FSB FINANCIAL STABILITY BOARD

The Implications of Climate Change for Financial Stability

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Executive summary

This report discusses the potential implications of climate change for financial stability. It investigates channels through which climate-related risks might impact the financial system. It also examines potential mechanisms within the financial system that might amplify the effects of climate-related risk as well as the cross-border transmission of risks. The report draws on existing work by the official and private sector. Such work is, in places, nascent in its consideration of risks to financial stability. In places, therefore, the report raises issues that go beyond those discussed in the existing literature.

Risks to financial stability from climate change can be divided into physical and transition risks. The value of financial assets/liabilities could be affected either by the actual or expected economic effects of a continuation in climate change (physical risks), or by an adjustment towards a low-carbon economy (transition risks).

Current central estimates of the impact of physical risks on asset prices appear relatively contained but may be subject to considerable tail risk. The manifestation of physical risks – particularly that prompted by a self-reinforcing acceleration in climate change and its economic effects – could lead to a sharp fall in asset prices and increase in uncertainty. This could have a destabilising effect on the financial system, including in the relatively short term. Market and credit risks could also be concentrated in certain sectors of the real economy and geographies. Disruption could also occur at national level. Some emerging market and developing economies (EMDEs) that are more vulnerable to climate-related risks, especially those in which mechanisms for sharing financial risk are less developed, may be particularly affected.

A disorderly transition to a low carbon economy could also have a destabilising effect on the financial system. This could be brought about by an abrupt change in (actual or expected) public policy not anticipated by market participants, including that due to the increased materialisation of physical risks, as well as technological developments. In such a scenario, physical and transition risks might combine, amplifying their overall effect on financial stability. Central estimates of the impact on asset prices of a well-anticipated transition to a low carbon economy are relatively contained, although there are many measurement uncertainties.

Climate-related risks may also affect how the global financial system responds to shocks. They may give rise to abrupt increases in risk premia across a wide range of assets. This could alter asset price (co-)movement across sectors and jurisdictions; amplify credit, liquidity and counterparty risks; and challenge financial risk management in ways that are hard to predict. Such changes may weaken the effectiveness of some current approaches to risk diversification and management. This may in turn affect financial system resilience and lead to a self-reinforcing reduction in bank lending and insurance provision.

The breadth and magnitude of climate-related risks might make these effects more pernicious than in the case of other economic risks. Moreover, the interaction of climate-related risks with other macroeconomic vulnerabilities could increase risks to financial stability. For instance, certain EMDEs that are particularly vulnerable to climate change are also dependent on cross-border bank lending.

There are various actions that financial institutions can take – and are taking – to reduce or manage their exposure to climate-related risks. However, some authorities find that these are not applied systematically by most firms. The efficacy of such actions taken by financial firms may also be hampered by a lack of data with which to assess clients' exposures to climate-related risks, or the magnitude of the effects described above. Actions taken by individual financial institutions may also not by themselves mitigate broader climate-related risks to financial stability. Robust risk management might be supported by initiatives to enhance information with which to assess climate-related risk.

1. Introduction

This report discusses the potential implications of climate change for financial stability. It investigates channels through which climate-related risks might impact the financial system. It also examines potential mechanisms within the financial system that might amplify the effects of climate-related risk as well as the cross-border transmission of risks. It also builds on existing work by the FSB and other international bodies.

In doing so, it identifies how risks to financial stability from climate change may differ from risks from other vulnerabilities or forms of structural change. The effects of climate change may be far-reaching in their breadth and magnitude, and could affect a wide variety of firms, sectors and geographies in a highly correlated manner. The impact of such risks may be irreversible.[1] Different types of climate-related risks (e.g. physical and transition) may also crystallise simultaneously, which might amplify their effect on the financial system. Risks to the financial system from climate change tend to be particularly uncertain in both their severity and the time horizon over which they might crystallise. They may also be more dependent on measures taken by policymakers.

It is difficult to quantify risks to financial stability from climate change precisely. The future path of climate change and its impact on the financial system are highly uncertain and could be non-linear over time. There is also a shortage of data through which to measure financial institutions' exposures to climate-related risks.[2] It is unclear whether the financial system's responses to past climate-related shocks have amplified their economic impact. This may partly be because there has not yet been a climate-related shock of a magnitude sufficient to trigger amplification mechanisms. This makes it difficult to assess the significance of such amplification mechanisms.

Nonetheless, the analysis that follows attempts to give a sense of scale of risks to financial stability, and the potential for the financial system to amplify them. Where possible, it does so by drawing on existing work by the official and private sector. Such work is, however, rather limited in its consideration of implications for global financial stability, both because it often pertains only to a subset of jurisdictions and financial institutions, and it gives only limited consideration of tail risks. In places, therefore, the report's discussion of financial stability risks raises issues that go beyond those supported by existing literature.

The report also draws on the FSB's stocktake of financial authorities' experience in including climate-related risks as part of their financial stability monitoring.[3] It also draws on analysis by both the official and private sectors. This includes that of the Task Force on Climate-related Financial Disclosures (TCFD), a private sector-led Task Force established by the FSB to develop recommendations for voluntary and consistent climate-related financial risk disclosures by companies.

The report does not discuss the possible implications of climate change for the broader macro economy or the functions and responsibilities of financial authorities beyond those relating to

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1 See Breeden, S, *Avoiding the Storm: climate change and the financial system*,

2 See FSB (2020), *Stocktake of financial authorities' experience in including physical and transition climate risk as part of their financial stability monitoring*.

3 *Ibid*.

financial stability. This includes those functions relating to monetary policy, securities regulation and portfolio management.

The report proceeds as follows. The next section sets out the ways in which physical and transition risks from climate change can affect financial stability, as well as the potential for these to interact. Section 3 examines how climate-related risks might be transmitted across, and amplified by, the financial system including via its interaction with the real economy. Section 4 examines the degree to which climate-related risks might be transmitted across borders, including through the exposures of financial institutions. Section 5 examines actions by market participants and regulators that might go some way towards mitigating climate-related risks to financial stability. Section 6 sets out some proposed next steps for the FSB's work in this area.

2. Climate-related risks to financial stability

At a high level, risks to financial stability from climate change are typically divided into:[4]

- **Physical risks**, that is, the possibility that the economic costs of the increasing severity and frequency of climate-change related extreme weather events, as well as more gradual changes in climate, might erode the value of financial assets, and/or increase liabilities.

- **Transition risks** that relate to the process of adjustment towards a low-carbon economy. Whilst such an adjustment may be a necessary part of the global economy's response to climate change, shifts in policies designed to mitigate and adapt to climate change could affect the value of financial assets and liabilities.

The magnitude of these risks and the relationship between them is likely to depend not only on the course of climate change, but also the course of action to mitigate it, including whether any transition to a low-carbon economy occurs in an orderly or disorderly way.[5] For example, a sudden and unanticipated policy response to climate change could reduce physical risks, but generate a disorderly adjustment to a low-carbon economy that could prompt the materialisation of some transition risks in the short-term. Conversely, avoiding or deferring such an adjustment might prevent such a materialisation in the near term, but the continued increase in emissions could lead to the increased crystallisation of physical risks (referred to by some as a 'hot house world' scenario).[6]

Physical and transition risks might also interact and crystallise in tandem. An increased materialisation of physical risks could prompt more significant policy action to stem them. This could then give rise to a disorderly transition to a lower-carbon economy, and the crystallisation of transition risks (referred to by some as a 'too-little-too-late scenario').[7]

4 *Ibid*.

5 See, for example, NGFS (2019), *A call for action – climate change as a source of financial risks,* p21.

6 *Ibid*.

7 See, for example, NGFS (2019).

The remainder of this section examines physical and transition risks to the financial system in turn. It briefly examines how these can result in liability risks, when parties are held liable for losses related to environmental damage.

2.1. Physical risks

Economic losses from natural catastrophes have increased in recent decades. The number of some types of extreme weather events globally has steadily increased (Graph 1, LH panel). The weight of scientific evidence suggests that such events have become more likely or more severe due to the anthropogenic effects of climate change, and that further anthropogenic warming will cause them to intensify.[8] Economic losses associated with such events have also increased (Graph 1, RH panel).[9]

These include losses stemming from changes in physical capital, as natural disasters destroy infrastructure and divert resources toward reconstruction and replacement.[10] Economic losses associated with severe weather can also impact natural capital, as, for example, rising sea levels and other changes in climate can affect the availability of land and reduce agricultural productivity.[11] The crystallisation of physical risks can also negatively affect human capital, through deterioration in health and living conditions.[12] Global and regional changes in climate can also have indirect effects, such as disruption to supply chains and reductions in the productivity of both human labour and physical assets. They can also reduce investment, given the prevailing uncertainty about future demand and growth prospects.[13]

Absent action to reduce the effects of climate change, physical risks to the global economy are likely to continue to increase in future. Analysis suggests that the frequency and severity of extreme weather events might increase non-linearly and become increasingly correlated with each other over time.[14] While this might impact a range of countries, including those that are advanced economies, it might also lead to disproportionate losses in emerging market and developing economies (see Box 1).[15]

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8 See IPCC (2014), *AR5 Synthesis Report* and IPCC (2018), *Special report: global warming*. The extent of physical risks is also likely to be dependent future official-sector policy, as well as the development of technology that may curb the effects of climate change.

9 See International Association of Insurance Supervisors (IAIS) and Sustainable Insurance Forum (SIF) (2018), *Issues Paper on Climate Change Risks to the Insurance Sector*, July and ESRB (2020), *Positively Green: Measuring climate change risks to financial stability*.

10 See IPCC (2018).

11 *Ibid*.

12 For example, a two-metre sea level rise triggered by the potential melting of ice sheets could displace close to 200 million people by 2100. See J. Bamber, M. Oppenheimer, R. Kopp, W. Aspinall, and R. Cooke (2019), *Ice Sheet Contributions to Future Sea-Level Rise from Structured Expert Judgment* Proceedings of the National Academy of Sciences of the United States of America 166 (23): 11195–200.

13 See IPCC (2018).

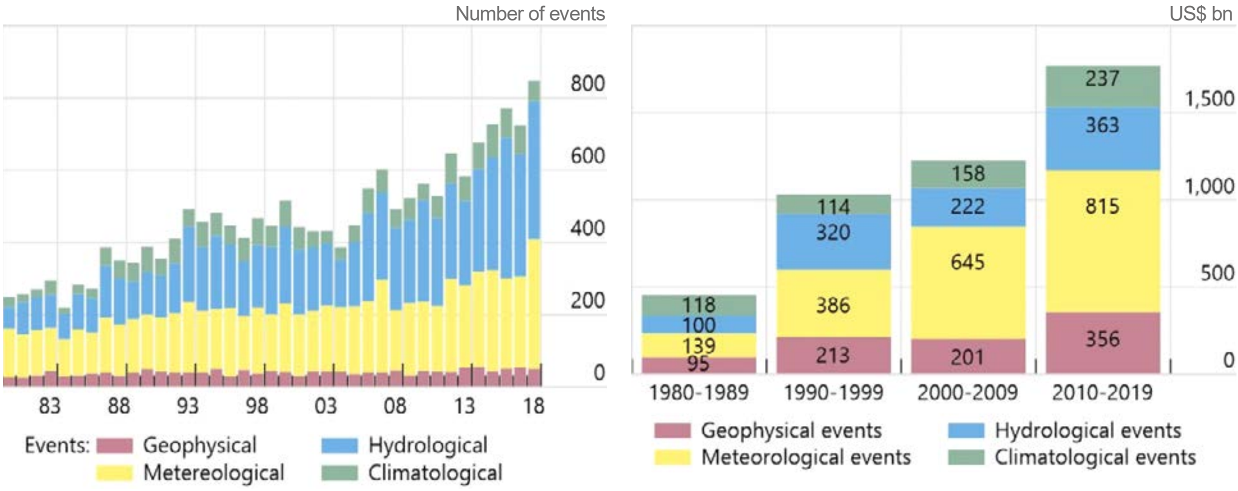
14 Some studies suggest that potential impacts could reduce global GDP by 2-3% annually by 2060; see OECD (2015), "The Economic Consequences of Climate Change", while IAIS and SIF (2018) note that future climate impacts may be non-linear and increasingly correlated – with multi-annual recurrence of "1-in-100" year events. Estimates of such impact remain dispersed; *see* Network for Greening the Financial System (2019), "*Macroeconomic and Financial Stability Implications of Climate Change: NGFS Technical Supplement*".

15 See G. Abel, M. Brottrager, J. Cuaresma, and R, Muttarak (2019), *Climate, Conflict and Forced Migration* Global Environmental Change 54 (January), pp 239–249; and World Bank (2018), "*Groundswell - Preparing for Internal Climate Migration*".

