

# Climate change as a risk to financial stability

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*In this study, we give an overview of risks to financial stability that result from climate change. We classify them according to their sources and show how they affect traditional categories of financial risk. Most financial institutions have yet to acknowledge these types of risk, with only a few having to date recognized climate change as a market opportunity. Over the past few years, both private and public institutions have, however, started to find better ways to identify, assess and manage climate-related risks, especially since the Paris Climate Agreement. Which data and indicators are needed to implement effective risk management in this area? While metrics and methods are available to financial intermediaries for this purpose, they are not yet widely used in practice. In the latter part of our study, we explore the awareness of Austrian financial intermediaries of climate-related financial risks empirically. Based on survey data, we find that some institutions have already integrated climate change into their business strategy and risk management systems, while a large share of institutions has not yet identified climate change as a financial risk at all. The fact that a majority of financial intermediaries had cited regulations and norms as effective motives for better adapting to the risks of climate change calls for future action by policymakers and regulatory authorities.*

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Awareness of the economic and financial consequences of climate change has been rising over the past years. By signing the Paris Agreement in 2015, which aims at keeping the global temperature increase well below 2°C by the end of this century, national governments committed to acting responsibly. That same year, Mark Carney, Governor of the Bank of England, outlined the negative effects of climate change for financial markets in a seminal speech in London. In 2017, a Network of Central Banks and Supervisors for Greening the Financial System (NGFS) was founded in Paris, which the OeNB joined in 2018. The NGFS is a voluntary forum for sharing best practices in identifying, managing and supervising climate-related risks in the financial sector and mobilizes funds for the transition toward a sustainable economy. Recent speeches by ECB board members attest to the relevance of climate change in the euro area (see Cœuré, 2018, and Mersch, 2018). It is important to bear in mind that climate change is one of several sources of risk to financial stability, next to issues of cybersecurity, rising inequality or geopolitical tensions.

Identifying climate change as a source of financial risks is essential for pricing assets. The expected payoff of any investment should compensate the investor for the risks taken. Therefore, higher risks lead to higher risk premiums. If investors are unaware of climate-related risks or if these risks are not disclosed appropriately, market prices cannot, and will not, reflect the appropriate risk-return tradeoff. Only if these risks are identified and assessed correctly, can they be monitored adequately and managed efficiently; and only then can financial markets allocate capital efficiently. By reflecting these risks properly, market prices will also convey a strong signal to foster the transition toward a low-carbon economy.

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This article gives an overview of the climate-related risks to financial markets and is structured as follows: section 1 defines these risks according to their sources and indicates how they affect economic and financial variables. Section 2 describes public and private initiatives that aim at improving both the assessment and management of these risks. Section 3 presents findings from a survey among Austrian financial intermediaries on their assessment of climate-related risks and section 4, among other things, briefly touches on the OeNB's role in raising awareness of climate-related risk to financial stability.

## 1 The financial risks of climate change

While the future is always unknown, we speak of risk if the probability distribution of possible future outcomes is known, and of uncertainty if it is not. In this sense, many consequences of climate change are rather subject to uncertainty as the current atmospheric concentration of CO<sub>2</sub> and other greenhouse gases (GHGs) has been unprecedented in the last 800,000 years (IPCC<sup>2</sup>, 2014). A further increase in global average temperatures by 5°C would constitute a unique environment never experienced before by humankind. Hence, we can only guess whether any subsequent damage would increase linearly or exponentially, or how such damage would be distributed across regions. Nordhaus (2016) explicitly addresses the uncertainty about future policy actions and technology developments and finds that it will be extremely difficult to achieve the 2°C target of the Paris Agreement even if drastic policy action is taken very soon.

In defining climate-related financial risks according to their origins, we follow the NGFS (2019): we cluster them into physical risks and transition risks that have distinctive economic and financial implications. While physical risks are direct effects of climate change, transition risks stem from the process of decarbonization that is aimed at preventing or mitigating global warming. Both categories are correlated because the more transition policies enter into force, the fewer physical risks are likely to materialize. On the other hand, the harder the economy is hit by physical risks, the stronger will be the demand for effective transition measures.

### 1.1 Physical risks

Physical risks encompass the effects of rising temperatures and of an increasing number of extreme weather events like droughts and floods or rising sea levels caused by climate change. According to the Task Force on Climate-Related Financial Disclosures (TCFD, 2017), these risks can be distinguished with respect to the term structure of the hazards that cause them. Acute hazards are severe, short-term events with a significant negative impact on the economy like droughts, floods and storms, and chronic hazards are continuous shifts in climate patterns such as increasing temperatures, rising sea levels and changes in precipitation. If acute hazards become more frequent due to climate change, their impact might eventually resemble that of chronic hazards. If, for example, a river becomes more prone to floods, its banks will be considered less habitable over time.

Physical risks can affect both the supply and the demand side of the economy. Global warming will have an impact on labor supply in many countries because

<sup>2</sup> The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change.

higher temperatures can erode public health and labor productivity. An increased frequency of extreme weather events can have a similar effect. Climate change may also lead to a faster corrosion of machines and buildings, speeding up the depreciation of the capital stock. As climate change proceeds, the combined negative effects on labor and capital are set to reduce future output.

