NGFS Occasional Paper

Biodiversity and financial stability: building the case for action

Study Group interim report

October 2021

INSPIRE

NGFS
Central Banks and Supervisors
Network for Greening the Financial System

About the NGFS

The Network for Greening the Financial System (NGFS), launched at the Paris One Planet Summit on 12 December 2017, is a group of central banks and financial supervisors, which on a voluntary basis are willing to share best practices and contribute to the development of environment and climate risk management in the financial sector, and to mobilise mainstream finance to support the transition towards a sustainable economy. The NGFS brings together 95 central banks and financial supervisors and 15 observers. Together, they represent five continents and countries which produce around 85 per cent of global greenhouse gas emissions and are responsible for the supervision of all of the global systemically important banks and two thirds of global systemically important insurers. The NGFS is chaired by Frank Elderson, member of the European Central Bank's Executive Board. The Secretariat, headed by Jean Boissinot, is provided by Banque de France.

About INSPIRE

The International Network for Sustainable Financial Policy Insights, Research, and Exchange (INSPIRE) is an independent research network built to support the central banks and financial supervisors of the NGFS in its work to manage climate and environmental risks and mobilise finance to support the transition to a sustainable economy. The INSPIRE secretariat is co- hosted by the Grantham Research Institute on Climate Change and the Environment at the London School of Economics and Political Science and the ClimateWorks Foundation. It is guided by an Advisory Committee and has commissioned over 30 research projects across a range of critical themes.

About the Joint NGFS-INSPIRE Study Group on Biodiversity and Financial Stability

The study group was established in April 2021 to establish a research-based approach to how central banks and supervisory authorities can fulfil their mandates in the context of biodiversity loss. It is co-chaired by Dr MA Jun (Chairman of the Green Finance Committee of the China Society for Finance and Banking and chair of the NGFS Workstream on Research) and Professor in Practice Nick Robins (London School of Economics and INSPIRE).

About this report

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Disclaimer

 This research has benefitted from funding by the Gordon and Betty Moore Foundation through The Finance Hub, which was created to advance sustainable finance. This funding has been used to support the INSPIRE secretariat at the London School of Economics and Political Science; none of the funding has gone to the NGFS or its members.

Foreword

It is now well known that the Central Banks and Supervisors Network for Greening the Financial System (NGFS) has played a critical role in raising awareness about climate-related risks among central banks and supervisors and in the financial community at large. Indeed, after acknowledging that climate change is a challenge with several economic dimensions and, in consequence, is a source of financial risks and a driver of economic developments (with impacts on growth and prices), central banks and financial supervisors have worked towards better understanding, assessing and managing these risks in order to fulfil their mandate.

It is less well known that, since its creation in 2017, the NGFS has also acknowledged the existence of other environmental risks beyond climate-related ones. As Article 1 of its Charter puts it, the NGFS seeks to 'contribute to the development of environment and climate risk management in the financial sector'.

Against this background, the community of central banks and financial supervisors has been following closely recent developments related to biodiversity, which over the past few decades has been declining at rates unprecedented in human history as the IPBES, for instance, explained in its 2019 report. The linkages between economics and biodiversity are now better understood, not least thanks to the recent publication of *The Economics of Biodiversity: The Dasgupta Review*. Biodiversity loss, both in and of itself as well as through its complex interactions with climate change, is also increasingly being discussed in international financial fora, on the grounds of the threats it poses to our societies and economies and in view of the ensuing financial risks.

It is therefore highly encouraging to see the NGFS and its research stakeholder INSPIRE join forces to assess the implications of biodiversity loss on the ability of central banks and financial supervisors to successfully pursue their mandates. Following the publication of a Vision Paper in June 2021, which set out the links between biodiversity loss and the macroeconomic and financial systems, this Interim Report delves deeper into the challenges related to the assessment of such links and provides potential ways forward for central banks and financial supervisors to incorporate these insights in the exercise of their tasks. Its publication ahead of the first part of the 15th meeting of the Conference of the Parties to the Convention on Biological Diversity in October is very timely.

I congratulate all the contributors to this groundbreaking Interim Report and look forward to the upcoming further work: this work is critical to enable us not only to understand the issues we are facing due to the unparalleled loss of biodiversity but also to define the actions that we, as central banks and financial supervisors, must take within our mandates in the collective effort to address this vital challenge.

Frank Elderson
Chair of the Network for Greening the Financial System

Contents

Executive summary

Assessing the financial risks from biodiversity loss

This report is the second output of the Joint NGFS-INSPIRE Study Group on Biodiversity and Financial Stability. The group was established to help central banks and financial supervisors fulfil their mandates in the face of financial risks stemming from biodiversity loss.

These risks are growing, as biodiversity is declining at unprecedented rates in human history, with growing evidence that this could have significant economic and financial implications. The decline of ecosystem services as a result of biodiversity loss poses physical risks for economic and financial actors that depend upon those services.

While an ecological transition towards a nature-positive economy would bring multiple benefits, it could trigger transition risks if financial institutions' portfolio allocations and strategies are not aligned with forthcoming policy developments. Policies aimed at protecting biodiversity are accelerating at the regional, national and sub-national scales. An international agreement on biodiversity protection, through the Convention on Biological Diversity (CBD), could provide a major boost to efforts to prevent biodiversity loss. The financial system therefore needs to be prepared for significant socioeconomic transformations.

The potential impacts of physical and transition risks related to biodiversity loss pose threats to financial stability, meaning that it falls within the mandates of central banks and financial supervisors to better understand and assess such risks.

Despite the scientific evidence, methodological challenges remain in the assessment of biodiversity-related financial risks, pointing to the need to utilise a variety of modelling approaches. The macroeconomic consequences of biodiversity loss are becoming clearer, and global estimates of the economic implications of biodiversity loss are increasingly being complemented by analyses of the geographical exposure of different regions to ecosystem collapse, for example. Although the models used can help to represent the linkages between the economy and biodiversity, they are subject to methodological limitations. This is due to the complexity of the issue, the fact that irreversible non-linear processes can occur when crossing tipping points, and the need to engage in a structural economic transition that will impact multiple sectors simultaneously.

Avenues for addressing these challenges and better assessing the relationship between financial stability and biodiversity are starting to emerge. These include embedding biodiversity–economy models into existing risk assessment frameworks and developing alternative approaches to assessing biodiversity-related financial risks. These can address, for instance, how biodiversity-related shocks could cascade through economic sectors and along supply chains, and how biodiversity-related financial risks could cause contagion throughout the financial system.

Four tasks for central banks and financial supervisors

To assess biodiversity-related financial risks while accounting for outstanding methodological challenges, central banks and financial supervisors can engage in four complementary tasks, as suggested by this report's analysis.