The impact of physical risks on the global economy has increased in recent decades **Graph 1**

Number of natural loss events

Estimated global economic loss from natural catastrophe events[1]



[1] Not all natural catastrophes enumerated in the chart result from climate change.

Sources: Bank for International Settlements, Banque de France and MunichRe.

Market and credit risks

Increased physical risks could result in both market and credit risks to the financial system. Market risks – that is, the risk of reductions in the value of financial assets – could result in losses for banks, asset owners, and other financial institutions. Market risks might also emerge due to abrupt increases in risk premia due to uncertainty concerning financial assets' future payoffs. Physical risks can also give rise to credit losses due to reductions in the income – or reductions in the profitability – of borrowers.[16] Credit risk might also result from reductions in the value of assets used as collateral. Together, these effects could have a broad range of impacts on the financial system, reducing the value of investments, and increasing risks to lenders and other financial market participants.

Estimates of the impact of physical risks on financial assets vary considerably. All are based on a number of assumptions and subject to numerous sources of uncertainty. First, estimates depend on the assumed future path of global emissions.[17] A given increase in global emissions results in a range of potential increases in global temperatures and associated increases in the severity and magnitude of extreme weather events.[18] Second, the impact of such physical risks on the global macroeconomy and financial assets is also highly uncertain and subject to numerous modelling assumptions.[19] Third, the resulting estimated reductions in the value of financial assets depend on the rate at which assets' future cash flows are

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[16] See S. Vladimir, J. Amado, and R. Connell (2011), *Climate Risk and Financial Institutions: Challenges and Opportunities*, World Bank Group.

[17] See S. Hsiang and R. Kopp (2018), *An economist's guide to climate change science*.

[18] The extent of climate change is also likely to depend on official-sector policy, as well as the development of technology that may curb its effects.

[19] See Hsiang and Kopp (2018).

discounted. Estimated impacts are much larger if they are discounted at a lower rate, which might reflect the view of a government that has a longer time horizon than some individual investors.[20]

Table 1: Estimated impact on the value of global financial assets by the year 2105 (percent)[1]

Study	Expected increase in global temperature[2]	Initial discount rate[3] (per cent)	Mean	Percentile 90th	95th	97th	99th
Dietz et al (2016)	2ºC	7.0	-0.7		-1.6		-4.0
		4.1	-1.2		-2.9		-9.2
	2.5ºC	7.0	-1.0		-2.4		-7.7
		4.1	-1.8		-4.8		-16.9
EIU (2015)	2ºC	5.5	-1.5	-1.9		-2.3	
		3.8	-4.2			-7.5	
	2010 Baseline scenario (~4ºC)	5.5	-2.9	-5.0		-9.7	
		3.8	-9.7	-12.9		-30.1	

Note: Blank cells indicate where no estimates are available based on these existing studies.

Source: Economist Intelligence Unit (EIU) (2015), 'The cost of inaction' and Dietz, S., Bowen, A., Dixon, C. and Gradwell P (2016), 'Climate Value at Risk of global financial assets'.

1 This analysis is based on an integrated assessment model (IAM) that links economic growth, greenhouse gas emissions and its effect on the real economy. Estimates of the impact on asset prices are based on the assumption that, in aggregate and over the long-term, the payoffs of a diversified portfolio of financial assets should grow at the same rate as the real economy. For further details, see EIU (2015), and Dietz et al (2016).

2 Estimated reductions in asset values in each row of the table are based on an assumed pathway for future emissions that is consistent with the expected increase in global temperatures since the pre-industrial era. 2.5/4ºC are expected increases in global mean temperatures occurring under two different pathways for global emissions. A 2ºC increase in temperatures relates to a pathway for emissions under which it is *likely* that increases in global temperatures will remain less than 2ºC, which is defined by the IPCC as a 66% probability of this being the case (see IPCC. (2014), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change).

3 Discount rates are assumed to correspond to future modelled GDP growth (see note 1) in the absence of climate change plus a premium to account for the compensation they demand for holding risky assets. Discount rates shown are those applied to near-term asset pay-offs. A higher discount rate corresponds to a lower present value of the future losses. Under both modelling approaches discount rates decrease towards the end of the century in line with slowing GDP growth.

Central estimates of the impact of physical risks on asset prices appear reasonably contained, but vary considerably with the expected degree of global warming. Results of two studies are shown in Table 1. Under a scenario where the increase in global mean temperature above pre-industrial levels is likely to remain within 2ºC, estimates of the mean reduction in global financial asset values are between 0.7 and 4.2% (US$ 1–6tr), depending on the study and discount rate.[21] Under a 'baseline' scenario in which policies to mitigate climate change that were in place in 2010 are extended indefinitely but there is no *additional* action to reduce emissions,[22] the expected temperature increase is around 4ºC and the estimated mean

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20 Such lower discount rates might be appropriate for long-run issues such as climate change, because they treat the wellbeing of future generations on a par with that of current generations; see Economist Intelligence Unit (2015), *The cost of inaction*. A lower discount rate is used elsewhere in the literature to reflect the possible longer time horizon of governments; see, for example, Stern, N (2013), *The structure of economic modelling of the potential impacts of climate change: grafting gross under estimation of risk onto already narrow science models*, Journal of Economic Literature, Vol 51, No. 3; and Nordhaus (2017), *Integrated assessment models of climate change*, NBER.

21 The estimates of percentage loss in asset value are independent of the initial stock value. Absolute values are estimated by applying the estimated percentage reductions to a global total $143 trillion in assets managed by non-bank financial institutions at end-2015 as estimated by Financial Stability Board (2015), *Global Monitoring Report*.

22 This corresponds to a 6.5% reduction in emissions in 2105, relative to a world of no further action whatsoever.

reduction in asset prices is between 2.9% and 9.7% (US$4-14tr), depending on the chosen discount rate. Other studies based on different methodologies estimate central case outcomes for a reduction in financial asset values that are of a similar order of magnitude.[23]

The uncertainties associated with the future path of climate change and its impact on asset prices mean that these potential outcomes are subject to considerable tail risk. This is shown in the right-hand columns of Table 1. For example, while the central estimate of the reduction in asset prices associated with a 2.5ºC increase in temperatures by 2105 is relatively modest (i.e. 1.0-1.8%), it is estimated with 5% probability that it could exceed 4.8%, and with 1% probability that they could exceed 16.9% (US$ 24tr). Under the baseline scenario, the most severe reported reduction in asset prices are 30.1% (US$ 43tr), which occurs with a 3% probability by 2105 under an assumed low discount rate.

An acceleration in the progression of climate change, and in the manifestation of physical risks, could have a destabilising effect on the financial system. The studies discussed above assume that increased physical risks will materialise gradually over time, with the majority of the impact on asset prices occurring in the latter half of the 21st century. Such a reduction in asset prices may, however, occur suddenly and be more likely to have a destabilising effect on the financial system. This could arise in part from how the dynamics of climate change may be self-reinforcing.[24] Increases in global temperatures may have positive feedback effects, whereby a small perturbation in temperatures alters the dynamics of climate in a way that causes further increases in temperature.[25] This raises the possibility of rapid non-linear short-term changes in physical, ecological and societal systems due to climate risks, whose impacts would be felt far sooner, and may be greater, than those captured by some central estimates. This has led some to call for more emphasis to be placed on research about the extreme tails of distributions rather than central tendencies.[26]

Market and credit risks resulting from physical risks could also be concentrated in certain sectors and geographies of the real economy. Many of the most directly affected firms might be those in sectors with less movable and capital-intensive infrastructure.[27] Some evidence already suggests, for example, that the price of real estate exposed to rising sea levels is less than that of similar properties in other locations.[28] To the extent that the prices of the assets and liabilities of firms in these sectors are adjusting to reflect physical risks, and/or investors/creditors are taking action to reflect them, this might reduce risks to financial stability. That said, it also

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23 For example, UNEP Finance Initiative (2019), _Changing Course_ estimates a 2.14% reduction in the value of financial assets, but acknowledge that this would increase significantly if global emissions are not curbed.

24 See T. Lenton, J. Rockström, O. Gaffney, S. Rahmstorf, K. Richardson, W. Steffen, and H.J. Schellnhuber (2019), _Climate Tipping Points — Too Risky to Bet Against_, Nature.

25 For example, the shrinkage of icepacks caused by global warming might reduce the reflection of solar radiation, thereby further increasing global warming. Similarly, the thawing of permafrost at high latitudes due to global warming might itself release greenhouse gases that in turn lead to further global warming. IPCC (2019), *The Ocean and Cryosphere in a Changing Climate – Summary for Policymakers*.

26 Martin L. Weitzman (2011), _Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change_, Review of Environmental Economics and Policy 5 (2): 275–292.

27 For example, UNEPFI (2019) finds that the impact of physical risk on the value of equities of firms in the construction sector could be twice that of firms in the utilities sector.

28 There is some evidence that homes exposed to sea level rise already sell at a discount relative to observationally equivalent unexposed properties equidistant from the beach. See A. _Bernstein, M. Gustafson, and Lewis (2019), Disaster on the Horizon: The Price Effect of Sea Level Rise, Journal of Financial Economics 134 (2): 253–272_.

serves to illustrate that risks might be concentrated in certain parts of the financial system. This could increase risks to financial stability, particularly if it triggers amplifying behaviours by some financial institutions (see Section 3).

Significant losses from physical risks could also result in disruption at national level, and be concentrated in certain countries. The impact of climate change is likely to be felt globally. Nonetheless, some EMDEs may be particularly vulnerable to physical risks, given their higher exposure and sensitivity to the effects of climate change (see Box 1). For example, in 2011, floods in Thailand resulted in a substantial (10%) reduction in GDP, and the value of major Thai equity indices fell by about 30% in the following 40 trading days.[29] Greater vulnerability to physical risks might also lead to a deterioration in sovereign creditworthiness, given the effects of natural disasters on tax revenues and fiscal expenditure (particularly in economies where risk transfer mechanisms are weaker; see Box 1).[30] To the extent that the creditworthiness of sovereigns, in some jurisdictions, affects and is affected by, that of financial institutions, this might also amplify shocks to the financial system (see Section 3.1)

Box 1 – Climate-related risks in EMDEs

Many EMDEs are particularly vulnerable to physical risks from climate change. Africa and the Asia Pacific – two regions with a large proportion of EMDEs – are amongst the most vulnerable to the negative effects of climate change, according to the ND-GAIN vulnerability index (Graph A, LH panel).[31] Like other countries, many emerging market jurisdictions are already affected regularly by floods, droughts and cyclones.[32] Recent analysis suggests that these physical risks have already had severe impacts on some countries' economies, as well as on their banking sectors.[33]

Countries' vulnerability to physical risks may be greater where there are less developed mechanisms through which to share risk, particularly where such risks coincide with broader macroeconomic vulnerabilities.[34] Graph A (RH panel) suggests that many of the countries that are more vulnerable to climate change also face large macroeconomic vulnerabilities. Recovery from weather-related natural disasters may be hindered by more limited public disaster relief funds, fiscal constraints and a lack of well-developed insurance markets. Their share of uninsured losses in EMDEs from natural disasters is more than twice that in advanced economies.[35] The lack of recovery funding can also increase firms' and households' credit risk, thereby amplifying losses borne by financial institutions.

Countries that are more dependent on fossil fuels may also be more susceptible to transition risks.[36] Exports of fossil fuels account for more than half of all exports for some countries. A disorderly transition to low-carbon economy – including that initiated by these countries' trading partners – could therefore

[29] See IMF (2020), *Global Financial Stability Report. Chapter 5: Climate Change: Physical Risk and Equity Prices*, April.

[30] One study finds that vulnerability to climate-related risks has already increased the average cost of debt in a sample of developing countries by 117 basis points, translating into USD 40 bn in additional interest payments on government debt over the past 10 years. See B. Buhr et al (2019), *Climate Change and the Cost of Capital in Developing Countries*.

[31] Countries' vulnerability to climate-related risks is proxied by the ND-GAIN vulnerability index – a measure of a country's propensity or predisposition to be negatively impacted by climate hazards; see C. Chen, I. Noble, J. Hellmann, J. Coffee, M. Murillo and N. Chawla (2015), *University of Notre Dame Global Adaptation Index, Country Index Technical Report*.

[32] See World Bank (2005), *Natural Disaster Hotspots – A Global Risk Analysis.*

[33] See, for example, IMF (2019), *The Bahamas 2019 Financial System Stability Assessment* (other FSAP results are forthcoming) and UNDP (2019), *Human development report*.