In addition to the impact on output levels, physical risks also produce a negative effect on output growth, as emphasized by Bowen and Dietz (2016). The damages to the capital stock will redirect more capital investment into repair and replacement, and proportionally fewer funds can be allocated to research and innovation, the drivers of productivity. Future lower capital productivity would imply a lower equilibrium interest rate.

The regional distribution of these effects is rather uncertain. Ciscar et al. (2014) estimate the biophysical impacts of climate change in five large EU regions, with the effects differing significantly. The melting of Alpine glaciers is expected to have a severe impact on the energy mix in Austria<sup>3</sup>. As more than half of the glacier surface is projected to disappear by 2050 (compared with the beginning of the century), the hydropower potential will decrease irreversibly in the long run.

On the demand side, increasing expenditures for repair and replacement will, *ceteris paribus*, reduce investment on and consumption demand for other goods. Uncertainty will probably cause subdued or delayed investment spending by firms. Households confronted with more frequent extreme weather events might increase precautionary saving, which would depress private consumption in general. If the likelihood of insured events increases due to climate change, the rising insurance risk will be reflected in higher premiums. Materializing physical (and potentially also transition) risks<sup>4</sup> will drive up insurance companies' liability risks as they are faced with increasing numbers of claims. If the polluter-pays principle were to be extended to climate change-induced damage, the liability risks of other companies (e.g. large emitters of GHGs) might also rise, but it would be difficult to attribute a specific consequence of climate change to a specific emitter.

## 1.2 Transition risks

Transition risks materialize when changes in regulation and taxation, technological innovations or shifts in consumer preferences alter the expected future cash flows from productive assets, which can turn the latter into stranded assets. In a widely cited paper, McGlade and Ekins (2015) estimate that, by keeping global temperatures within the Paris target range, approximately one-third of the current oil reserves, half the gas reserves and almost 90% of the coal reserves would become stranded assets. The NGFS (2019) provides a range of estimates for the value of stranded assets caused by the energy transition, and it presents some transmission channels of transition risks to the balance sheets of financial corporations. All studies emphasize that an early and smooth transition results in much fewer risks; according to Breeden and Hauser (2019), too rapid an adjustment of asset prices due to a late transition might eventually bring about a climate Minsky moment.

<sup>3</sup> It should be noted that the 2°C objective of the Paris Agreement is a global target; its accomplishment would most likely translate into a temperature increase of 4°C in Austria.

<sup>4</sup> Whereas materializing physical risks affect insurance companies mostly on the liability side of their balance sheet via an increasing number of claims, transition risks affect them (and other financial intermediaries) on the asset side.

The limit to global warming of below 2°C agreed at the 2015 Paris climate change conference defines clear boundaries for future emissions. This implies that the transition from the current economic system to a decarbonized economy is inevitable as well as risky. Decarbonization requires some major changes in the modes of production. Therefore, the sooner the transition starts, the more gradual can it be implemented. It will then also be less disruptive, even though some disruption is most likely to occur. The disruptions will differ from industry to industry depending on the pre-transition levels of GHG emissions, and, as Schoenmaker (2019) shows, even intra-industry differences in the exposure to transition risks are quite significant.

The negative externalities of CO<sub>2</sub> emissions prevent the functioning of a market solution for decarbonization, which is why effective policy actions are needed. Regulation and taxation can incentivize firms to divest from carbon-intensive assets and thereby change the emission path of the economy. If this divestment happens abruptly and system-wide, financial stability might suffer. However, political considerations might delay necessary up-front policy action, as the burden of such policies is felt immediately by current voters while their benefits might manifest themselves only decades later. Kotlikoff et al. (2019) show in a large-scale OLG climate-change model that even by taking selfish behavior of different generations into account, a carbon tax combined with appropriate intergenerational redistribution can make all current and future generations better off. The later policy changes are implemented, the greater must be their impact so that they can trigger a sufficient resource allocation away from fossil assets. A stronger impact is often more disruptive and poses a greater risk to financial stability.

When regulatory reforms or new taxes change relative prices in favor of green assets, firms are not only incentivized to divest from brown, i.e. carbon-intensive, assets, they are also more likely to fund research in carbon-free innovations. If these innovations yield marketable products or processes, incumbent technologies will be replaced. According to the NGFS (2018), it might be rather difficult for some industries (e.g. aviation) to find carbon-free technologies and, therefore, their production is likely to be scaled down significantly, which might create more financial distress for owners and creditors alike.

