FSB FINANCIAL STABILITY BOARD

The Availability of Data with Which to Monitor and Assess Climate-Related Risks to Financial Stability

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Executive summary

Climate-related risks differ from other risks to financial stability. They are global in nature, but their effects differ substantially across entities, sectors and economies, depending on their locations and activities. Climate-related risks may be highly non-linear, and their effects on the financial system subject to substantial uncertainty and tail-risk. The breadth of climate-related risks – including their possible simultaneous crystallisation across multiple jurisdictions and sectors – also has implications for the resilience of the financial system. Their crystallisation may result in sharp increases in the correlation of risk premia across different assets, and could be amplified by the interaction of different financial sectors or through feedback loops with the real economy.

Data to monitor and assess climate-related risks to global financial stability should therefore:

- Capture *exposures of financial firms to climate-related risks*, particularly those of a scale or concentration that might threaten financial stability. This requires data on financial firms as well as non-financial firms to which they are exposed. These data need to be sufficiently granular to capture differences between entities' locations and activities – as well as their broader operating environments and supply chains – at the level of individual firms and sectors.

- Support a *global comparison and aggregation* of financial firms' exposures to climate-related risks. Data need to be reliable and comparable across jurisdictions, firms and sectors. Common metrics of the broader potential effects of climate-related risks on financial firms, including those arising via their impact on the macroeconomy, are also needed.

- Support *forward-looking assessments* of climate-related risks to financial stability. Historical data on exposures to climate-related risks, as well as their impact where they have crystallised, may be a poor guide to the nature and scale of future risks. Forward-looking metrics (e.g. climate-value-at-risk) can help capture uncertainty and potential tail risks concerning the impact of climate change on both non-financial and financial firms.

- Capture climate-related *risk transfer and mitigation*. Climate-related risks may be transferred via the provision of insurance or through financial markets. Data on the holders of such financial instruments, the penetration of insurance and gaps in the protection it provides, as well as the provision of government guarantees and subsidies, can support assessments of the future availability, reliability and effectiveness of such risk transfer and mitigation.

There remain limitations and gaps in the availability of data along all these dimensions:

- A growing number of *firms (both financial and non-financial) disclose data on their exposures* to climate-related risks. However, absent globally consistent international reporting standards of the sort that apply to other financial risks, such disclosures lack consistency across firms, sectors and jurisdictions.

- Data on *entities' exposures to the drivers of physical risks* (e.g. severe weather events, policies to reduce emissions) lack consistency and granularity. There is also a lack of data on firms' supply chains, as well as the broader potential impact of the crystallisation of

physical and transition risks on such supply chains, the macroeconomy, and how physical and transition risks might transmit across sectors.

- Some information on exposures to *transition risk* is provided by rating and classification systems (e.g. ESG ratings and climate classification systems and taxonomies). Such information is designed for purposes other than risk management, however. Differences in their construction across jurisdictions and providers also limit their use in assessing transition risks.

- A lack of granular data on *financial institutions' exposures* in some jurisdictions may prevent the assessment of climate-related risks, particularly where they are concentrated in certain financial institutions or counterparties. The potential impacts of climate-related risks on financial institutions are subject to substantial uncertainty. This uncertainty is not captured by standard financial metrics of their central expectations (e.g. loss-given-default).

- *Forward-looking financial metrics* of the potential future impact of the crystallisation of climate-related risks on the financial system (e.g. climate-value-at-risk and implied temperature increases) offer insight into the nature and degree of the uncertainty concerning such risks. Further work is needed to develop these metrics and improve their consistency across firms and jurisdictions.

- *Scenario analysis* is increasingly being used to generate insights into the future resilience of the financial system to climate-related risks. Continued development of methodologies and forward-looking data will further improve their effectiveness.

- Some of these data gaps are particularly acute in some emerging market and developing economies (EMDEs), particularly where there are few resources to collect and process data.

The following priority areas of work – some of which are already in progress – should address certain important data gaps to improve the monitoring and assessment of climate-related risks to financial stability. Work in these areas should be undertaken in a manner appropriate to authorities' mandates and domestic legal frameworks.

- Financial authorities, in cooperation as appropriate with other official-sector bodies, should work to improve the availability and consistency of data on the underlying drivers of climate-related risks. In doing so, financial authorities should consider, the data needed to understand entities' exposures to physical risks, as well as comparable data on the scale and nature of jurisdictions' climate-change targets and progress in meeting them.

- The FSB welcomes the IFRS's programme of work to develop a baseline global sustainability reporting standard under robust governance and public oversight, built from the TCFD framework and the work of an alliance of sustainability standard setters, involving them and a wider range of stakeholders closely, including national and regional authorities. This work will begin with consistent corporate disclosures regarding climate-related financial risks, building from a framework based on TCFD Recommendations and the work of the alliance of sustainability standard-setters as the basis for climate-related financial disclosures. Such international standards for disclosures as a global baseline would not preclude authorities from going further or at a faster pace in their jurisdictions.

- Financial authorities should consider how to improve the quality and consistency of data on financial institutions' exposures to climate-related risks arising from their exposures to non-financial counterparties, including exposures that arise due to firms' supply chains.

- Financial authorities should consider developing – including via their engagement with private-sector providers of data – forward-looking metrics on climate-related risks, both at the level of individual firms and the financial system as a whole.

- Financial authorities should work together to widen and harmonise data on the degree to which individual financial institutions' exposures to climate-related risks are mitigated by insurance provision.

- The FSB should bring financial authorities together to compare their experiences of implementing scenario analysis as a means of assessing the resilience of the financial system to climate-related risks, and to identify relevant data gaps. Such data gaps might include those concerning data and metrics necessary to assess the degree to which climate-related risks might be amplified and mitigated by the actions of different financial sectors, and by feedback loops with the real economy.

- The NGFS should continue its work to refine and develop scenarios, which financial authorities should make use of in their scenario analysis, as appropriate, in order to align the data and methodologies used in such analysis.

Table 1: A summary of the features of climate-related risks, implications for the data required to monitor and assess them, and related data gaps and challenges

Features of climate-related risks	Implications for data needed to monitor and assess risks	Data gaps and challenges
Climate change is inherently global in nature and could affect multiple jurisdictions, entities and markets simultaneously. Its effects vary substantially depending on economic environments (location, production patterns) of entities, sectors, and economies.	• Need data that are sufficiently consistent across jurisdictions, sectors and firms to facilitate a comparison of climate-related risks globally. • Need data on the broader potential impact of climate-related risks on entities' supply chains and macroeconomic environment. • Need data granular enough to capture (i) the degree to which differences in entities' economic environments affect their exposure to climate-related risks, and (ii) differences between – and concentrations of risk within – financial firms' exposures.	• Disclosures of climate-related risks lack consistency across firms, sectors and jurisdictions (absent globally consistent international reporting standards). • Lack of data on firms' supply chains, the broader impact of physical and transition risks on such supply chains and the macroeconomy, as well as how the crystallisation of physical and transition risks might transmit across sectors and borders. • Lack of granular data on financial institutions' exposures may prevent the assessment of climate-related risks, particularly where they are concentrated in certain financial institutions or their counterparties.
The underlying drivers of climate-related risks are not economic in nature, and lie beyond the constellation of data normally considered by financial authorities. Climate-related risks are subject to considerable uncertainty and tail risk.	• Need information and tools with which to translate outcomes for climate change – as well as policies to mitigate and adapt to their effects – into economic variables and changes in cash flows and the value of assets and liabilities. • Need metrics of climate-related risks that account for uncertainty and tail risks.	• Lack of historical data to assess the impact of the crystallisation of climate-related risks on financial firms. • Lack of consistent forward-looking metrics across firms and jurisdictions that provide information on uncertainty and tail-risks of exposures to climate-related risks (e.g. climate-value-at-risk).
The pervasive nature of climate-related risks may affect financial stability both through financial institutions' exposures and the availability of risk transfer and mitigation. The widespread nature of climate-related risks may lead to sharp increases in the correlation of risk premia on different assets Non-linearities in the drivers of climate change, and its corresponding climate-related risks mean that past data are a particularly poor guide to the scale and nature of future risks, and the financial system's resilience to these.	• Need data on financial exposures to climate-related risks in the non-financial sector and the degree, effectiveness and future availability of climate risk transfer, insurance availability and other risk mitigation mechanisms. • Need to use scenario analysis to explore the future evolution of different combinations of climate-related risks and their effects on the financial system. • Such scenario analysis should consider the degree to which climate change could be amplified by the interaction of financial sectors and activities, and via feedback effects with the real economy.	• Lack of data to measure the degree to which the financial system exposures to climate-related risks are transferred via insurance and financial securities (e.g. insurance-linked securities or catastrophe bonds). • Lack of data and metrics necessary to assess the degree to which climate-related risks might be amplified or mitigated by the actions of different financial sectors (including the interdependence of banks and insurance firms), and by feedback loops with the real economy.

1. Introduction

This report examines the availability of data with which to monitor and assess climate-related risks to financial stability. It is the latest in a series of FSB reports concerning climate change. These include the FSB's *stocktake of financial authorities' experience in including climate risks as part of their financial stability monitoring,* which was published in June 2020;[1] and *The Implications of Climate Change for Financial Stability*, which was published in November 2020.[2]

Risks to financial stability from climate change differ in their nature and magnitude from other risks to the financial system.[3, 4] Climate change is a global phenomenon and can impact financial systems across all jurisdictions. However, its impact differs substantially across entities, sectors and economies, depending on their locations, assets and activities. Climate-related risks may be highly non-linear, and their effects on the financial system subject to substantial uncertainty and tail risk. The breadth of climate-related risks – including their possible simultaneous crystallisation across multiple jurisdictions and sectors – may also affect the resilience of the financial system. The crystallisation of climate-related risks may also result in sharp increases in the correlation of risk premia across assets, and be amplified by the interaction of different financial sectors or through feedback loops with the real economy.

The specific nature of climate-related risks has a bearing on the data needed to monitor and assess their implications for financial stability. First, data should capture the drivers of physical and transition risks that could affect the value of assets and liabilities.[5] Second, data are needed on the exposures of entities, sectors and economies to these risks. One key challenge in this regard is translating environmental and other non-economic data into metrics that allow for a quantification of financial risks. Third, data are needed to assess financial systems' exposures to climate-related risks, including via their exposures to individual entities, sectors and economies, including those exposures that arise from firms' supply chains. Such data also need to shed light on the degree to which such exposures are affected by the transfer of risk via both insurance and financial instruments. Finally, there is a need for data that support assessments of the financial system's resilience to climate-related risks. Uncertainty concerning the nature and magnitude of climate-related risks, combined with their non-linearity, long time-horizons and interaction with the macroeconomy, underlines the importance of data that support forward-looking assessments of risk, including those obtained from scenario analysis.[6]

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1 FSB (2020a), *Stocktake of financial authorities experience in including physical and transition climate risks as part of their financial stability monitoring*, July.

2 See FSB (2020b), *The implications of climate change for financial stability*, November.

3 *Ibid.*

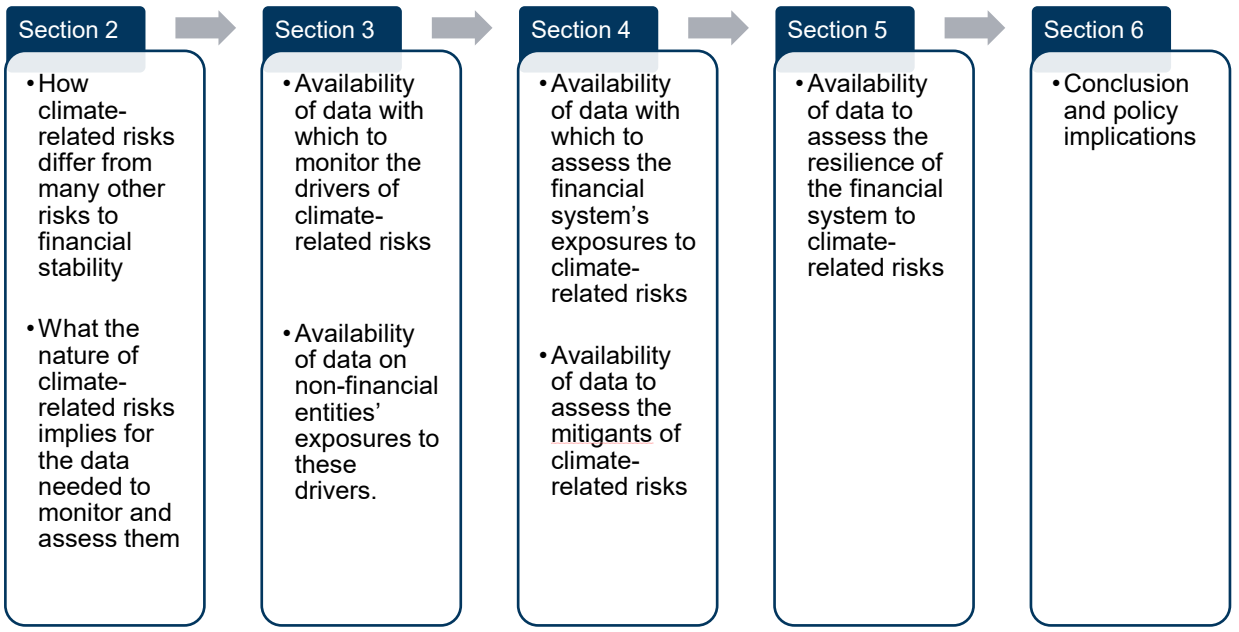
4 Climate-related risks to the financial system comprise both vulnerabilities (properties of the financial system that may lead to systemic disruptions) and potential shocks (that act upon such vulnerabilities).

5 Physical risks refer to the economic effects of the increasing severity and frequency of extreme weather events, as well as more gradual changes in the environment (e.g. increases in sea level), due to climate change that might erode the value of financial assets or increase liabilities. Transition risks relate to the process of adjustment towards a low-carbon economy, and the possibility that changes in policies, technologies, or consumer preferences to mitigate and adapt to climate change could affect the value of financial assets and liabilities

6 The financial system may, through the pricing of climate related risks and the allocation of finance, affect climate risk. For example, financing of green investment may reduce climate risks over time. Such potential endogeneity of climate change to the financial system is not considered in this report, however.

The report is structured as follows. The next section discusses in more detail how climate-related risks differ from many other risks to the financial system, and what this implies for the data needed to monitor and assess them. Section 3 examines the availability of data with which to monitor the drivers of climate-related risks, as well as non-financial entities' exposures to them. Such entities include non-financial corporates, which account for the majority of financial firms' exposures to climate-related risks, as well as households and sovereigns. Section 4 focusses on the availability of data with which to assess the financial system's exposures to climate-related risks, including via financial firms' exposures to the non-financial entities discussed in Section 3. It also discusses the availability of data to assess the mitigation and transfer of climate-related risks to and across financial firms, including via the provision of insurance and via securities. Section 5 examines the availability of data with which to assess the resilience of the financial system to climate-related risks. This includes data needed to assess the resilience of financial markets and institutions to climate-related risks, including via scenario analysis. A final section concludes and discusses the implications of this report for policymakers. This includes discussion of priority areas of work – some of which are already in progress – that should be undertaken to address the data gaps discussed earlier in the report. This is summarised in Figure 1.