[34] See E. Feyen et al. (2020), *Macro-Financial Aspects of Climate Change*.

[35] See IMF (2020), *Global Financial Stability Report April 2020*.

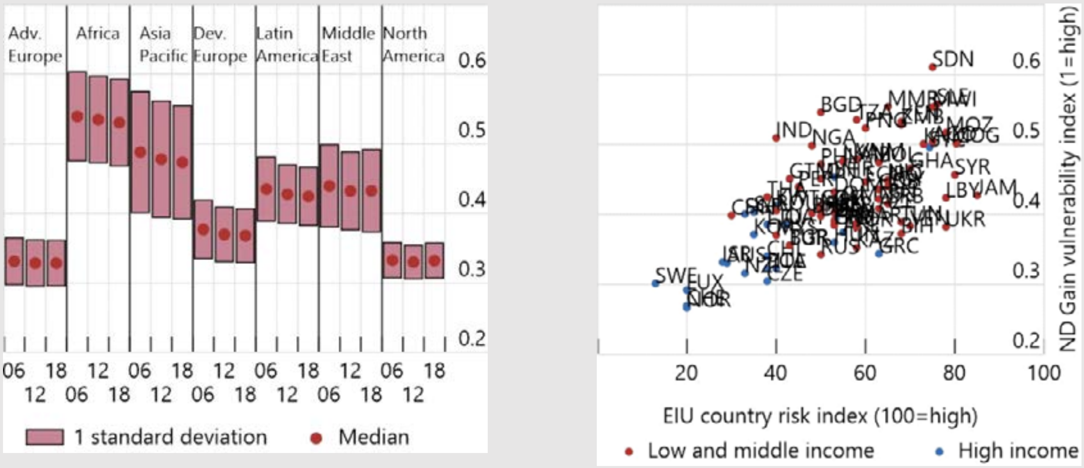
[36] See World Bank (2020), *Diversification and Cooperation in a Decarbonizing World: Climate Strategies for Fossil Fuel-Dependent Countries*.

leave banks and other investors bearing large losses on fossil fuel-related assets (i.e. credit and market risk). It could also have a broader impact on government revenues and creditworthiness, particularly in those countries whose governments rely heavily on revenues from fossil fuels. At the same time, some EMDEs are expanding their reliance on fossil fuel assets, which could also expose those who finance these activities to transition risks.[37]

EMDEs are vulnerable climate-related risks particularly where these tandem with other macro-financial vulnerabilities **Graph A**

Climate change vulnerability per region, 2006-2018[1]

Regional and national relationships between climate-related and other macrofinancial vulnerabilities[2]



[1] Red dots indicate the median in each period/region. Red bars represent plus/minus one standard deviation. Vulnerability to the negative effects of climate change is measured using the ND-GAIN vulnerability index.

[2] Data are as at 2017. The Economist Intelligence Unit (EIU) country risk index captures sovereign, currency, and banking risks.

Sources: EIU Credit Risk Model, Notre Dame GAIN.

In the longer run, climate-change might also lead to geopolitical tensions in some regions that might amplify risks to financial stability. A global increase in temperature and its associated sea-level rise could have substantial socioeconomic impacts, including increased risk of flooding in coastal cities and lower productivity in regions close to the equator.[38, 39] Such local changes in climate may cause people and capital to relocate on a scale that has adverse outcomes for both geopolitical and financial stability. For example, one study finds that an increase in drought can exacerbate conflict, which in turn explained a significant portion of asylum seeking in the period 2011-2015.[40]

Insurance underwriting risks

More frequent and severe extreme weather events have resulted (and could continue to result) in underwriting risks: that is, higher-than-expected claims against firms that provide insurance for physical risks. Claims faced by non-life insurers with respect to certain

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[37] For example, the US Energy Information Administration (EIA) forecasts a 1% annual growth rate in energy-related carbon dioxide emissions in non-OECD member countries between 2018-2050, driven by increases in the use of natural gas (+1.7%), petroleum liquids (+1.2%), and coal (+0.6%). Another estimate projects coal demand in Southeast Asia to grow by more than 5% per year through 2024. See US Energy Information Administration (2019), "*International Energy Outlook 2019*, *September and "International Energy Agency Coal 2019*, December.

[38] See IMF (2018), *The effects of weather shocks on economic activity: what are the channels of impact?*

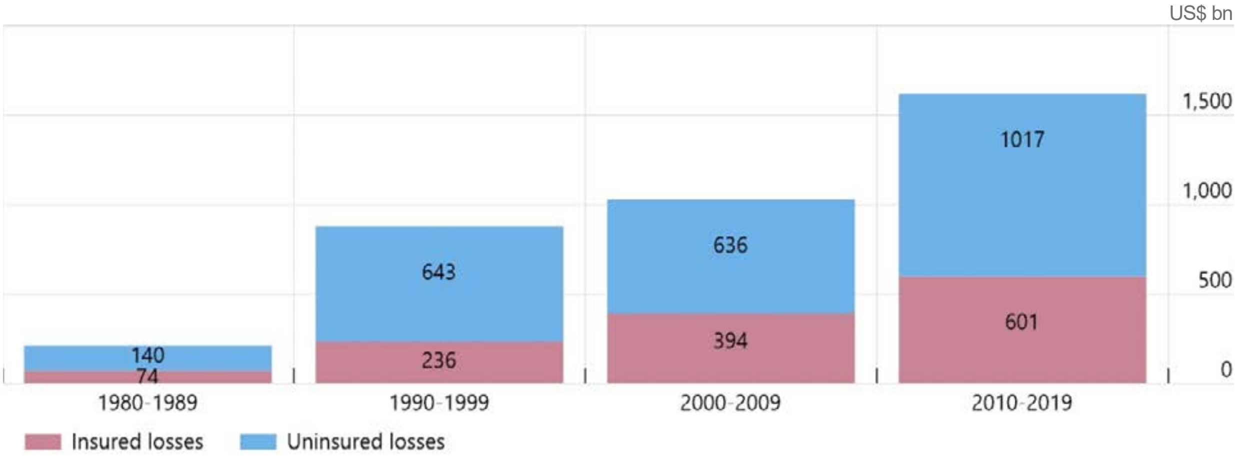
[39] See S. Hallegatte, C. Green, R. Nicholls, and J. Corfee-Morlot (2013), *Future flood losses in major coastal cities, Nature Climate Change 3,* pp 802-806.

[40] See G. Abel, M. Brottrager, J. Cuaresma, and R, Muttarak (2019).

weather-related catastrophes have increased in recent decades (see Graph 2). While part of this increase may be due to increases in exposure (i.e. increasing value of property in areas prone to physical risks), it may also be due to increases in severe weather events (Graph 1).[41] Physical risks could, over time, also result in greater claims for life and health insurers, if they impact policyholders' mortality and demographics.[42]

Economic losses resulting from weather-related catastrophes have increased significantly[1] **Graph 2**

Global insured (and uninsured losses) resulting from weather-related natural catastrophes (2019 prices)



Source: SwissRe (2020).

[1] Data may not match those used in Graph 1 due to differences in the scope.

The degree to which insurance underwriting risks act as a channel of risk to financial stability would depend in part on the degree to which they might undermine insurers' resilience. Most non-life insurers' products are short-term and can be repriced or withdrawn as a result of increased physical risks on an annual basis (or more frequently). This might reduce the impact of physical risks on the resilience of individual insurance firms.[43] That said, the increasing frequency and severity of severe weather events has resulted – and could continue to result – in claims that substantially exceed those witnessed historically.[44] This, combined with uncertainty concerning the future path of climate change, could undermine insurers' ability to price risks adequately, particularly if the severity of physical risks were to accelerate unexpectedly (see above).[45] This might mean that increased losses due to physical risks could come to weigh on some insurance firms' resilience.[46] However, **actions taken by individual insurers to reduce their exposure to climate-related risks could have negative consequences for the financial system as a whole.** If large numbers of firms significantly

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41 For example, weather-related catastrophe losses accounted for over 80% of insured catastrophe losses in 2018 globally. See ECB (May 2019), *Financial Stability Review*.

42 IAIS and SIF (2018).

43 This is in line with the opinions of some market participants to whom the FSB has discussed this channel of risk. See FSB (2020), Annex 4.

44 For example, weather-related claims in Canada amounted to an average of around CAD$1bn per year between 2006 and 2016. However the severity of the 2017 Fort McMurray wildfire brought the total liabilities to about CAD$4.5bn; see IAIS and SIF (2018).

45 Indeed, the impact on the insurance industry from climate-related risks has been greater where risks are systematically underestimated. See Herweijer, Ranger and Ward (2009) *Adaptation to Climate Change: Threats and Opportunities for the Insurance Industry,* and IAIS and SIF (2018).

46 See Finansinspektionen (2016), *Climate Change and Financial Stability*.

increase premiums or withdraw their coverage of certain climate related risks, this might leave households and firms without cover. This might amplify the resulting risks to financial stability (see discussion in Section 3).

Operational risks

Financial institutions may also be exposed to operational risks as a result of climate change. Extreme weather events could disrupt firms' operations, and affect other firms (financial and non-financial) to whom they provide financial services. This also may amplify risks to financial stability (see Section 3.3).

2.2. Transition risks

Transition risks stem from the possible process of adjustment to a low carbon economy and its possible effects on the value of financial assets and liabilities. Limiting the rise in global average temperatures to well below 2°C above pre-industrial levels requires an unprecedented reduction in global emissions.[47] Such a transition to a low carbon economy would imply significant structural changes to the economy, including a major reallocation of investment (Graph 3, LH chart). This could have a significant impact on firms involved in the production of fossil fuels, such as coal, oil and gas, as well as other sectors whose business models rely on using such fossil fuels or that are energy intensive (such as utilities, heavy industry, and the transportation sector).[48] There is already evidence that the market value of equities of firms in some heavily polluting industries is being impacted by policy measures and market trends related to a transition to a low-carbon economy.[49]

Such changes in asset prices need not, in themselves, pose risks to financial stability. Rather, they may be symptomatic of a well-functioning financial system that channels investment towards more climate-neutral investments. In particular, the depreciation of some assets as a result of transition to a low-carbon economy might also be offset by the positive effects of growth in less carbon-intensive sectors and firms. In addition, climate policies aimed at achieving the structural economic change described above might also boost innovation and investment, including in less carbon-intensive technology.[50] This might benefit some parts of the global economy, and result in the increase in some asset prices.[51] Evidence of this effect on innovation is, however, mixed.[52]

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47 In order to meet a 2°C target for increases in global temperatures, emissions would need to drop by 3% each year until 2030 (and by 8% to reach the 1.5°C target). See UNEP (2019), *Emissions gap report 2019*, November.

48 See Bank of England (2018), *Transition in thinking: The impact of climate change on the UK banking sector*, September.

49 For example, the Dow Jones Coal Index fell by 85% in 2011-2018 in line with significant increase in the use of natural gas for power generation and climate-related policy measures; see Bank of England (2018).

50 See NGFS (2019).

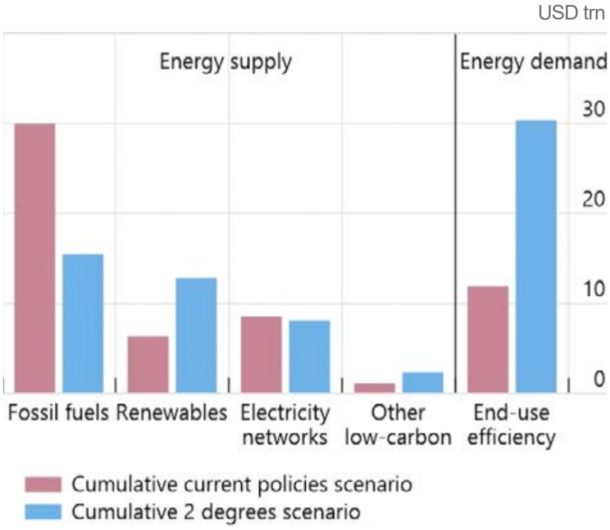
51 This notion is called the 'Porter Hypothesis'. See Porter and van der Linde (1995), *Toward a new conception of the environmental-competitiveness relationship*, Journal of Economic Perspectives, Vol. 9.

52 See, for example, Jaffe, Newell and Stavins (2000), *Technological Change and the Environment*, Working Paper No. 7970, National Bureau of Economic Research; Berman and Bui (1998), *Environmental Regulation and Productivity: Evidence from Oil Refineries*, NBER Working Paper No. 6776; Gray and Shadbegian (1997), "Environmental Regulation, Investment Timing, and Technology Choice," Working Paper No. 6036, National Bureau of Economic Research.