While technological innovations are almost by definition hard to foresee, we have some ideas which regulatory changes are warranted; they cover policy areas from market regulation to fiscal policy. To change the relative prices of carbon-intensive and carbon-free assets, governments could either charge a carbon tax, impose a mechanism for emission trading, subsidize green investment or indirectly change the cost structure via command-and-control regulation. Acemoglu et al. (2012) find that the optimal policy response to climate change combines a carbon tax with a mission-oriented innovation policy (i.e. subsidies for promoting research in clean technologies). In January 2019, an initiative by U.S. economists<sup>5</sup> proposed the introduction of a carbon tax which should be raised each year until emission reduction goals are met. The revenues from this tax should be returned directly to U.S. citizens so they would benefit from a “carbon dividend,” which should improve public acceptance of the new tax. The initiative also proposes the establishment of

<sup>5</sup> The initiative was published by the Climate Leadership Council (<https://www.clcouncil.org/economists-statement/>) and its signatories include all living former chairs of the Federal Reserve System and 27 Nobel Laureate economists.

a border carbon adjustment system which works like a tariff on carbon-intensive imports and would trigger some transition risks in other countries. It should be noted that a border carbon adjustment system would be consistent with WTO rules as it would not unfairly favor domestic producers over foreign firms, but instead provide a level playing field in the market. The unilateral implementation of a border carbon adjustment system by one or several major economies might, however, cause distortions in international trade and disrupt global value chains.

As more and more market participants recognize the potential impact of climate change on their own business, firms that do not contribute sufficiently to decarbonization might be shunned by both consumers and investors. Financial intermediaries might not only end up with stranded assets on their balance sheets but could also face the reputational risk of being perceived as ignorant of concerns of great social importance because they are financing GHG emitters.

Companies are also prone to increasing liability risk if they do not manage transition risks well. In accordance with the polluter-pays principle, entities negatively affected by unmitigated climate change could seek compensation from those who had caused or allowed the damage and thereby at least partially internalize the

Table 1

### Climate-related financial risks for banks: physical risks

Financial risk category	Physical risk	Impact on banks
Credit risk	<ul style="list-style-type: none"> <li>Erosion of the value of capital due to natural disasters</li> <li>Reduction of debt service capability due to natural disasters</li> <li>Reduction of productivity and earnings due to rising temperatures</li> <li>Devastation of entire regions by floods and storms</li> </ul>	<p>Higher loss given default</p> <p>Higher probability of default, increase in nonperforming loans (NPLs)</p> <p>Higher probability of default, increase in NPLs</p> <p>Regional lenders face concentration risk</p>
Market risk	<ul style="list-style-type: none"> <li>Increase in price volatility due to natural disasters</li> <li>Rising uncertainty about natural disasters</li> <li>Sudden capital outflows due to natural disasters</li> <li>Increase in country risk due to rising sea levels</li> </ul>	<p>Increased volatility of real interest rates</p> <p>Higher risk premiums</p> <p>Higher exchange rate volatility</p> <p>Decline of sovereign bond prices, fewer risk-free assets</p>
Liquidity risk	<ul style="list-style-type: none"> <li>Sudden withdrawals in case of natural disasters</li> <li>High demand for emergency loans in case of natural disasters</li> </ul>	<p>Risk of maturity mismatch, regional bank runs</p> <p>Risk of maturity mismatch</p>
Operational risk	<ul style="list-style-type: none"> <li>Destruction of banking infrastructure due to natural disasters</li> <li>Rising insurance costs</li> <li>More expenditures for climate-change adaptation</li> </ul>	<p>Revenue losses, repair costs</p> <p>Reduced profits</p> <p>Reduced profits</p>
Reputation risk	<ul style="list-style-type: none"> <li>Contagion through proximity to affected sector or region</li> </ul>	<p>Rising risk premiums</p>
Systemic risk	<ul style="list-style-type: none"> <li>Widespread underestimation of natural disasters in risk models</li> <li>Rising correlation of defaults when the economy is hit by more natural disasters</li> </ul>	<p>Capital depletion, "too big to fail"</p> <p>Higher correlation risk</p>

Source: Authors' compilation.

negative externalities<sup>6</sup>. Firms that issue “green bonds” or other climate-friendly financial products may face legal action if their claims cannot be substantiated, i.e. if they engage in “green washing.”

Whereas an active policy stance on decarbonization might give rise to transition risks, a lack of adequate ambition can create negative confidence effects. If firms and consumers realize that policy inaction precipitates the economy to stay behind agreed targets of decarbonization, they might fear negative consequences in the form of more disruptive policy measures in the future to make up for the lost ground or sanctions by supranational (e.g. European) authorities. This negative sentiment could have a negative impact on investment or consumption.

According to Article 39 of the Austrian Banking Act (Bankwesengesetz – BWG) banks are obliged to apply due diligence in the assessment, management and monitoring of all risks relevant to their business. The law lists several risk categories that should be considered in banks’ risk management procedures. In table 1 and 2, we illustrate how climate-related financial risks play into traditional categories of banks’ risk management. Table 1 maps the risk management categories into physical risks and gives examples of how banks are affected when specific physical risks materialize; table 2 does the same for transition risks. The presentation is by no

