Framework for Disaster Risk Reduction emphasizes several economy-wide characteristics that matter for resilience in the face of disasters (UNDRR 2015).[15] The academic literature also finds that economy-level institutional strength and financial development level can help mitigate the impact of disasters on GDP growth (Melecky and Raddatz 2011; Felbermayr and Gröschl 2014; Hsiang and Jina 2014).

This chapter focuses on the effect of two key economy-wide characteristics that can increase resilience: insurance penetration and sovereign financial strength. Risk-sharing mechanisms offered by financial markets, such as insurance, weather derivatives, and catastrophe bonds, reduce the losses incurred by nonfinancial sector firms (as well as some financial firms) in times of disasters and thus can be expected to limit the impact on equity prices (see Online Box 5.1 for a discussion of catastrophe bonds).[16] Yet economies vary widely in insurance penetration, measured by the ratio of non–life insurance premiums to GDP, with the ratio ranging from 0 to 5 (Figure 5.5, panel 1). The variation in protection gap (share of uninsured losses) with respect to climatic disasters is also large, as shown in Figure 5.5, panel 2. Even in advanced economies, only two-thirds of losses related to climate disasters are covered by insurance. A sovereign's financial strength is also likely to matter because it affects both the ability of the government to respond to disasters through financial relief and reconstruction efforts and its capacity to offer some forms of explicit insurance programs.

Consistent with such expectations, econometric analysis confirms that a higher rate of insurance penetration and greater sovereign financial strength (proxied by sovereign credit rating) dampen the impact of a large disaster on equity returns. Specifically, focusing on the impact of these two characteristics on cumulative abnormal returns 40 trading days after disaster onset for the aggregate stock market, as well as for the banking, non–life insurance, and industrial sectors, the results show a generally statistically significant association between greater insurance penetration and higher returns in the immediate aftermath of a disaster. Perhaps unsurprisingly, the effects are quantitatively larger and statistically stronger when looking at the left tail of the equity return distribution—that is, on disasters with the largest negative impact on returns.[17] A 1 percentage point increase in non–life insurance penetration improves banking and industrial sector returns by about 1.5 percentage points on average. In the left tail—that is, when returns are particularly low—the improvement is about 3–4 percentage points (Figure 5.6, panel 1). Similarly, sovereign

[13]Klomp (2014) finds that disasters have an adverse impact on bank soundness in emerging market economies.

[14]US banks reported only $1.3 billion in loan impairment charges due to Hurricane Katrina and Hurricane Rita (Bauerlein 2005), while insured losses amounted to more than $50 billion.

[15]The framework emphasizes (1) understanding disaster risk; (2) strengthening disaster risk governance to manage disaster risk; (3) investing in disaster risk reduction for resilience; and (4) enhancing disaster preparedness for effective response and to "build back better" in recovery, rehabilitation, and reconstruction. https://www.undrr.org/implementing-sendai-framework/what-sf.

[16]Financial risk-sharing solutions have evolved in reaction to the occurrence of large disasters. For example, catastrophe bonds were created and first used in the aftermath of Hurricane Andrew in the mid-1990s. Hurricane Andrew also revealed that Florida's vulnerability to hurricanes had been seriously underestimated, leading to large changes in the US property insurance market and US insurers' risk-management practices (McChristian 2012). Looking ahead, further financial developments along these lines could help contain the macro-financial impact of disasters.

[17]The analysis controls for the damage-to-GDP ratio.

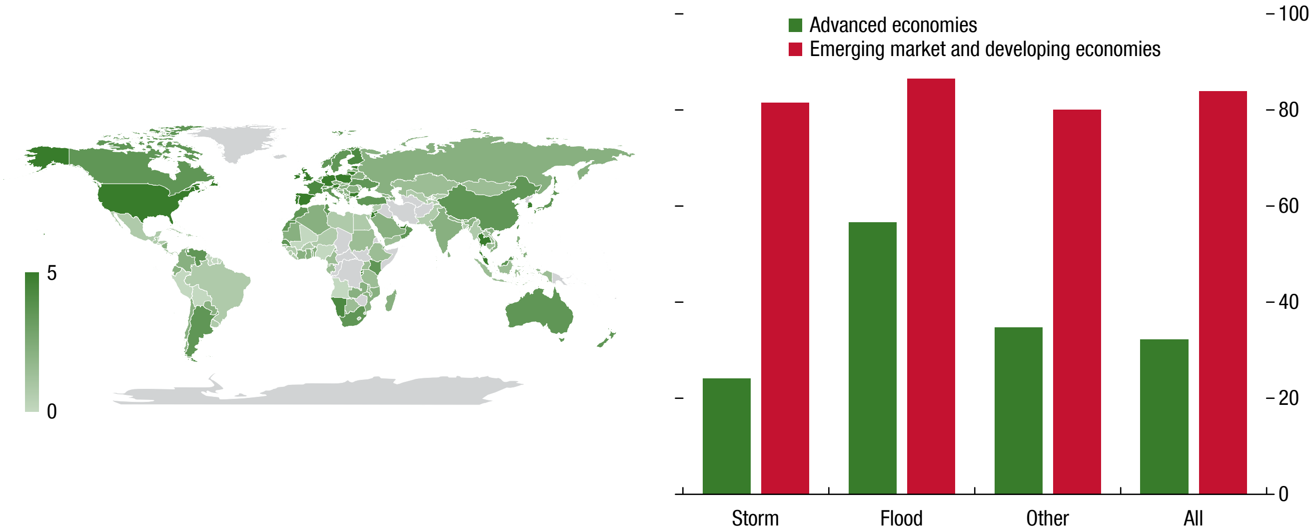
Figure 5.5. Insurance Penetration and the Protection Gap