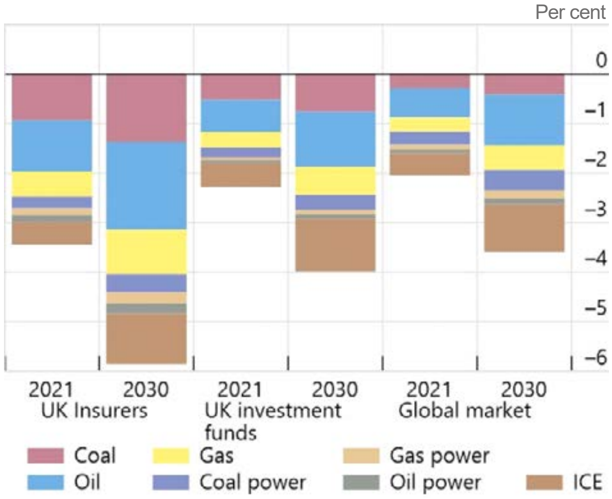
Estimated capital relocation resulting from transition risks and potential effects on equity valuations

Graph 3

Capital reallocation in the global energy sector consistent with a 2°C pathway



Estimated change in value of global equities and corporate bonds in sectors most exposed to transition to a low-carbon economy were a transition to begin in 2021 or 2030[1]



Sources: International Energy Agency World Energy Outlook (2017), Bank of England.

[1] Estimated change in asset prices consistent with a rapid economic adjustment consistent with a path for emissions that limits increases in global temperatures to less than 2°C greater than industrial levels in either 2021 or 2030. Analysis is based on IEA's New Policies Scenario[53] and detailed data on insurer and investment fund portfolios.

However a disorderly transition to a low-carbon economy, unanticipated by market participants, could have a destabilising effect on the financial system. Such a disorderly transition might be brought about by sudden changes in technology.[54] It could also be triggered by an unexpected change in public policy. Such radical policy action might arise due to the increased materialisation of physical risks (see discussion of the 'hot house world scenario' above). In such a scenario, physical and transition risks would affect the financial system in tandem, and thereby be more destabilising.[55]

A disorderly transition to a low-carbon economy could also lead to increased credit risk in some industries. A transition to a low-carbon economy might reduce some borrowers' capacity to generate sufficient income to service and repay their debts.[56] This could occur as companies in carbon-intensive industries face higher operating costs (e.g. on carbon-intensive inputs) or due to reduced demand for certain goods or services, reducing their profitability. Credit risk could also result from reductions in the value of collateral against which transactions are secured, particularly when such collateral takes the form of immovable or capital intensive infrastructure that might be particularly affected by climate-related risks (see above).

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[53] See International Energy Agency (2019), *World Energy Model*, November.

[54] For example, innovations in photovoltaic technology have led to an 80% fall in the cost of renewable energy from some small-scale power generators; see OECD (2018), *A Chain Reaction: Disruptive Innovation in the Electricity Sector*.

[55] Such an unanticipated and disorderly adjustment in asset prices as a result of transition risks has been termed a 'climate Minsky moment'; see Carney (2015).

[56] *See* Pierre Monnin (2018), *Integrating Climate Risks into Credit Risk Assessment Current Methodologies and the Case of Central Banks Corporate Bond Purchases*, Council on Economic Policies, December.

Central estimates of the impact on aggregate equity and corporate bond portfolios of a gradual and anticipated adjustment in the value of assets and liabilities of firms in sectors most exposed to transition risks appear relatively contained. Such estimates of the impact of transition risks vary significantly, due to differences in the estimation of exposures to carbon-intensive production, and in the assumed path of transition to a low carbon economy. They also differ in terms of the scope of losses they consider. Some studies, for example, consider losses stemming only from reductions in the value of firms' existing capital (sometimes referred to as 'stranded capital'). Others consider broader losses that might result from reductions in expected future cash flows. Despite these differences, one study, for example, finds that the discounted loss in global wealth that could result from stranded assets may range from US$1 trillion to US$4 trillion, or less than 3% of global managed financial assets.[57] Central estimates of the effect on financial sector aggregate equity and corporate bond portfolios are quite benign - e.g. 2-4% of aggregate portfolio values were transition to occur by 2030 (Graph 3, RH panel**).** This reflects the fact that the equities and bonds issued by firms included in this study comprise only 7% of global listed equity and bonds. Reductions in the value of these securities alone could, however, reach around US$ 2 trillion, or 50% of their current market value.[58] Were such reductions in prices to occur gradually, then they might be less likely to have material implications for financial stability.

Similarly, central estimates of some financial institutions' exposures to the most climate-sensitive sectors appear, in aggregate, fairly contained. In the case of the euro area, for example, banks' exposures to more carbon-intensive firms (as measured by firms' carbon emissions to total sales) are less than 5% of their large exposures (Graph 4, LH panel).[59] The median exposure to the most carbon-emitting firms, either through lending, bond or equity holdings, did not exceed 9% of assets in 2017.[60] Similar analysis suggests that euro-area insurance companies, pension funds and investment funds have exposures to carbon-sensitive sectors of between 2% and 8% of their overall portfolios (Graph 4, RH panel**).**[61] This might indicate that, at a sectoral level, risks to the financial system, at least from an orderly transition to a low-carbon economy, are relatively contained.

However, a transition to a low-carbon economy may not occur in as gradual and anticipated a way as in the central case estimates in the studies referred to above. Policy, technology and/or consumer preferences may shift more rapidly than is modelled in many transition scenarios. One way this might occur, for example, is via the possible interaction of transition risks with physical risks (see above). Unlike for physical risks, there are, however, few

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57 See J. Mercure, H. Pollitt, J. Vinuales, N. Edwards, P. Holden, U. Chewpreecha, P. Salas, et al. (2018), *Macroeconomic Impact of Stranded Fossil Fuel Assets*, Nature Climate Change 8 (7): 588–93.

58 Bank of England calculations using data from MorningStar, Global Data and WardsAuto.

59 See ECB (2019). Large exposures refer to firms reporting of large exposures under the European Capital Requirements Regulation (CRR), which requires that firms report every exposure to clients or groups of connected clients where its value is equal or exceeds 10% of the eligible capital of the institution.

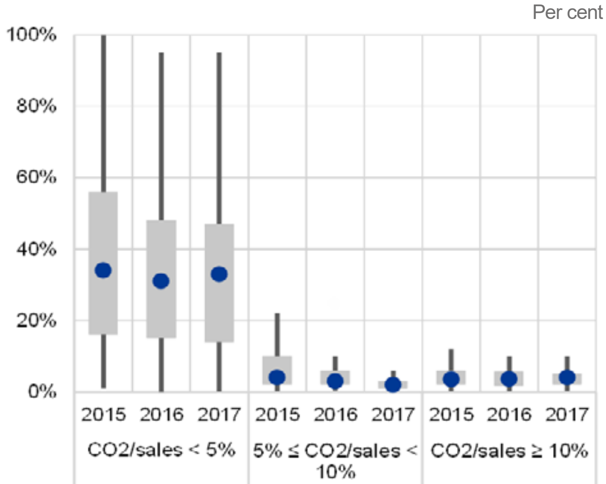
60 Other studies of bank exposures in other jurisdictions also find bank exposures to most climate sensitive sectors to be relatively small. For example, a study by the Bundesbank did not identify a significant carbon risk factor for the majority of enterprises with which German banks and insurers have a credit relationship; see Deutsche Bundesbank (2019), *Financial stability report*.

61 A recent analysis of U.S. insurance companies found that exposure to the most carbon-intensive companies represented on average 1.1% of their total balance sheet, including 1.6% of their equity portfolio and 3.5% of their corporate bond exposure; see IMF (2020), "United States: Financial Sector Assessment Program-Technical Note-Risk Analysis and Stress Testing the Financial Sector".

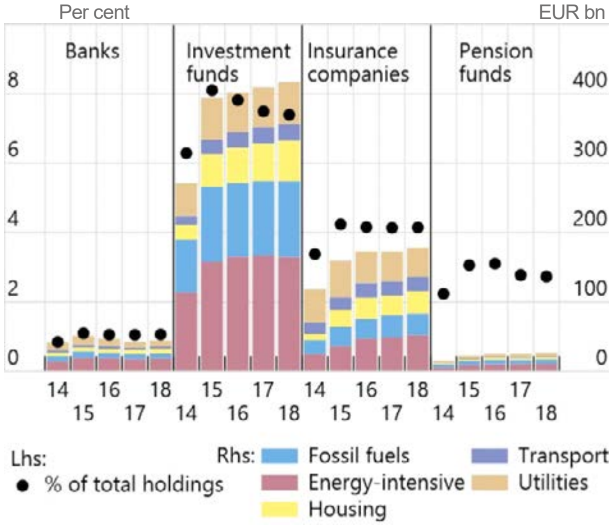
existing studies that attempt to assess tail risks – including those arising from such interactions of different risks – around these central case estimates.

Headline exposures to more polluting sectors appear fairly contained Graph 4

Distribution of large exposures of euro-area banks to firms with different carbon intensities



Euro-area investment exposures to climate-sensitive sectors



Source: ECB.

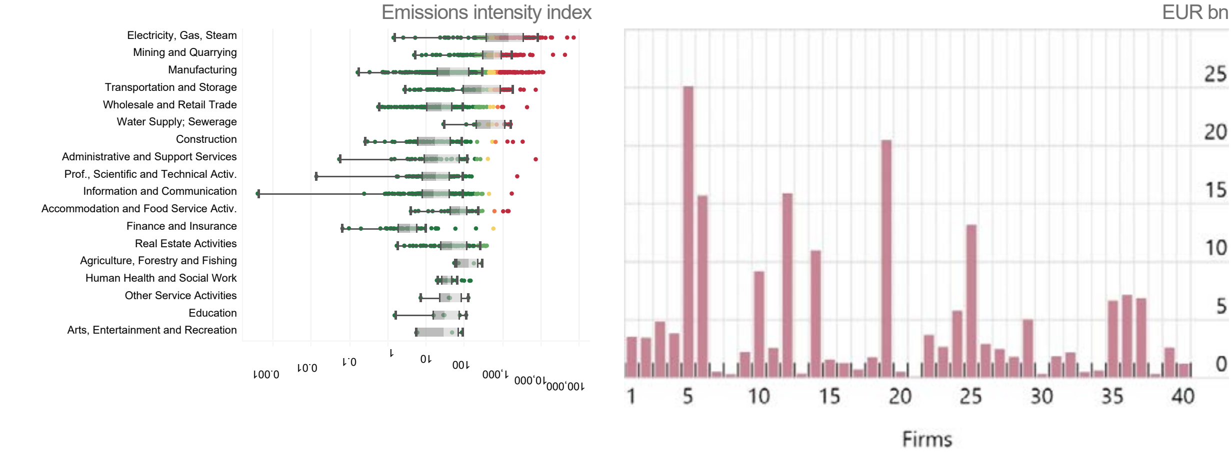
Moreover, the widespread effects of climate change mean that analysis of exposures at a sectoral level might underestimate the true level of emissions involved in firms' overall value chains. Firms' vulnerability to transition risks is a function not only of their operations, but also those of their suppliers and customers. Even if a firm's operations are not themselves carbon-intensive, the widespread effects of climate change might mean that a transition to low carbon economy might increase the cost of its supplies, or decrease its customer base, thereby affecting its profitability. To the extent that these suppliers and customers are in different sectors, this might mean that sectoral analysis underestimates firms' true exposure to transition. This might help explain why estimates of financial institutions' exposures to policy-related transition risks – though they are of a similar order of magnitude – vary to some degree, depending on the nature of the data on which they are based.[62]

62 For example, the DNB finds that fossil fuel producers represent 6% of Dutch pension fund portfolios and 1% of insurance portfolios. EIOPA found that climate-sensitive exposures of European insurers amount to 10-13% of total assets in 2017. Similarly, the Banque de France/ACPR estimated that approximately 10% of French insurers' investments were in carbon-intensive sector in 2017; see FSB (2020).

Exposures to firms with high emissions could be concentrated within individual counterparties or financial institutions **Graph 5**

Firm-level emissions within economic sectors and loans

Euro-area banks' exposures to 40 firms with highest carbon emissions



Source: ECB.