Table 2

### Climate-related financial risks for banks: transition risks

Financial risk category	Transition risk	Impact on banks
Credit risk	<ul style="list-style-type: none"> <li>Severe devaluation of carbon-based assets</li> <li>Depressed revenues of debtors due to new carbon taxes</li> </ul>	Higher probability of default, more write-offs
	<ul style="list-style-type: none"> <li>More investment in new, inherently riskier technologies</li> </ul>	Higher probability of default
Market risk	<ul style="list-style-type: none"> <li>Changing customer behavior</li> <li>Missing the tipping point toward climate-neutral assets</li> </ul>	Demand shifts, price volatility Stranded assets, more write-offs
	<ul style="list-style-type: none"> <li>Rising inflation expectations due to carbon taxes</li> </ul>	Greater uncertainty about real interest rates
	<ul style="list-style-type: none"> <li>Severe devaluation of carbon-producing industries/countries</li> </ul>	Stranded assets, higher risk premiums
	<ul style="list-style-type: none"> <li>Rising uncertainty about future technologies or regulations</li> </ul>	Higher risk premiums
Liquidity risk	<ul style="list-style-type: none"> <li>Stranded assets can no longer be traded in markets</li> </ul>	More write-offs, capital depletion
Operational risk	<ul style="list-style-type: none"> <li>Rising prices of carbon-based technologies</li> <li>More emission-reporting obligations</li> </ul>	Higher operating cost Higher operating cost
	<ul style="list-style-type: none"> <li>Missing awareness of climate-related financial risks</li> </ul>	Downgrade in ratings, higher risk premiums
Reputation risk	<ul style="list-style-type: none"> <li>Stigmatization of firms</li> </ul>	Loss of clients, less employee attraction
	<ul style="list-style-type: none"> <li>Simultaneous divestment from potential stranded assets</li> </ul>	Higher asset price volatility, more write-offs
Systemic risk	<ul style="list-style-type: none"> <li>Lock-in effects due to wrong or delayed policy decisions</li> </ul>	Higher risk premiums, higher probability of default

Source: Authors’ compilation.

<sup>6</sup> In 2018, the Hague Court of Appeal upheld a ruling by a district court that the Dutch government’s inadequate action on climate change violated a duty to protect its citizens under the European Court of Human Rights (ECHR).

means complete and does not cover all the risk categories listed in the Austrian Banking Act, but it is meant to give an idea of how climate change affects banks' financial risk and of which indicators to use in risk assessments.

## **2 Initiatives to manage climate-related financial risks**

The NGFS (2019) recommends the integration of climate-related risks into the prudential supervision framework. A precondition for assessing exposure to climate-related risks is the transparent and reliable disclosure of relevant information. For the time being, both private initiatives and official regulatory proposals aim at making climate-related financial risks more transparent. Despite these efforts, barriers to better management of climate-related financial risks remain. In many instances, climate-related risks do not crystallize within the planning horizon of financial corporations and are therefore ignored. Moreover, some of the risks cannot be processed in traditional risk models for lack of sufficient comparable data or long-enough time series. Also, some of the metrics used by the financial industry suffer from methodological shortcomings (see box below).

### **2.1 Task Force on Climate-related Financial Disclosures**

In 2015, the Financial Stability Board established the Task Force on Climate-related Financial Disclosures (TCFD), which is chaired by Michael Bloomberg. It was tasked with developing voluntary and consistent climate-related financial risk disclosures for well-informed investment, lending and insurance decisions. The TCFD created a framework for companies to disclose their risks in existing reports more effectively. Published in 2017, this framework refers to the application of metrics and targets the measurement of climate-related risks, their incorporation in firms' risk management systems, strategic control of these risks and firm-specific governance around climate-related risks. As the TCFD is a voluntary initiative, its recommendations are not binding. In its 2018 status report, the TCFD presented the results of a review of disclosure practices among more than 1,700 firms worldwide. Only few companies had incorporated climate-related risks in their governance or their risk management processes, but more had already developed or applied metrics to identify such risks and tackled related strategic issues. The 2019 status report finds that disclosure of climate-related financial information has increased since 2016. However, it is still insufficient for investors and more clarity is needed about the potential financial impact of climate-related issues on companies. During Climate Week in September 2019, a Handbook (TCFD, 2019) was published which covers best practices across governance, strategy, risk management, and metrics and targets in different sectors, including financial oil firms and banks.

Box 1

### Indicators for assessing the current exposure<sup>7</sup> to climate-related risks

Financial intermediaries are exposed to climate-related risks less through their own operations than through linkages to firms that issue debt or equity instruments. The assessment of financial intermediaries' exposure relies on the disclosure of risks by these companies. The TCFD (2017) has recommended several metrics for measuring and assessing climate-related risks, two of which will be presented in this box.

Many climate-related risks are linked to the emission of CO<sub>2</sub> and other GHGs. These emissions are usually categorized by three scopes according to their generation in the production process. Scope 1 refers to all direct emissions resulting from the operations of a reporting company. Scope 2 refers to indirect emissions from consumption of purchased energy. Finally, 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. As it is rather difficult to compile such information, scope 3 data are often not available.