Non–life insurance penetration varies considerably across economies ...

... and the protection gap for climatic disasters is large, particularly in emerging market and developing economies.

1. Insurance Penetration
(Non–life insurance premium, percent of GDP, 2017)

2. Protection Gap, 2009–18 Average
(Percent)



Sources: Emergency Events Database (EM-DAT); World Bank; and IMF staff calculations.
Note: Insurance penetration is defined as the ratio of the non–life insurance premium volume to GDP. Protection gap is defined as the share of uninsured losses from disasters.

financial strength has a positive and generally statistically significant impact on returns. A one-notch improvement in sovereign rating (on a scale of 1 to 21) boosts aggregate market returns by 0.2 percentage point, and banking and industrial sector returns by 0.3 percentage point on average. When returns are low, the improvement is about 0.6–1.0 percentage point for the aggregate market and these two sectors, and 1.6 percentage points for the non–life insurance sector (Figure 5.6, panel 2).[18] These effects are large relative to the size of cumulative average abnormal returns around disasters (between 1 percent and 2 percent, as discussed above).

As mentioned in the introduction, climate scientists have warned that some climatic hazards will become more frequent and severe in the future (IPCC 2014). Even though much progress has been made toward a better understanding of these hazards, substantial uncertainties remain, especially over long time horizons. The results presented in this section indicate that regardless of the size of future climatic shocks, insurance coverage and sovereign financial strength will be key factors in maintaining financial stability.[19]

Equity Pricing of Future Climate Change Physical Risk

With climate change predicted to increase physical risk, financial market participants appear to have started to place a greater focus on physical risk as a potential source of financial vulnerability (BlackRock 2019; IIF 2019; McKinsey 2020; Moody's Analytics 2019). Still, only a very small proportion of global stocks are held by sustainable funds (Figure 5.7), which are likely to pay greater attention to climate risk and tend to have a more long-term view.[20] A 2018 survey of institutional investors found that beliefs in

[18]The correlation between insurance penetration and sovereign financial strength is high. When the two characteristics are considered jointly in the analysis, the effect of sovereign financial strength appears more robust.

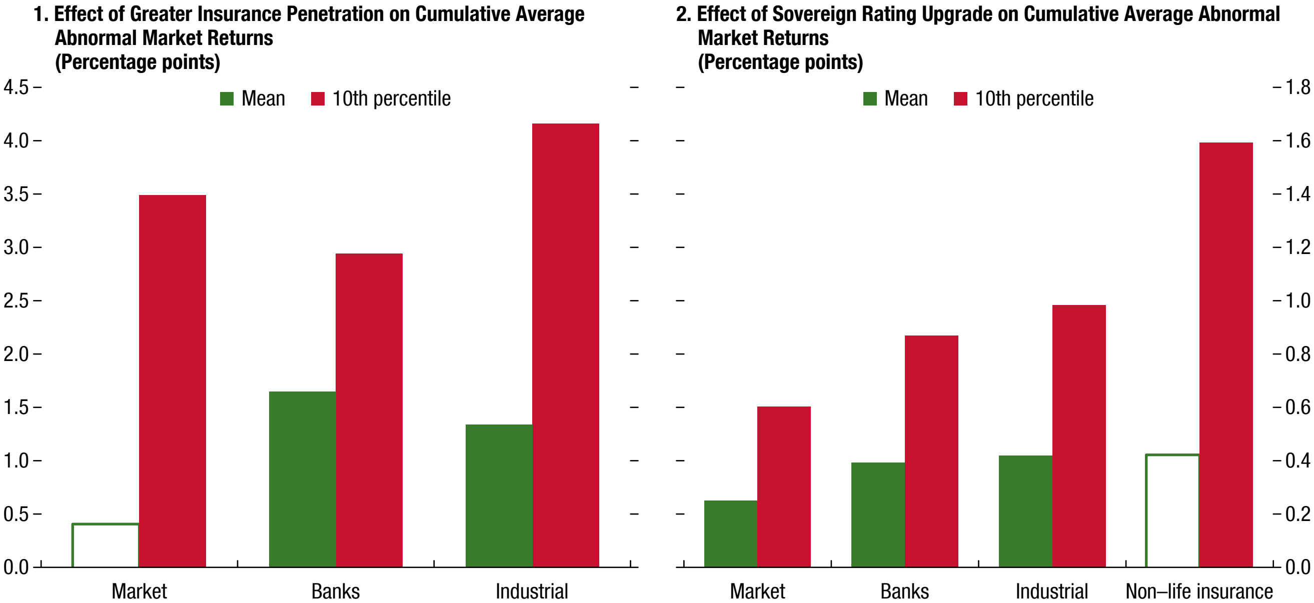
[19]The effectiveness of insurance as a mechanism to share risk in the financial system may be reduced if future climatic disasters become increasingly pervasive and correlated.