The structure of this report **Figure 1**



This report was prepared in close coordination with other international bodies and draws on a number of inputs. In particular, it has benefited from contributions from the BCBS, IAIS, IMF, IOSCO, OECD and the World Bank. It has also been informed by the work of the Task Force on Climate-related Financial Disclosures (TCFD). Details of the work of the TCFD, and industry progress in making disclosures in line with its recommendations, are given in Annex 2. Other inputs include a survey of members of the FSB's Analytical Group on Vulnerabilities (AGV), which gathered information on the data FSB member authorities use to monitor and assess climate-related risks to financial stability (see Annex 1 for details). The FSB also held a workshop with representatives of the private sector and academia to examine their use of data in this area, a summary of which is given in Annex 3.

The report complements the NGFS's Workstream on Bridging Data Gaps. This NGFS workstream is undertaking a more comprehensive assessment of the availability of data, including to facilitate the scaling up of green finance. A progress report by the NGFS released in May highlights data gaps in this regard as well as guidance and recommendations as to how these can be addressed.[7]

2. The nature of climate-related risks to financial stability and implications for the data needed to monitor and assess them

Climate change is inherently global in nature and has the potential to impact multiple sectors, markets and jurisdictions. The severity and frequency of extreme weather events, as well as more gradual changes in climate, are likely to reflect worldwide trends in climate change. Similarly, policy measures in one jurisdiction can foreshadow – or may be perceived to foreshadow – those in others, including international agreements to coordinate emissions reductions targets. There may also be spillovers across sectors, both due to the length and complexity of firms' supply chains, and due to the potential for the crystallisation of physical and transition risks to impact the broader global macroeconomy.

The effects of climate change also vary substantially due to differences in the locations and economic environments of entities, sectors and economies. Slight differences in the location of firms' operations and assets – as well as those of their customers and suppliers – can result in radically different physical risks. Small variations in firms' activities – for example, their reliance on renewable energy, or how sustainably their products are used – can vastly alter their vulnerability to a possible transition to a low-carbon economy. Differences in regulation across jurisdictions also result in differing policy and regulatory regimes that result in differences in transition risk for similar activities across countries.

Monitoring and assessing climate-related risks to financial stability therefore requires consistent data across jurisdictions to facilitate a global comparison of risks, and data that are granular enough to capture variation in entities' locations and economic environments, as well as interlinkages via their supply chains. Such granular data are also instrumental in uncovering concentrations of exposures to climate-related risks of individual financial firms and their counterparties, including those of a scale sufficient to affect financial stability.[8] They also aid individual firms' and financial authorities' understanding and pricing of climate-related risks, and allow market participants to price, manage and internalise them. To the extent that this strengthens the resilience of financial institutions and markets to climate-related risks, it also helps underpin financial stability.

The underlying drivers of climate-related risks are not economic in nature, and financial authorities do not typically collect data on their nature and scale. This complicates the process of assessing climate-related risks to financial stability. For example, assessing climate-related risks requires data and tools with which to translate the effects of extreme weather events, or

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7 See Network for Greening the Financial System (2021), Progress report on bridging data gaps.

8 FSB (2020b), Section 2.ii.

changes in the cost or permitted quantity of entities' emissions, into changes in the value of financial assets and liabilities. Similarly, measuring the impact of policies to reduce emissions requires data with which to assess the impact of decreases in – or increases in the price of – carbon emissions on firms' cash flows and balance sheets.

The exposure of the financial system to climate-related risks is also subject to substantial uncertainty. The underlying drivers of climate-related risks, including the future path of emissions, are themselves highly uncertain. Estimates of increases in global temperatures and changes in both the physical and transition risks also vary considerably. The potential impact of the crystallisation of such risks on the financial system and macroeconomy is subject to considerable tail risks. These multiple layers of uncertainty mean that the impact of climate-related risks on the financial system is subject to uncertainty that may exceed that concerning other types of financial risk.

Metrics of the exposure of the financial system to climate-related risks should incorporate and convey information on the scale of these uncertainties and associated tail-risks. Such information needs to go beyond that incorporated in standard metrics of financial risk, many of which focus on central expected outcomes (for example, probabilities or losses-given default). Metrics of exposure to climate-related risks can offer insight into the wider distribution of the impact of risks. They should, to the extent possible, also be forward looking, and incorporate an assessment of how risks may change in the future including due to the non-linearities in their underlying drivers (see below).

The far-reaching nature of climate change means that it can affect not only entities' exposure to climate-related risk (including that incurred via their supply chains), but also the effectiveness of risk transfer and mitigation mechanisms. Quantifying the potential impacts of the crystallisation of climate-related risks on the financial system therefore requires data on the entities exposure to these risks, as well as their mitigation – including through the transfer of risks via insurance provision and via financial instruments. It also requires information on future availability of such insurance, including that provided via official-sector guarantees and subsidies. This is because the widespread crystallisation of climate-related risks (and losses incurred by insurance firms) could lead – and may already be leading – to a reduction in the availability of insurance. The efficacy and reliability of risk transfer via financial securities also depends on securities holders' ability to absorb losses arising from the crystallisation of risks, including in circumstances where they crystallise in scale.

Data on past changes in climate may also be a particularly poor guide to future climate-related risks to the financial system. This is because future changes in the drivers of climate-related risks may be non-linear, and prone to rapid acceleration.[9] Increases in global temperatures may also be subject to positive feedback effects, as they could prompt an increase in emissions levels that themselves cause further increases in temperatures. This reduces the degree to which historical trends can serve as a guide to the future magnitude and dynamics of climate-related risks.

9 See FSB (2020b).

Table 2: Data required to monitor risks to financial stability under different scenarios (scenarios are taken from NGFS (2019)).[10]

(C) Disorderly transition: sudden and unanticipated policy response causes disruptive but sufficient enough to meet climate goals **Requires data on the** • Effects of sharp changes in cost and quantity of emissions on the financial system. • Effects of sharp changes in energy sources (e.g. from fossil fuels to renewables) • Effect of other government policies to curb emissions (e.g. direct regulation, subsidies) and changes in consumer preferences on supply/demand across sectors and geographies. • Sectors of the economy at most risk of technological disruption.	**(D) Too little, too late: We don't do enough to meet climate goals, the presence of physical risks spurs a disorderly transition** **Data requirements are a combination of those in (B) and (C)**
(A) Orderly transition: We start reducing emissions now in a measured way to meet climate goals In this scenario risks to financial stability are more minimal but there may be material impacts to specific counterparties and sectors. This may require data on the: • Relative ease with which companies and sectors can reduce their emissions	**(B) Hot-house world. We continue to increase emissions, doing very little, if anything, to avert the physical risks** Requires long-run data on the: • Effects of increased frequency and severity of extreme weather-related events – as well as more gradual changes in climate – on the financial system. • Measures being taken to adapt to greater physical risks across different countries/sectors

Increasing transition risks…

Increasing physical risks…

Some financial authorities and firms have used scenario analysis to address these issues. This analysis typically examines the economics effects of future possible pathways for a range of variables related to climate change, including climate policy, technology and consumer or investor preferences.[11] Doing so can provide a framework with which to examine the potential effects of climate-related shocks on the financial system, including those whose scale may exceed those witnessed previously.[12]

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10 See NGFS (2019), *A call to action - Climate change as a source of financial risks*, April, p 21.

11 See NGFS (2020), *Guide to climate scenario analysis for central banks and supervisors*, June.

12 *Ibid*.

Such scenario analysis should, to the extent possible, provide a basis for the consistent examination of different combinations of climate-related risks across different jurisdictions and sectors. Any given scenario should consist of a coherent set of outcomes for future global temperature increases and changes in emissions as well as assumptions as to the nature and timing of climate-related policies and technological developments. These variables also require translation into economic and financial outcomes, including their effects on the balance sheets and cash flows of affected firms. Multiple scenarios can also be used to capture different combinations and interactions of physical and transition risks. For example, a sudden and unanticipated policy response to climate change could reduce future physical risks, but generate a disorderly adjustment to a low-carbon economy that could prompt the crystallisation of some transition risks. Conversely, avoiding or deferring such an adjustment might reduce near-term transition risks, but lead to greater physical risks in the longer-term. Some illustrative scenarios – together with a high-level illustration of their possible data requirements – are shown in Table 2.

Scenario analysis – and other forward-looking assessments of climate-related risks – should also capture the degree to which the crystallisation of climate-related risks might be amplified by the interaction of different financial sectors, as well as feedback loops with the real economy. The crystallisation of climate risks could trigger widespread reductions in bank lending, either due to reductions in the availability of insurance (see above), or due to widespread losses for the financial sector that amplify the effect of climate-related risks on the real economy, and result in larger and self-reinforcing losses for banks.[13]

3. Availability of data with which to assess the exposure of non-financial entities to climate-related risks

This section examines the availability of data to assess the exposure of non-financial entities to climate-related risks. These non-financial entities, including firms, sovereigns and households, constitute the majority of financial firms' exposures to climate-related risks.[14]

Assessing the exposure of such entities to climate-related risks requires two types of data:

- First, data on the drivers of physical and transition risks – e.g., information on the current and projected future hazard events, such as the occurrence of extreme weather events (as well as more gradual changes in climate) across different locations; and on how official sector policies are likely to affect the operations and profitability of entities' activities (as well as those of their supply chains).

- Second, data on the exposures of non-financial entities to physical and transition risks. This includes data on the location of entities' operations, assets and supply chains, as well as the sensitivity of their balance sheets and cash flows to the price and quantity of emissions. Crucially, it also includes information on the sensitivity to climate-related risks of entities' broader operating environments and macroeconomies.

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13 See FSB (2020b).

14 See NGFS (2020), *Overview of Environment Risk Analysis by Financial Institutions*, September. While financial institutions may have direct exposures to environment- and climate-related risks (for example, their headquarters may be located in coastal areas at risk of flooding), most exposures are indirect and arise from their clients' and investees' exposures to these risks.

These two types of data are examined in turn. Throughout, the availability of data to assess risks to financial stability is judged against the requirements set out in Section 2. That is, the degree to which data on the exposure of non-financial entities to climate-related risks are consistent and comparable across jurisdictions, sectors and firms, and granular enough to capture significant differences in climate-risk exposures that arise from differences in entities' locations and activities.

3.1. Data on the drivers of climate-related risks to non-financial entities

3.1.1. *Drivers of physical risks to non-financial entities*

Data with which to assess the drivers of physical risks include both those on the prevalence of extreme weather events across geographic locations, as well as on more gradual changes in climate. The most commonly used data on extreme weather events are those on the prevalence of flooding, droughts, wildfires and storms.[15] Data with which to monitor more gradual changes in climate includes those on projected sea-level rise or concentrations of hazardous airborne pollutants. Existing data generally provide information on the past and future predicted occurrence of physical risks at a given location or across a set of locations.

Existing data on drivers of physical risks differ in terms of their scope – that is, the breadth of locations and types of physical risks they incorporate – and their spatial granularity. This is illustrated in Table 3. On the one hand, some data are wide in scope, and provide aggregate information on the prevalence of multiple types of physical risks across multiple locations globally. For example, one frequently used dataset on the prevalence of physical risks is the ND-Gain Index, which provides information on changes in climate across different countries.[16] Such data typically combine information on physical risks from a number of data sources, and have the advantage of being simpler, and less computationally intensive, to analyse. They are frequently used in studies that aim to assess the drivers of physical risks at the jurisdictional level.[17]

Conversely, other data are more spatially granular – that is, available at a finer spatial scale – but are only available for certain types of physical risks in some jurisdictions.[18] These data have the advantage of providing information on how small differences in location can result in large changes in the drivers of physical risks – for example, differences in the prevalence of flooding across locations that are geographically proximate, but differ in elevation. They are therefore

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15 35% of survey respondents reported using data to monitor the susceptibility of assets to flood risks, 20% to storms (including tropical storms and hurricanes), and 15% to droughts. Similarly, 15% of the datasets examined in the literature review concern flooding, and about 35% concern flooding, sea level rise, droughts, and typhoons.

16 Another example is the Centre for Research on the Epidemiology of Disasters' *Emergency Events Database (EM-DAT)*, which provides data around the world on the occurrence of over 22,000 mass disasters, including on floods, wildfires, glacier outbursts, droughts, and snowstorms. The location of the disasters is generally given at regional level.

17 For example, the ND-GAIN index has been used to measure the macro-financial aspects of climate change across jurisdictions. See, for example, E. Feyen, R. Utz, I. Zuccardi Huertas, O. Bogdan, J. Moon (2020), *Macro-Financial Aspects of Climate Change*, Policy Research Working Paper No. 9109, World Bank.

18 For example, Banque de France and ACPR's pilot climate exercise includes data on air quality degradation at the level of different regions within France; the UK's Environment Agency's flood risk planning maps that show the flood zone in which a property is situated. Other financial authorities have also conducted quantitative analysis of the impact of floods on non-financial firms using flood statistics pertaining to certain jurisdictions; see Bank of Japan (2021), Financial System Report, April.

generally used in more detailed studies where this information is particularly pertinent for certain jurisdictions, such as of the effect of flooding on coastal property in Europe and Asia,[19] and the effect of extreme heat on agriculture and the financial impact of droughts[20] in Central and South America.[21] One example is geospatial data, which provides detailed information on the physical location of assets, and that be used in conjunction with advanced data analysis techniques to forecast the effects of physical risks.[22]

Table 3: Selected data on the drivers of physical risks to non-financial entities, by geographical scope and granularity[23]

Spatial Granularity Scope	Country	Region (county, etc)	Municipality or zip code	Street or exact location
Global	• The ND-GAIN Country Index • Germanwatch Global Climate Risk Index	• Maplecroft Climate Change Vulnerability Index • International disasters (EMDAT) database • Sigma explorer from SwissRe	• University of East Anglia Climatic Research Unit data	
Individual jurisdictions			• ARCLIM (Climate Change Risk Atlas) (CL) • ISPRA flood risk maps (IT) • Flood statistics (JP) • Drought Vulnerability Indices (MX)	• Flood hazard maps from the Environment Agency (UK) • Flood hazard map (JP)

There is, however, a lack of globally comprehensive granular data on the drivers of physical risks across different locations. Survey respondents report that this prevents comparison of the drivers of physical risks across jurisdictions globally. This data gap prevents the comparison of physical risk exposures of non-financial entities (and thus financial institutions) across jurisdictions, particularly where granular locational data is crucial in determining entities' exposures (e.g. in the case of mortgage lending, see Section 3.2).

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19 For example, see L. Bakkensen and L. Barrage (2017), *Flood Risk Belief Heterogeneity and Coastal Home Price Dynamics: Going Under Water?*, Working Paper No. 23854, National Bureau of Economic Research.

20 Assunção, J., Chein, F., Frisari, G. and Koyama, S. (forthcoming), *Another boiling frog: the impact of climate-related events on financial outcomes in Brazil*.

21 Banco de México (2020), *Financial Stability Report*, December.

22 UK Geospatial Commission (2020), Unlocking the power of location.

23 These data are not exhaustive; rather they are illustrative examples based on the results of the survey (see Annex 1). Some data are on the susceptibility of assets to extreme weather events, others to more gradual changes in climate.