The **weighted average carbon intensity** (WACI) indicator measures the exposure of a portfolio to carbon-intensive firms, expressed in tons of CO<sub>2</sub> per revenue, and is calculated according to the formula:

$$\sum_{i=1}^n \left( \frac{\text{investment in firm}_i}{\text{total value of portfolio}} \times \frac{\text{scope 1 and 2 emissions of firm}_i}{\text{revenue of firm}_i} \right)$$

The calculation is fairly straightforward, and the results are easy to communicate to market participants. On the downside, the revenues of a firm depend on its market power, therefore firms with similar technologies and similar emission profiles may differ in their contribution to the weighted average carbon intensity of a portfolio, although their exposure to transition risks is the same. Hence, the WACI is an imperfect measure for these risks.

The **carbon footprint** is defined as total emissions for a portfolio normalized by its market value and is given by:

$$\frac{\sum_{i=1}^n \left( \frac{\text{investment in firm}_i}{\text{market capitalization of firm}_i} \times \text{scope 1 and 2 emissions of firm}_i \right)}{\text{total value of portfolio}}$$

The carbon footprint can be used to compare portfolios with one another or with benchmarks, but it is sensitive to changes in the market value which are not related to climate-related risks. Monnin (2018) finds that "carbon footprints are currently the main indicators used by financial market participants to integrate climate change in their valuation models."

## 2.2 Regulatory proposals

The EU's Non-financial Information Directive (Directive 2014/95/EU) and the Austrian Sustainability and Diversity Improvement Act (Nachhaltigkeits- und Diversitätsverbesserungsgesetz, NaDiVeG) oblige certain Austrian companies, depending on their size and sector, to report on nonfinancial aspects and diversity-related information in their annual reports. This nonfinancial reporting duty also refers to information on environmental concerns. The scope and depth of these reports differ quite significantly from firm to firm and, hence, they do not allow for a comprehensive assessment of climate-related risks. Nevertheless, the directive is likely to have raised awareness of sustainability and climate change.

<sup>7</sup> It should be noted that these indicators are useful for assessing the current exposure to transition risks, but do not cover the exposure to physical risks, the management of which also poses a severe challenge.



In March 2018, the European Commission (2018) adopted an action plan to make financial risks stemming from climate change more manageable. The plan contains ten actions, the first of which was to establish an EU classification system for sustainable economic activities. The classification system, or taxonomy, which was compiled by a technical expert group on sustainable finance, identifies activities which contribute positively to climate change mitigation and adaptation. This should allow financial market participants to reorient their investments toward a more sustainable economy and this way help reduce climate-related risks. However, from a risk management perspective, it would be useful to pay greater attention to those economic activities which are more prone to climate-related risks as described in section 1. Later in 2018, the Commission put forth three legislative proposals (1) on the framework to create a unified taxonomy, (2) on the disclosure requirements on how institutional investors and asset managers integrate environmental, social and governance (ESG) factors in their risk processes, and (3) an amendment to the benchmark regulation which will create a new category of low carbon and positive carbon impact benchmarks. In the meantime, the regulations on disclosures and on benchmarks have been adopted by the European Council and the European Parliament.

The EU action plan (European Commission, 2018) also asked for reflecting climate-related risks in prudential regulation in a way that would not endanger the EU's current prudential framework and its purpose. The Commission announced it would explore the feasibility of the inclusion of climate-related risks in institutions' risk management policies and the potential calibration of capital requirements of banks as part of the Capital Requirement Regulation (CRR) and Capital Requirement Directive (CRD). The latter refers to the "green supporting factor," a factor in support of bank lending to green finance and that is analogous to the existing SME supporting factor introduced by the CRR. Whereas the integration of climate-related risks into risk management practices would be aligned with recommendations by the TCFD and the NGFS, a recalibration of capital requirements to foster investments in sustainable assets seems inappropriate. On the one hand, there is no empirical evidence supporting the conjecture that current capital requirements reduce the funding of sustainable investment projects. Generally, there seems to be a lack of appropriate climate-friendly investment projects rather than a lack of funds to be invested in such projects. As a case in point, green bond issuances are often heavily oversubscribed. On the other hand, investments in, or credits to, climate-friendly projects do not automatically carry less risk. Funding innovative technologies, e.g. those needed to transform energy generation or currently fossil-fueled production processes, is an inherently risky business. Allowing banks to hold less capital because they assume such risks on their balance sheets would send wrong signals to the markets.

In accordance with its national climate strategy, the Austrian government has, in 2019, established an expert focal group on green finance, which aims at improving the regulatory framework of financial markets in favor of climate-friendly investments. The focal group is coordinated by the Austrian Ministry of Finance and the Ministry for Sustainability and Tourism. As an active member of the focal group, the OeNB has emphasized the importance of integrating climate-related risks into the risk management of financial institutions. The activities of the focal group are work in progress and should produce a green finance agenda by the end of 2019.

### 2.3 Central banks' risk assessments

Some central banks have already assessed climate-related risks to financial stability and issued guidance for financial firms. In April 2019, the Bank of England published a Supervisory Statement on enhancing banks' and insurers' approaches to managing the financial risks from climate change, which set out expectations about the integration of climate-related risks into the risk management of financial intermediaries.