[20]There is no single definition of what constitutes a sustainable fund. This chapter relies on the Morningstar classification of sustainable funds.

Figure 5.6. The Effect of Insurance Penetration and Sovereign Financial Strength on Equity Market Performance Immediately before and after Large Disasters

Greater insurance penetration cushions the negative impact of large disasters on equities and banks, especially when the impact is large ...

... as does greater sovereign financial strength.



Sources: Emergency Events Database (EM-DAT); Refinitiv Datastream; World Bank; and IMF staff estimates.
Note: Panel 1 shows the impact of increasing the non–life insurance premium-to-GDP ratio by 1 percent on the cumulative average abnormal returns (CAAR) (mean and 10th percentile of the distribution) 40 trading days after large climatic disasters relative to 20 trading days before disasters. Panel 2 shows the impact of increasing the sovereign rating by one notch (on a scale of 1 to 21) on the cumulative abnormal returns (mean and 10th percentile) 40 trading days after large climatic disasters relative to 20 trading days before disasters. CAARs are computed at the sector level based on a single global factor model using daily returns in the year preceding each disaster. In both panels, solid bars indicate significance at the 10 percent level or less.

the lack of financial materiality of physical risk were more pronounced among short- and medium-term investors, while investors with a larger share of sustainable funds ranked climate risk higher in terms of its overall relevance for performance (Krueger, Sautner, and Starks 2019).

Equity investors face a daunting informational challenge in pricing the anticipated increase in physical risk into equity portfolios. Based on climate science, expected climate change mitigation policies, and adaptation actions, they need to form views on the likelihood of various climate scenarios and their implications for physical risk across the world.[21] For each firm, they then need to form a granular view on the future location of its production sites, supply chain and suppliers' location, and geographic distribution of customers under these climate risk scenarios. In addition, even if investors had the ability to correctly price the change in physical risk, the time horizon over which this change is likely to unfold may be longer than the investment horizon of most investors, including institutional investors.

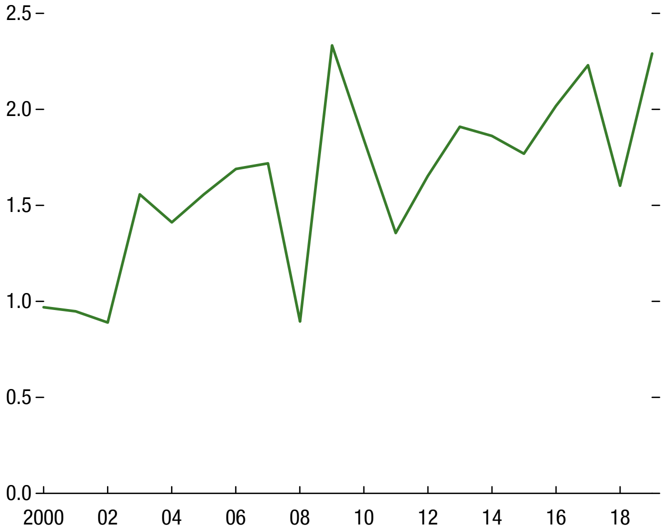
To test whether climate change is a risk factor priced into equities, the standard empirical asset pricing approach would require a time-varying measure of future physical risk. Given the difficulties in precisely measuring future physical risk—after all, even insurance companies rarely offer contracts over multiple years, and catastrophe bonds have a maximum maturity of only five years—and the scarcity of firm disclosures regarding their exposure to physical risk (both present and future), it is hardly surprising that empirical evidence on whether the valuation of equities (or other types of financial assets) today reflects future physical risk is scant.

[21]Barnett, Brock, and Hansen (2020) distinguish among three forms of uncertainty: (1) risk—what probabilities does a specific model assign to events in the future? (2) ambiguity—how much confidence is placed in each model? and (3) misspecification—how are models that are not perfect used?