- **First, they can begin building the skills, capacities, tools and cooperation to address biodiversity-related economic and financial risks.** That biodiversity loss poses a risk to macroeconomic and financial stability is now well-established and scientifically-grounded. Central banks and financial supervisors need to extend and complement their work on climate change and make a similar effort – both individually and through forums such as the NGFS – on biodiversity loss.
- **Second, they can assess the dependencies and impacts of their financial institutions – through the economic activities they support – on ecosystem services and biodiversity.** While an analysis of impacts and dependencies is not strictly a risk assessment, this would enable them to become familiar with the materiality of the linkages between biodiversity, the economy and the financial system, and could therefore pave the way for future work.
- **Third, they can become more familiar with existing biodiversity–economy models and develop ad hoc methodological approaches that better capture the risk of impacts cascading through economic and financial actors.** These approaches could include the development of biodiversity-related scenarios – which should ideally interact with climate-related scenarios – that would create a common language through which central banks and financial supervisors can assess the resilience of their financial systems to specific shocks and better understand interlinkages.
- **Finally, they could signal to the financial institutions that they supervise, other economic actors and policymakers the importance of understanding the risks arising from their dependencies and impacts on biodiversity.** In addition, and within the remit of their mandates, they should support governments' efforts to reverse biodiversity loss, in particular regarding the implementation of the post-2020 Global Biodiversity Framework by addressing financial risks and preparing the financial infrastructure required for nature-positive financing.

Looking forward

In addition to these recommendations, this report offers the first overview of emerging central bank activity relating to biodiversity issues, and consideration of the role the financial system might play in the proposed post-2020 Global Biodiversity Framework.

This Interim Report sets the stage for a final report from the Study Group, due to be published in early 2022. That report will explore in further detail linkages between biodiversity loss, the macroeconomy and the financial system, drawing on existing research and leading practice. The report will more comprehensively consider options for central banks and financial supervisors to address the micro- and macroprudential risks that biodiversity loss poses, as well as setting out a research agenda.

1. Introduction

This report builds on the Vision Paper published by the joint NGFS-INSPIRE Study Group in June 2021. That paper (NGFS and INSPIRE, 2021) set out the rationale for the work of the Study Group, which aims to establish an evidence-based approach to how central bankers and financial supervisors may need to consider biodiversity loss in the context of their mandates to protect economic and financial stability. This Interim Report, published ahead of the first part of the critical 15th Conference of the Parties (COP 15) to the Convention on Biological Diversity (CBD – see Box A on page 9), takes forward and seeks to further explore the issues raised in the Vision Paper. Specifically, the report provides:

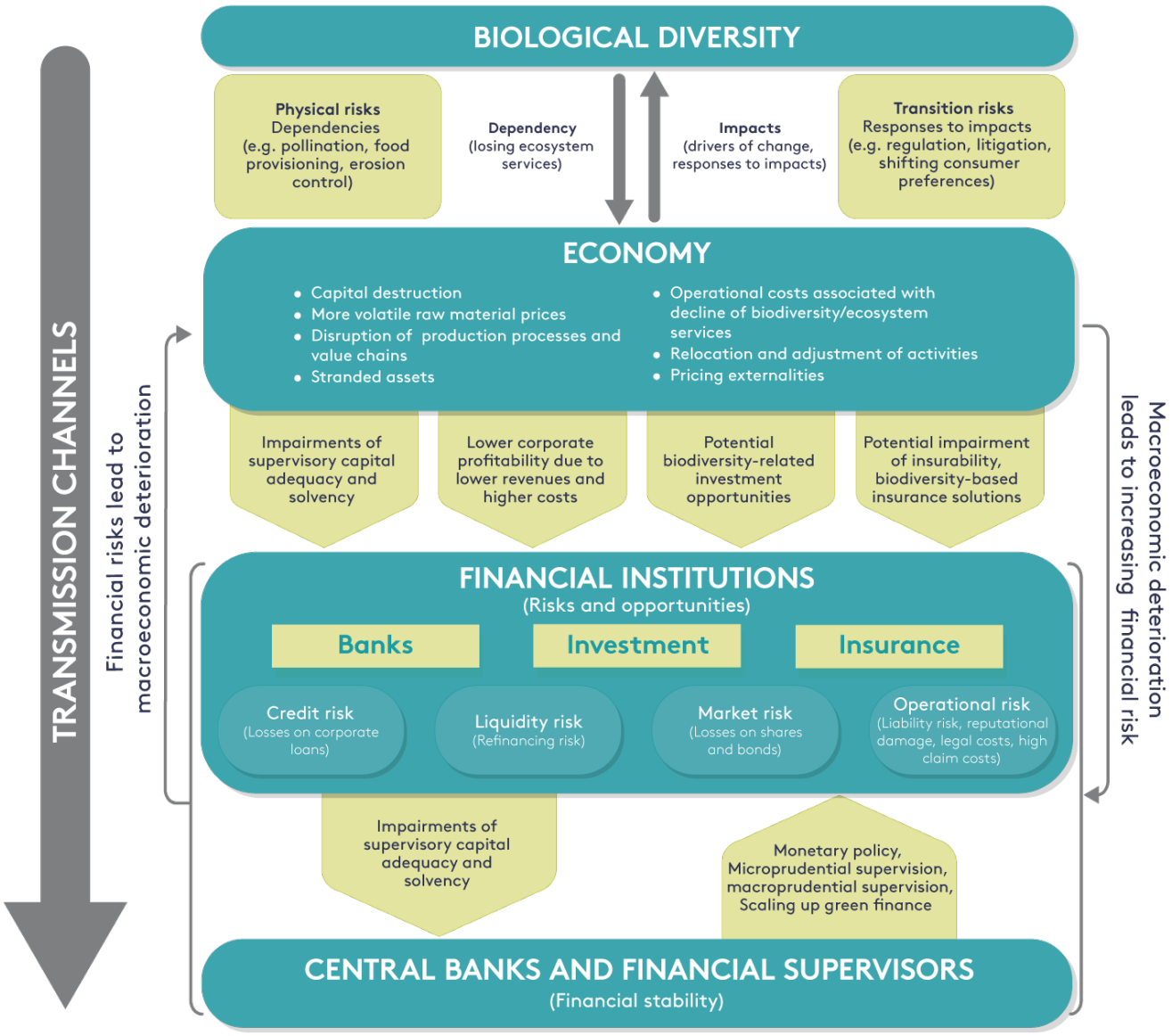
- A clearer picture of the potential economic and financial impacts of biodiversity loss, grounded in the latest scientific evidence on this issue.
- A discussion of the challenges associated with assessing biodiversity-related financial risks, and potential ways forward for central banks and financial supervision authorities, with a focus on the assessment of economic and financial sector dependencies and impacts on biodiversity as a first step, and the development of climate-related scenarios as a future step.
- The first overview of emerging central bank and private financial actors' activity relating to biodiversity issues.
- Consideration of the role the financial system might play in the proposed post-2020 Global Biodiversity Framework.
- Suggested options that central banks and financial supervisors might wish to consider regarding biodiversity loss.