Analysis based on sectoral exposures might also conceal concentrated exposures *to* a given counterparty, or *borne by* certain financial institutions. Analysis based on sectoral exposures also overlooks substantial variation in emissions within a given sector. Some firms in sectors that might generally be considered highly exposed to transition risks have relatively low emissions (e.g. mining), and some in sectors that might be considered less polluting have relatively high emissions (e.g. information and communication) (Graph 5, LH panel). Such differences might arise, for example, from variation in the degree to which firms' production processes and technological investment are consistent with a reduction in emissions. Exposures to more polluting firms might also be concentrated within some counterparties (Graph 5, RH panel). Overall, euro-area banks' exposures to the twenty firms with largest carbon emissions are equivalent to 20% of these banks' reported large exposures.[63]

2.3. Liability risks

Liability risks might arise when parties are held liable for losses related to environmental damage that may have been caused by their actions or omissions.[64] To the extent that this might reduce the value of such firms' liabilities, it might also have implications for the financial system. Liability risks are of particular relevance to insurance firms. This is because some such risks can (at least in part) be transferred by means of liability protection insurance.[65]

63 See ECB (2019).

64 See Bank of England (2015), *The impact of climate change on the UK insurance sector*, which distinguishes three types of legal risks: failure to mitigate, failure to adapt and failure to disclosure.

65 See M. Scott, J. van Huizen, and C. Jung (2017).

3. Transmission and amplification mechanisms

This section examines how shocks due to the crystallisation of climate-related risks might be transmitted through, and amplified by, the financial system.

The breadth of climate-related risks – combined with the uncertainty concerning their timing and magnitude – might reduce the degree to which market participants are able to properly price and manage them. For example, the widespread and uncertain nature of climate related risks (see Section 2) might lead to increases in risk premia across a broad range of assets. This may change – and in places, increase – the degree of co-movement between asset prices, and reduce the degree to which financial market participants were able to diversify exposure to climate-related risks. It might also reduce the efficacy of other channels through which financial market participants seek to insure against climate risks (e.g. via some derivatives markets).

It might also increase the degree to which such risks are amplified within the financial system. The materialisation of physical or transition risks, and their effects on financial institutions and markets, could give rise to 'feedback loops' within the financial system, or between the financial system and real economy. These arise when actions taken by agents in their individual interest interact in ways that together amplify effects on the financial system and real economy. Such amplification has occurred in response to other types of economic shocks.[66] However, the breadth of climate-related risks might increase their perniciousness compared to that elsewhere. For example:

- **If widespread increases in risk premia were to materialise as a result of climate-related risks, they might cause financial market participants to behave procyclically**. Large-scale shifts in investor portfolios might amplify changes in asset prices. This effect might be particularly prevalent where there are substantial commonalities between investors' portfolios or concentrations of exposures both through certain financial products (such as derivatives). It might also be amplified by changes in collateral values, as well as changes in perceptions of counterparty creditworthiness and liquidity.

- **The behaviour of financial institutions – including reductions in lending by banks, and in coverage by insurance firms – could lead to widespread reductions in their support to the real economy.** This might amplify the effects of climate-related risks on the non-financial sector, and lower economic growth could in turn increase losses faced by financial institutions.

  Uncertainty concerning the scale of climate-related risks – and the difficulties some financial intermediaries might face in assessing their impact – might also magnify these effects on financial institutions.

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[66] During the 2008/9 financial crisis, for example, falling asset prices and slowing economic activity – combined with growing uncertainty concerning bank creditworthiness – led to a withdrawal of bank funding. This caused further asset sales by banks and reductions in lending, which in turn led to further falls in asset prices and slowing economic activity. This feedback mechanism has been dubbed 'the Paradox of Prudence'; see Markus K. Brunnermeir and Yuliy Sannikov (2016), *The I Theory of Money*, August.

These effects are examined in turn in the sub-sections that follow.

3.1. Changes in the pricing and management of financial risks

The widespread and uncertain nature of climate-related risks mean that their manifestation might lead to an increase in risk premia across a wide range of assets. They might also lead to changes – and potential sharp increases – in the co-movement of asset prices. Uncertainty around the future path of climate change, as well as its economic impact, [67] might mean that this was unanticipated by market participants.[68] Such an unanticipated shift in the co-movement of asset prices might challenge the effectiveness of market participants' ability to diversify their exposure to climate-related risks.

Possible reductions in the efficacy of insurance obtained via financial markets

Some financial markets play an important role in facilitating the diversification of investor portfolios, even in the face of the widespread materialisation of climate-related risks. The use of weather derivatives contracts, for example, allows risks to be borne by economic agents that are best placed to monitor and bear them. Climate-related risks can also be transferred via the issuance of insurance linked securities (ILS), such as catastrophe bonds of collateralised reinsurance.[69] The size of the global market for such instruments has increased substantially in recent decades (Graph 6), though remains small relative to the size of economic costs from weather-related catastrophes (Graph 2**)**. Other financial instruments may also help in managing climate risks. Credit, equity and oil derivatives, for example, can serve to hedge the risks associated with stranded assets, as well as the physical risks of extreme weather.

It is possible, however, that the widespread and uncertain effects of climate-related risks could reduce the efficacy of such risk-sharing mechanisms. The efficacy of such mechanisms relies in part on the ability/willingness of holders of ILS securities and providers of reinsurance to continue to bear climate-related risks, and on the creditworthiness of derivatives counterparties. Uncertainty concerning the scale of risks might also reduce the market participants' ability to price such financial products.

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67 This difficulty may be exacerbated where firms' business models rely on long and complex supply chains, where exposures depend non-linearly on the severity of climate-related risks and on the capacity of firms to adapt to them, and/or materialise over a long time horizon. See P. Bolton, M. Despres, L.A. Pereira Da Silva, F. Samama, and R. Svartzman (2020) *The green swan - Central banking and financial stability in the age of climate change*, Bank for International Settlements and Banque de France, Section 3.3.

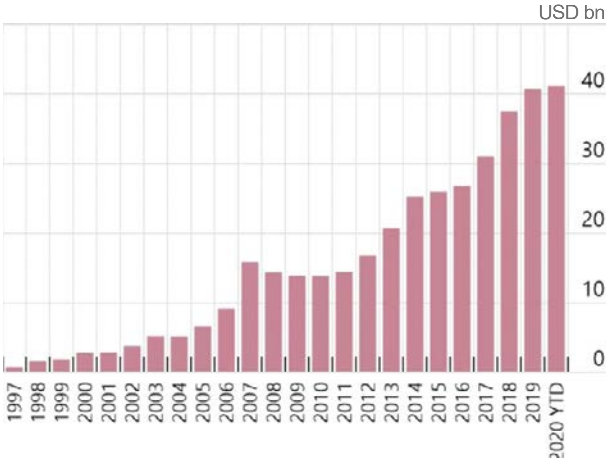
68 See FSB (2020).

69 See Bank of England (2015), *Insurance and financial stability*.

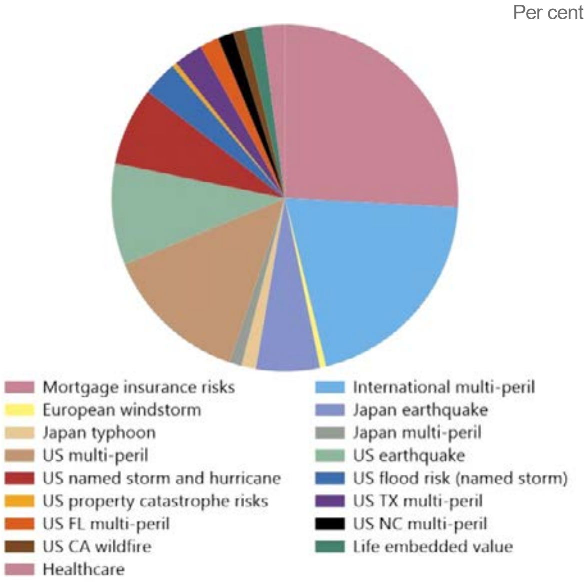
The global market for catastrophe bonds

Graph 6

Catastrophe bond & ILS risk capital outstanding



Catastrophe bonds & ILS risk capital outstanding by risk or peril



Source: ECB.

3.2. Potential for pro-cyclical behaviour by market participants

Widespread increases in risk premia – and unanticipated changes in asset price co-movement – that might result from the materialisation of climate-related risks might also be amplified by the resulting sales of affected assets by investors.[70] Whilst this dynamic is not specific to climate-related risks, it could be more pernicious if the effects of climate-related shocks were more widespread and correlated across assets than investors had previously expected.[71]

The potential for large-scale simultaneous sales of assets in response to the manifestation of climate-related risks might be greater if there are substantial similarities across investors' portfolios. One way of measuring the commonality of exposures to climate-related risks is to compare the holdings of securities issued by firms in sectors with the highest carbon emissions, which might be most exposed to transition risks. Graph 7 (LH panel) shows the securities held by different types of euro-area financial institutions that are issued by firms in three carbon-intensive sectors (manufacturing, transport and electricity supply)[72] as a proportion of these financial institutions' total holdings of securities issued by non-financial corporates. Euro-area investment funds, insurance firms and banks all appear to have common and economically significant exposures to these sectors. This may mean that a climate-related shock affecting the value of such securities could be increased if there were widespread simultaneous selling of securities across financial institutions in different sectors. Such common sectoral

[70] See G. Girardi, K. Weiss Hanley, S. Nikolova, L. Pelizzon, and M. Getmansky Sherman (2020), *Portfolio Similarity and Asset Liquidation in the Insurance Industry*.

[71] See Blackrock (2019), *Getting physical: assessing climate risks*, and IMF (2020).

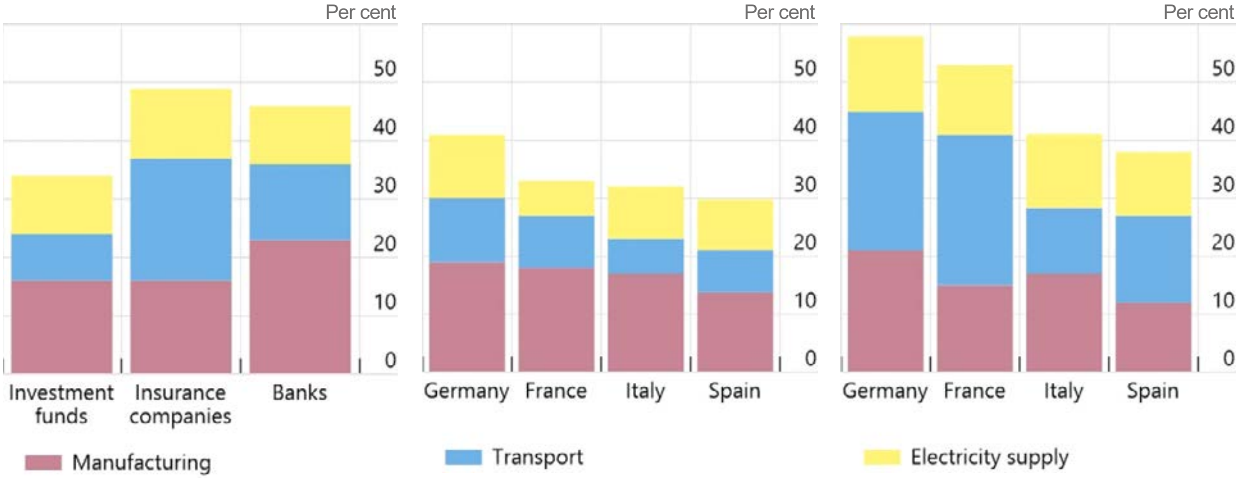
[72] An analysis of euro-area firms found these sectors to have the highest carbon emissions; see ECB (2019), Chart A.3.

exposures also appear to be present in several jurisdictions: Graph 7 (middle and RH panels) shows the same exposures for investment funds and insurance firms in the four largest euro-area jurisdictions by GDP.

Commonality of exposures to securities issued by carbon-intensive sectors by euro-area financial institutions

Percentage of holdings of securities issued by non-financial corporates in selected sectors. **Graph 7**

…across the entirety of euro-area financial institutions | …by investment funds in selected countries | …by insurance firms in selected countries



Source: ECB.

It is unclear whether such analysis under- or overstates the scope for shocks to the financial system to be amplified by common holdings across sectors. On the one hand, use of sectoral data might overstate the degree to which selling of securities in one sector results in sales of securities issued by different firms in the same sector. Differences in production process may mean there are substantial differences in exposure to climate-related risks of firms in the same sector – for example, firms reliant on renewable versus non-renewable electricity. On the other hand, sector-level analysis might understate the potential commonality of exposures across firms in different sectors, particularly if the materialisation of climate-related risks lead to a widespread increase in risk premia across firms whose future prospects had previously seemed relatively unrelated (see above).