3.1.2. *Drivers of transition risks to non-financial entities*

Data used to assess drivers of transition risks to non-financial entities typically aim to examine how official-sector policies designed to facilitate the transition to a low carbon economy – as well as shifts in consumer preferences and technology – affect firm and household balance sheets.[24] Such data are often aggregated into metrics of 'shadow carbon prices' that aim to show the cost to corporates and households of changes in the future cost and quantity of greenhouse gas emissions (either through government taxes or official-sector limits on such emissions), as well as changes in energy demand, government subsidies or anticipated technological disruptions.[25,26]

Firms having sufficient expertise and modelling capabilities can use climate data themselves to estimate such metrics. However, few organisations – particularly smaller entities with fewer resources – have sufficient expertise and resources to estimate such risk factors in-house. As such, a number of data providers and international organisations provide 'off the shelf' paths of future carbon prices under different scenarios for the future transition to low carbon emissions. These are also frequently used in scenario analysis of the future impact of transition risks (see Section 5).

3.2. Data on non-financial entities' exposure to climate-related risks

3.2.1. *Non-financial entities' exposures to physical risks*

Assessing non-financial firms' vulnerability to physical risks is frustrated in part by a lack of data on the locations of their assets and activities. 32% of financial authorities from surveyed jurisdictions reported that they lack data on the location of firms' and households' assets (including location data for mortgage collateral).[27] Where such data are available, they generally include only the location of the headquarters or central site of firms' operations, rather than that of their broader operations and supply chains. This makes assessments of exposure to physical risks particularly uncertain in the case of larger firms with multiple commercial locations.

There are also a number of challenges in matching data on the location of entities with that on the drivers of physical risks across these locations. Data on location of entities and drivers of physical risks may lack a common 'data key' that facilitates their aggregation. Survey respondents report, for example, that data on non-financial entities' locations (such as mortgage collateral) frequently take the form of postal codes, whereas those on the drivers of physical risk

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[24] Some countries have considered introducing direct emission taxes or other strict emission curtailing measures. Others are attempting subsidies for electric vehicles or reduced emissions According to the International Energy Agency, the potential for the removal of global fossil-fuel subsidies amounted to USD320 bn in 2019.

[25] Some studies estimate the exposure of firms and households to transition risk by using data on energy consumption and prices to estimate the sensitivity of their energy demand to changes in energy in prices, including those that could result from carbon taxes; see, for example, Faiella, I et al (2021), 'A bottom-up climate stress-test of households and firms'.

[26] In the case of sovereigns, the *Climate change performance index (CCPI)* tracks countries' efforts to meet the goals of the 2015 Paris Agreement. This index may be used as a proxy for transition risks, at least to the extent that countries that have made less progress in meeting such goals can be assumed to be more exposed to transition risks.

[27] Several workshop participants also raised this issue. One said that they were able to obtain data on the location of only 10% of the assets of firms they analysed.

may be in the form of geo-locational grids of various formats, and spatial resolutions. Matching these data types may require significant computing skills and human judgement.[28]

Efforts to quantify the exposure of non-financial entities to physical risks tend to focus on the immediate impact of the crystallisation of risks on firms themselves, rather than their broader operating environments. Studies generally focus on the monetary cost of damages incurred by firms from severe weather events. These are quantified through variables such as output, profitability ratios, total factor productivity, or credit constraints.[29]

There is, however, a lack of data with which to quantify the broader exposure of non-financial entities to physical risks, including those arising via their supply chains. Physical risks have the potential to impact non-financial entities via their effects on their supply chains, meaning that data on the location of a firm's headquarters and assets may not be sufficient to assess fully its exposure to physical risks. Such exposure might extend beyond a firm's own production, storage and distribution facilities, but also to those of its suppliers and customers.[30] Such broader exposures to physical risks are generally harder to quantify, however, given the increased complexity of supply chains, including those that span multiple jurisdictions.[31, 32]

There is also very limited data available on the broader – and potentially substantial – effects of physical risk on the macroeconomy. There is evidence that the longer-term macroeconomic effects of a gradual increase in global temperature may be greater than the impact of natural disasters alone in some jurisdictions. For example, some analysis suggests that changes in temperature and precipitation in some countries are likely to have profound effects on labour force productivity in some jurisdictions.[33] There is, however, a lack of timely and consistent data on such effects – particularly those that lie outside of historical experience, or that arise due to events that are low frequency.[34] As a result, it is likely that existing data give rise to underestimates of the full extent of physical risks.

A more holistic assessment of entities' exposure to physical risks is also confounded by a lack of data on the degree to which the impact of the crystallisation of physical risk might transmit across different sectors. Physical risks have the potential to affect government finances via the reduced tax revenues from impaired households and firms. Higher government spending may result from efforts to compensate for the broader negative macroeconomic impacts of natural disasters on local economies. The impairment of corporates might also compound the impact of

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28 See, for example, N. Garbarino and B. Guin (2020), *High Water, No Marks? Biased Lending after Extreme Weather*, Staff Working Paper, Bank of England.

29 See, for example, M. Dell, B. Jones and B. Olken (2012), *Temperature Shocks and Economic Growth: Evidence from the Last Half Century*, American Economic Journal: Macroeconomics 4(3): 66–95; H. Hong, F. Li and J. Xu (2019), *Climate risks and market efficiency*, Journal of Econometrics 208 (1): 265-281; P. Zhang, O. Deschenes, K. Meng and J. Zhang (2018), *Temperature effects on productivity and factor reallocation: Evidence from a half million Chinese manufacturing plants*, Journal of Environmental Economics and Management 88: 1-17; B. Collier, A. Haughwout, H. Kunreuther and E. Michel–Kerjan (2019), *Firms' Management of Infrequent Shocks*, Journal of Money, Credit and Banking 52(6): 1329–1359; J. Brown, M. Gustafson and I. Ivanov (2020), *Weathering Cash Flow Shocks*, Working Paper.

30 See Basel Committee on Banking Supervision (BCBS) (2020), *Climate related risk drivers and their transmission channels*, April.

31 See V. Andreoni and A. Miola (2014), *Climate Vulnerability of the Supply-Chain: Literature and Methodological review*, Publications Office of the European Union.

32 One prospective source of data as to the broader effects of physical risks are disclosures in line with Taskforce for Climate-related Financial Disclosures (TCFD). For further details see Annex 2.

33 See FSB (2020b).

34 Some insurance firms vary the pricing of general insurance policies on the basis of investments made by policyholders to protect against the effects of physical risks; it is unclear, however, to what degree these are systemically reported.

physical risks on local employment prospects. However, data that link the impact of physical risks on these different sectors tend to be far harder to source than those on the more immediate effects of physical risks.

Finally, there is also very limited quantitative data available on adaptation measures taken to protect entities and their assets against physical risks. Such information is hard to quantify, because it generally involves measures (e.g. flood defences) that reduce the potential impact of physical risks in ways that are difficult to measure and compare across entities. Several survey respondents suggested the need for more data on firms' strategies to adapt to climate change.

3.2.2. *Non-financial entities' exposure to transition risks*

There are generally more data with which to assess the exposure of non-financial entities to transition risks than to physical risks. This is in part due to the increasing number of firms that disclose their exposure to transition risks. Such disclosures include both information on firms' exposure to transition risks (e.g. via their greenhouse-gas (GHG) emissions), as well as information on targets adopted by firms to manage and reduce their emissions. All else equal, firms that give rise to greater emissions – or those with less stringent targets for the reduction in such emissions – are likely to be more exposed to transition risks as they will be more affected by official-sector measures to reduce emissions (or increase their costs). The proportion of firms disclosing such emissions has increased in recent years. Around a quarter of firms recently surveyed by the TCFD report emissions on a Scope 1 or Scope 2 basis.[35]

However, the extent of such disclosures currently varies considerably according to firms' size, sector and region, as well as the scope of their activities. Disclosures are more prevalent amongst large companies. A TCFD survey of 1,701 large firms across 69 jurisdictions and eight industries found that 40% of companies with a market capitalisation of greater than $10 billion disclosed information on Scope 1, 2 and 3 GHG emissions in 2019, whereas the equivalent figure for companies with a market capitalization of less than $2.8 billion was only 16%.[36] Such disclosures are also more common amongst firms in carbon-intensive sectors.[37] Few firms also disclose data on GHG emissions along their entire supply chains ('Scope 3' data). This is likely due both to a lack of data on reporting firms' supply chains, as well as to difficulties encountered in calculating emissions across them. Further details are given in Annex 2.

Reported data on firms' exposure to transition risk are also generally inconsistent across firms, sectors and jurisdictions. This partly reflects a lack of standardised metrics with which to calculate – and characterise targets for reducing – climate-related risks.[38] Metrics of climate-related risks do not currently benefit from the sort of well-established accounting standards that

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35 Scope 1 refers to all direct GHGs. Scope 2 refers to indirect GHG emissions from consumption of purchased electricity, heat, or steam. Scope 3 refers to other indirect emissions not covered in Scope 2 that occur in the value chain of the reporting company, including both upstream and downstream emissions. Scope 3 emissions could include: the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. transmission and distribution losses), outsourced activities, and waste disposal.

36 TCFD (2020), *2020 Status Report*, October. From a sample of 1,701 large companies from 69 countries in eight industries.

37 *Ibid*.

38 These conclusions were reflected in analysis recently conducted by the TCFD to understand the challenges firms face in implementing its disclosure recommendations; see TCFD (2020), *2020 Status Report*, October, p 46.

are applicable to other financial risks.[39] International standards for such disclosures – including those based on the recommendations of the TCFD – have the potential to increase the consistency of such information on non-financial firms' exposure to transition risks.[40]

Such inconsistencies across data are particularly acute in the case of data on the degree to which potential future official sector policies – as well as changes in consumer preferences and technology – might impact firms' finances. This may be due to a lack of standardised information on firms' plans to mitigate and adapt to the effects of climate change as part of their climate-related financial disclosures (see above), which are typically highly complex, and particularly unamenable to standardised reporting. Several survey respondents mentioned that this lack of data on firms' plans to adapt to the effects of climate changes limits the degree to which they are able to assess the future effects of transition risks on their businesses.[41]

There are also limited data on the exposure of sovereigns to transition risk. A shift to a low-carbon economy may negatively affect economic growth in some countries, particularly those that are heavily reliant on fossil fuels.[42] This may in turn impair government tax revenues, and hence sovereign finances. International agencies collect data on government tax revenues, as well as the proportion of these revenues that stem from the generation of energy from fossil fuels across different jurisdictions. These can be used to give broad estimates how a transition away from fossil fuels would affect tax revenues from these industries. However, there are few – if any – estimates of how a transition to a low carbon economy would affect broader government finances, including knock-on effects from declines in growth from other industries dependent on these sectors.[43]

3.2.3. *Other metrics of exposure to transition risks provided by third-parties*

Other ratings and data classification systems provided can – in principle – be a source of information on firms' exposure to transition risks. Such information, some of which is supplied by third-parties and are designed to facilitate green investment by providing a guide to the degree to which different entities support the transition to a low carbon economy, rather than for the

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39 Climate Disclosure Standards Board, 'The case for consistency in corporate climate-change related reporting'.

40 Unlike with non-financial firms, there are no global standards or databases for assessing the exposures of households to transition risk. There are however some granular data available in some jurisdictions that offer insight into households' exposures to transition risk. One example is data on energy efficiency ratings/labels that give data on efficiency of residential buildings' energy consumption. In Germany, such data have been used to assess the effects of energy efficiency on rental prices (e.g. Pommeranz and Steininger (2021), *What Drives the Premium for Energy-Efficient Apartments – Green Awareness or Purchasing Power?*, Journal of Real Estate Finance and Economics 62 (3): 220–241). Such data can be used to analyse the effects of climate scenarios (via energy prices) on prices of real estate. However, granular data directly linking properties to energy efficiency seem to be available only in few jurisdictions.

41 Several survey respondents mentions this lack of comparability in firms' transition plans. Some mentioned jurisdiction-specific efforts to fil this gap. For example, national authorities in France have conducted surveys to gather forward-looking information on insurance companies such as commitments to align with the Paris agreement, and mitigation measures/disinvestment policies adopted.

42 For further discussion of the effect of transition risks on sovereigns see FSB (2020b).

43 The FTSE Climate Risk-Adjusted Government Bond Index weights each country taking into account the relative climate risk performance, measured across three distinct and quantitative, climate-related pillars (physical risks, transition risk and resilience). In particular, its resilience pillar scores uses a broad range of indicators to assess a country's preparedness and actions to cope with its level of climate related risk exposure and could be serve as proxy of a country's vulnerability to climate related risks.

purpose of risk assessment. In principle, however, they can also provide a high-level indication of whether entities may be more or less exposed to transition risks.

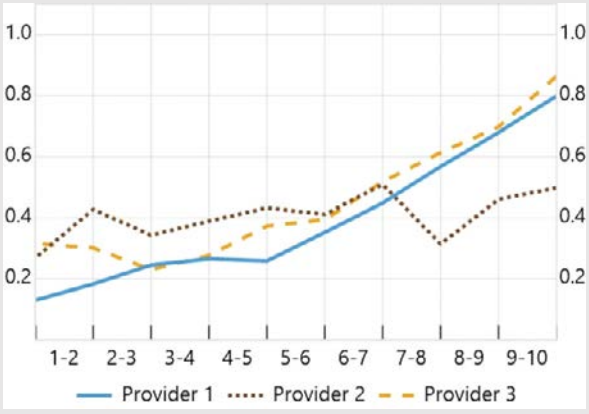
One such source of information is Environmental, Social and Governance (ESG) ratings, the environmental (or 'E pillar') of which incorporates a range of information on firms' susceptibility to and/or impact on the environment. In the case of some firms, ESG ratings may both include and complement information from firms' disclosures (see above). To the extent that such ratings provide information on firms' current or planned future emissions, they provide data on firms' exposures to transition risk.[44] Further details on ESG ratings are given in Box 1.

Box 1: What do ESG ratings tell us about non-financial firms' exposure to transition risks?

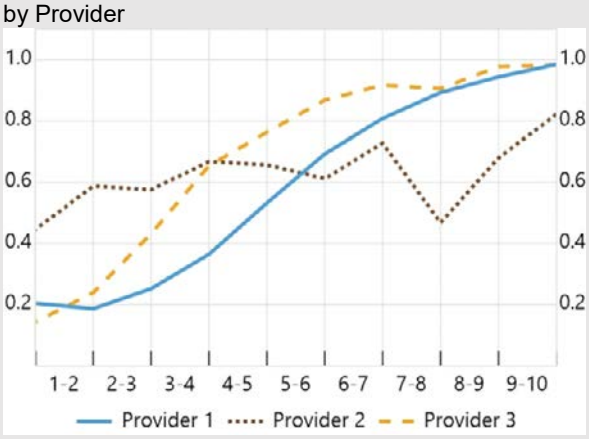
ESG investment approaches have grown considerably and are fast becoming a mainstream tool investors use to align finance with long-term value, including with respect to climate-related risks and opportunities. Environmental "E" pillar scores integrate metrics on the intensity of firms' carbon emissions, environmental performance, climate risk mitigation, and strategies towards renewable energy. There is little evidence that the environmental pillar of firms' ESG ratings are positively correlated with their emissions intensity.[45] However, ESG ratings are positively correlated with measures of firms' awareness of climate-related risks, as well as the strength of their intention to reduce emissions (Figure 1). They could – at least in principle – provide an indication of which firms are more/less exposed to transition risks.[46]

The 'E-pillar' scores of firms' ESG ratings are positively correlated with firms' awareness of climate risks and intention to reduce emissions **Figure 2**

Climate Change Risks/Opportunities E pillar score by Provider



Emission Reduction Processes/Policies E Pillar Score by Provider



Note: The Climate Change Risks/Opportunities metric measures "Is the company aware that climate change can represent commercial risks and/or opportunities?" and Emission Reduction Processes/Policies measures "Does the company have a policy to improve emission reduction?". The metrics range from 0 to 1, and are commonly binary options (Yes=1 or No=0).