The work of the Study Group to date has met with considerable interest among the central banking community and interested stakeholders in seeking to understand biodiversity-related financial risks. The Study Group, which comprises more than 70 members, has held four online workshops and seen high levels of engagement in terms of contributions to its work plan and research agenda. Central bankers and financial supervisors are starting to recognise the potential risks posed by biodiversity loss, growing scientific and public concern, and increasing attention paid to the subject by policymakers, regulators and investors.

The Study Group has identified a need to better understand the transmission channels between biodiversity loss and measures to reverse it, economic impacts and risks to financial institutions and the financial system as a whole (see Figure 1.1 on the next page). Biodiversity loss (see Box B on page 12) is primarily driven by land-use change, overexploitation, climate change, pollution and invasive species (IPBES, 2019). As discussed in Chapter 2, economists are attempting to incorporate biodiversity loss into economic modelling and, as Chapter 3 covers, to use modelling to better understand the risk that biodiversity loss poses to financial stability.

As with climate-related financial risks, biodiversity-related financial risks can be characterised as either *physical* or *transition* risks. Physical sources of risk include, for example, the disappearance or decline of ecosystem services on which economic actors depend. These risks can be chronic (e.g. gradual decline of numbers and species diversity of pollinators resulting in reducing crop yields, or increasing costs of manual pollination) or acute (e.g. pests wiping out significant parts of a harvest because of the disappearance of natural predators, or disease spreading as a consequence of reduced natural resistance, potentially leading to pandemics), or both (e.g. disruption to micro-climates and the hydrological cycle caused by deforestation).

Figure 1.1. Biodiversity, the economy and the financial system



Source: NGFS-INSPIRE

Box A | A post-2020 global biodiversity framework

Developments at the international policy level, specifically around the Convention on Biological Diversity (CBD), could give biodiversity protection a fillip similar to that delivered by the Paris Agreement in 2015. The CBD is a multilateral and legally binding treaty, drawn up in 1992 at the Rio Earth Summit, alongside the UN Framework Convention on Climate Change (UNFCCC). The CBD, which has since been ratified by 196 parties, has three main goals: the conservation of biological diversity (or 'biodiversity'); the sustainable use of its components; and the fair and equitable sharing of benefits arising from genetic resources.

At the 15th Conference of the Parties to the CBD (COP 15), taking place in Kunming, China, virtually in October 2021, and in person in April and May 2022, governments are expected to reach agreement on a post-2020 global biodiversity framework. The framework will be a successor to the 2010 Aichi Biodiversity Targets, and it is likely, as was the case with the Paris Agreement for climate, to spur international, regional, national and sub-national policy responses around the world to protect biodiversity.

This framework aims to set in motion an economic transition that puts biodiversity on a path to recovery by 2030. It will likely do this through a series of goals and targets, such as allocating 30 per cent of the Earth's land and sea areas to conservation, focused on reducing threats to biodiversity, meeting people's needs and developing tools and solutions to integrate biodiversity considerations into policies, regulations, planning and investment decisions. The framework will also likely seek to ensure alignment of activities and financial flows with biodiversity values, aiming to deliver transformative change by mainstreaming the integration of biodiversity-related impacts and risks in economic sectors and the financial system.

None of the Aichi Targets were met in full but insight can be gained from where progress was made that could indicate where sources of immediate transition risk may lie for financial institutions. For example, nearly half of Parties are on track to meet Target 11, which called for them to extend protected status to at least 17 per cent of their terrestrial jurisdiction and 10 per cent of their coastal and marine areas. On the other hand, poor progress was made on the targets that addressed biodiversity-damaging subsidies (Target 3), overfishing (Target 6), minimising anthropogenic pressures on marine habitats and other vulnerable ecosystems (Target 10), and restoration effects that consider the needs of women, indigenous and local communities, and the poor and vulnerable (Target 14) (Secretariat of the Convention on Biological Diversity, 2020b). Not only were many targets missed, but some were insufficient to adequately address nature lost.

Parties and stakeholders have called for the post-2020 global biodiversity framework to include more ambitious targets as a result, such as allocating 30 per cent of each country's exclusive economic zone – including land, inland fresh water and marine habitats – to protected areas. The framework focuses on reducing threats to biodiversity, meeting people's needs through sustainable use and benefit-sharing, as well as developing tools and solutions to integrate biodiversity considerations into policies, regulations, planning and investment decisions.

The finance sector will have a key role in supporting the delivery of the goals of the framework, while policies intended to protect biodiversity will have impacts on the global economy and on the financial system. For both these reasons, the outcomes of the talks in Kunming are of direct interest to central banks and financial supervisors (Secretariat of the CBD et al., 2021). The possible implications are discussed in Chapter 4.

Transition risks result from a misalignment between financial institutions' portfolio allocations and strategies and developments aimed at reducing or reversing the damage to biodiversity and ecosystems, such as government measures, technological breakthroughs, litigation and changing consumer preferences. Physical and transition risks can interact and affect economic agents through various channels, before materialising into traditional sources of financial risks (e.g. credit or market risks).

Identifying the sources of risks and how they flow towards economic and financial actors is made more pressing by, among other things, the powerful inter-relationships between climate change and biodiversity loss (Box B, page 12). Climate change and biodiversity loss share a number of characteristics of particular relevance to financial policymakers. They both call for assessing complex systems, and are subject to tipping points, non-linear change, feedback loops and cascading impacts. These impacts are subject to high levels of uncertainty, including regarding the time horizons and locations over which they will materialise. There is no historical precedent for their current trajectories, making forecasting challenging.

Future policy responses could be abrupt, risking economic and social disruption. Moreover, as recently emphasised by a joint IPBES-IPCC[1] workshop, climate change is exacerbating risks to biodiversity and ecosystems, while both natural and managed ecosystems play a key role in the emission and sequestration of greenhouse gas emissions and in supporting adaptation to a changing climate (Pörtner et al., 2021). Key drivers of biodiversity loss such as deforestation are also major sources of greenhouse gas emissions, so action to reform land use and curb deforestation can achieve win-win benefits. A failure to manage - both, as parts of the same complex problem but each with its specific features and needs, therefore risks leading to actions that are suboptimal for either crisis.