3.3. Self-reinforcing reductions in bank lending and insurance provision

The widespread nature of climate-related risks could also trigger self-reinforcing feedback loops to arise whereby losses suffered by the financial system cause a reduction in the financing of the real economy.[73] The intensification of climate-related risks could trigger a widespread reappraising of the creditworthiness of large portions of the real economy. This might reduce the willingness of firms to provide financial services, reducing access to (or raising the cost of) bank lending, corporate finance and insurance. By further

[73] See, for example, Lael Brainard (2019), *Why Climate Change Matters for Monetary Policy and Financial Stability*, November.

depressing macroeconomic prospects, this could then result in further losses for the financial system, which in turn could lead to a reduction in finance.[74]

Potential for self-reinforcing reductions in bank lending

If banks were to suffer widespread losses as a result of the crystallisation of physical risks, this could cause an increase in their leverage and reduction in their lending (prompted by a need to preserve their solvency). This could then amplify the shock to the real economy. To the extent that this, in turn, results in larger losses for banks, this effect could also be self-reinforcing, resulting in a further retrenchment in bank lending. This effect might be exacerbated by any increase in banks' cost of funding and reductions in profitability, which might further reduce bank solvency and prompt reductions in lending.[75]

It is unclear whether the financial system – either globally or in any particular jurisdiction – has experienced a climate-related shock of a scale and breadth sufficient to trigger such a feedback effect. Some existing studies suggest that bank lending has remained reasonably resilient in the face of past natural disasters, at least where banks' exposures are relatively diversified across geographic regions.[76] There remains, however, the possibility that a larger shock (or series of shocks) – for example, that affecting a large number of institutions and/or jurisdictions and that might imply a longer-lasting impact than those of individual natural disasters – might trigger a negative feedback loop between bank lending and the real economy.

Existing data on the behaviour of bank capital, lending, and the macroeconomy can be used to simulate how banks might amplify a future, more severe, shock emanating from the crystallisation of climate-related risks. Graph 8 shows the effects of two shocks arising from the crystallisation of transition risks in the euro area. One shock involves an abrupt introduction of policies aimed at mitigating carbon emissions. The other involves a technological breakthrough that allows the share of renewable energy production to double over a five-year period.[77] The policy shock results in a reduction in banks' capital ratios and lending to the real economy. Both effects are economically meaningful, but gradually fade over a five-year period. These results are much less negative in the case of the innovation shock, because new technology leads to higher potential growth and banks are willing/able to provide finance to these profitable projects. Nonetheless, the global nature of these shocks, their potential propagation across borders – together with the possibility that exposures are concentrated within certain financial institutions (see Section 2) – could result in larger effects than those estimated in this euro-area exercise.

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[74] See NGFS (2019).

[75] These dynamics are described in detail in ECB & ESRB (2020), *Positively green: measuring climate change risks to financial stability*; IMF (2011), *Durable Financial Stability-Getting There from Here*; and Sujit Kapadia, Matthias Drehmann, John Elliott, Gabriel Sterne (2012), *Liquidity risk, cash flow constraints, and systemic feedbacks*.

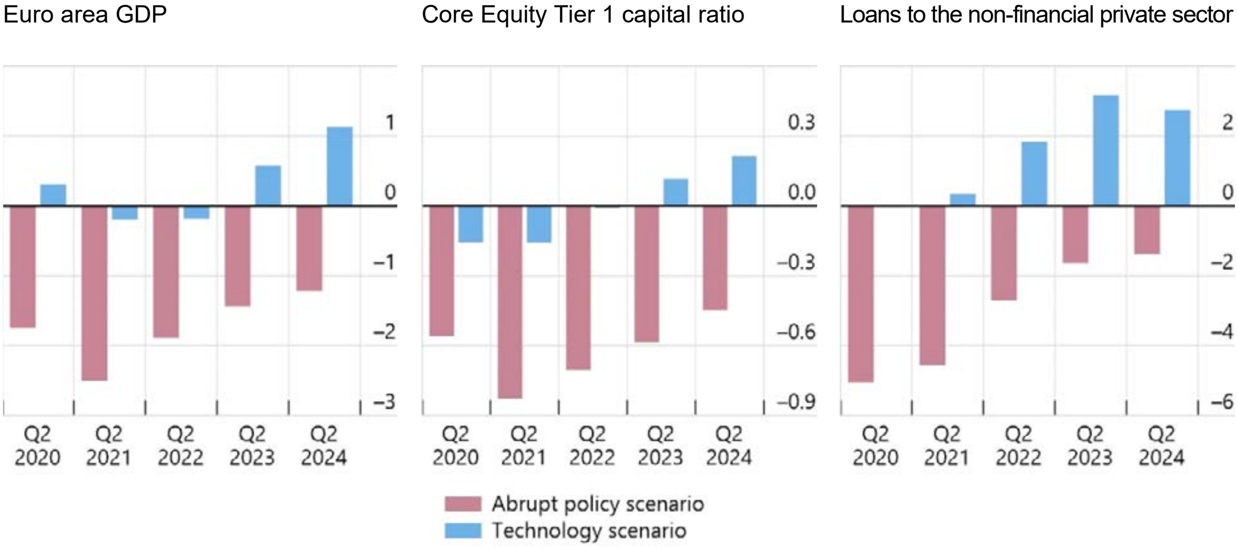
[76] For example, Ulrich Schüwer, Claudia Lambert, Felix Noth (2019), *How Do Banks React to Catastrophic Events? Evidence from Hurricane Katrina*, Review of Finance, 23(1): p75–116 show that some banks' risk-based capital ratios increased following Hurricane Katrina, due to the appreciation of their holdings of US government securities. Romero Cortés and Strahan (2017), *Tracing out capital flows: How financially integrated banks respond to natural disasters*, show that some large banks accommodate an increase in the demand for credit in areas affected by natural disasters, and do not reduce lending in other areas. On the other hand there is evidence that following the August 1999 earthquake in Turkey, the average cost of Turkish bank's domestic lending increased as a result of losses; see Yusuf Soner Basakaya and Șebnem Kalemi-Ozcan (2016), *Sovereign Risk and Bank Lending: Evidence from 1999 Turkish Earthquake*, June.

[77] These results are based on ESRB (2020), *Positively green: Measuring climate change risks to financial stability*. The methodology and scenarios are described in Vermeulen et al. (2018), "The Heat is on : A framework measuring financial stress under disruptive energy transition scenarios".

Estimated effect of climate-related shocks on euro-area GDP and bank capital and lending

Percentage changes

Graph 8



Source: ESRB.

Some climate-related risks could have wider effects on the financial system that increase this amplification effect. For example, physical risks could materialise in a way that impairs financial institutions' operations (see Section 2). This might further reduce their ability to extend credit or process customer transactions. This might occur if, for example, severe weather events were to affect their premises, systems, communications and/or staffing (or those of their outsourced business functions). This might further amplify the contraction in the supply of credit to the real economy, over and above that caused by the initial losses suffered by financial institutions. Such operational vulnerabilities might also affect banks' customers' ability to meet their credit obligations, leading to a further contraction in credit.[78]

A widespread manifestation of climate-related risks could also give rise to an increase in the credit and liquidity risk of financial institutions.[79] Widespread reductions in borrower creditworthiness – combined with reductions in collateral issues – might lead to a widespread deterioration in financial-sector solvency. Losses due to the materialisation of climate-related risks for one financial institution could result in deterioration of its solvency that then leads to losses for other financial institutions. One estimate suggests that, in the case of European banks, such second round of losses that arise via the lending between financial institutions might lead to losses that far exceed those caused directly by the initial climate-related shock.[80]

78 See M. Daly (2019), *Why Climate Change Matters to Us, Speech*, Federal Reserve Bank of San Francisco, November.

79 These effects are discussed in more detail in German Ministry of Finance (2016), *Final report: potential impact of climate change on financial market stability*.

80 See S. Battiston, A. Mandel, I. Monasterolo, F. Schütze and G. Visentin (2017), *A climate stress-test of the financial system*, Nature Climate Change 7: pp 283-288.

The effects of reductions in insurance provision

If the materialisation of climate-related risks were to lead to large increases in insured losses from physical risks (see Section 2), this might reduce the degree to which households and financial and non-financial firms can insure against these risks. This might occur either because insurers no longer offer such cover, or increase its price to a degree that is not economic for end-users.[81]

A range of factors determine the level of insurance coverage purchased by end-users of the financial system. There is, however, already evidence that increases in severe weather events in some areas has left households unable to obtain insurance against such risks.[82] Globally there remains a substantial proportion of economic losses resulting from natural catastrophes that are uninsured (Graph 9). Such a 'protection gap' is not only due to the effects of climate change.[83] Nonetheless, underinsurance may worsen if more extreme climate events crystallise. Representatives from some insurance firms have said that under certain scenarios for climate change, exposures to some physical risks would no longer be insurable.[84] The availability of reinsurance – through which most insurers transfer portions of their risk – could, like general insurance also decrease (or become prohibitively costly).

Such a reduction in insurance cover might leave risks borne by households, firms and other financial institutions in a manner that is detrimental to growth and financial stability. A lack of insurance might reduce the viability of some businesses, and have a detrimental effect on investment. For example, there is some evidence that recent reductions in the availability of insurance against severe weather events in some areas has led to a reduction in mortgage lending and a decrease in house prices beyond that commensurate with damage caused by weather itself.[85] Reductions in the availability of insurance could also increase risks to other financial institutions. For example, if physical assets (e.g. property) are uninsured, this may increase the credit risk borne by banks that use such assets as collateral to secure their lending.[86]

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81 In 1992 after Hurricanes Andrew and Iniki hit the US, the price of insurance against extreme weather events increased sharply, with an a rise in premiums of up to 40% in some areas; see Carney (2015).

82 *Ibid*.

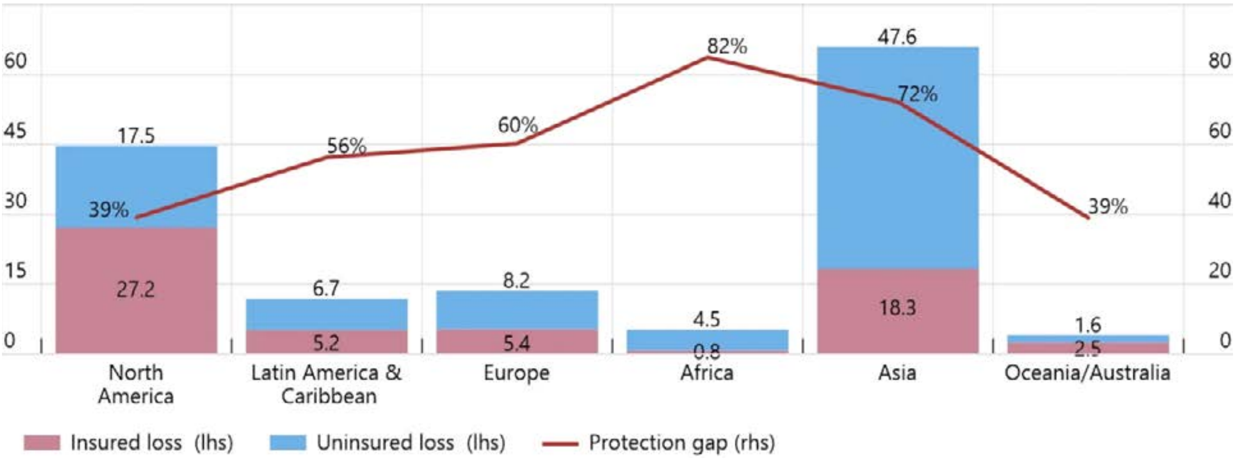
83 Protection gaps also occur due to lack of consumer awareness, a lack of penetration of financial services (particularly in EMDEs), possible imperfections in reinsurance markets, and a lack of enforcement of mandatory insurance; see Kenneth Froot (2008), *On the Pricing of Intermediated Risks: Theory and Application to Catastrophe Reinsurance* and Swiss Re Institution (2019), *Sigma*.

84 See FSB (2020).

85 In some extreme cases, householders in the Caribbean have found storm patterns render them unable to obtain private insurance cover, prompting mortgage lending to decrease and house values to fall; see Carney (2015).

86 For example, damage to assets serving as collateral could create losses that prompt banks to restrict their lending in certain regions which could put downward pressure on property values, further exacerbating the financial impacts of physical events; see M. Scott, J. van Huizen, and C. Jung (2017).

Insured and uninsured losses from natural catastrophes	Graph 9
USD bn in 2019 prices	Per cent



Source: SwissRe.