Source: Boffo, R., C. Marshall and R. Patalano (2020), *ESG Investing: Environmental Pillar Scoring and Reporting*, OECD Paris.

ESG scores differ substantially in their calculation across different providers. These differences stem from both the underlying data on which scores are based, and how these data are used, weighted and – in places – extrapolated in the calculation of the overall rating. These differences are reflected in the

44 Some studies use ESG ratings to measure firms' vulnerability to transition risk, see for example: NGFS (2020), *Overview of Environment Risk Analysis by Financial Institutions*, September, Box 8. .

45 OECD (2021), *ESG investing and environmental pillar scoring reporting*.

46 ESG rating providers can range from stand-alone entities to arms of larger index providers or credit rating agencies that rank companies according to specific ESG criteria.

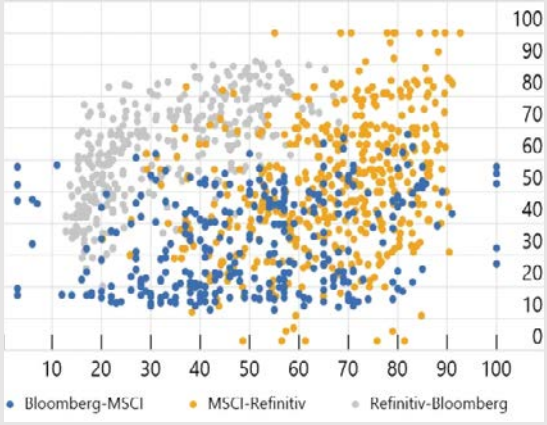
low correlation both between ESG scores from different ratings providers (Figure 2 LH panel) and between overall ESG scores and their E-pillar constituents (Figure 2, RH panel).[47]

End-users may have difficulty in discerning the drivers of differences between ESG ratings, given that their providers disclose only limited information of the data and methodologies on which ratings are based. Such opacity is not unique to ESG ratings, and might be common to other types of external ratings, including those of counterparties' credit risk. However, in the case of ESG ratings, such opacity might be further compounded by insufficient standardisation and consistency of underlying data, which – unlike information from firms' financial statements that informs credit ratings, does not benefit from well-established accounting standards.[48]

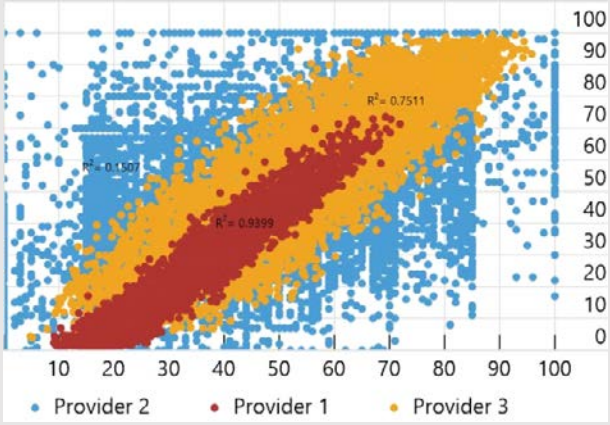
This variation in ESG ratings' data and methodologies – combined with their opacity – means that, in practice, ESG ratings (and the E scores within them) are limited in their use as a tool to monitor firms' exposure to transition risks.[49] In addition, for some ESG rating providers, high E pillar scores are positively correlated with high carbon emissions. This suggests that firms' plans to reduce their emissions play a significant (and positive) role in determining their E scores, rather than their current level of emissions. In addition, despite a correlation between E pillar scores and some forward looking transition metrics such as climate change risks and opportunities (Figure 1), these are often binary metrics that measure only the existence of disclosures. As such, they give higher ratings to firms that have transition plans, rather than for the quality of such plans and the extent to which they will ensure the issuer manages climate risks.[50]

There is a lack of correlation among ESG scores from different providers, as well as between ESG scores and their and E-pillars **Figure 3**

Correlation of S&P 500 ESG scores across ESG rating providers, 2019



Correlation of E pillar score and ESG ratings by selected ESG rating providers



Note: Panel A: Providers' names in the legend correspond to the Y axis when at the left and to the X axis when at the right. For full methodology, refer to OECD (2020), ESG Investing: Practices, Progress and Challenges.

Source: OECD (2020), OECD Business and Finance Outlook 2020: Sustainable and Resilient Finance, OECD Publishing, Paris

47 R. Boffo and R. Patalano (2020), *ESG Investing: Practices, Progress and Challenges*, Organisation for Economic Co-operation and Development.

48 See BCBS (2021), *Climate-related financial risks: measurement methodologies*, April.

49 OECD (2020), *OECD Business and Finance Outlook 2020: Sustainable and Resilient Finance*, September.

50 R. Boffo, C. Marshall and R. Patalano (2020), *ESG Investing: Environmental Pillar Scoring and Reporting*, Organisation for Economic Co-operation and Development.

In practice, however, differences in the construction of ESG ratings across providers prevent them from supplying consistent and comparable information on transition risks across firms and jurisdictions. ESG ratings are opaque in their calculation and differ substantially in the metrics on which they draw, as well as the methodologies used in their calculation. These tend to differ substantially across different providers, and result in a lack of correlation between ESG scores supplied by different firms (see Box 2).[51] They typically rely on techniques such as data extrapolation, particularly in the case of firms with limited disclosures.[52] Estimation methods also vary between and within each provider.[53] These findings broadly reflect those of IOSCO's current work on ESG ratings and examination of ESG data providers.[54]

Another potential source of information on exposures to transition risk are classification systems/taxonomies that are used to categorise the resilience of economic activities or assets to climate-related risks. By providing a high-level indication of the resilience of entities – via their activities or liabilities – to climate change, these classification systems/taxonomies can also serve as a basic source of information on whether firms are more or less exposed to transition risks. In some instances, financial authorities have also classified sectors as more or less exposed to transition risks based on these classification systems/taxonomies.[55, 56] Such information has the advantage of being more straightforward to use and analyse than those on individual firms.

Indications of transition risk based on classification systems/taxonomies also, however, suffer from the draw back that they are not consistent in their construction across jurisdictions. Further details of classification systems/climate taxonomies, and some key differences in their constructions, are given in Box 2.

Box 2: Classification systems/taxonomies and their application in assessing climate-related risks to financial stability

Classification systems/ taxonomies are used to identify activities or assets based on pre-determined criteria and/or thresholds. They are generally intended to facilitate the integration of climate-related considerations into investment decisions. For example, green classification systems/taxonomies in some jurisdictions may allow for the identification of firms that are more resilient to climate-related risks, and therefore may be less exposed to transition risks than their peers. As such, classification

51 Institut Louis Bachelier et al. (2020), *The Alignment Cookbook - A Technical Review of Methodologies Assessing a Portfolio's Alignment with Low-carbon Trajectories or Temperature Goal*, October.

52 Refinitiv ESG (2020), *Carbon data and estimates model.*

53 T. Busch, M. Johnson and T. Pioch (2020), *Corporate carbon performance data: Quo Vadis?*, Journal of Industrial Ecology.

54 The IOSCO report is in progress and will be available at www.iosco.org once finalised.

55 The classification of firms into sectors also used sectoral classification schemes such as NACE, NAICS and ISIC codes. The Statistical classification of economic activities in the European Community, abbreviated as NACE, is the classification of economic activities in the European Union (EU); the term NACE is derived from the French Nomenclature statistique des activités économiques dans la Communauté européenne. [NAICS, ISIC are…] Such classifications of sectors (e.g. energy) can be useful.

56 For example, sectoral data on emissions has been used to estimate the share of banks exposures through their loan portfolios to those sectors with the highest carbon emissions per value added (more than CO2 emissions over 0.11 kg per euro of value added) and therefore with greater susceptibility to energy transition. See M. Delgado (2019), *Energy transition and financial stability. Implications for the Spanish deposit-taking institutions*, Financial Stability Review Issue 37, Banco de España; and I. Faiella and L. Lavecchia, *The Carbon Footprint of Italian Loans*, The Bank of Italy Occasional Papers (Questioni di economia e finanza) No. 557. Similar analysis have been conducted by financial authorities in other jurisdictions such as Korea and Mexico.

systems/ taxonomies can also facilitate a simple and high-level assessment of whether firms are more/less exposed to transition risk.

Different classification systems/taxonomies categorise different objects and use different criteria to do so. This gives rise to differences in their data requirements:[57]

- Some financial authorities use classification systems/taxonomies that categorise sectors – for example the approach in Battiston et al.[58] This approach has the advantage of usability and compatibility with existing economic and financial datasets (many of which are also at sector-level). However, it also lacks granularity and abstracts from differences in the intensity of emissions between firms within a given sector.
- Other classification systems/taxonomies – such as the EU[59] and the Chinese taxonomies[60] – categorise economic activities. They can provide greater granularity of information, and – in principle – give an indication of whether firms' are more or less exposed to transition risk based on their activities. They are more complex to construct, however, due to a lack of data on the activities of some firms.
- Other classification systems/taxonomies directly categorise assets. Such a classification system/taxonomy is used in the Climate Bonds Initiative.[61] Taxonomies of assets are, however, quite complex to construct and apply, as classifying assets requires in-depth examination of their production processes and use in order to determine their classification.

One example of the practical application of classification systems/taxonomies in financial stability risk analysis is that being conducted by the IAIS in its Global Insurance Market Report (GIMAR) (whose publication is expected in Q3 2021). Based on data collected from more than 30 IAIS members from different regions, this analysis examines the investment exposures of the insurance sector to climate-related risks.

The IAIS used techniques from academic research[62] to identify six economic sectors that are more exposed to climate-related risks. The ND-GAIN index was used to make a similar assessment in the case of jurisdictions. Insurance supervisors were asked to map insurers' assets to these sectors (based on internationally recognised industry classification systems)[63] and jurisdictions, in order to determine which were more/less exposed to climate-related risks.

4. Availability of data with which to assess financial system exposures to climate-related risks

This section examines the availability of data with which to assess financial system exposures to climate-related risks. This includes the information necessary to translate information on the exposure of *non*-financial entities to climate-related risks examined in Section 3 – including

57 See NGFS (2020), *A Status Report on Financial Institutions' Experiences from working with green, non-green and brown financial assets and a potential risk differential*, May.

58 Some studies use NACE classifications to determine which sectors are most at risk to climate change; see, for example, S. Battiston, A. Mandel, I. Monasterolo, F. Schütze and G. Visentin (2018), *A climate stress-test of the financial system*, Nature Climate Change 7: 283–288.

59 Regulation (EU) 2020/852 (Taxonomy) on the establishment of a framework to facilitate sustainable investment

60 "Green bond endorsed projects catalogue", People's Bank of China.

61 See Climate Bonds Initiative (2021), *Climate Bonds taxonomy*, January.

62 See Battiston et al (2018).

63 Including NACE, NAICS and ISIC classifications; see above.

changes in the cash-flows and valuation of assets and liabilities of households, non-financial firms and sovereigns – into their impact on financial institutions.

- The section begins by examining the availability of data to measure the exposures of financial institutions to the non-financial entities discussed in Section 3 (i.e. exposures to households, firms and governments, as well as financial securities issued by such entities).

- It then discusses the availability of data with which to assess the strength and nature of mechanisms to transfer and mitigate climate-related risks. This includes data on the provision of insurance against climate-related risks by insurance firms, as well as guarantees and subsidies provided by governments.

- The section concludes by discussing the availability of metrics that capture the exposures of financial firms and the financial system to climate-related risks. This includes forward-looking metrics that are informative as to the nature and extent of uncertainty and tail-risks concerning the financial system's exposure to such risks and how they may change in future.

4.1. Data with which to monitor and assess the exposures of financial institutions to climate-related risks

Assessing financial institutions' exposures to climate-related risks first requires data on the exposures of financial institutions' assets and liabilities to such risks. Such information can be obtained from proprietary firms or some supervisory datasets. These include supervisory data on financial institutions' investment portfolios, banks' loans portfolios and insurance companies' underwriting portfolios. While these datasets are not specifically designed to capture climate-related risks, they sometimes nonetheless facilitate the estimation of such exposures.[64] Table 4 shows some examples of such data in the case of banks, insurance firms and asset managers.

Some financial authorities lack the granular loan or insurance level data necessary to facilitate a granular assessment of financial institutions' exposures to climate-related risks in their jurisdiction. Survey respondents in many jurisdictions stated that they lack loan or policy-level data to monitor banks' and insurers' exposures. In many cases, this is because such data (such as loan-level location data or sector identification) are not reported to regulators.

This lack of granular data may mask *concentrations* of exposure – both in certain financial firms, and in their counterparties.[65] In the case of transition risks, for example, analysis by euro-area financial authorities suggests that euro-area banks' exposures to the twenty firms with the largest carbon emissions are equivalent to 20% of these banks' reported large exposures.[66] Such

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64 European Systemic Risk Board (ESRB) (2020), *Positively green: Measuring climate change risks to financial stability*, June.

65 P. Bolton, M. Despres, L. Pereira da Silva, F. Samana and R. Svartzman (2020), *The green swan: central banking and financial stability in the age of climate change*, January.

66 For example, euro-area banks' exposures to the twenty firms with largest carbon emissions are equivalent to 20% of these banks' reported large exposures (see FSB (2020b)).

concentrations of exposure to climate-related risks may – if they are of sufficient magnitude – have systemic consequences for the financial system.