A dynamic and comprehensive approach to biodiversity-related financial risks also suggests that it is important to consider not only the impacts of biodiversity loss (or the measures taken to reverse it) on financial actors, but also the impacts that financial actors have on biodiversity. As discussed above, loss of biodiversity can have material impacts on economic actors who depend upon nature for inputs or other types of ecosystem service, and on the financial institutions exposed to them. However, economic actors and the financial institutions that fund them can also cause biodiversity loss, thereby contributing to both physical risks faced by themselves or other actors, and transition risks to their own assets as policy and markets move to a

1 The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the Intergovernmental Panel on Climate Change (IPCC) are intergovernmental bodies that provide scientific and policy advice on biodiversity and climate, respectively.

more sustainable and nature-positive economy (Oman and Svartzman, 2021; Täger, 2021). This two-way approach, also referred to as 'double materiality', can be a useful framework when discussing biodiversity loss. While this approach is supported in some jurisdictions (e.g. European Commission, 2019), it is a relatively new concept that is not necessarily favoured by, nor within the central bank mandates of, every jurisdiction at present. In other words, biodiversity-related financial risks are at least in part endogenous, without suggesting that financial institutions bear the full responsibility for the impacts on biodiversity loss.

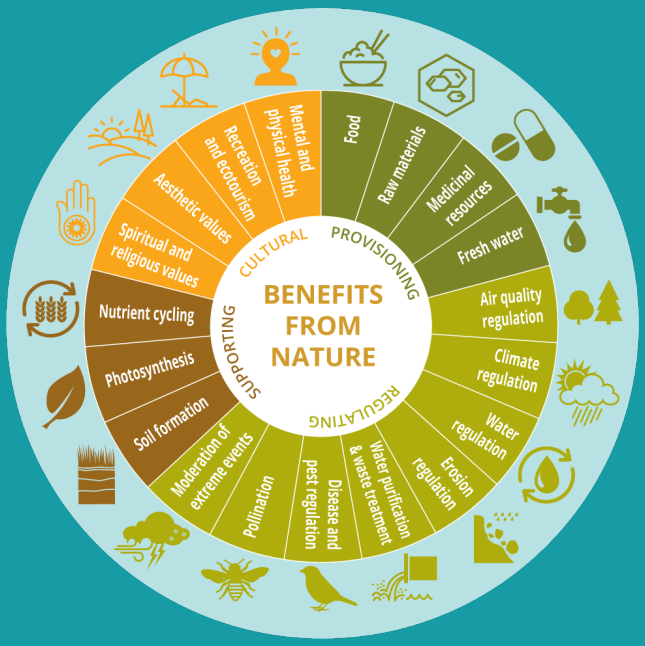
This report is intended as a stocktake of the current context for central bank and financial supervisory action on biodiversity loss. It sets out the state of understanding on the linkages between biodiversity-related risks and financial stability, provides examples of emerging central bank and private finance activity, and identifies key themes, challenges and open questions. It will consider emerging options for action and research and set the stage for the Study Group's more elaborated Final Report in early 2022.

Box B | Defining our terms

While **nature** is an ambiguous term, open to different interpretations, we use it to refer to the natural world, including living organisms as well as air, water, land and minerals. **Ecosystems** are dynamic complexes of communities of plants, animals and micro-organisms and their non-living environments. The **biosphere** is the sum of all the world's ecosystems (Secretariat of the CBD et al., 2021). **Natural capital** refers to the stock of renewable and non-renewable resources within the natural world, which combine to provide a flow of benefits to people, known as **ecosystem services.** These are often divided into provisioning, regulation and cultural services, as well as the supporting (or maintenance) services necessary for the production of all others (Figure 1.2).

Biodiversity is the variability among living organisms and the ecological complexes of which they are part. It includes diversity within species (genetics), between species and of ecosystems. It underpins the ability of the natural world to generate flows of ecosystem services. **Biodiversity loss** leads to a decline in the provision of those services, with negative economic impacts on individuals, households, organisations and countries.

Figure 1.2. Ecosystem services



Source: WWF (2018). © 2018 WWF All rights reserved.

Biodiversity is declining at rates unprecedented in human history, with most ecosystems and biodiversity indicators deteriorating. Around 1 million plant and animal species face extinction, according to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019). This loss of biodiversity is undermining the ability of nature to provide the ecosystem services on which we rely, and could therefore generate "extreme risk" for our socioeconomic and financial systems (Dasgupta, 2021).

It is in this context that this report focuses on **biodiversity-related financial risks**. These are the financial risks associated with the decline in the provision of ecosystem services as a result of biodiversity loss – risks that can affect individual financial institutions and/or the financial system as a whole.

It is noteworthy that some biodiversity-related risks may have major social consequences (e.g. an increase in food insecurity among the world's poorest due to overfishing by large companies does not necessarily translate into financial risk because the world's poorest tend to be less included financially). This means that the risk-based approach followed by central banks and financial supervisors is only one component of the responses needed, but multiple actions that fall beyond the financial system's reach will be necessary to address biodiversity loss.

This report uses the term biodiversity-related financial risks but notes there is a recent trend within the academic literature and within policy circles to favour the use of the term **nature-related financial risks** when considering the financial risks associated with economic dependencies and impacts on nature. We see these risks as a subset of environment-related financial risks, with strong interconnections with climate-related financial risks.

2. The economic context for central banks' work on biodiversity

A first step to understanding how biodiversity-related risks could cause financial instability is to evaluate how biodiversity loss or measures undertaken to reverse it could impact the macroeconomy. As part of this, it is important to appreciate the challenges associated with identifying the linkages between biodiversity and the economy.

This chapter presents some of the growing evidence that biodiversity loss has the potential for macroeconomic impacts. It also discusses some of the modelling that is emerging to systematically measure those impacts, as well as some of its limitations. A better understanding of the biodiversity–economy linkages will be crucial for central banks and financial supervisors aiming to assess the financial risks that could arise from such linkages. As such, the goal of this chapter is not to offer an exhaustive review but rather to provide the reader with the necessary background to be able to better assess the question of biodiversity and financial stability.

2.1. The potential for macroeconomic impacts from biodiversity loss

It is increasingly recognised that the accelerated deterioration of the biosphere could have significant economic implications. Ecosystem productivity and resilience are both vital for economies, as every economic activity ultimately relies on some form, or combination of, ecosystem services. For instance, some studies estimate that around half of global GDP is moderately or highly dependent on biodiversity and the provision of ecosystem services (Herweijer et al., 2020; Swiss Re Institute, 2020). Costanza et al. (2014) estimate that the annual value of ecosystem services amounts to US$125 trillion, i.e. about 1.5 times global GDP at the time of the study. As discussed below, such quantifications should nevertheless be assessed cautiously and we should note that, ultimately, "we are embedded in Nature" and life could not exist without biodiversity and ecosystem services (Dasgupta, 2021). In other words, the interest of these studies does not lie in estimating how much activity could exist without biodiversity (the scientific response being none) but rather in providing growing evidence of the multiple ways in which the economy depends on the biosphere.