Lack of adequate private insurance provision has led some governments to step in and assume some risks. One early example is the National Flood Insurance Program in the United States. This program was created in 1968 due to the lack of availability of private insurance and sustained increases in federal disaster assistance due to floods.[87] Another example is FloodRe – a joint initiative between the UK government and insurers, which allows insurers to pass the flood risk element of home insurance policies to the government for a fixed price.[88] This ensures that households at high risk of flooding continue to have insurance cover. Some governments may, however, be discouraged from assuming such risks given constraints on their fiscal expenditure and potential implications for sovereign creditworthiness (see Section 3.1).

Interaction of financial institutions' and sovereigns' creditworthiness

Climate-related risks could also lead to a self-reinforcing deterioration of prospects for sovereigns as well as the financial sector.[89] Significant uninsured losses from physical risks have – and could in future – result in economic disruption at a national level, reducing tax revenues and increasing fiscal expenditures (see Section 2).[90] Increased sovereign default risk can lead to losses for banks and insurers via their holdings of government bonds and of other credit to governments and government agencies.[91] The resulting deterioration in the outlook for the financial sector might cause a further deterioration in sovereign creditworthiness (i.e. a

87 See NAIC (2020), *Flood Insurance*, October.

88 Note that Flood Re is intended to be transitional (until 2039), by which point insurance pricing will need to reflect flood risks (rather than being subsidised). Other examples include Consorcio de Compensacion de Seguros in Spain, the Natural Catastrophe Insurance of Iceland, the Danish Storm Council, or the Florida Hurricane Catastrophe Fund.

89 See Serhan Cevik and João Tovar Jalles (2020), *This Changes Everything: Climate Shocks and Sovereign Bonds*, IMF (June), show that countries that are vulnerable to climate change, as well as developing countries with weak adaptation capacity, have higher sovereign bond yields and spreads.

90 See IMF (2016), *Small states' resilience to natural disasters and climate change – role for the IMF*, December, finds that natural disasters have an increasingly negative impact on growth, fiscal balances and trade in smaller states.

91 See Stefano Battiston and Irene Monasterolo (2019), *A Climate Risk Assessment of Sovereign Bonds*, estimate that, under some scenarios, a disorderly introduction of climate policies, not fully anticipated and priced in by investors, would have a non-negligible impact on insurers' sovereign bond portfolios.

sovereign-bank nexus). There is evidence that, in some jurisdictions, this dynamic has taken hold in response to previous large-scale shocks to the financial system.

The amplifying role of uncertainty

Difficulties in assessing the impact of climate-related risks might increase the perniciousness of the dynamics described above. Complex and low probability risks may not be fully internalised and reflected in the actions of financial intermediaries.[92] This could lead to excessive exposures and mispricing of those risks, with potential for significant impacts and asset price falls when risks materialise. Similar dynamics could also arise if banks or other financial intermediaries were using off-the-shelf models to assess their exposure to climate-related risks. This might lead them to underestimate risks, and/or lead to greater correlation in their exposures and selling behaviour,[93] particularly where models are based on past data.[94] For example, there are questions whether climate-related risks are properly built into banks' credit approval processes, particularly with respect to longer term lending.[95]

Lack of information about financial institutions' exposure to climate risk could further contribute to the amplification of risks. A financial intermediary that is uncertain about the impact of climate shocks on its counterparties might decide to withdraw from existing relationships when facing heightened risk.[96] Similarly, incomplete/asymmetric information about exposures can give rise to contagion where different sectors or intermediaries are bundled together by other market participants due to a lack of information to properly differentiate across counterparties.[97]

4. Cross-border transmission of climate-related risks

Shocks to the financial system from climate change can also be transmitted across borders. This could give rise to global contagion that further amplifies the consequences of these shocks through real and financial channels.

One way in which climate-related shocks could be transmitted across borders is via the co-movement in risk premia on assets exposed to climate-related risks in different jurisdictions. Such spillovers might be particularly prevalent in the case of climate-related risks, where local physical climate risks can indicate global trends, and policy measures taken in one

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92 See N. Gennaioli, A. Shleifer, and R. Vishny (2012), *Neglected risks, financial innovation, and financial fragility*.

93 According to Bank of England (2018) only 10% of firms are taking a 'strategic approach' to climate risks that involves 'actively assessing and mitigating risks at portfolio or individual counterparty level by assessing the sensitivity of their clients to the financial risks from a transition to a low carbon economy'.

94 Supervisory guidance from one financial authority specifically acknowledges that past data are unlikely to be a good predictor of climate-related risks, and so expects firms to go beyond using historical data in assessing such risk; see Bank of England (2018).

95 See, for example, N. Garbarino and B. Guin (2020), *High water, no marks? Biased lending after extreme weather*, Bank of England find that lender valuations do not 'mark-to-market' against falls in asset prices that arise from climate-related risks, nor do they adjust for such risk by adjusting the cost or quantity of their lending.

96 There is evidence that this was the case during the 2008-09 financial crisis; see R. Caballero and A. Krishnamurthy (2008), *Collective risk management in a flight to quality episode*.

97 See G.B. Gorton and E.W. Tallman (2018), *Fighting Financial Crises*.

country can foreshadow the future path of policy in others. The materialisation of physical risks in one jurisdiction might, for example, trigger a change in market expectations as to the prevalence of related risks in another jurisdiction – either as to the likelihood of future physical risks or of policy action to stem them (i.e. transition risks). Similarly, a disorderly transition towards a low-carbon economy in one jurisdiction might prompt expectations of a similar transition in another jurisdiction. An unexpected acceleration in policy to stem climate change in one jurisdiction might, for example, trigger beliefs that this will be mirrored in other jurisdictions.

Another channel through which climate-related risks can be transmitted across borders is via the exposures of financial institutions.[98] Financial institutions that provide cross-border finance face the risk that climate-related risks in the jurisdiction to which they have provided finance are a source of credit and market risk (see Section 2). Those receiving finance from overseas face the risk that climate-related risks arising in their own jurisdiction give rise to the withdrawal of cross-border finance, leaving them without funds. Cross-border investments by insurance companies and other asset owners could also create financing strains for local equity or bond issuers should they choose to divest from climate-vulnerable locations.

The cross-border transmission of climate-related risks via financial institutions could serve both to amplify – and to mitigate – risks to financial stability. On the one hand, it could give rise to diversification, by transferring risks to those best placed to bear them globally.[99] For example, a global pool of insurers is likely to absorb the losses stemming from large-scale climate events more easily. Similarly, a diversified set of foreign lenders might be well positioned to absorb country-specific losses. On the other hand, cross-border exposures can also amplify risks. Cross-border lending might lead to risks affecting one country being concentrated in another jurisdiction. To the extent that such jurisdictions, and the financial systems within them, are not resilient to such risks, this might create financial stability risks.

Some evidence suggests that cross-border financial exposures to climate-related risks tend to lie with those countries that are more resilient to such risks. Graph 10 (LH panel) compares jurisdictions' cross-border liabilities (such as those arising via lending, foreign direct investment and portfolio investment) with a measure of their resilience to climate-related risks.[100] This analysis suggests that countries' with larger cross-border liabilities tend to be those that are more resilient to climate-related risks. In aggregate, therefore, according to this analysis, cross-border exposures do not appear to be a source of amplification of climate-related risks.

Graph 10 (middle panel) compares the cross-border exposures of each jurisdiction's banking system (blue bars), to the same exposures *weighted by borrower jurisdictions' relative vulnerability to climate-related risks* (red bars).[101] The difference between the two approximates the degree to which banks in one country are exposed to climate-related risks via

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98 These spillovers might materialise even without obvious financial linkages. The manifestation of transitions risk in a country, say more stringent domestic environmental regulation, might also affect asset prices in other countries, as governments or the public there might be more inclined to pursue environmental goals. Changes in perceptions of global climate risks can also affect asset prices worldwide without cross-border financial flows or common investor base.

99 For further discussion, see FSB (2019), *FSB Report on Market Fragmentation*.

100 Countries' resilience to climate-related risks is measured by the ND-GAIN Country Index. This index includes a measure of a country's vulnerability to climate change and other global challenges in combination with its readiness to improve its resilience to such risks; see University of Notre Dame, ND-GAIN index.

101 Cross-border bank exposures are given by the BIS International Banking Statistics. Vulnerabilities to climate related risks are given by the inverse of the ND-GAIN index; see above.

their cross border lending, relative to those in other countries. If the weighted exposures (red bars) exceed the unweighted exposures (blue bars) for a given country, then banks in that country are more exposed to climate risks than are banks on average across jurisdictions in which banks are cross-border lenders.

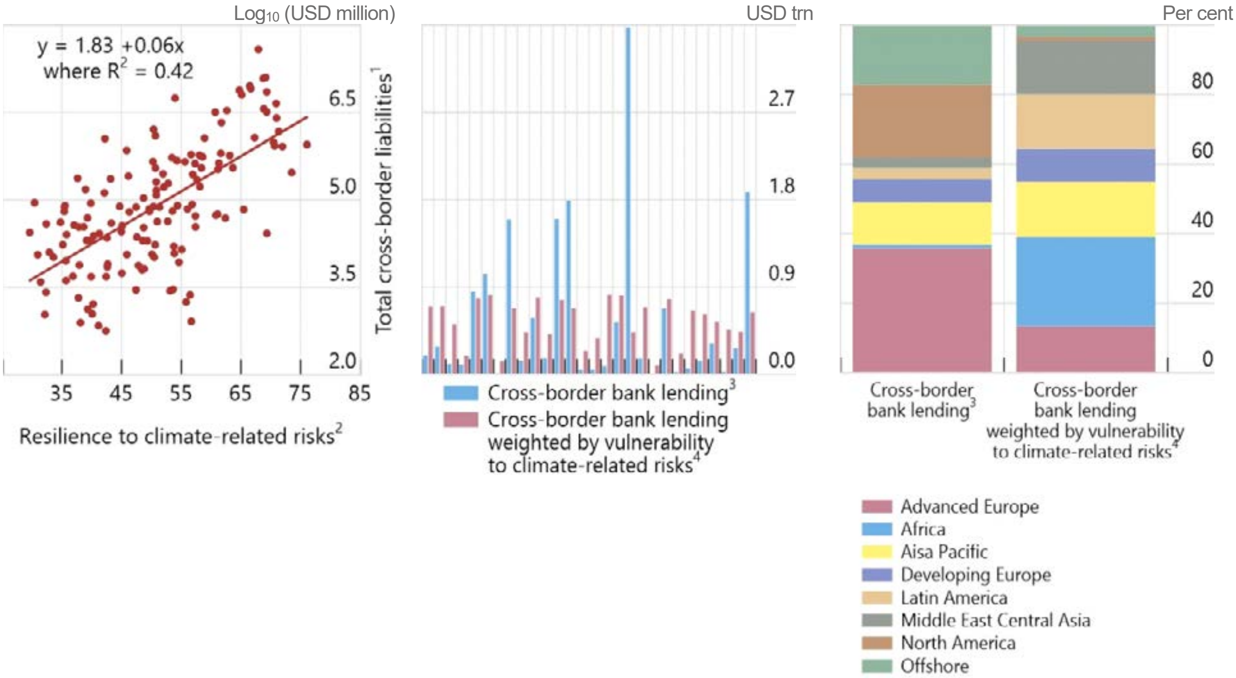
Cross-border transmission of financial risks from climate change **Graph 10**

Countries' resilience to climate-related risks and cross-border liabilities

Total cross-border bank claims, and cross-border bank claims weighted by vulnerability of borrowers to climate-related risks

By lending country

By region of borrower



[1] Total cross-border liabilities consistent with countries' international investment position. Includes direct investment, portfolio investment and other investment in other countries. Latest available data for each country. [2] Countries' resilience to climate-related risks is given by the ND-GAIN index (see above). [3] Total cross-border claims of banks in relevant country, given by BIS Consolidated Banking Statistics. [4] Total cross-border bank claims weighted by the inverse of ND-Gain index of country that the recipient of funds. Values are scaled so that aggregate values correspond to total (unweighted) cross border lending of each country. Bank lending data are as of Q4 2019; ND-GAIN index of 2018.

Sources: Notre Dame Global Adaptation Initiative; BIS, Consolidated banking statistics; IMF.

According to this analysis, cross-border bank lending does not seem to result in material concentrations of risks in those countries whose banks are engaged in such lending. The difference between the nominal exposures of banking systems in these countries (blue bars in Graph 10, middle panel) and those weighted by the recipient countries' vulnerability to climate-related risks are relatively small, albeit with some exceptions. Cross-border bank lending might therefore play a role in diversifying, rather than amplifying, climate-related risks across a range of lending countries.