Figure 5.7. Growth in the Sustainable Equity Fund Market

The share of assets under management by sustainable equity funds relative to the overall market capitalization has been increasing but remains small.

Ratio of Total Global Assets Held by Sustainable Equity Funds to Total Global Stock Market Capitalization
(Percent)



Sources: Morningstar; Refinitiv Datastream; and IMF staff calculations.
Note: The figure shows global assets under management by sustainable funds as classified by Morningstar.

An alternative, albeit more complicated, approach would be to develop a comprehensive asset pricing model that takes into account the projected impact of climate change on each economy and to compare the model-implied equity risk premium—defined as the financial compensation above the risk-free rate an equity investor should require to hold equity risk—with the market-implied equity risk premium.[22] A stylized version of such a model is presented in Online Box 5.2. It suggests that market-implied equity risk premiums as observed in 2019 are in line with those obtained in a scenario with no further warming (possibly implying that climate risk is not being factored in). Moreover, it shows that the premiums in a no-further-warming scenario are significantly smaller than those obtained under a high-warming scenario, suggesting that equity valuations should be lower if the high-warming scenario were to materialize.

In the absence of granular firm-level information and time-varying measures of future physical risk, the approach here is to use simple cross-country econometric analysis to determine whether aggregate equity valuations as of 2019—captured by the price-to-earnings ratio of the stock market index—are sensitive to current proxies for future changes in physical risk under various climate change scenarios.[23] All else equal, economies where these changes are predicted to be smaller would be expected to have higher valuations if future physical risk were financially material and markets were pricing it correctly.[24]

To conduct the analysis, economy-specific projections of hazard occurrence from the World Bank Climate Change Knowledge Portal are used. These projections, each corresponding to the changes between 1986–2005 and 2020–39, cover the number of extreme heat days, drought likelihood, heat wave likelihood, and the number of extreme precipitation days. Each projection is available for the four emission scenarios presented by the Intergovernmental Panel on Climate Change (labeled RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5, in which a higher number is associated with higher emissions over multiple time horizons). In addition, measures of projected sea level rise by 2100, and a Climate Change Hazard Index capturing several climate hazards, both current and future (under RCP 8.5), are used.[25]

Overall, there is no evidence to suggest that equity valuations in 2019 were negatively associated with these projected changes in hazard occurrence.[26] This can be seen in a simple scatter plot of the composite Climate Change Hazard Index and price-to-earnings ratios (Figure 5.8, panel 1) as well as the association between predicted changes in hazard occurrence and price-to-earnings ratios based on econometric analysis. The association is in fact

[22]Asset pricing models that incorporate climate-related disasters imply risk premiums that are positive and increasing over time due to climate change (Bansal, Kiku, and Ochoa 2019; Karydas and Xepapadeas 2019).

[23]Findings are similar when equity valuations are measured by price-to-book ratios or dividend yields.

[24]The econometric analysis always controls for three financial variables: mean annual growth rate of earnings per share, standard deviation of annual growth of earnings per share, and the three-month Treasury bill rate.

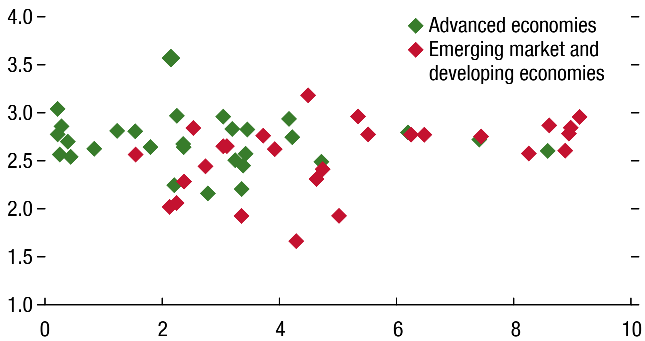
[25]The Climate Change Hazard Index assesses the degree to which economies are exposed to the physical impacts of climate extremes and future changes in climate over the subsequent three decades. The Climate Change Physical Risk Index captures not only hazard risk but also exposure and vulnerability.

[26]See Online Annex 5.3 for a description of the econometric methodology and additional robustness tests.

Figure 5.8. Climate Change Physical Risk and Equity Valuations

There is no association between measures of predicted changes in climatic hazard occurrence and equity valuations ...

1. Price-to-Earnings Ratio (in logs; *y*-axis) and Climate Change Hazard Index (*x*-axis)



... even when controlling for fundamentals.

2. Sign of Coefficients from Regressions of Price-to-Earnings Ratio on Indicators of Predicted Changes in Climatic Hazard Occurrence (Various climate change scenarios)

Sign consistent with the pricing of climate change physical risk, but the coefficient is not statistically significant

	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Δ Extreme heat exposure	+	+	+	+
Δ Extreme precipitation	+	+	+	+
Δ Drought likelihood	–	–	–	–
Δ Heat wave likelihood	+	+	+	+
Sea level rise index				+
Climate change hazard index				+

A greater projected increase in hazard risk combined with a greater sensitivity to climate change is not associated with lower valuations ...