The extent and the depth of direct dependencies on biodiversity and ecosystem services varies across sectors and companies. Primary industries – such as agriculture, forestry and fisheries – tend to rely heavily on direct extraction from ecosystems. With a growing global

population, demand for food is increasing, and growing affluence is driving increased demand for more input-intensive meat and dairy products. Alongside, about 85 per cent of global arable land is threatened by erosion, salinisation, soil compaction or pollution, resulting in estimated economic costs of up to US$10.6 trillion per annum (ELD Initiative, 2015). In Europe alone, 84 per cent of 264 agricultural crops are pollinated by bees and other pollinating animals. On a global scale, 71 out of the 100 most commonly used crops, which deliver around 90 per cent of our nutrition, are pollinated naturally (European Business and Biodiversity Campaign, 2019). With the fragmentation and loss of habitats, changes in patterns of crop diversification and overall extinction of species, the genetic pool among plants is shrinking and an associated dramatic reduction in world food production is possible, due to reduced resistance to pests and disease.

Land use change exemplifies interlinkages between climate and biodiversity and their impacts on the macroeconomy. Land use change, such as deforestation and forest degradation, is a key driver of biodiversity loss. Converting forests to cropland negatively impacts biodiversity but it also both reduces carbon absorption capacity and releases carbon into the atmosphere, thus exacerbating biodiversity- and climate-related financial risks. These risks are already materialising in Brazil. Deforestation across the Amazon has contributed to prolonged droughts that have impacted agricultural yields and Brazil's hydropower production (Harris, 2021). These impacts reduce the revenues of agricultural firms and power producers, and affect the macroeconomy through rising food and electricity prices, contributing to inflation and rising global commodity prices (Harris and Pulice, 2021).

Biodiversity loss could affect many economic sectors and regions that may not immediately appear to be particularly exposed. Secondary and tertiary industries – including energy production, manufacturing, tourism, real estate, retail and transport – also rely, often more indirectly but no less importantly, on ecosystems' regulating and maintenance services, such as protection from natural hazards, a stable climate and disease control, to produce their goods and services. For example, coral reef tourism was recently valued at US$36 billion per annum (Spalding et al., 2017) and, in the United States alone, national parks contribute over US$20 billion to GDP through direct and indirect economic multipliers such as labour and supply chains (Cullinane Thomas and Koontz, 2020). These secondary and tertiary sectors also often rely on the supply of natural resources that depend on ecosystem services. For instance, in the case of the pharmaceutical industry, biological diversity is essential for the screening and development of new drugs: roughly 70 per cent of all cancer drugs have a natural origin, and nearly 80 per cent of the 150 most prescribed medications in the United States were developed from natural resources (European Business and Biodiversity Campaign, 2019).

The World Health Organisation (2021) has highlighted the conservation of biodiversity and restoration of ecosystems as significantly contributing to the regulation of infectious diseases (see also World Health Organisation, 2015, for a review).

Biodiversity loss also threatens socioeconomic elements that may not be adequately captured in economic indicators, but which could have economic impacts through more complex channels. Subsistence farmers rely on ecosystem services but declines in their productivity due to biodiversity loss are often poorly reflected in official statistics, and indirect impacts can hardly be accounted for. For instance, if biodiversity loss were to materialise in increasing food insecurity, this could have dramatic implications for social and political stability in multiple regions (Barrett, 2013). A reduction in agricultural yields could lead to the migration of people and to higher food prices and higher commodity prices in general, therefore impacting multiple economic agents and sectors.

Biodiversity loss also has potential implications for price stability. There has been limited research on the inflationary risks posed by biodiversity loss, although it is intuitive to observe that a reduction in the supply of ecosystem services is likely to feed through to higher prices. Further work is needed on this topic.

Against this backdrop, it is critical to gain a more comprehensive understanding of how the economic system depends on biodiversity and ecosystem service

2.2. Integrated ecosystem service–economy models

While climate–economy models (the so-called integrated assessment models) have now been developed for decades, fewer models are available that represent the dependence of the macroeconomy on biodiversity. This has started to change, as integrated ecosystem service–economy models have emerged, suggesting the potential materiality of nature loss for economic systems and economic stability. We briefly outline two of these below.

The bounded global economy model (BGEM)

The Dasgupta Review on the economics of biodiversity presents a formal economic growth model, the bounded global economy model (BGEM), which is underpinned by an ecological understanding of how ecosystems function, how economic activity depends on ecosystems, and how those ecosystems are affected by economic activity (Dasgupta, 2021). This includes the extraction of natural resources for production and consumption, and the waste produced through these activities, which ultimately damages ecosystems and undermines their ability to provide the services on which the real economy relies.

The BGEM model distinguishes between the stock and flow elements of natural capital. First, natural capital appears as a stock, supplying regulating and maintenance services.[2] Second, natural capital appears as a flow of extracted provisioning services. The model accounts for the different roles of provisioning services and regulating and maintenance services in supporting economic activity. It builds on the fact that the processes governing the supply of regulating and maintenance services are complementary to one another, which means that if one of them is disrupted sufficiently, the others will be disrupted as well.