Vermeulen et al. (2018) analyzed the potential impacts of disruptive transition risks on the Netherlands. The analysis focused on four severe, but plausible scenarios with a view to assessing tail risks of the transition process. The scenarios included a technology shock (increase of renewable resources in the energy mix by 100%), a policy shock (increase in the price of CO<sub>2</sub> by USD 100 per ton), a double shock that combined these two and a confidence shock resulting from uncertainty about future policies and technologies. Whereas the impact of the policy shock is dampening GDP growth and accelerating inflation over the projection horizon, the technology shock yields more positive results. The combined shock results in a temporary decline of GDP growth and a more permanent rise of the inflation rate. Finally, the confidence shock has a dampening effect on GDP growth and inflation rates. The analysis shows that the transition vulnerability is attributable to the sectoral composition of the economy, which reflects the emissions embodied in production. In a similar vein, the Bank of England (2019) announced that in its 2021 biennial exploratory scenario, it will stress test the U.K. financial system's resilience to the physical and transition risks of climate change by integrating climate scenarios with macroeconomic and financial system models.

An analysis of the potential impact of physical risks on the loan book of Italian banks was conducted by Faiella and Natoli (2018). They identified floods as the most prevalent hydrogeological events in Italy for the period 1950 until 2011. To develop a risk indicator for these events, they used data of the Italian Institute for Environmental Protection and Research to calculate the share of local business units in every Italian municipality that is located in an area faced with an elevated risk of flooding. Their analysis implies a negative correlation between the exposure to flooding risk and the availability of credit. Faiella and Natoli (2018) also find low insurance penetration for these risks among Italian firms, especially among small firms and in southern Italy.

The effects of climate change on a central bank's balance sheet were studied by Battiston and Monasterolo (2018). They carried out a carbon risk assessment of the OeNB's nonmonetary portfolio by pricing climate transition risk in individual contracts (i.e. equities, sovereign bonds, corporate bonds). All assets were benchmarked according to their contribution to GHG emissions, and then the transition to a 2°C scenario was modeled as a negative shock to the future value added of the carbon-intensive sectors. As a result, each asset was attached with a positive or negative risk spread that would inform investors about the likely impact of transition risks on their portfolio. Given the probable transition risks of climate change, such an assessment is a valuable instrument for institutional investors. From a systemic viewpoint, it would be desirable to have a model for the aggregate financial sector that allows analyzing the feedback loops from climate change to financial intermediaries and the latter's reactions to each other because the correlated response of many intermediaries to the same shock might aggravate the adversity. The forthcoming climate biennial exploratory scenario of the Bank of England (2019) will be designed to model exactly these risks.

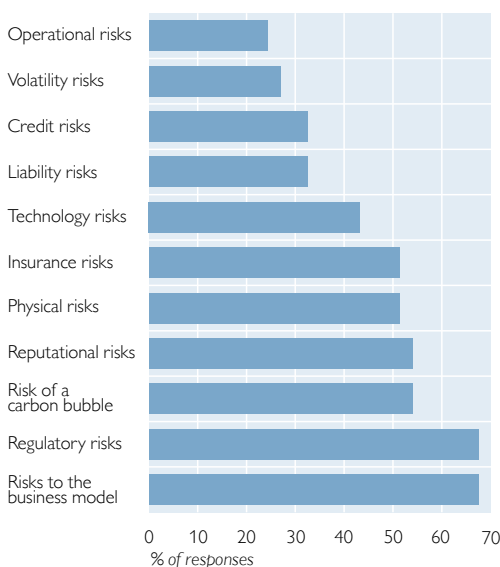
### 3 The Austrian financial sector's awareness of climate-related risks

In 2017, the Environment Agency Austria (Umweltbundesamt) started a multi-annual research project to analyze the Austrian financial sector with a view to mitigating climate change by curbing greenhouse gas emissions. Part of this project was a survey on the financial market implications of climate change, which was conducted online among banks, insurers, asset managers, regulators, social partners and researchers between July and September 2018 (see Environment Agency Austria, 2019). The agency kindly shared their survey data with us, and, in the following, we present results, focusing on the responses by financial intermediaries<sup>8</sup>.

From the 148 respondents of the survey, 37 were identified as representatives of financial intermediaries, of which 21 were bankers, 11 asset managers and 5 insurers. Their occupational tasks varied from board members to risk managers, sustainability officers and treasurers. Two-thirds of them agreed that the importance of climate-related risks had increased since the signing of the Paris Agreement in 2015, and, according to 86%, climate-related business opportunities had risen over the same period. 73% of those surveyed did not think that the current system of asset pricing leads to the consideration of climate-related risks. 62% claimed to consider climate-related risks in their corporate or business strategies, but only 24% said that they systematically identify, analyze and assess climate-related risks and opportunities. A report by the Bank of England's Prudential Regulation Authority (2018) based on a similar survey conducted in 2017 concluded that "many banks have some way to go to identify and measure the financial risks from climate change comprehensively."

Chart 1

#### Perceptions of climate-related risks in the financial sector



Source: Environment Agency Austria.