Table 4: Examples of indicators of transition and physical risks for banks, insurers and assets managers (some examples are based on survey respondents, others from ESRB (2020)[67])

Sector	Exposure indicator	Financial risk category	Examples of available data
Physical risks			
Banking	Loan book exposure to sectors and counterparties subject to physical risk – e.g. flood risk	Credit and market risk	Supervisory data, credit registers, balance sheets, ECB's Statistical Data Warehouse (SDW)
	Bond and equity holdings – exposure to vulnerable firms located in risky areas	Credit and market risk	ECB's Securities Holding Statistics, Supervisory data, credit registers, balance sheets, SDW
Insurance	Equity and bond holdings – exposure to vulnerable firms, sectors and sovereigns	Market risk	Exposure data available in supervisory reporting in some jurisdictions
	Dramatic rise in claims due to covered catastrophe events that were not considered in premiums	Underwriting	Information required on individual policy level and current reserving practices, including market developments, reinsurance prices. Data are not available in structured format/reporting
Banking & insurance	Residential and commercial real estate exposure to physical risks (e.g. floods, fires, storms); also possibly transition risks	Credit and market risk	Supervisory data, credit registers, national hazard maps, Private data providers like credit rating agencies, insurance companies Distribution of energy performance labels
Investment Funds (physical risk)	Equity, bond and derivative holdings – exposure to vulnerable firms, sectors, and sovereigns	Credit, market and counterparty risk	Supervisory data available in some jurisdictions, disclosed holdings, private data providers like credit rating agencies and research companies, national hazard maps
Transition risks			
Banking	Loan book exposure to carbon intensive sectors or firms at risk	Credit risk	Large exposures, credit registers and AnaCredit
	Equity and bond holdings	Credit and market risk	Securities Holding Statistics

67 ESRB (2020).

Insurance	Equity and bond holdings – exposure to carbon-intensive sectors and sovereigns	Credit and market risk	Exposure data available in supervisory reporting in some jurisdictions
Investment Funds	Equity, bond and derivative holdings – exposure to carbon-intensive sectors and sovereigns	Credit, market, and counterparty risk	Supervisory data available in some jurisdictions, disclosed holdings, private data providers

There is also a lack of data with which to assess financial institutions' cross-border exposure, which may constitute a particularly acute data gap in the case of climate-related risks. Several survey respondents noted that financial authorities in their jurisdictions had only limited access to data on financial institutions' cross-border exposures. This includes both data on exposures that arise due to the direct exposures of financial institutions across borders, as well as the cross-border exposures of their clients (including those that arise from cross-border supply chains, see Section 3). Whilst this may limit the monitoring of a range of cross-border financial risks, it may represent a particularly acute data gap in the case of climate-related risks. Climate-related risks to financial firms differ substantially across jurisdictions due both to differences in their location and economic activities, as well as differences in government policies with respect to transition policy. A lack of data on cross-border exposures may therefore limit the degree to which financial authorities can monitor the scope for climate related risks to be transmitted across borders.[68]

4.2. Data to assess mitigants of financial institutions' exposures to climate-related risks

A holistic assessment of climate-related risks to the financial system also requires data on the mechanisms through which risks to financial institutions are mitigated and transferred. Such mechanisms generally include the provision of insurance, and hedging such risks via the use of financial instruments. By transferring risks across the financial system, such mitigants do not reduce the totality of risks faced by the overall financial system, but do change the exposure of individual firms. An assessment of the degree to which they do so requires robust information as to their reliability and efficacy in transferring risk, including in periods of stress.

There are only limited data on the degree to which individual financial institutions' exposures to climate-related risks are mitigated by insurance provision. Supervisors in some jurisdictions have detailed data on the policies extended by insurers, and the assets they cover. Some insurance use geospatial data on the location of assets to ensure that their policies reflect the risk of extreme weather events (see Section 3.1.1). However, it can be difficult to match this with data on banks' exposures or the collateral against them (e.g. the degree to which real estate serving as mortgage collateral is insured). Other aggregate sources of data also provide estimates of the degree to which physical risks are covered by insurance.[69] However, such data tend to be

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68 *Ibid*.

69 According to Swiss Re (2020), *Socio-economic developments and climate-change effects to drive rising losses from severe weather events, sigma says*, global economic losses from natural catastrophes were USD 137 billion in 2019 and USD 166 billion in 2018. Of these economic losses stemming from natural catastrophes respectively 38% and 51% was covered by insurance.

relatively high-level (e.g. at the level of jurisdictions), and so give little insight into the protection gap across jurisdictions. Together, this means it is highly uncertain to what extent financial institutions' exposures to climate-related risks are mitigated by insurance contracts with the private sector.[70]

There is also a lack of data on the degree to which the availability of insurance might change over time. If the increased crystallisation of physical risks were to lead to large increases in insured losses, this might cause insurers to reduce the cover they offer households and firms against such risks (or increase its price, potentially to a point that coverage it is no longer affordable).[71] Whilst there is some limited historical data on such reductions in insurance coverage, this generally pertains to a limited number of emerging market jurisdictions. The potential for such change in the nature or extent of such insurance cover is, therefore, highly uncertain.

The extent to which governments may offer compensation or guarantees following the crystallisation of physical risks is also highly uncertain. Such government interventions could take the form both of governments assuming some of the costs of recovery from natural disasters (e.g. by extending grants for rebuilding homes or infrastructure), or by extending alternative insurance in advance of them.[72] However, the extent to which they do so, and how this varies across jurisdictions and time is highly uncertain. It is unclear to what degree governments would be liable for damage in the event of large-scale crystallisation of physical risks, particularly if such liabilities are implicit or at the discretion of governments. There is also little, if any, data on the broader impact of the crystallisation of physical risks on government finances – both due to increases in government expenditure that might be necessary to support economies negatively affected by physical risks, or due to the government's role in the provision of insurance

Financial markets also facilitate the transfer of climate-related risks between entities. The use of weather derivatives contracts, for example, allows risks to be transferred to economic agents that are best placed to monitor and bear them.[73] Climate-related risks can also be transferred via the issuance of insurance linked securities (ILS), such as catastrophe bonds of collateralised reinsurance. Available data on the markets for these securities suggests that their size has increased substantially in recent decades (though remains small relative to the cost of weather-related catastrophes).[74] Other financial instruments – including credit and energy derivatives – may also play a role in managing climate risks, by allowing the hedging of risks associated with both stranded assets and extreme weather events, for example.

An assessment of the efficacy of such markets in transferring climate-related risks relies on the availability of information as to the holders of such instruments, and their ability to bear risk in times of stress. The degree to which such instruments transfer risks relies upon their holders

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70 See BCBS (2021).

71 See FSB (2020b). There is already empirical evidence that increase in severe weather events in some areas have left households and corporates unable to obtain insurance against such risks.

72 Several large global reinsurers can be a useful resource to better understand the impact of physical risk from climate change since they publish data on insured weather related losses. But such data tends to be at a global or regional scale, be backward looking, and overall provide limited information on the effects of climate change (see "Swiss re sigma publications", such as Swiss Re (2021), *sigma 1/2021 - Natural catastrophes in 2020*, March.)

73 See FSB (2020b).

74 *Ibid*.

being able to bear such risks in the case of their widespread crystallisation. The efficacy of these instruments in transferring risk depends in part on the resilience of the market participants that hold them, and the degree to which they are concentrated in certain sectors or parts of the financial system. If the holders of such instruments default on their obligations – or if they declined to assume such risks in future – this would reduce the degree to which climate-risks had (or could in future be) transferred.

Data on the holders of financial contracts that facilitate the diversification of climate-related risks varies by both market and jurisdiction. Whilst there is detailed global data available on ILS transactions, by sponsor, risk, and other variables, there is no data on the holders of ILS instruments across different types of investors. There is no data available, however, to assess concentration of ILS holdings by investors or groups of investors (e.g. investor type, jurisdiction). As such, climate-related risks could build up in unobservable pockets of the financial system.

There are, however, more detailed data available on the holders of derivatives, at least in the case of derivatives contracts traded on regulated markets. These data allow direct monitoring by market regulators of large traders' positions. Where data are publicly available they are typically aggregated, and so can support market-level analysis of risks and a better understanding of market participants' ability to manage risks, including those related to climate change.[75]

4.3. Metrics of climate-related risks to financial institutions

Quantifying climate-related risks to financial institutions involves translating the exposures and mitigants described above into metrics of financial risk. Such metrics seek to summarise the losses that financial institutions – or groups of financial institutions – could face were climate-related risks to crystallise.

Metrics of financial institutions' exposures to climate-related risks are generally subject to greater uncertainty than those relating to other financial risks.[76] This is partly because the drivers of climate-related risks arise from outside the financial system. Multiple layers of uncertainty therefore arise in their translation into economic variables.[77] Modelling the impact of these estimates on the future values of assets and liabilities of financial institutions introduces further uncertainty. Several market participants reported that substantial human judgement is involved in both calculating the impact of climate-related risks on financial institutions, particularly in the case of channels of risk that are more peripheral to counterparties immediate operations (e.g. costs incurred from supply chain disruption and via impacts on the macroeconomy).[78] This leads

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75 A report by the CFTC highlights that asset allocation strategies – including those involving derivatives – can provide possible hedging of climate-related risks, at least to the extent that investors have sufficient information on the exposures of underlying firms in which they are invested.

76 United Nations Environment Programme Finance Initiative (UNEP FI), Oliver Wyman and Mercer (2018), *Extending our horizons - Assessing credit risk and opportunity in a changing climate. Part I: Transition-related risks and opportunities*, April.

77 For example, there is a lack of historical data on the relationship between climate-related events and PD and LTV ratios. UNEP FI (2018), *Navigating a New Climate: Assessing Climate Risk and Opportunity in a Changing Climate*, July.

78 NGFS (2020), *Guide to climate scenario analysis for central banks and supervisors*, June.

to uncertainty concerning, and inconsistencies between, the estimates of climate-related risks across individual financial institutions, and across financial institutions in different jurisdictions.[79]

Standard financial metrics of climate-risks to financial institutions may also be subject to greater tail-risks than those of other financial risks. For example, in the case of credit risk, estimates of metrics such as probability-of and loss-given default only offer a central expectation of climate-related risks to either individual, or sets of, financial institutions. They may therefore provide only limited information on the tail-risks around these estimates, which in the case of climate-related risks can be particularly substantial.

There is also a lack of reliable historical data with which to assess the accuracy of metrics of climate-related risks. Financial models that infer the impact of vulnerabilities on financial institutions generally rely on past data on their past impact. In order to ensure such inferences are robust, such past data needs to be extensive in its history, and consider multiple instances of the crystallisation of risks. However, in the case of climate-related risks, historical observations of the impact of climate-related risks on financial institutions are very limited (see Section 3). Possible non-linearities in the progression of climate change over time also suggest that data on past impacts might be a particularly poor guide to those in the future.

Given these challenges, some financial authorities and institutions are developing forward-looking metrics that offer greater insight into the levels of uncertainty and tail risk concerning the impact of climate-related risks. Such metrics typically give insight into the quantiles of the distribution of the impacts of climate-related risks aside from just their central expectations, thereby giving insight into the degree of uncertainty concerning the central estimates discussed above. They are also typically 'forward looking', in that they use models and scenarios for the future progression of climate change to capture sources of tail-risk and non-linearity discussed above. Examples of such forward-looking metrics include:[80]

- Climate value-at-risk (VaR), which applies the VaR framework - an established metric for measuring financial risk. Climate VaR estimates the potential losses a firm would suffer due to climate-related risks crystallising with a given probability over a given time horizon.[81]

- Implied temperature rises (ITR) that estimate the future global temperature risk associated with the emissions of a selected entity (or group of entities), if all entities in its sector had the same emissions intensity.[82] An ITR is typically expressed as a single temperature unit or range that is comparable to widely understood potential climate outcomes (e.g. 1.5/2/3.5 degrees Celsius).

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79 See workshop findings in Annex 2.

80 For further details see TCFD (2020), *Forward looking financial sector metrics: consultation*, October.

81 See S. Dietz, A. Bowen, C. Dixon and P. Gradwell (2016), *Climate Value at Risk of Global Financial Assets*, Nature Climate Change 6: 676-679 and The Economist (2015), *The cost of inaction: Recognising the value at risk from climate change*.

82 Institute of International Finance (IIF) (2020), *Prudential Pathways: Industry Perspectives on Supervisory and Regulatory Approaches to Climate-related and Environmental Risks* and S. Battiston and I. Monasterolo, (2018), *A carbon risk assessment of central banks' portfolios under 2°C aligned climate scenarios*, Working Paper.

- Alignment of asset portfolios with a particular scenario pathway. An example of this approach is the Paris Agreement Capital Transition Assessment (PACTA) tool or the Science Based Targets initiative.[83] The output of these tools serve to inform to what extent a given portfolio[84] is aligned with a given climate scenario, based on forward-looking asset-level data and their GHG emissions (such as the production plans of a manufacturing plant over the next five years).

- Alignment of insurance portfolios with a particular scenario pathway. In a more recent initiative, several insurers and civil society partners have started to develop a methodology for "Net Zero underwriting", to align underwriting policies to the Paris Agreement target of limiting temperature rises to 1.5 degrees.[85]

Such forward-looking metrics have increased in their use in recent years, particularly as some financial authorities are developing regulatory expectations that firms demonstrate a forward-looking understanding of their climate-related risk exposure.[86]

The calculation of such metrics by both firms and financial authorities are, however, reliant on the availability of detailed information on firms' exposures to climate-related risks. Gaps in such data – particularly that concerning non-financial firms' future exposures to climate-related risks and how these might change in the future (see Section 3) – present a substantial barrier to their calculation.[87]

The degree to which such metrics can facilitate a global comparison of climate-related risks may also be limited by differences in their calculation methodologies across firms, sectors and jurisdictions. Forward-looking metrics are relatively complex to calculate and are highly uncertain. They vary both in their choice of input data (e.g. scope 1/2/3 emissions) and in their methodologies (including whether these estimated changes in emissions are based on firm, or sector/jurisdiction-level targets). These differences result in substantial variation in estimates of climate-related risks across firms and jurisdictions. The TCFD is examining further the benefits and drawbacks of disclosing forward-looking metrics. TCFD recognises that disclosures of these metrics are not a substitute for disclosures of emissions and future climate-related targets and strategies.

Box 3: The gaps in the availability of data to monitor and assess climate-related risks in emerging market and developing economies (EMDEs)

Many of the data gaps concerning climate-related risks to financial stability are more acute in EMDEs than in advanced economies. In the case of physical risks, they often include a lack of granular spatial data with which to assess the susceptibility of different locations to extreme weather events, which typically requires advanced disaster risk modelling. Where such data are available, their use in estimating the potential impact of the crystallisation of physical risks in EMDEs is complicated by there being less detailed information on mechanisms that mitigate risks to individual firms. This is partly due

83 For further details, see Science Based Targets.

84 Equity, fixed income, as well as corporate lending portfolios.

85 For further details, see UNEP FI (2021), UN-convened Net-Zero Insurance Alliance.

86 TCFD (2020), *Forward-Looking Financial Sector Metrics - Consultation* October.

87 *Ibid*.

to the lower availability of risk transfer instruments and more uncertainty regarding the scale of government support after major disasters.[88]

The availability of granular data on financial exposures to physical risks varies considerably across jurisdictions. For example, some financial authorities in EMDEs have very granular data on the exposure to physical risks in their bank credit portfolios, whereas in other jurisdictions such data are very coarse or do not exist at all. Data for financial institutions' exposures to transition risks are also subject to numerous gaps. For example, GHG emissions data are rarely available at the level of individual firms, and those data that are available are in some cases limited to Scope 1 (direct) GHG emissions, rather than capturing emissions across their value chains.

The ability of many EMDEs to assess the broader macroeconomic implications of climate change is complicated by how many EMDEs already face substantial broader macrofinancial vulnerabilities.[89] The assessment climate-related risks may require consideration of their interaction with these broader vulnerabilities.[90] This increases the complexity of such analysis and scope of its data requirements.

Financial authorities in EMDEs also face particular challenges in analysing current and future climate-related physical risks. Many EMDEs lack the data and methodologies with which to estimate the expected economic impact of severe natural disasters, as well as the impact of climate change on the frequency and severity of natural disasters over time. This is especially true for financial supervisors in EMDEs, many of which have only a limited capacity to investigate the financial and economic impact of natural disasters. Some commercial data providers have developed catastrophe risk models that can be purchased by governments and corporations to provide an estimate of expected losses from specific climate related disasters. Many such models are, however, rarely available in the case of EMDEs. Those that are available tend to focus on specific impacts of climate-related risks, such as damage to property.