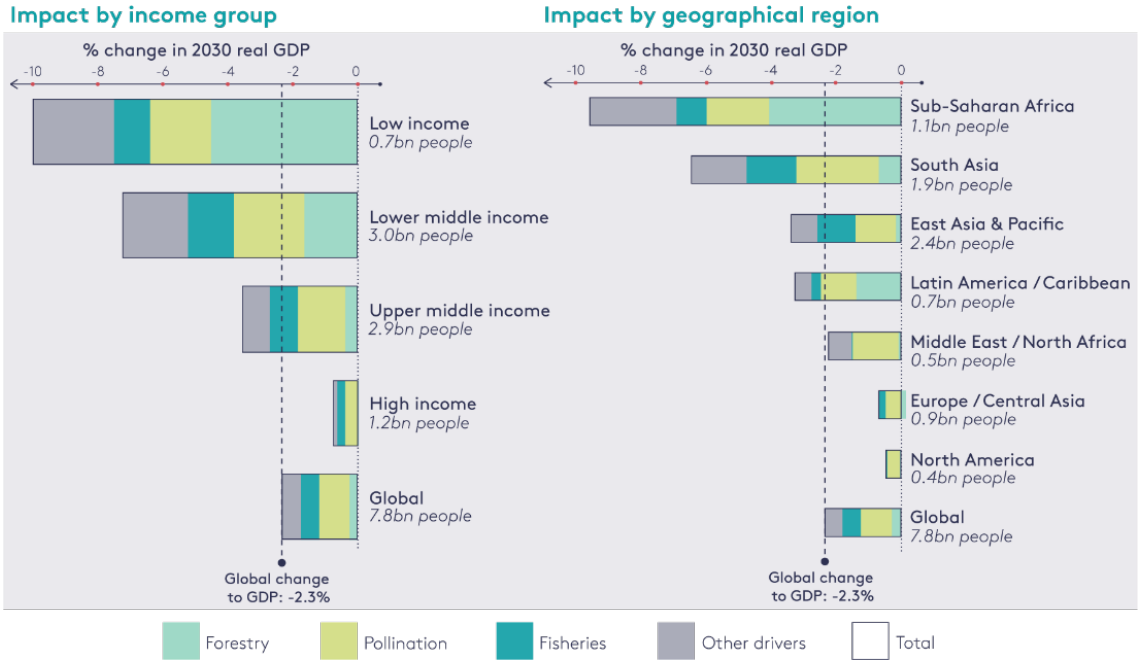
The global Earth–economy model

The World Bank has developed a global Earth–economy model, building on the work of the Global Futures Project and in partnership with the University of Minnesota and Purdue University. The model aims to estimate how ecosystem loss affects the economy as well as how economic policy changes can contribute to improving outcomes (Johnson et al., 2021). The model estimates how the collapse in select ecosystem services – defined as a 90 per cent reduction in wild pollination, marine fisheries and timber provision from native forests – could affect the global economy in 2030. It finds that, even without crossing tipping points, global real GDP in 2030 would contract by US$2.7 trillion (equivalent to a change of -2.4 per cent) compared with a baseline where such collapses do not occur. Non-extractive primary output is forecast to contract globally by 8 per cent, affecting key exporting countries the most (Johnson et al., 2021).

The model's results suggest that partial ecosystem collapse would have particularly dire effects on low- and lower-middle-income countries. This is due to their higher reliance on pollinated crops and forest products, and their limited ability to switch to other production and consumption options. Low-income countries would see a 10 per cent drop in real GDP in 2030 (equivalent to US$81 billion), and lower-middle-income countries a 7.3 per cent drop (equivalent to US$734 billion; see Figure 2.1 on the next page). At the regional level, Sub-Saharan Africa and South Asia could be hit particularly hard. The two regions would experience the greatest contraction of real GDP in percentage terms – a loss of 9.7 per cent (US$358 billion) and 6.5 per cent (US$320 billion), respectively. Fifty-one countries, with a forecast population of 1.6 billion people in 2030, are projected to experience a 10–20 per cent decline in real GDP (Johnson et al., 2021).

2 Including the stock of natural assets supplying regulating services as a multiplicative factor. The latter is absent from nearly all contemporary economic growth and development models. Its inclusion in the BGEM captures the fact that the economy is embedded in the biosphere.

Figure 2.1. Change in 2030 Real GDP in the global Earth-economy model, under 'partial ecosystem collapse' scenario compared with 'no tipping-point' scenario



Source: reproduced from Johnson et al. (2021)

2.3. Ongoing methodological challenges and potential ways forward

By integrating biodiversity and ecosystem services into macroeconomic models, such approaches represent a step forward that could feed into assessments of biodiversity-related financial risks. However, it is important to emphasise that several sources of methodological uncertainty remain. Some of these are outlined below, before their potential implications for the assessment of financial stability are explored in the next chapter.

- **First, natural systems and processes are subject to complex, non-linear dynamics and potentially irreversible changes.** In this context, monetary valuations of ecosystem services (or their loss) may provide meaningful estimations of changes at the margin but not under large, non-linear changes such as those that characterise ecological tipping points (Kedward et al., 2020). Using the planetary boundaries framework, Steffen et al. (2015) estimate that four of nine such boundaries – climate change, genetic diversity, land-system change and changes in biogeochemical flows – have passed beyond their safe operating zones, thereby increasing the risk that tipping points will be crossed. When this occurs, the monetary value of the income generated by a particular ecosystem service becomes significantly

impacted by destabilising regime shifts (Spash and Hache, 2021). This is a view shared by the Dasgupta Review, which acknowledges that the model it uses is designed to study economic possibilities only within the biosphere's stable operating zone (Dasgupta, 2021).

- **Second, many approaches challenge the prevailing notion that the essential services provided by biodiversity can be infinitely substituted by human capital** – that is, if natural capital were to be severely depleted (even if not completely), manufactured capital or labour could adjust to compensate without affecting overall output. The Dasgupta Review emphasises that the regulating and maintenance services provided by biodiversity and ecosystems underpin all economic production and, if they were to decline to zero, output would not be possible.[3] It further argues that while improvements in technology, institutions and practices can improve the efficiency with which we rely upon the natural world, that efficiency cannot be increased to infinity. This means that human demands on natural capital must remain within the regenerative capacity of natural systems to be sustainable over the long run. Otherwise, we eventually threaten the life support systems that make human activity possible (Dasgupta, 2021).[4] In contrast, existing macroeconomic models tend to consider that the importance of an ecosystem service is proportional to its contribution to output. This can lead to problematic results, especially in high-income countries: sectors especially exposed to biodiversity loss such as agriculture typically represent a small percentage of their overall economy, meaning that their partial or even total collapse would, in themselves, have only marginal impacts on GDP. In practice, the social and economic ramifications of an

3 This is encapsulated in the following modified Cobb-Douglas production function:

$$Y = A \cdot S^{\beta} \cdot K^{a} \cdot L^{b} \cdot R^{(1-a-b)}, \beta > 0;\ a, b, (1-a-b) > 0$$

where output (Y) is not only a function of labour (L), manufactured capital (K), and total factor productivity (A) – as per convention – but is also dependent upon biodiversity in the form of regulating and maintaining services (S) (e.g. climate regulation, nitrogen cycles, disease control) as well as provisioning services (R) (e.g. water, timber, fibres, food). The main novelty in this model is the addition of S in the form of a separate multiplicative factor that underpins all production: were this public good to decline to zero, output would not be possible.

4 It proposes the following inequality: $\frac{N \cdot y}{\alpha} > G(S)$ where N is global population, y is economic activity per capita, α is the efficiency with which the biosphere is converted into GDP and the extent to which it is transformed by waste products, and G is the rate at which the biosphere regenerates, which itself is a declining function of S – the aggregate stock of the biosphere.

ecosystem collapse could be profound but these are not accounted for by existing models. Similarly, in some lower-income countries agricultural sector collapse could lead to social unrest and unaccounted cascading economic effects.