3. Sign of Coefficients from Regressions of Price-to-Earnings Ratio on the Interaction Term between Predicted Changes in Climatic Hazard Occurrence and Climate Change Sensitivity Index (Various climate change scenarios)

Sign consistent with the pricing of climate change physical risk, but the coefficient is not statistically significant

	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Δ Extreme heat exposure × climate change sensitivity	–	–	–	+
Δ Extreme precipitation × climate change sensitivity	+	–	–	–
Δ Drought likelihood × climate change sensitivity	+	+	–	+
Δ Heat wave likelihood × climate change sensitivity	+	+	+	+
Sea level rise index × climate change sensitivity				–
Climate change hazard index × climate change sensitivity				+

... neither is a greater projected increase in hazard risk combined with a lower capacity to adapt to climate change.

4. Sign of Coefficients from Regressions of Price-to-Earnings Ratio on the Interaction Term between Predicted Changes in Climatic Hazard Occurrence and Climate Change Adaptive Capacity Index (Various climate change scenarios)

Sign consistent with the pricing of climate change physical risk, but the coefficient is not statistically significant

	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Δ Extreme heat exposure × adaptive capacity	+	–	–	–
Δ Extreme precipitation × adaptive capacity	–	–	+	–
Δ Drought likelihood × adaptive capacity	+	–	–	+
Δ Heat wave likelihood × adaptive capacity	–	–	–	–
Sea level rise index × adaptive capacity				+
Climate change hazard index × adaptive capacity				–

Sources: Refinitiv Datastream; Verisk Maplecroft; World Bank Group, Climate Change Knowledge Portal; and IMF staff calculations.
Note: In panel 1, the index ranges from 0 to 10. Panels 2–4 show the coefficients from cross-sectional regressions of the price-to-earnings ratio on climate change physical risk indicators. Each regression controls for expected future earnings, the equity risk premium, and interest rates. Representative Concentration Pathway (RCP) 2.6, RCP 4.5, RCP 6.0, and RCP 8.5 are International Panel on Climate Change (IPCC) emission scenarios, in which a higher number is associated with a higher level of emissions. Extreme heat exposure, extreme precipitation, drought likelihood, and heat wave likelihood are projections for the horizon 2020–39. The sea level rise index is based on projections for the year 2100 under RCP 8.5. The Climate Change Hazard Index is based on projections up to 2050 under RCP 8.5. None of the coefficients in panels 2–4 is significant and has a sign consistent with pricing of climate change physical risk.

positive—the opposite of what would be expected were hazards priced into equity valuations—across five of the six types of hazard measures, regardless of the climate change scenario considered (Figure 5.8, panel 2). The association is negative only for the change in drought likelihood but is not statistically significant.

However, looking simply at predicted changes in hazard occurrence may be misleading. As explained, physical risk is the result of an interaction among climatic hazard, exposure, and vulnerability. To proxy for the combination of exposure and vulnerability, the analysis relies on two readily available indicators: a Climate Change Sensitivity Index and a Climate Change

Adaptive Capacity Index.[27] A higher value of the Sensitivity Index would be expected to amplify the adverse effects of climatic hazards, resulting in greater physical risk, while a higher value of the Adaptive Capacity Index would be expected to dampen them, resulting in lower physical risk. If equity valuations were responsive to predicted changes in physical risk, one would expect to find a negative association between valuations and the interaction between hazards and the Sensitivity Index, and a positive association between valuations and the interaction between hazards and the Adaptive Capacity Index. No such associations are found when conducting a similar econometric exercise as above—reinforcing the earlier results that climate change physical risk is not being factored into equity valuations. For the Sensitivity Index, the association is generally positive and is not statistically significant when it is negative (Figure 5.8, panel 3). The opposite is true for the Adaptive Capacity Index, regardless of the climate change scenario envisaged (Figure 5.8, panel 4).

There is a further twist. The preceding analysis of the reaction of equity prices to large climatic disasters concludes that insurance penetration and sovereign financial strength cushion equity markets from the adverse effects of disasters. This suggests that the analysis of equity valuations as of 2019 should consider these two characteristics. Yet results are equally inconclusive when the exercise is augmented with an interaction between proxies of changes in physical risks and any of the two characteristics.