Together, specific country features and data limitations often require climate risk assessments in EMDEs to be conducted at a coarser resolution across entities and locations compared to those in advanced economies. Limited availability of models and data means analyses of physical risks in EMDEs are often based on coarse location data that are available as to the susceptibility of different locations to natural disasters, including those at country level.[91] This makes estimates of climate-related risks less precise and open only to directional comparison across jurisdictions. These limitations in data and modelling can also lead to an underestimation of the magnitude of climate-related risks – for example, when there is no regional or spatial breakdown available for certain asset types. Differences in the capacity of both official and private-sector entities to collect and process data may also mean that the prioritisation of steps to address data gaps in EMDEs may differ from those in advanced economies.

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88 Regions that have a relatively high uptake of risk transfer instruments include North America, the Caribbean, Central America, and East Asia-Pacific.

89 See FSB (2020b).

90 See E. Feyen, R. Utz, I. Huertas, O. Bogdan and J. Moon (2020), *Macro-Financial Aspects of Climate Change*, Policy Research Working Paper No. 9109, World Bank.

91 This is amongst others observed within modules on climate risk and opportunity assessment that have been piloted as part of the joint World Bank and IMF Financial Sector Assessment Program (FSAP). See for example International Monetary Fund (2021), *Philippines: Financial System Stability Assessment*, Country Report No. 2021/074.

5. Availability of data with which to monitor and assess the resilience of the financial system to climate-related risks

This section of the report examines the availability of data both to assess the potential for widespread changes in risk premia across assets, as well as the resilience of financial markets and institutions to such repricing.

- It begins by examining the availability of data with which to assess the potential for widespread increases in risk premia. Such data include those with which to assess the degree to which asset prices already incorporate the effects of climate-related risks, including those that might be far reaching in their potential impact.
- It then examines the degree to which there is sufficient data to examine the effect of such a widespread increase in risk premia on the financial system. Such data include both those to assess the commonality of exposures to climate-related risks across financial institutions, as well as those to assess the reliability and efficacy of certain financial markets – including those for insurance-linked securities – in diversifying risks.
- A final section examines the availability of data with which to perform scenario analysis. This is motivated by the fact that past changes in climate – and in the degree of co-movement between asset prices to which it gives rise – may also be a particularly poor guide to those in future.

5.1. Data to assess the potential for widespread changes in risk premia due to climate change

The widespread and uncertain nature of climate-related shocks might lead to increases in risk premia across – and the degree of correlation of risk premia between – a broad range of assets (see Section 2).[92] These could occur due to the crystallisation of climate-related risks, including those that are far reaching in their effects across different sectors and geographies.

Data on the prices of financial assets and liabilities can be combined with estimates of the nature and extent of climate-related risks to which they are exposed, to assess the degree to which market prices incorporate climate-related risks. Several studies that do so find evidence that asset values in some sectors reflect climate-related risks to some degree. For example, there is evidence that firms with high-levels of carbon emissions have higher equity price returns, consistent with investors demanding a premium for bearing climate-related risks.[93] Other studies find that firms engaged in the extraction of fossil fuels have recently faced a higher cost of funding.[94] With respect to sovereign exposures to climate-related risks, there is some evidence

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92 FSB (2020b).

93 There is evidence that this premium has been increasing since the Paris agreement to reduce worldwide emissions; see P. Bolton and M. Kacperzyk (2021), *Global Pricing of Carbon-Transition Risk*, Working Paper No. w28510, National Bureau of Economic Research.

94 For example, Mesonnier et al. (2020) find that mandatory disclosures for French institutional investors led to divestment from fossil fuel companies. A recent report from the NGFS (2021) also highlighted that investors in certain energy-intensive sectors

that investors demand a premium to hold sovereign bonds more exposed to physical risks.[95] Other studies find that bonds of US municipalities that are more likely to be affected by climate change pay higher underwriting fees and initial yields to issue long-term bonds.[96] There is also evidence that investors have begun to require higher risk premia in return for holding assets that are more exposed to transition risks in certain sectors.[97]

There is, however, little evidence that broader market prices incorporate risk premia commensurate with the scale and nature of climate-related risks across different sectors. For example, IMF (2020)[98] finds that, in aggregate, equity prices do not reflect the potential impact of the future crystallisation of physical risks under various adverse climate change scenarios. This may be because investors lack the information they require to assess climate-related risks, pay insufficient attention to such risks, or struggle to incorporate them in their pricing of risk due to their complexity.

Financial authorities' ability to assess the potential for such correlated moves in asset prices is limited by there being only limited data available on investor expectations regarding climate change and the future transition to a low carbon economy. It is unclear to what degree investors are aware of the possibility of widespread revaluations of assets as a result of climate-related risks. The limited survey data that are available suggest that some investors believe that some equity valuations do not fully reflect climate risks, but that any perceived overvaluations are generally small in nature.[99] There is, however, a lack of more detailed investor surveys as to investor expectations of the degree to which more granular climate-related risks (e.g. physical versus transition risks, including those at sector level) are reflected in markets prices. This may constitute a substantial data gap, given that, for example, in the case of transition risks, sudden changes in consumer preferences might result in widespread changes in asset prices across sectors.

A full assessment of the degree and combination of climate-related risks embodied in asset prices also entails methodological challenges. This assessment requires a range of climate-related risks to be embedded in asset valuation models. However, such models face complex methodological challenges, e.g. the need to model the actions and expectations of economic agents over a long time period, as well as the interactions between physical and transition risk and technological change.

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may be more sensitive to climate disclosures by issuers. Alessi et al. (2021) show the existence of a negative 'greenium' in the European equity market.

95 S. Cevik and J. Jalles (2020), *Feeling the Heat: Climate Shocks and Credit Ratings*, International Monetary Fund Working Paper No. 2020/286.

96 See Cevik and Jalles (2020) and M. Painter, (2020), *An Inconvenient Cost: The Effects of Climate Change on Municipal Bonds*, Journal of Financial Economics 135 (2): 468-482.

97 See P. Bolton and M Kacperczyk (2021), *Global pricing of carbon-transition risks*, NBER working paper.

98 Insert full reference to GFSR chapter

99 Another example where investor expectations are implicitly modelled is Aberdeen Standard Investments (2021), which bases its pricing model on a baseline scenario supported by consultations with its own investment teams and finds that pricing of climate risks as of the first quarter of 2020 varied substantially across and even within sectors.

5.2. Data to assess the potential resilience of the financial system to widespread increases in risk premia

The degree to which widespread increases in the risk premia may affect the financial system can be assessed in part using data on financial institutions' assets and liabilities discussed in Section 4. In principle, such data allow for the estimation of the degree to which widespread changes in the value of assets and liabilities affect financial institutions' solvency. This also allows for an assessment of the degree to which multiple financial institutions (including of systemic importance) might be affected by common exposures to the same assets, as well as the degree to which such firms might be affected by changes in market values that affect the value of their liabilities (e.g. via their cost of funding). [100]

That said, data on financial institutions' assets and liabilities suffer from various shortcomings (discussed in Section 4) that might prevent an accurate assessment of the impact of such widespread changes in asset prices. The granularity and availability of data on financial firms' exposures available differs substantially across jurisdictions. For example, in some jurisdictions, there is a lack of granular data on exposures to certain non-financial firms, including those that might be particularly exposed to climate-related risks (both physical and transition; see Section 3) as well as data on the potential amplification of risks between different sectors. There is also a lack of data on exposures of non-financial firms' broader supply chains to climate-related risks (e.g. via Scope 3 data). These data gaps mean that financial authorities have only limited insight into the degree to which the crystallisation of climate-related-risks may impact multiple firms and sectors simultaneously, with resulting implications for the solvency of financial institutions.

Moreover, past data on the co-movement of asset prices provides only limited information on the degree of their *future* co-movement. The breadth of climate-related risks – combined with uncertainty concerning their timing and magnitude of their crystallisation – might result in sharp increases in the degree of co-movement between the prices of previously unrelated assets. This might affect market participants' ability to properly manage climate-related risks.[101] This – as well as the broader possibility that past data on the crystallisation of climate-related risks are a poor guide to their future manifestation – motivates the use of forward-looking methodologies such as scenario analysis (see below).

5.3. Availability of data with which to perform scenario analysis

Scenario analysis is a means of examining the economic effects of different future pathways for climate change, as well as pathways for climate policy, technology and consumer/investor preferences, and their impact on the financial system. In doing so, it helps circumvent the issue of how past data on the crystallisation of climate-related risks might provide a particularly poor guide to its future impact on the financial system (see Table 1). This subsection discusses some of its associated shortcomings in terms of data, as well as the role that scenario analysis can

[100] For an example of such analysis in the case of commonality of exposures to securities held by euro-area financial institutions, see FSB (2020b).

[101] See FSB (2020a).

play in incentivising firms to fill some data gaps. Scenario analysis is, however, still under development. As such, substantial progress is being made to address these challenges.

The efficacy of scenario analysis in making comparable and consistent assessments of climate-related risks across the global financial system is dependent on having common scenarios for use by financial authorities in different jurisdictions. Until recently, there was no consensus on meaningful global scenarios for use in such analysis. This was in part because historically, future scenarios for climate change (including those developed, for example by the IPCC, World Energy Council) were developed to guide non-financial policy-making. Other relevant challenges in establishing generally acceptable benchmark scenarios included amongst others the choice of the models and the underlying assumptions.

Multiple scenarios – and associated sets of climate-related variables – are necessary to fully assess the resilience of the financial system to climate-related risks. This is in part due to the multiple paths for the future progression of climate change, which depend on the possible future measures by policymakers to reduce emissions (see Section 2). In addition, the uncertainty concerning the impact of climate change on the financial system (see Section 4) means that multiple combinations of drivers of transition risks (e.g. changes in policy, technology and investor/consumer sentiment) could lead to the same future path for temperature increases, but radically different outcomes for economies and the financial sector.

The set of global reference scenarios established by the NGFS[102] provide a common starting point for central bank climate risks scenario analysis[103]. They include meaningful projections or aggregated and disaggregated data aiming for an "off the shelf" use, and a range of scenarios fitting in three categories (Orderly, Disorderly, Hot House World[104]) to provide users with a reference of the severity and potential impact across different potential future paths of climate change (see Table 2). The NGFS scenarios rely on assumptions with respect to official-sector policy (temperature targets, policy timing, etc.), technology (costs, availability of carbon sequestration technologies, etc.), society (population growth, diets and preferences, etc.) and various other modelling parameters. These are based on a range of modelling techniques, including methodologies and assumptions based on academic literature.[105] Societal assumptions have been standardised by the academic community as the Shared Socioeconomic Pathways (SSPs)[106]. Building on those assumptions, the NGFS provides, for each scenario, a set of variables that are designed to be consistent with one another (see Table 5). The use of various modelling approaches helps establish the range of possible results, thereby accounting for model risk.

Variables given in scenario analysis must be complemented with more granular data necessary for scenario analysis run by specific jurisdictions. The NGFS scenarios released in June 2020

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[102] NGFS (2020), *NGFS Climate Scenarios for central banks and supervisors*, June.

[103] NGFS scenarios have been developed primarily for use by central banks and supervisors, but may also be useful to the private sector, government and academia.

[104] Orderly scenarios to explore low transition and physical risks, disorderly scenarios for high transition and low physical risks, hot house world scenarios for low transition but high physical risks).

[105] The NGFS modelling framework includes three Integrated Assessment Models, with various modelling approaches. Comparing scenarios across the three models make users able to get a sense of the range of possible results.

[106] NGFS scenarios rely on SSP2, which assumes that society evolves broadly in line with past trends.

lack certain variables that are tailored to the circumstances of individual jurisdictions - either due to missing variables (e.g. macroeconomic, sectoral and firm-level financial variables), or because some countries' data are aggregated at a regional level. In June 2021 the NGFS published an expanded set of variables for use in its scenarios that are of increased sectoral granularity.[107]

Table 5: Examples of variables available as part of scenario analysis (non-exhaustive extract of variables that form part of the NGFS Climate Scenarios (June 2020))

Climate risk variables		Macro-financial variables
Physical variables	Transition variables	
• Global and regional temperature trajectories • Frequency and severity of chronic climate related perils • Crop yield • Land use	• Carbon price pathways • Emission trajectories • Commodity and energy prices • Energy demand • Energy mix • Investment in energy • Energy prices	• GDP (and its components) • Unemployment • Inflation • Productivity • Household disposable income • House prices • Interest rates • Exchange rates • Equity prices

The need to tailor scenarios to the circumstances of individual jurisdictions can give rise to data gaps concerning the path of climate-related variables specific to certain jurisdictions. Financial authorities therefore need to complement such variables with missing data, including that necessary to tailor the scenarios to the circumstances of individual jurisdictions (e.g. specifics of their climate policies and adaptation to climate risks, or more precise meteorological data at the national level). [108, 109] This requires additional modelling work and underlying assumptions that can present a particular burden on some financial authorities that lack the specific expertise (see Box 5 on EMDEs). [110]

The implementation of scenario analysis can also expose data gaps concerning the exposures of financial firms to climate-related risks. Whether financial authorities' – or firms themselves –

[107] See NGFS (2021), NGFS Climate Scenarios for central banks and supervisors, June.

[108] E.g. Bank of England (2020), Climate Biennial Exploratory Scenario.

[109] Supervisors can also use physical impact data more tailored to their specific needs. In the Banque de France/ACPR exercise, climate data for France were computed by the national meteorological services (Meteofrance), and their financial impacts on financial institutions (given their exposures) by the Caisse Centrale de Réassurance ; outside of France, banks were asked to estimate in-house the financial consequences, using NGFS climate data or any data aligned with the RCP of the provided scenario. In the Bank of England Climate Biennial Exploratory Scenario, more granular detail was added (e.g. flood damage by postcode).

[110] For example, in the ACPR / Banque de France exercise, the estimation of asset prices by sector and regions is made via a Dividend Discount Model that builds on scenario data and a certain number of assumptions

encounter such data gaps depends on whether scenario analysis is bottom-up or top-down.[111] In the case of top-down approaches, the impact of a given scenario on financial institutions is estimated by the financial authorities themselves. This may expose data gaps concerning financial authorities' information on financial firms' exposures to climate-related risks which are particularly prevalent in some jurisdictions (see Section 4). For bottom-up analysis, financial institutions calculate the impact of each scenario themselves, with the potential to make a more detailed assessment of exposures. Doing so may, however, expose data gaps on the part of firms themselves, where they lack granular data on the impact of the scenario on their counterparties (e.g. counterparties' GHG emissions in the case of transition risk or precise location of assets in the case of physical risk) (see Section 3).[112] That said, bottom-up exercises can provide financial authorities with further insight into the nature of these data gaps on the part of individual firms and can provide impetus to financial firms to bridge some of these gaps.[113]

Such data gaps on firms' exposures are particularly acute in the case of longer-term scenarios, which go beyond the horizons typically considered by firms and their supervisors in their stress testing of other types of financial risks. Longer-term scenarios (e.g. beyond five years) typically require financial institutions to account for how their balance sheets might evolve in the course of the scenario, including, for example, to actions taken by their management to reduce their exposure to climate-related risks. Such dynamic balance sheets clearly allow the results of scenario analysis to be more realistic, but come at the cost of more demanding data requirements and greater uncertainty. This includes information on the strategic reallocation of financial institutions' portfolios, which needs to be consistent with projections of the future structure of the economy (see Section 4).[114] Projections under longer-term scenario analysis are significantly more uncertain than those of stress-testing of other sorts of risk manifesting over shorter horizons. Some firms circumvent this issue by assuming their balance sheets to remain fixed over time when running such scenarios.