- **Third, given the multiple components that make up an ecosystem, it is difficult (if not impossible) to aggregate different aspects of biodiversity under a common unit of measurement, which would imply they are commensurable (i.e. measurable by the same standard) and comparable.** By contrast, ecologists generally consider biodiversity and the benefits it provides to be 'greater than the sum of its parts' and largely incommensurable and incomparable (e.g. one cannot say that one species is by definition preferable to another). This is in contrast to climate change, where a universal metric (units of CO_2-equivalent emitted) is relevant. This poses challenges when designing comprehensive scenarios to, for example, assess how a global decline in biodiversity would impact GDP, or how economic sectors would be affected by specific pricing mechanisms. However, this cannot serve as an excuse for not acting on biodiversity, as the latter would amount to ignoring or denying the scientific consensus around the socioeconomic threats posed by biodiversity loss. In short, biodiversity loss presents significant challenges to conventional economic thought, and these need to be addressed rather than avoided.

These limitations suggest that better assessing the linkages between biodiversity and the economy calls for exploring various modelling approaches, while remaining aware of the deep or radical uncertainty at stake (Kedward et al., 2020; Svartzman, Després et al., 2021). Some of these approaches are discussed in the next chapter, in the context of financial stability assessment.

Box C | The climate–biodiversity nexus

Climate change and biodiversity loss have important characteristics in common. Both are potentially existential threats; are global and local phenomena (e.g. climate change is global but its impacts differ from one location to another, and biodiversity loss takes place at local scales but its impacts such as pandemics can be global); involve potentially irreversible tipping points; operate on multiple time horizons; are subject to significant risks and uncertainties that tend to diverge from the past; are complex; and are happening on an unprecedented scale.

The two issues are closely interconnected. Climate change is one of the five key drivers of biodiversity loss, affecting the survival of plant and animal species as well as impacting other environmental processes such as soil moisture and water cycles. Meanwhile, biodiversity loss exacerbates climate change. For example, land use change can be a significant source of carbon emissions and can undermine the ability of ecosystems to provide resilience against climate impacts.

An important link between biodiversity and climate change is in the dominant role that forests and oceans play as carbon sinks. Forests and oceans currently absorb more than half of the carbon dioxide the world emits (IPBES-IPCC, 2021). However, the ability of tropical forests to act as carbon sinks is weakening as trees die and dry out from drought and higher temperatures, risking the transformation of forests from carbon sink to carbon source (Hubau et al., 2020), and accelerating climate change. This is already happening in the south-eastern Amazon Rainforest, which is no longer a carbon sink because of local warming and deforestation (IPCC, 2021). Continued land use change in this part of the Amazon will impact global climate change and pose threats to food and water security in the region. Protecting and restoring ecosystems is vital to reducing the extent and impacts of climate change.

Actions taken to tackle either climate change or biodiversity loss can result in consequences to the other. Measures to protect biodiversity are almost always beneficial to the climate. Reducing deforestation and forest degradation is estimated to reduce emissions by 0.4 to 5.8 gigatonnes of CO_2-equivalent per year (IPCC, 2019). However, some measures to mitigate or adapt to climate change could have harmful effects on biodiversity. For example, poorly planned tree planting, mining for materials needed to develop renewable energy technology, and altering natural environments to build renewable energy infrastructure (e.g. solar or large hydro) can harm biodiversity (IPBES-IPCC, 2021). In practice, these interactions are likely to be much more complex, especially if irreversible tipping points are crossed in specific ecosystems, potentially leading to cascading effects in other ecosystems.

Biodiversity loss could exacerbate climate-related financial risks and create new sources of financial risks. Given the interrelated nature of climate change and biodiversity loss, focusing on climate-related risks without considering other environmental-related risks, such as those related to biodiversity, could lead financial institutions to significantly under-price risks within their portfolios (Finance for Biodiversity, 2021), which could impact the wider financial system.

It is nevertheless important to keep in mind that biodiversity loss could also introduce new sources of risk that are unrelated to climate-related risks – such as zoonotic diseases, water pollution and species extinction. These events could translate into risks to the financial system, meaning that biodiversity-related financial risks can also be explored on their own, i.e. not only because of their interactions with climate-related financial risks.

3. Assessing financial stability in the context of biodiversity loss: challenges and potential ways forward

Central banks and financial supervisors operate within mandates that vary across jurisdictions but typically include the maintenance of financial stability. Given the complexity of the relationships between biodiversity and the economy, central banks and financial supervisors face challenges in understanding the transmission of biodiversity-related risks from the macroeconomy to the individual financial institutions and financial systems that they oversee. Analytical efforts to explore these efforts are now getting underway.

Building on an increased understanding of the potential for biodiversity loss to generate material economic and financial impacts, the next question for central banks and financial supervisors is: **how do we assess the potential for biodiversity loss, and measures taken to address it, to create financial risks that threaten individual financial institutions and overall financial stability?** This is the topic of this chapter.

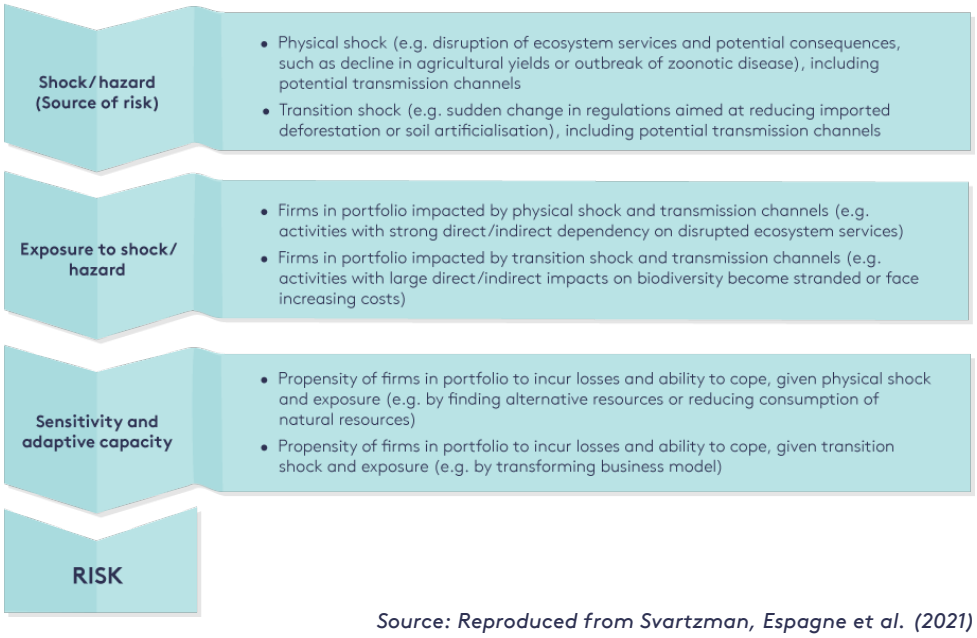
3.1. How to proceed to a forward-looking biodiversity-related analysis

To understand how biodiversity-related risks (or indeed any environmental risk) could impact financial stability, three elements are needed, as set out in Figure 3.1 (page 22):

1. A scenario of the hazards or shocks that could translate into financial risks.
2. Metrics of exposure of financial institutions' portfolios of assets to those hazards/shocks.
3. Tools to determine how vulnerable those financial institutions and the companies in their portfolios are, in terms of their sensitivity and ability to adapt.