However, climate-related vulnerabilities might be concentrated in certain (less developed) economies that are the recipients of cross-border bank lending (Graph 10, RH panel). Cross-border exposures to countries weighted by their vulnerability to climate-related risks far exceed unweighted exposures for jurisdictions in Africa and Latin America. This is consistent with cross-border bank exposures to jurisdictions in these regions being a source of climate-risk. The opposite is true in North America and Advanced Europe, where exposures weighted by climate-related vulnerabilities are smaller than unweighted exposures. These differences may reflect differences in economic development, and the relative prevalence of mechanisms to transfer financial risk (see Box 1).

Cross-border lending may therefore serve to amplify climate-related risks in countries that are the *recipients* of cross-border border lending. The crystallisation of physical risks in such countries might prompt the large-scale withdrawal of funding from foreign investors. This effect might be amplified in the case of developing economies by macroeconomic vulnerabilities, including rapid exchange rate depreciation and wider capital outflows.

5. Mitigating climate-related risks

This section considers actions that financial institutions and authorities are taking and/or could take to mitigate risks from climate change. It also considers the extent to which these have been adopted by firms. While a growing number of financial institutions are considering, and taking some action to address, climate-related risks, some authorities find that most institutions in their jurisdiction are not yet taking a sufficiently comprehensive, strategic, and/or long-term approach to addressing climate risks.[102]

Actions taken by individual firms likely go some way in reducing their direct exposures to climate-related risks. However, they may not reduce risks to the financial system as a whole. As described in Section 3**,** some actions taken by financial institutions that are in their *individual interest* could merely shift risks, or amplify risks to the wider financial system. For example, reductions in finance and/or underwriting – including those designed to reduce financial institutions' exposure to climate-related risks – could worsen prospects for economic sectors most exposed to climate risk. In addition, even if a given financial institution has mitigated its direct exposure to climate-related risks, its exposures to other financial institutions – which may themselves have greater direct exposures to climate-related risks – could act to amplify risks to financial stability (see Section 3.2).

The efficacy of actions taken by firms to mitigate their exposure to climate-related risks may be reduced by a lack of data with which to assess their *clients'* exposures to climate-related risks. Substantial progress has been made at the international level to establish voluntary frameworks for disclosure of climate-related risks, including amongst non-financial firms. The TCFD found, however, that while the proportion of companies disclosing climate-related information has increased in recent years, it is still fairly low in absolute terms.[103] The availability of data related to climate risks, along with any potential data gaps, are not discussed further here, but will be the subject of further work by the FSB (see Section 6).

In addition, even where individual financial firms take actions to mitigate risks, climate-related risks to financial stability might be sustained by a lack of disclosure by financial firms of their own financial exposures to climate-related risks and risk management

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102 See Bank of England (2018) and Banque de France (2019), *Climate change: what are the risks to the French financial sector?* Bulletin de la Banque de France 225/8; Banca d'Italia (2020), *The climate risk for finance in Italy*, Questioni di Economia e Finanza (Occasional Papers) Number 545.

103 In a survey conducted by the TCFD none of its disclosure recommendations had been implemented by more than 50% of firms; see TCFD (2019).

processes. For example, a recent TCFD status report found that only 12% of banks surveyed disclose details on their climate scenario analysis.[104] Even if financial firms are taking steps to mitigate their individual exposures to climate-related risks, gaps in information about financial institutions' exposures to climate risk could further contribute to the amplification of risks. This might have wider implications for financial stability (e.g. by causing their creditors to withdraw from lending to exposed institutions) (see Section 3.2).

5.1. Actions by financial institutions

Some financial institutions have incorporated – and could in future continue to incorporate – their exposure to climate risks in their investment, lending and underwriting decisions, and integrated these risks into their broader risk management processes. This might go some way towards limiting firms' exposures to both physical and transition risks (see Section 2). Examples of actions taken by some financial institutions include:

- **Heightened due diligence or categorical rules**. Some financial institutions undertake negative screening in their selection of firms to whom they lend, in which they invest or whom they underwrite. Many financial firms that implement some sort of exclusion policy include industries with high exposure to climate-related risks as part of such policies.[105]

- **Engagement with investees and clients.** Many investors engage collectively with companies in order to encourage them to reduce their emissions.[106] Some banks also engage clients in the energy sector to do so.[107] Insurers are increasingly taking steps to reduce their exposure to climate-related risks by providing incentives for customers to mitigate such risks and guidance as to how they might do so.[108]

- **Use of metrics that track (and in some cases reduce) financial firms' exposures to climate risk.[109]** Within the TCFD framework, such metrics focus on transition risk and include, for example, firms' carbon footprint, carbon intensity, or financed emissions. That said, only a minority of financial institutions define exposure limits based upon these metrics, or use an explicit framework to measure emissions (though some are in the process of developing such frameworks).[110] Specific environmental and climate-risk scores have also proliferated in recent years and gained traction as a tool to support investment decisions and portfolio allocation.

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104 See Task Force on Climate-related Financial Disclosures (TCFD) (2020), *2020 Status Report*, October

105 See J. Colas, I. Khaykin, and A. Pyanet (2019), *Climate Change: Managing a New Financial Risk*, Oliver Wyman.

106 See UN PRI (2020), *PRI Climate Snapshot 2020*.

107 See Boston Common Asset Management (2019).

108 See Geneva Association (2018), *Climate Change and the Insurance Industry: Taking Action as Risk Managers and Investors* and IAIS and SIF (2018) pp 18-20.

109 See IIF and EBF (2020) and UN PRI (2020), *PRI Climate Snapshot 2020*.

110 See IIF and EBF (2020) and J. Colas, I. Khaykin, and A. Pyanet (2019).

- **Integrating climate-related risks into their assessments of borrower credit risk and investment decisions**.[111] In one survey of 45 financial institutions, most respondents that capture climate-related risks in their assessments of borrower creditworthiness reported doing so by adjusting other variables in their credit risk models or making a qualitative override to their internal credit ratings.[112] A minority directly integrate climate-specific variables into their models of credit risk. In a separate survey of 28 large banks, only around a third integrate climate change at *all* stages of the credit risk assessment process.[113,] Newer climate-based models and techniques have also emerged to support management of climate risk in investments. These include climate Value-at-Risk (VaR), which aims to provide a forward-looking and return-based valuation assessment to measure climate related risks and opportunities in an investment portfolio.[114]

- **Integrating climate risk management into institution-wide governance, strategies and risk management frameworks**. Many financial institutions, particularly larger firms, place accountability and management responsibility of climate-related risks with their Board and/or senior management.[115] Many also integrate consideration of climate-related risks into their business strategy.[116] An increasing number of financial institutions are integrating climate-related risks into their overall risk management frameworks, but only a minority do so fully.[117]

  In 2018 in the UK, the Prudential Regulation Authority found that only 10% of banks were taking a strategic, forward-looking view of climate risk, grounded in their long-term interests.[118] The ECB also recently reported that "*the vast majority of banks have not yet established internal processes that allow them to systematically identify and manage climate-related risks*".[119]

- **Financial institutions may use scenario analysis to identify and assess the potential implications of climate change, and to test the resilience of firms' overall approach to climate-related risks.[120]** Scenario analysis is typically based on a range of pathways for the progression of climate change as well as firms' exposures to climate-related risks.[121] Scenarios are hypothetical constructs, not designed to deliver precise outcomes or forecasts, but to let organisations consider how the future

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111 For an overview, see NGFS (2020), Overview of Environmental Risk Analysis by Financial Institutions.

112 See J. Colas, I. Khaykin, and A. Pyanet (2019).

113 See Moody's (2020).

114 See Asset Owners Disclosure Project (2018) *Got it Covered? Insurance in a Changing Climate*. It is unclear how widespread the use of such techniques is at present, however.

115 See CDP (2019), *Global Climate Change Analysis 2018*; UN PRI (2020) and GARP Risk Institute (2020) *Second Annual Global Survey of Climate Related Risk Management*.

116 See CDP (2019); UN PRI (2020); Boston Common Asset Management (2019); ShareAction (2020) *Banking on a Low-Carbon Future II* and GARP Risk Institute (2020) *Second Annual Global Survey of Climate Related Risk Management*.

117 IIF and EBF (2020) and Bank of England (2018).

118 See Bank of England (2018).

119 See ECB (2020), *ECB report on banks' ICAAP practices*.

120 See Task Force on Climate-related Financial Disclosures (TCFD) (2019), *2019 Status Report*.

121 For an overview of these approaches, see BIS (2019), Financial Stability Institute Insight on policy implementation No.20: *Turning up the heat – climate risk assessment in the insurance sector*.

might look if certain trends continue or conditions are met – for example, how various combinations of climate-related risks may affect its businesses, strategies, and financial performance over time. According to some surveys, 16-30%[122] of financial institutions are currently implementing some degree of climate scenario analysis and about the same proportion are working on doing so in the near term.[123]

The major credit rating agencies (CRAs) also now consider environmental, social and governance (**ESG**) **factors, including climate risks, in their ratings, to varying degrees.**[124] Climate risk is a driver of ratings changes in certain sectors, including for sovereigns exposed to climate risk, utilities and power companies, and fossil fuel sectors.[125] However, other evidence, such as work by the Principles for Responsible Investment, has identified challenges to the effective integration of climate risks into credit ratings.[126] These include long and uncertain time horizons, the variability of potential policy measures, and lack of standardised or consistent disclosures by companies.

5.2. Financial authorities' actions

Some financial authorities are exploring possible approaches to reduce climate-related financial risks. They are generally less developed than tools to address other types of financial risk, however.

Microprudential policy

Financial authorities are beginning to assess how climate-related risks are managed by financial firms, and to take actions to encourage firms to mitigate such risks.[127] Most financial authorities have engaged in awareness raising of climate risks and many have surveyed the institutions they supervise to understand how they manage climate risk. Some authorities have issued or are in the process of issuing supervisory expectations, which tend to cover some set of institutional risk management elements (i.e., governance, strategy, scenario analysis, and/or risk management; see Section 5.2). Some financial standard-setting bodies are also starting to work on supervisory guidance related to climate risk.

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122 See FitchRatings (2020), *ESG Credit Trends 2020*; Colas et al (2019); UN PRI (2020).

123 See J. Colas, I. Khaykin, and A. Pyanet (2019) and TCFD (2019).

124 See FitchRatings (2020), *Climate Change Impacts on Sovereign Ratings: A Primer*; Moody's Investment Services (2018), *Heat map: 11 sectors with $2.2 trillion debt have elevated environmental risk exposure*; S&P Global Ratings (2017), *How Environmental and Climate Risks and Opportunities Factor Into Global Corporate Ratings - An Update*.

125 One credit rating agency identified 10 sectors where carbon transition risk is already a significant credit consideration and a further 22 sectors with moderate credit exposure to environmental and climate risks. Moody's Investment Services (2018) *Heat map: 11 sectors with US$2.2 trillion debt have elevated environmental risk exposure*. Another found that climate change materially influenced approximately 10% of ratings actions in recent years; see S&P (2019), *Environmental, Social, And Governance: Delays In Addressing Global Warming And The Longer-Term Ratings Implications*.

126 See UN PRI, *Credit risks and ratings initiative*.

127 See FSB (2020).

Macroprudential policy

Three-quarters of financial authorities are considering climate risks in their financial stability monitoring and some are starting to quantify those risks.[128] Scenario analysis (see above) can be used by financial authorities to quantify the totality of exposures of financial institutions to climate-related risks within their jurisdiction (this is sometimes called a 'climate stress test').[129] Such estimates are similar to firm-specific scenario analysis described above, but are based on a common scenario (or scenarios) specified by financial authorities, which allow for a comparison of results across firms. To date, such scenario analysis is being developed by the Bank of England, Banque de France/ACPR, and the European Central Bank.[130] Other financial authorities have said they plan to run analyses along similar lines in the future.[131]

Some authorities have also voiced support for considering macroprudential policies to mitigate the climate related risks to financial stability.[132] Due to the inherent uncertainty of climate risks and its systemic nature, consideration might be given to the possible use of macroprudential instruments, which may be used to build resilience.

6. Next steps

The FSB will conduct further work to assess the availability of data through which climate-related risks to financial stability could be monitored, as well as any data gaps.

This further work will be completed by October 2021.

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128 *Ibid*.

129 *Ibid.*

130 *Ibid*.

131 See M. Carney (2020), *The Road to Glasgow*.

132 F. Villeroy de Galhau (2018), *Green finance – A new frontier for the 21st century*, Bank of International Settlements; P.R. Lane (2019), *Climate Change and the Irish Financial System*, Economic Letter Vol.2019 No.1.