Survey participants were also asked what sources of climate-related risks to the financial sector they had identified (see chart 1). Less than one-third of the respondents considered operational risks, increasing price volatility, credit risks or liability risks to be affected by climate change. Among the bankers, at least 52% perceived climate change as a source of increasing credit defaults, but the remaining 48% did not agree that climate change might have an impact on their credit risk. 43% of the surveyed financial intermediaries considered the replacement of traditional fossil fuel-based technologies by new innovative technologies a financial risk.

Insurance risks were said to be on the increase due to climate change according to 51% of the

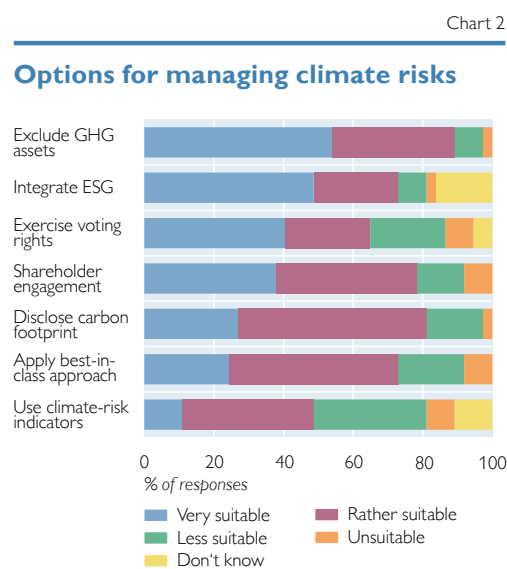
<sup>8</sup> Bourtembourg et al. (2019) report the findings of a survey on climate-related risks and sustainable finance among Belgian financial intermediaries.

financial intermediaries. Interestingly, one out of five the surveyed insurers did not consider climate change a driver for rising insurance risks. 51% of the respondents also acknowledged that climate change can cause physical risks which endanger financial institutions' operations. Even more (54%) regarded climate change and the process of decarbonization as a source of rising reputational risks in their industry. Just as many respondents agreed that investments in assets that rely on carbon or other GHG-intensive technologies encompass the risk of sudden revaluations ("carbon bubble").

The two main risk categories identified by financial intermediaries in this survey were regulatory risks and physical risks related to the business model of entire industries. Regulatory risks to financial stability have been described in section 1.2. The risk that climate change and global warming might disrupt certain sectors so severely that many or most companies no longer have a business case in Austria was exemplified in the survey by tourism and agriculture. This problem might not affect whole industries but is relevant for subsectors within them. Global warming might render skiing impossible in many of the existing ski resorts in Austria. Agriculture may be affected by climate change in many ways. Extreme weather events may destroy entire harvests and melting Alpine glaciers could lead to water stress and lower agricultural productivity. If those risks materialize, banks that have been lending to ski hotel owners or farmers as well as companies that have provided insurance to them might be affected.

The survey also asked which options are best suited to manage climate-related risks. Most respondents considered it best to exclude GHG-intensive assets (e.g. investments in producing or processing fossil fuels) from their portfolios (see chart 2). If the sample in the survey is representative of the financial sector in Austria, this response implies that companies causing severe GHG emissions might face difficulties to fund their operations in the future. 49% of the respondents also found that an integrated ESG approach would be a solid option. Such an integrated approach refers to the systematic inclusion of "environment, social and governance" criteria in market analysis and portfolio management. Clearly, the ESG focus is broader and not only concentrated on climate-related risks, but climate change does have social consequences, too, and the governance structure of a firm is critical to its managing climate-related risks. About 40% of the respondents also regarded exercising voting rights in shareholder meetings and shareholder engagement in general as very suitable. Such a stance implies pursuing an active dialogue on climate risks with both board members and managers.

The last three options shown in chart 2 require comprehensive access to firm-specific information and a

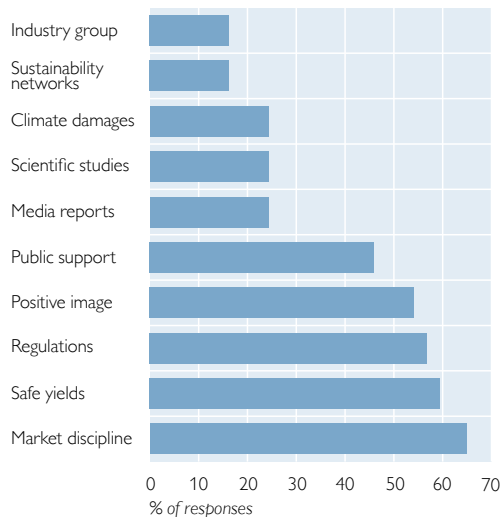


Source: Environment Agency Austria.

Note: GHG stands for greenhouse gas and ESG for environment, social and governance.