Overall, notwithstanding data and measurement limitations, the evidence in this section does not indicate that equity investors are pricing climate change physical risk.[28] By contrast, there is some evidence for the pricing of climate change physical risk in other asset classes. In the United States, counties projected to be adversely affected by rising sea level face higher costs when issuing long-term municipal bonds (Painter 2020). Similarly, Online Box 5.3 documents that sovereigns facing a greater projected change in physical risk—at least for some available proxies—pay higher spreads for long-term bonds relative to short-term bonds, all else equal.[29] One reason for this apparent difference in pricing of climate change risk between equity and bond investors might be that there is a closer geographic match between the climatic disasters and issuers' assets and sources of income in the case of sovereigns than in the case of listed firms, reducing the informational challenge that investors face.[30] Investors' investment horizon may play a role as well. Another reason could be that equity investors expect governments to bear a greater share of the costs of future climatic disasters than listed firms. In addition, it remains a possibility that long-term government bond investors discount less and pay more attention to long-term risks than equity investors.

Equity Investors' Attention to the Effect of Temperature on Pricing

Another, more indirect way to assess whether equity investors have been paying attention to climate change is to focus the analysis on temperature, a climate variable that is observable at high frequency and does not suffer from the same measurement challenges as climate change variables. This section builds on Kumar, Xin, and Zhang (2019), which documents a temperature-related pricing anomaly by showing that returns of a portfolio of US firms with a high sensitivity to temperature underperform relative to other stocks, after controlling for standard equity pricing factors. The discussion here extends that study's analysis to a sample of 27 economies over 1998–2017.[31] A firm's temperature sensitivity is defined as the absolute value of the "temperature beta," which captures how firms' stock return

[27]The Climate Change Sensitivity Index assesses the human population's susceptibility to the impacts of extreme climate-related events and projected climate change. The Climate Change Adaptive Capacity Index assesses the current ability of a country's institutions, economy, and society to adjust to, or take advantage of, existing or anticipated stresses resulting from climate change. See Online Annex 5.1 for details.

[28]It may be that climate change physical risk is heavily discounted by equity investors because of its long-term nature. Bolton and Kacperczyk (2019) provide evidence that equity investors demand a premium for transition risk, elements of which are arguably easier to model, and which could materialize at a shorter horizon than physical risk.

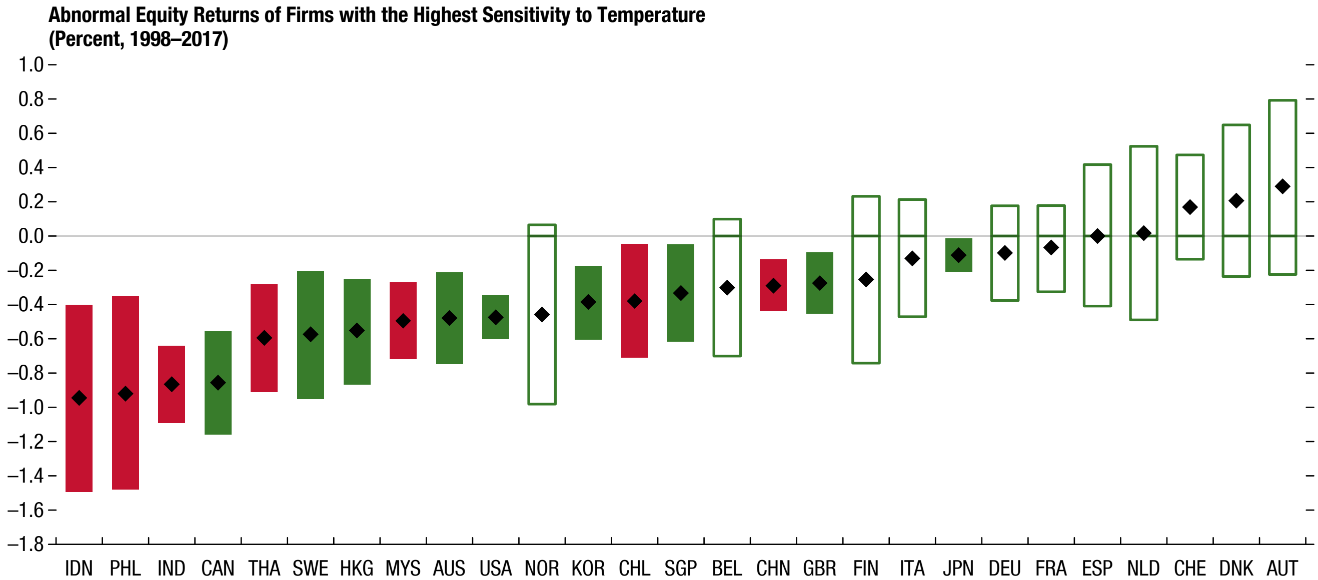
[29]There is no consensus in the literature as to whether real estate markets price climate change physical risk. Bernstein, Gustafson, and Lewis (2019) and Baldauf, Garlappi, and Yannelis (2020) find that coastal homes vulnerable to sea level rise are priced at a discount relative to similar homes at higher elevations, but Murfin and Spiegel (2020) find no such effect.

[30]Firms' location of listing, production facilities, customers, and supply chains can be in multiple economies.