More generally, there are limitations as to the degree to which scenario analysis is able to capture the broader effects of climate-change on the financial system and macroeconomic environment. Although the variables used in scenario analysis include both those related to the macroeconomy (e.g. GDP) and drivers of climate-related risks, the underlying models and data do not fully capture the dynamics between them. For example, some commonly used Integrated Assessment Models used in scenario analysis are not sufficiently comprehensive to capture the response of the macroeconomy to an unexpected change in climate -related policy (e.g. the introduction of a tax on carbon emissions). In the case of physical risk, economic modelling frameworks often consider only the impacts of chronic physical risks (e.g. increases in temperature), but not the future impacts of more frequent or intense severe weather events. In order to circumvent these difficulties, some financial authorities have used additional models that

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[111] Further discussion of the mechanics and relative merits of top-down bottom-up approaches to scenario analysis are discussed in FSB (2020a).

[112] In an attempt to circumvent this problem, the Bank of England's Climate Biennial Exploratory Scenario limited the number of firms for which participants had to carry out counterparty-level analysis. In the ACPR/Banque de France exercise, banks were asked to segment their corporate portfolio at the sectoral sector instead of going to the counterparty level. It should be noted that those exercises had a conceptual purpose, and will be useful in identifying data gaps and improving banks' capabilities.

[113] As part of the Bank of England's Climate Biennial Exploratory Scenario, financial firms were encouraged to engage with their counterparties to fill data gaps with respect to counterparties' vulnerability to climate-related risks.

[114] In the case of ACPR-Banque de France pilot exercise (2020), the dynamic balance sheet approach requires strong assumptions (eg on the evolution of the structure of the economy, behaviour, etc.) and conceptual adjustments.

proxy the impact of such climate-related risks via more standard economic models (e.g. changes in energy prices, or broader changes in productivity) These models, being calibrated on historical data and statistical relationships, may not adequately capture climate scenario dynamics, however.

Scenario analysis is limited in the degree to which it captures the mechanisms though which climate-related risks might be amplified by the interaction of different sectors of the financial system. This is in part because some such amplification effects may arise from the potential future termination or inefficacy of mitigants used by financial firms to reduce their exposures to climate risk. The increased crystallisation of physical risks, for example, could cause insurers to reduce the cover they offer to current and potential future policyholders against severe weather events (see Section 4). Such effects are often not included specifically in scenarios, which generally include only consideration of first-order impacts of climate-related risks rather than how the financial system responds to their crystallisation. This reduces the ability of financial authorities to assess the degree to which reductions in coverage might have negative effects on other financial institutions – subsequently reducing banks' lending to affected entities, and subsequent economic activity. In order to partially address this shortcoming, the Bank of England's and the Banque de France's exercises examine the extent to which the results of scenario analysis that are reported by banks and insurance firms are compatible. This includes an assessment of whether the level of insurance coverage assumed by banks on their mortgage portfolios is comparable with the degree to which insurance firms assume such coverage to be retracted as climate risks become uninsurable.

Scenario analysis is also limited in the degree to which it captures how the response of the financial sector to climate-related risks might amplify their impact. For example, if the banking sector were to suffer widespread losses as a result of the widespread crystallisation of climate-related risks, this could cause a large reduction in their lending. This, in turn could amplify the effect on the real economy, and result in larger and self-reinforcing losses for banks.[115] There is evidence, however, that financial firms currently have only limited ability to consider these effects in estimates of their future lending decisions, including those produced as part of bottom-up scenario analysis. This may be because firms' risk management is generally geared more toward direct and short-term exposures, rather than toward the longer-term and second-order effects necessary to capture such dynamics.[116] Again, scenario analysis can, however, serve a role in bridging this data gap in so far as the information it provides on the potential direct impacts of climate-related risks provide a starting point for the consideration of such second-round effects.[117]

[115] See FSB (2020b).

[116] See BCBS (2021).

[117] For example, the Bank of England is considering adding a second round to its Climate Biennial Exploratory Scenario, in which it could ask participants to consider how the impact of climate-related risks might be amplified in light of the possible response of the financial sector to such risks.

6. Conclusion and policy implications

Substantial progress is being made to improve the data and metrics with which to monitor and assess climate-related risks to financial stability. Nonetheless, this report has identified significant remaining data gaps.

Financial authorities should take steps to address these data gaps, as appropriate to their mandates and domestic legal frameworks. This should include steps to increase the availability of existing data, where appropriate to domestic legal frameworks. Doing so will allow for better assessments and monitoring of climate-related risks to financial stability. It will also allow market participants to incorporate climate-related financial risks better in their decisions, including the pricing and allocation of capital. The close relationships and interconnections between the risks faced by different participants in the financial system reinforce the case for coordinated action to fill data gaps, and ensure as great a degree of comparability of data as possible across jurisdictions, firms and sectors. Filling some data gaps may also require coordination and cooperation between financial authorities and official sector bodies with broader responsibilities (e.g. environmental or statistical agencies). The FSB roadmap on addressing financial risks from climate change will serve as a mechanism for coordinating this work.[118]

The following priority areas of work – some of which are already in progress – should address certain important data gaps to improve the monitoring and assessment of climate-related risks to financial stability

1. *Drivers of climate risk*. The FSB supports the work of NGFS and IMF to improve the availability and consistency of data on the underlying drivers of climate-related risks. Such work should include the data and metrics necessary to assess the current and projected future susceptibility of non-financial entities to physical risks. This includes steps by the official sector to improve the availability and comparability of granular geophysical data sets across jurisdictions, as well as the ease and robustness with which they can be aggregated. Additional and internationally comparable data on the drivers of transition risk – including on the scale and nature of jurisdictions' climate change targets and progress in meeting these – are also important.

2. *Corporate disclosures.* The FSB welcomes the IFRS's programme of work to develop a baseline global sustainability reporting standard under robust governance and public oversight, built from the TCFD framework and the work of an alliance of sustainability standard setters, involving them and a wider range of stakeholders closely, including national and regional authorities. The building block approach proposed by the IFRS Foundation aims to allow flexibility in the implementation of standards while helping improve the extent and consistency of firms' disclosures of climate-related risks. Such international standards for disclosures as a global baseline would not preclude authorities from going further or at a faster pace in their jurisdictions. In the lead up to international sustainability reporting standards, the FSB continues to promote the consistent implementation of a more common approach to disclosure among national and regional financial authorities, using a framework based on the TCFD Recommendations, in line

[118] FSB (2021), *FSB Roadmap for addressing climate-related risks to financial stability*

with domestic legal and regulatory frameworks. Further numerical data on financial implications for companies of the possible future crystallisation of climate-related risks – both concerning the value of their assets, as well as their cash flows and profitability – will also be needed. Data on firms' broader exposures to climate-related risks – including those arising from their value chains – are particularly important in this regard.

3. *Financial institutions' exposures*. Financial authorities should consider how to improve the quality and consistency of data on financial institutions' exposures to climate-related risks, including those that arise from their exposures to non-financial counterparties (including their supply chains). These should be sufficiently granular to assess concentrations of, and interlinkages between, climate-related risk exposures – both to certain financial institutions, and to certain non-financial sectors or individual counterparties – that might have implications for financial stability. Continued work at the international level, including through the NGFS, to identify appropriate degrees of granularity and aggregation, can aide the consistency and effectiveness of such efforts.

4. *Forward-looking financial stability metrics.* Financial authorities should consider developing forward-looking metrics on climate-related risks both at the level of individual firms, and for the financial system as a whole. The TCFD is developing guidance on the development of consistent forward-looking metrics of the impact of climate-related risks, for use by individual companies or individual financial institutions. In order to maximise their usefulness in allowing an assessment of risks to financial stability, such metrics should go beyond providing information on the central expectations of the impact of climate change, and incorporate information on uncertainty and tail-risks (e.g. climate-value-at-risk).

5. *Risk transfer in the financial system.* Financial authorities should work together to widen and harmonise data on the degree to which financial institutions' exposures to climate-related risks are transferred between different financial sectors. One important data gap in this regard is the degree to which the individual financial firms' exposures to climate-related risks are mitigated by the provision of insurance, including that provided implicitly by the official-sector in the form of measures to mitigate the impact of climate-related risks. There are currently also only limited data on the holders of related financial securities that share risk, such as insurance-linked securities or catastrophe bonds. Standard-setting bodies – including those responsible for the oversight of banks, insurers and markets – could usefully work together to fill these data gaps.

6. *Scenario analysis.* Recent advances in the use of scenario analysis are assisting financial authorities in their assessment and monitoring of the degree to which the financial system is resilient to climate-related risks. The FSB should bring financial authorities together to compare their experiences of implementing scenario analysis in order to identify relevant data gaps. As part of that effort, the NGFS should continue to refine and develop scenarios, which financial authorities should make use of in their scenario analysis, as appropriate, in order to align the data and methodologies used in such analysis. Relevant data gaps might include those data and metrics necessary to assess the degree to which climate-related risks might be transferred, amplified or mitigated by different financial sectors (including the interdependence of banks and insurance firms), and how this varies across different jurisdictions. It might also include those data necessary to assess the

degree to which risks might be amplified by feedback loops with the real economy. Coordination by the FSB in this area – including through its work with other international fora, such as the NGFS – could also foster the integration of scenario analysis into financial authorities' frameworks to assess broader risks to financial stability.

Looking beyond these near-term priorities, enhancing the set of data to assess and manage climate-related financial risks will also remain important in the medium term:

7. *Effects of climate risks on the broader macroeconomy.* Building on progress made in the areas listed above, financial authorities should also consider how to expand and improve data with which to assess how climate-related risks could impact the financial sector via their effects on the broader macroeconomy. This should include expanding the availability of data on the potential impact of climate-related risks beyond that on corporates and financial firms, to include sovereigns and households, and on how these sectors might interact. This might for example, include data that shed light on how tax revenues and government spending might be affected by the impact of physical risks on households and firms.

Annex 1: Survey responses

The table below shows responses to the survey of AGV members that gathered information on the data FSB member authorities use to monitor and assess climate-related risks to financial stability.

Respondent	Financial authorities and organisations	Banks Supervisor	Insurance Supervisor	Asset Manager Supervisor	Monitor Financial Stability
AU	Reserve Bank of Australia (RBA), Australian Prudential Regulation Authority (APRA)	Yes	Yes	Yes	Yes
BIS	Bank for International Settlements	No	No	No	Yes
BR	Banco Central do Brasil	Yes	No	No	Yes
CH	FINMA, Swiss National Bank (SNB)	Yes	Yes	Yes	Yes
CL	Banco Central de Chile	No	No	No	Yes
CN	China Banking and Insurance Regulatory Commission, The People's Bank of China	Yes	Yes	Yes	Yes
DE	Deutsche Bundesbank	Yes	No	No	Yes
ES	Banco de España (BdE), Comisión Nacional del Mercado de Valores (CNMV, National Securities Markets Commission), Dirección General de Seguros y Fondos de Pensiones (DGSyFP, Directorate General for Insurance and Pensions Funds), and General Secretariat of the Treasury	Yes	Yes	Yes	Yes
ESMA	European Securities Markets Authority	No	No	No	Yes
FR	Banque de France, ACPR	Yes	Yes	Yes	Yes
HK	Hong Kong Monetary Authority (HKMA), Insurance Authority (IA)	Yes	Yes	No	Yes
IMF	International Monetary Fund	No	No	No	Yes
IT	Banca d'Italia	Yes	No	Yes	Yes

Respondent	Financial authorities and organisations	Banks Supervisor	Insurance Supervisor	Asset Manager Supervisor	Monitor Financial Stability
JP	Bank of Japan (BoJ), Japan Financial Services Agency (JFSA)	Yes	Yes	Yes	Yes
KR	Bank of Korea (BoK)	No	No	No	Yes
MX	Banco de México	Yes	No	No	Yes
NL	De Nederlandsche Bank (DNB)	Yes	Yes	Yes	Yes
OECD	Organisation for Economic Co-operation and Development	No	No	No	No
RU	Central Bank of the Russian Federation	Yes	Yes	Yes	Yes
SG	Monetary Authority of Singapore	Yes	Yes	Yes	Yes
UK	Bank of England (BoE) and Prudential Regulation Authority (PRA)	Yes	Yes	Yes	Yes
US	Federal Reserve Board, Securities and Exchange Commission, Commodity Futures Trading Commission, Federal Reserve Bank of New York, Department of the Treasury.	Yes	No	Yes	Yes
WB	World Bank	No	No	No	Yes

Annex 2: Firms disclosures that are in line with the recommendations of the TCFD

This Annex examines the information that is available from firms' disclosures of their exposure to climate-related risks. It focusses on firm disclosures that are in line with the recommendations of the Taskforce on Climate-related Financial Disclosures (TCFD), which was established by the FSB in 2015 to develop a set of voluntary, consistent disclosure recommendations. These recommendations were released in 2017.

Background on the work of the TCFD and its recommendations

Since 2018, the TCFD has published annual status reports that describe the alignment of firm disclosures with the TCFD Recommendations. The 2020 status report reviewed 1701 public companies for climate-related financial information, using artificial intelligence technology to determine whether such disclosures are aligned with the TCFD Recommendations.

The TCFD's recommendations – and the disclosures to which they have given rise – are meant to address disclosures made at the firm level. They are not intended to provide information on risks to financial stability, but rather a framework through which companies can provide effective disclosures that facilitate transparency concerning climate-related risks, and decision-useful information for appropriate pricing of risk and capital allocation.

That said, companies' reporting disclosures climate-related risks, including those aligned with TCFD Recommendations, can provide information of use in assessing risks to financial stability. For example, the TCFD recommends that firms disclose the metrics and targets they use to assess and manage climate-related risks and opportunities, where such information is material. The recommended disclosures include:

- Metrics used by the company to assess climate-related risks and opportunities in line with a firm's strategy and risk management processes;
- Scope 1, Scope 2 and, if appropriate, Scope 3, greenhouse gas (GHG) emissions
- The targets used by the company to manage climate-related risks and opportunities, and performance against targets.

Current extent of TCFD-aligned disclosures on metrics and targets[119]

Firms' disclosure of metrics and targets used to assess and manage climate-related risks and opportunities have increased since the release of the TCFD Recommendations in 2017 (Chart A). Around a quarter of firms surveyed now report Scope 1 and 2 emissions, and around a third report climate-related targets. Larger companies are more likely to disclose these metrics and targets than smaller companies. Disclosure also varies across regions. Disclosures are higher

[119] TCFD Recommendations are broader than those concerning metrics and targets, and include recommendations on firms' governance, strategy and risk management. These are not discussed here, however.