Chart 3

### Motives for acting in a climate-friendly way



Source: Environment Agency Austria.

good understanding of innovative concepts of risk management. Chances are that, because of this, not many firms considered them very suitable. Calculating and disclosing the carbon footprint of a portfolio (for more information on this indicator, see the box above) was considered by less than one-quarter of the respondents to be very suitable. Despite the activities of the TCFD, only 59% of the surveyed intermediaries had already concerned themselves with the idea of disclosing climate-specific information in any form. The best-in-class approach is an investment strategy that promotes the selection of stocks and bonds of companies with the lowest carbon footprint in each sector. Here, the availability of reliable firm-specific emission

data is likewise crucial but often wanting. Finally, the computation of climate risk indicators like the climate value at risk (VaR), which gives the maximum loss due to climate change for any portfolio, was considered less suitable or unsuitable by 40% of the respondents and was unknown to 11% of them.

The survey also explored options for the financial sector to contribute to a more climate-friendly economy. The respondents were asked about factors that could motivate financial market participants to act in a more climate-friendly way (see chart 3). 16% of the responding financial intermediaries considered support by industry groups or membership in sustainability networks effective drivers. About as many named a further increase in damage due to extreme weather events, scientific studies that show the negative impacts of climate change or more media reports about these issues. Almost half of those surveyed thought that new public support programs focusing on climate change might work; after all, who would decline public subsidies or government guarantees when they are offered?

54% of the respondents said that a more positive, modern image for their organization would motivate managers to act in a more climate-friendly way. This corresponds to the anecdotal evidence that some banks in Austria deal with climate-related issues under the corporate social responsibility agenda of their public affairs divisions. Regulations and norms like laws, directives or standards were considered effective by 57%. As some of these norms are legally binding, it might be surprising that not more respondents see them as potent drivers. 59% said that safe long-term yields for investments in climate-friendly firms would motivate them to act in a climate-friendly way. And most respondents (65%) said that demands by clients, business partners and authorities (labeled “market discipline” in chart 3) would motivate them to adopt more climate-friendly strategies.

In light of these survey results and the financial stability risks outlined above, we find that awareness of climate-related financial risks could be improved further in the Austrian financial sector, particularly with respect to the potential negative

impacts on banks. On average, more than half of the respondents representing financial intermediaries denied the existence of climate-related risks to their industry. Mostly, they see such risks for other sectors like agriculture. Compiling indicators to assess climate-related risks is not standard practice in the financial industry, although some institutions have already put some effort into this task. While many respondents regard market forces as an effective motivator, they seem to have experienced little demand from clients or authorities for integrating climate-related risks into their risk management. For policymakers, it is worth noting that financial intermediaries consider regulations and laws to be strong motives to act in a more climate-friendly way. Also, financial intermediaries appreciate stable returns on their investments, which corresponds to a predictable and steady regulatory environment without too many discrete policy changes.

#### 4 Concluding remarks

Climate change poses significant risks to financial stability. The sources of these risks are physical hazards that stem from global warming and the consequential increase in extreme weather events, rising sea levels and melting glaciers as well as the transition processes from current modes of production to a decarbonized economy. Decarbonization relies on technological innovation, shifting preferences and regulatory changes, of which at least the latter can be shaped by policymakers.

Most policymakers and market participants have indeed recognized the importance of climate change. On the one hand, market-based initiatives like the Task Force on Climate-related Financial Disclosures (TCFD) advocate for the improved disclosure of climate-related risks by corporations. On the other, several policy initiatives currently tackle the financial stability dimension of climate change. At the European level, the Commission has put forth legislative proposals to make climate-related risks more transparent and to identify climate-friendly economic activities. In Austria, the government has initiated an expert focal group on green finance. This group strives to improve the framework for investments in climate-friendly activities and to integrate climate-related risks in the risk management of financial institutions. Grasping the importance of climate change for financial stability, central banks have established a Network of Central Banks and Supervisors for Greening the Financial System (NGFS) to learn from each other and to conduct further research in this area.

Among Austrian financial intermediaries, awareness of the financial stability implications of climate change is not as widespread as it could be, given the amount of available information and the legal obligation to address sustainability issues in nonfinancial reporting. Whereas some institutions are well prepared and have developed climate-related risk indicators for their investment portfolios, others fail to understand that climate change could cause credit defaults to go up. Additional activities are warranted to raise awareness in the financial sector and disseminate information about business practices that support financial intermediaries in identifying and assessing climate-related risks by financial intermediaries. The OeNB contributes to these activities by conducting research, publishing reports and hosting events to facilitate the exchange of ideas and foster the diffusion of innovative tools for risk monitoring, assessment and management. In this respect, the OeNB

follows the recommendations of the NGFS to build awareness and intellectual capacity as well as encourage technical assistance and knowledge sharing.

Survey data compiled by the Environment Agency Austria show that only one-quarter of the respondents representing Austrian financial intermediaries have started to systematically manage their climate-related risks. Most of the respondents are, however, aware that such risks exist. Survey results from other central banks indicate that this is an attitude that is quite common among financial intermediaries even though rules on due diligence require them to identify and assess all relevant risks. It seems clear that more information on climate change will probably not change that attitude much. Instead, regulatory reforms and shifts in clients' demands are more likely to cause financial intermediaries to integrate climate change into their risk management.

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