[31]The multifactor equity pricing model is known as the Fama-French three-factor model. See Online Annex 5.4 for methodological details.

Figure 5.9. Equities' Temperature Sensitivity

In many countries, stocks with the highest sensitivity to temperature earn lower returns than the others, after controlling for standard risk factors, suggesting mispricing, and lack of attention to temperature-related variables.



Sources: Refinitiv Datastream; and IMF staff calculations.
Note: Black diamonds show the difference in stock return performance between firms with high temperature sensitivity (top quintile) and all other firms. Red (emerging market and developing economies) and green (advanced economies) bars show the 90 percent confidence intervals of the differences. Solid bars indicate significance at the 10 percent level or less. Data labels use International Organization for Standardization (ISO) country codes. See Online Annex 5.4 for a definition of temperature sensitivity.

comoves with temperature extremes.[32] A finding that these risk-adjusted returns are different from zero—in other words that a portfolio of firms with high temperature sensitivities would generate returns that cannot be explained by a standard asset pricing model—can be interpreted as a violation of the efficient market hypothesis.

The analysis not only confirms the findings in Kumar, Xin, and Zhang (2019) for the United States, but also documents a similar temperature-related pricing anomaly in more than half of the economies considered (Figure 5.9). In 10 of the economies, a portfolio composed of the top 20 percent of stocks most sensitive to temperature underperformed by at least 0.5 percent a month, on average, over the sample period, controlling for standard risk factors. The presence of such a pricing anomaly indicates that equity investors in most economies have not paid enough attention to climate variables and suggests that they may not be paying sufficient attention to climate change risk either.[33]

Conclusion and Policy Recommendations

Climate change is a source of physical and transition risks for the financial sector and could have significant implications for financial stability. Pricing the impact of future climatic hazards into asset prices is a challenging task because it requires an understanding of the future behavior of climatic and nonclimatic variables, which are both subject to a large degree of uncertainty. Focusing on climate change physical risk, the analysis and evidence provided in this chapter suggest that the aggregate equity valuations as of 2019 did not reflect this risk; thus, equity investors may be paying insufficient attention to climate variables.

[32]More specifically, the analysis measures the comovement with the so-called temperature anomaly, defined as the difference between the temperature in a given month and the average temperature over the preceding 30 years in the same month. By taking the absolute value, the pricing of firms with both high and low sensitivities is considered. The sensitivity is measured over rolling windows of 60 months.

[33]The chapter's finding echoes that of Hong, Li, and Xu (2019), which documents global stock markets' underpricing of drought risk in the food sector. Bansal, Kiku, and Ochoa (2019), however argues that there is a pricing factor related to temperature that is priced.

The chapter documents that the reaction of equity prices to large climatic disasters has been modest over the past 50 years. However, country characteristics matter. Insurance penetration and sovereign financial strength can lessen the impact of climatic disasters on equity prices, including of the financial sector. These findings imply that, regardless of the magnitude of future climatic hazards, financial stability will be better preserved in economies that score well along these dimensions[34]:

- Non–life insurance is a source of financial resilience because it increases economies' ability to recover from disasters. Yet the protection gap (the share of uninsured losses) remains significant, especially in emerging market and developing economies. For private insurance markets to thrive, a sound legal and regulatory system is essential. Policymakers may also consider mandating coverage for climatic disaster risks for some assets (such as those used as loan collateral), subsidizing climatic disaster insurance, or enabling insurer-of-last-resort solutions where economic agents have difficulty obtaining insurance. Awareness of the benefits of insurance could be encouraged by increasing financial and risk literacy. Other protection gap challenges related to lack of information and expertise in modeling underinsured areas or types of risk can be addressed through the establishment of risk-sharing arrangements between the public and private sectors, such as Protection Gap Entities.[35]
- A sovereign's financial strength allows it to respond forcefully to disasters and reduce the economic and financial impact of the shock. Building fiscal buffers, establishing contingent lines of credit, and developing a sound public financial management system are important in this regard. State contingent debt instruments can also be useful to allow for greater policy flexibility in bad times (IMF 2017).

To help the public, including market participants, better understand future physical risk, policymakers should consider strengthening climate change literacy by enhancing the visibility of relevant findings in climate science, climate economics, and climate finance.

Granular, firm-specific information on current and future exposure and vulnerability to climate change physical risk would help lenders, insurers, and investors better grasp these risks. An increasing number of firms have begun to voluntarily disclose climate change risk information, in line with the recommendations set out by the Taskforce on Climate-related Financial Disclosures (TCFD). However, going further by developing global mandatory disclosures on material climate change risks would be an important step to sustain financial stability. In the short term, mandatory climate change risk disclosure could be based on globally agreed principles. In the longer term, climate change risk disclosure standards could be incorporated into financial statements compliant with International Financial Reporting Standards.