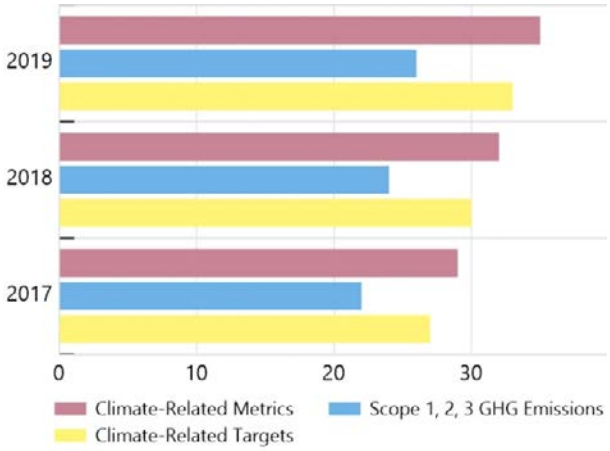
by European firms. This may in part be due to the European Commission's integration of the TCFD Recommendations into its Guidelines on reporting climate-related information.

Some evidence suggests that disclosures of transition risks are more advanced than that of physical risks.[120] This may be because exposure to transition risks is easier to summarise in a single quantitative metrics – such as the quantity of emissions – than that on physical risks.

Progress on TCFD-aligned disclosures for metrics and targets

In per cent **Chart A**

By year



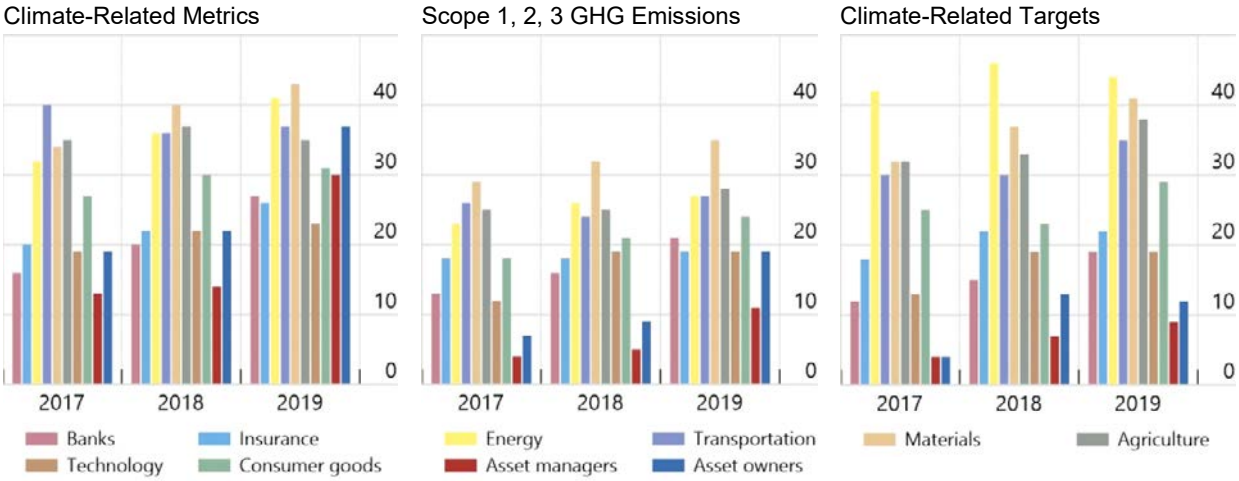
By company size

Recommended Disclosure	<$2.8B Market Capitalization (613)	$2.8B – 10B Market Capitalization (539)	>$10B Market Capitalization (549)
Climate-Related Metrics	20%	30%	56%
Scope 1, 2, 3 GHG Emissions	16%	25%	40%
Climate-Related Targets	19%	28%	52%

Source: TCFD, (2020), "Task Force on Climate-related Financial Disclosures: 2020 Status Report."

Disclosures by Sector

In percent **Chart B**



Source: TCFD, (2020), "Task Force on Climate-related Financial Disclosures: 2020 Status Report."

Chart B summarises the extent of reporting across sectors. Reporting of metrics and targets is most advanced in the energy and materials/buildings sectors. Reporting of Scope 1 and 2 GHG emissions is less advanced for banks and insurance firms, though has increased in recent years.

[120] How can climate change disclosures protect reputation and value? | EY - US

Asset managers and owners have made substantial progress in reporting climate-related metrics, but have made less progress in reporting GHG emissions and targets.

Disclosures of Scope 1 and 2 emissions are generally more available than those of Scope 3. This is likely due to difficulties encountered by reporting firms in calculating emissions across the entirety of their value chain.

Annex 3: Write-up of AGV virtual workshop on the availability of data with which to monitor and assess climate-related risks to financial stability

This note summarises the findings of a series of virtual workshops that AGV held with representatives of private sector firms. This took place on 8 and 9 February 2021.

The workshop was attended by twenty representatives of private-sector firms. These included representatives of banks, asset managers, insurance firms, data providers, academia and other international private sector associations and organisations. Such participants generally represented firms whose use and development of climate-related data are reasonably advanced, relative to that of their peers. Fifty-five representatives of official-sector institutions attended the workshop, the majority of whom represented financial authorities that are members of the AGV.

The workshop comprised five sessions. These focused on the perspective of (i) banks, (ii) asset managers, (iii) insurance firms and (iv) data providers concerning the availability of data with which to monitor and assess physical and transition risks. A final session discussed the data available to monitor the resilience of the financial system to climate-related risks, including issues concerning scenario analysis. Each session included short introductions from a panel of external stakeholders, followed by open discussion.

This note begins by summarising the key takeaways from the workshop. It then gives a more detailed account of the discussion in each session. It first sets out findings in terms of the availability of data to monitor physical and transition risks, before moving to set out takeaways on the resilience of the financial system including the use of scenario analysis and associated challenges.

The findings that follow do not necessarily represent the views of FSB member authorities, nor reflect any consensus views of external stakeholders.

Key takeaways

Several overarching key points emerging from the discussion at the workshop that were relevant to the AGV's report:

- There is a need for more consistent and comparable data with which to assess the impact of physical risks on the financial system. Participants thought there exists, at least in some jurisdictions, quite granular and consistent data on the severity of physical risks (e.g. flood risk in the UK, typhoons in Japan). However, such data is not consistent across jurisdictions. There is also less data on the degree to which firms have adapted to physical risks.

- Data availability on transition risks is more consistent and comparable than data on physical risks, in large part due to the steps some firms have taken to disclose their emissions. However, reporting of emissions data is skewed towards the largest firms and reporting of scope 1 and 2 emissions is more advanced than that of scope 3. Workshop participants thought it would be helpful if metrics on transition risks go beyond

data on emissions and capture the forward-looking nature of transition risks (e.g. firms' transition plans, timing and of policies to reduce emissions, adaptation/mitigation measures). Data on metrics such as firms' transition plans is not currently consistent across firms or jurisdictions.

- There are difficulties involved in translating data on climate change to economic variables: There was general agreement on the difficulty of translating data on assets' exposure to physical/transition risks to changes in economic variables, including firms' balance sheets/cash flows. This generally requires significant expertise and human judgement. There is no standardised way to translate climate risks into PDs/LGDs, so methods for doing so often involve substantial ad-hoc judgement. Participants expressed concern that this leads to inconsistencies in how financial institutions report climate-related risk. There was also general agreement as to the difficulties in matching data on the susceptibility of assets to physical and transition risks to data on financial institutions' exposures to those assets.

- Quality scenario analysis requires both standardization and customization: Participants agreed that scenario analysis of climate-related risks differs substantially to other types of stress testing. Time horizons need to be longer, risks are highly non-linear and dependent on short-term policy actions, and back-testing is hard or impossible because of limited past data. Market participants heard there was a balance to be struck between the need for standardised scenarios, versus the need to tailor to the specifics of risks faced by different firms.

Availability of data with which to monitor and assess physical risks

Most workshop participants engaged in some sort of analysis of their firms' exposures to physical risks. There was a general sense, however, that granular data on financial exposures to physical risks was specific to certain jurisdictions and not consistent globally. Representatives from the banking sector and asset management industry mentioned that their institutions have high-quality granular data on flood risk in their home jurisdictions, but that this level of granularity is harder to obtain for their foreign exposures. Several participants also mentioned that their clients' disclosures of their exposures to physical risks were generally incomplete. One participant mentioned the challenges of assessing large clients' exposures to physical risk, particularly multi-national firms with a large number of locations across the world.

Some participants pointed to the challenges they faced in translating data on the occurrence of physical risks into changes in the value of assets. One representative from an insurance company noted that location data on physical risks (e.g. flooding) often needs to be highly granular, and can be hard to translate consistently into changes in asset values.

Some participants thought there was insufficient data on how firms are adapting to physical risks. This was thought to be a notable data gap, given that it can have bearing on the calculation of changes in asset values that result from the occurrence of such risks. A representative from an insurance company noted a lack of sufficient data on how structures such as mines and dams may be retrofitted with adaptations to prevent the effects of physical risks. A representative from the banking sector mentioned there is a lack of data on how firms mitigate flood risks, and gave the example of how mining firms in some jurisdictions had raised the entrance to their mines to

reduce water egress. Consistent and quantifiable information on such developments is very difficult to obtain, but certainly implies climate risk identification and mitigation on the part of the mine.

Several participants also mentioned challenges concerning the translation of physical risks into economic variables. There was general agreement that there is a lack of standardised methodologies for translating outcomes for physical risks into changes in firms' balance sheets and cash flows. A representative from a bank gave an example of the difficulty of calculating the cost of business disruption due to physical risks, and how this required substantial human judgement. Representatives from the banking sector mentioned that it was possible to get information on the exposures to physical risks only of their largest clients. One representative from a bank mentioned that of its largest 100 client exposures, 70% acknowledged physical risks, but only 45% calculated their financial impact. They also said that it is hard to calculate the total impact of physical risks to large firms since many have upwards of 5000 different asset locations, but may only report the exposure of a small subset of these to physical risks.

A number of participants from the banking sector highlighted the difficulty of matching data on assets' exposures to physical risks, with data on their financial institutions' exposures to those assets. One representative from the banking sector said they had very granular data on building flood risk, but struggled to match this with the bank's internal data on its exposure to these buildings (including via their use as mortgage collateral). The process of doing so required a good deal of manual data cleaning, geographic information system (GIS) or geocoding expertise, and human judgement. A number of other participants said they also encountered similar issues.

Availability of data with which to monitor and assess transition risks

There was broad agreement that the availability of data on firms' exposure to transition risks is generally greater than for physical risks. This is in large part because some firms now disclose data on their GHG emissions. However, a representative of a data analytics firm on climate highlighted potential issues with the reliability of such data, and its consistency across firms, particularly given that it was generally not verified by a third party or subject to audit.

Participants also generally agreed that data on GHG emissions is mainly confined to larger listed firms. Some representatives of asset managers mentioned the challenges involved in obtaining data on transition risk exposures – including emissions – from smaller firms. Some asset managers have engaged directly with small companies in an attempt to try to improve their disclosures and fill in their data gaps.

Participants also observed a regional and industry bias to firms' climate-related disclosures. There was an agreement among the panellists on the greater availability of data for firms in Western Europe and the Nordic countries, followed by Japan, while disclosures from US firms are increasing. There is more data on GHG emissions, including Scope 3 emissions, for firms in sectors with the highest emissions, such as oil and gas companies.

Participants generally agreed that while the reporting of GHG emissions has been improving over time, particularly for Scope 1 and Scope 2, important challenges remain. A representative of a commercial data provider mentioned that reasonable-quality data on GHG emissions is only available only for a third of the companies they monitor. Several data providers use internal

models, including machine learning techniques, to fill the gaps and estimate historical and future GHG emissions, which improves the consistency and comparability of their own data but lead to some differences across providers. There was some scepticism about future progress on disclosing Scope 3 emissions given the challenges involved in collecting data, and calculating emissions figures, for firms' entire supply chains.

Many participants emphasised a need for better, more standardized and transparent data on firms' climate-related financial disclosures. The EU Sustainable Finance Taxonomy was generally seen a constructive step towards achieving this. A participant from academia mentioned that a standardised science-based classification of stranded assets is also needed.

Some discussants thought that metrics of firms' transition risks should go beyond emissions and include more granular and forward-looking information on transition risks. These could include metrics such as climate-value-at-risk and implied temperature increases. Some participants mentioned the need of more detailed and granular data on firms' revenues across different business lines, investment in R&D, exposures to carbon tax, carbon price premium, transition strategy/plans and climate-related policies.

A representative of a commercial data provider mentioned that many of these core input variables are not reported by the companies they monitor. Therefore, a large part of the data they use to assess/monitor climate-related risks comes from their internal models. This leads to a lack of standardisation across the data provided by different commercial data providers.

Similar to physical risks, many participants said there is little data on the measures firms are adopting to transition to a lower-carbon economy. There was a consensus that data on firms' transitions are not disclosed in a standardised manner and that this limits the degree to which comparisons can be made across firms. For example, one participant noted that data on firms' targets for emission reductions are often articulated differently across firms (e.g. one firm uses per cent vs one firm using volume, or two firms citing different target years), making comparison almost impossible. The participant also said that differences in accounting standards also contribute to the lack of consistent data across regions and companies.

Many participants mentioned that there are also no standardised methodologies for mapping emissions data into measures of financial firms' exposures to transition risks – e.g. how to translate the impact of emissions reduction policies into variables such as probability of defaults (PDs) and loss given defaults (LGDs) that affect financial firms' balance sheets and cash flows. There was some discussion on whether net or gross exposures should be used to measure the impact of increasing costs of emissions on measures of firms' profitability. Participants had varying approaches toward considering firms' supply chains, including whether to include the ability to pass carbon-cost to clients into the analysis. Some participants also mentioned the high levels of uncertainty inherent in the exercise, for instance, uncertainty over policy timing or uncertainty over how to measure disruption cost far into the future with incomplete data, which may lead to too many assumptions and increases model risk.

While the 'E pillar' of ESG ratings could, in principle, provide data on firms' exposure to transition risks, some participants discussed issues concerning a lack of consistency across rating providers. One participant said that the way rating providers consider transition plans vary, while a couple of participants said that the ways the weight is given to scope 1, 2 or 3 emissions differ. A couple of participants mentioned it might not be necessary (or even desirable) to strive for

correlation across ESG ratings as long as there is transparency on their methodologies and easy access to the underlying data.

Use of scenario analysis in monitoring the resilience of the financial system to climate-related risks

There was an agreement among the participants that climate scenario analysis is very different to other, more traditional, methodologies to model risks. Climate-related risks require a longer time horizon, are path dependent and non-linear. Scenario analysis is also hindered by the greater degree of uncertainty concerning the future progression of climate change as well as difficulties translating climate variables to variables relevant to financial institutions. Another challenge mentioned is the difficulty to know whether the results are reasonable with back-testing, since it may be hard or impossible to obtain past data on the past occurrence or effects of risks.

A few participants mentioned that it is important to have clear sense of the question you want to answer when running scenario analysis. By limiting and narrowing the questions – for example, coverage of physical or transition risks – it is possible to reduce the associated data challenges. Some participants discussed the factors that affect their choice of scenarios – for example, those that have the largest impact on financial institution's portfolios. A participant from academia mentioned that is important to consider seriously adverse scenario (e.g. a very disorderly scenario).

There was also a discussion on the pros and cons of using standardised scenarios across different firms and jurisdictions versus more tailored analysis. Although there is some comparability and operational advantages on using standardised scenarios across firms and jurisdictions, there are also some potential risks. Using only standardised scenarios for climate-risks analysis could be a channel for amplification of risks if everyone uses the same set of scenarios and they are wrong. In addition, some participants highlighted the important role of local markets in transition risks and the need for some tailored scenarios.