It would be useful for these standards and disclosures to be anchored in proper measurement of financial exposure to climate risk and to be based on adequate taxonomies. For financial firms, climate change stress testing, and scenario analysis more broadly, can play a potentially important role in providing a better sense of the size of the exposures at a highly granular level.

Although not explicitly analyzed in the chapter, adaptation and risk reduction measures that decrease (or at least limit) the exposures and vulnerabilities of economies to climate hazards are highly desirable. These include the enhancement of early warning systems and the management of population density in areas at risk, as well as the implementation of regulation (such as land-use regulation) and investment in infrastructure that helps boost physical resilience, such as through "build back better" programs.[36]

Of course, strong policy actions to mitigate climate change would reduce greenhouse gas emissions and future physical risk in the first place, conferring benefits to mankind that extend well beyond the realm of financial stability. Yet, from a financial stability perspective, this transition to a lower-carbon economy needs to be carefully managed to avoid abrupt and unanticipated repricing of portfolios and economic dislocation.[37] These issues will be explored further in future issues of the *Global Financial Stability Report*.

[34]These findings are consistent with those of IMF (2019), which discusses physical and financial resilience in developing economies vulnerable to large natural disasters.

[35]See the discussion in Jarzabkowski and others (2019).

[36]A recent report finds that a global $1.8 trillion investment in adaptation measures over the next decade could generate $7.1 trillion in total net benefits (Global Commission on Adaptation 2019).

[37]The benefits of gradual but ambitious, clear, and predictable mitigation policies for the transition path are discussed in the October 2019 *Fiscal Monitor*. Krogstrup and Oman (2019) provides an overview of available policy tools.

Box 5.1. Stress Testing for Physical Risk in the Financial Sector Assessment Program

The IMF pioneered the use of stress tests for assessing financial stability in the Financial Sector Assessment Program (FSAP) 20 years ago. Every year, under the FSAP, the IMF carries out in-depth financial stability assessments for 12–14 economies. Stress testing using confidential supervisory data is a cornerstone of the FSAP's risk analysis. The tests capture physical risks related to climatic disasters, such as storms, floods, and droughts, whenever relevant. Over the past decade, one in five FSAPs contained an examination of such risks. Most related to small island states and other economies prone to climatic disasters with economy-wide impacts, but FSAPs for advanced economies with systemically important financial sectors (such as France, Sweden, and the United States) also covered physical risks in insurance stress testing.

The 2019 FSAP for The Bahamas provides an example of a stress test that incorporates a climatic disaster. The country was hit by 11 hurricanes with average costs of 4.3 percent of GDP in the 20 years before the FSAP. The analysis examined the effects of hurricanes on tourism, employment, and financial sector assets, showing how more frequent and more severe hurricanes amplify risks to economic growth. Domestic banks typically required catastrophic risk insurance, and domestic insurance companies reinsured abroad—so growth and employment were the main channels of hurricanes' impact on the financial system. Banks' direct credit exposures to tourism were small, mitigating the risk of large business loan losses, though hotel and infrastructure damage could lead to unemployment and bank losses on mortgages and consumer loans. A key finding was that the financial stability effects of hurricanes were nonlinear and dependent on the broader macroeconomic context: a US recession combined with a hurricane would significantly amplify macro-financial losses. Three months after the FSAP concluded, The Bahamas was hit by Hurricane Dorian, the worst climatic disaster in the country's history. The financial sector appears to have weathered the hurricane well, thanks to limited exposures to uninsured assets and adequate reinsurance of domestic insurance companies abroad. At the same time, insurance penetration, especially in the residential segment, remains low, leaving many homeowners in dire straits. The IMF therefore suggested new approaches to extend insurance coverage as part of a broader disaster risk management strategy.

Stress tests for climate-related risks are evolving. The FSAP has already been moving from narrow exercises concentrating on non–life insurance to stress tests that incorporate broader macro-financial feedback effects. While the focus so far has been on "acute" manifestations of physical risk, future assessments may also consider stability implications of slow-moving consequences of climate change, such as migrations due to water shortages and crop failures. Forthcoming FSAPs that are expected to consider physical risk are, for example, those for the Philippines and South Africa.

Ongoing assessments, such as the FSAP for Norway, have started, on a pilot basis, examining consequences of changes in public policy and technology related to the transition to a low-carbon economy. These transition risks are potentially relevant for all economies, with many country authorities recognizing that the transition may not be smooth, and that changes in policies and technology may lead to abrupt changes in asset valuations. Leverage and interconnectedness in the financial system could exacerbate these shocks.

The IMF staff has engaged with the World Bank, central banks, and other stakeholders on these issues. In emerging market and developing economies, the IMF carries out FSAP assessments jointly with the World Bank. The joint work provides an opportunity to leverage the World Bank's expertise in financial sector development, catastrophe risk modeling, and sustainable finance.

This box was prepared by Martin Čihák.

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