The challenges discussed in the previous chapter, however, make it difficult to develop a complete picture of each of these components. It is noteworthy that similar challenges apply to the assessment of climate-related financial risks, although the complexity related to biodiversity-related financial risks makes it even more important to address such issues.

Figure 3.1. From environmental hazard to financial risk



Source: Reproduced from Svartzman, Espagne et al. (2021)

First, the nature of potential biodiversity-related hazards or shocks is uncertain, as are the channels by which they are potentially transmitted to economic agents (as discussed in the previous chapter). Moreover, no ad hoc scenarios for use by central bankers and financial supervisors have yet been created, in contrast to climate-related financial risks (see NGFS, 2021). As with climate change, the physical and transition impacts of biodiversity loss can be acute (sudden) or chronic (dispersed over time). Ecosystems could collapse suddenly, while policies could be introduced that would lead to a rapid repricing of assets. Conversely, physical hazards could materialise gradually, and policies to reverse biodiversity loss could be implemented incrementally. These gradual changes could nevertheless lead to sudden asset repricing once they are revealed to investors (Brunetti et al., 2021).

Second, assessing the exposure of economic and financial agents is made difficult by the fact that hazards and shocks are, in many cases, likely to have highly localised effects (requiring specific localised data and/or understanding of local natural phenomena and processes), but ones that can also spill over across ecosystems and supply chains. For example, the extension of protected areas would primarily affect businesses with production facilities or suppliers in the future protected area. However, globalised supply chains can transmit local impacts around the world, potentially turning small-scale impacts into ones much more widely felt. Similarly, physical impacts in one ecosystem's functioning, for example disruption of disease control, could lead to a new zoonotic disease that could, as with COVID-19, have profound global impacts.

Third, exposure does not necessarily translate into vulnerability, as some agents, sectors or countries will be better able to adapt than others. To assess risk, it is necessary to understand the sensitivity of agents to shocks and their ability to cope with these impacts or losses. A company with most of its facilities or its suppliers in a newly designated protected area may easily be able to relocate those facilities or find new suppliers. Conversely, a company may have limited exposure to a specific supplier but may find that supplier impossible to substitute.

This suggests that as central bankers and financial supervisors start working on the assessment of biodiversity-related financial risks it is important to keep in mind that we are facing a situation of deep or radical uncertainty (Bolton et al., 2020; Chenet, et al., 2021; Kedward et al., 2020). That is, deep uncertainties associated with natural processes and ecosystem tipping points are such that no single model or scenario can provide a full picture of the potential macroeconomic, sectoral and firm-level impacts caused by biodiversity loss.

3.2. Medium- to long-term avenues to assess impacts of biodiversity loss on the economy and financial system

In this context, central bankers and financial supervisors have two main medium- to long-term ways to assess biodiversity-related financial risks, with a number of short-term actions suggested in section 3.3 below. These avenues can be understood as complementary rather than exclusive, as they provide different lenses through which one can assess the linkages between biodiversity, the economy and the financial system.

Embedding biodiversity–economy models into existing risk measurement approaches

First, existing biodiversity–economy models, such as those presented in Chapter 2, could be used as inputs to the assessment of financial risks. A case in point is one of the assessments of physical risks conducted by Calice et al. (2021) in Brazil. The authors build on the global Earth-economy model presented in the previous chapter, which provides country-specific estimates of the decline in GDP growth through to 2030 (using 2021 as a baseline) due to a collapse in a selection of ecosystem services. The model's outputs suggest that Brazil's GDP growth could be 10 per cent lower by 2030 than in a business-as-usual scenario. The authors then 'plug' these results into a financial risk assessment, using studies that assess the historical sensitivity of Brazilian banks' asset quality to macroeconomic conditions (specifically, the relationship between borrowers' repayment capacity and macroeconomic conditions). They find that the GDP losses associated with the collapse in ecosystem services could translate into a cumulative long-term increase in corporate nonperforming loans (NPLs) by around 9 percentage points, other parameters being equal.

It is important to keep in mind that, given the inherent limitations of biodiversity–economy models, as outlined in Chapter 2, the exercise only provides conservative estimates of the economic and financial implications of collapsing ecosystem services, as acknowledged by the authors.

Ad-hoc methodological approaches to focus on cascading impacts from biodiversity loss

Given these challenges, the second way to proceed is to develop alternative approaches to assess biodiversity-related financial risks. Two recent developments in the literature offer promising avenues to understand the transmission of biodiversity-related shocks to the financial system.

To start with, it is possible to build on a recent literature on climate-related financial risks to better appreciate how biodiversity-related shocks could cascade throughout economic sectors and along global supply chains. One study uses input-output tables to show how climate-related impacts due to asset stranding can pass from one sector to other parts of the economy that rely on the first for inputs to their own production (Cahen-Fourot et al., 2021). Similar approaches would be particularly relevant in assessing the transmission of risks were non-substitutable forms of natural capital to become stranded. A better understanding of these cascade effects enables the exposure of specific firms (but not their adaptive capacity) to be better estimated. For instance, Godin and Hadji-Lazaro (2020) use two financial indicators (net debt over gross operating surplus, and net debt over total assets) to assess the financial consequences of a loss of exports from carbon-intensive sectors cascading to other sectors.

Future assessments of biodiversity-related financial risk could also be applied to the risk of contagion throughout the financial system. Such contagion could occur, for instance, if biodiversity-related shocks hit market valuations for some sectors and firms and reduce the ability of some borrowers to service debt. Focusing on climate-related financial risks, Roncoroni et al. (2021) show that relatively mild initial environmental shocks can end up propagating throughout the financial system, through the network valuations of financial assets. Because of the low substitutability of natural capital, there may be numerous channels through which biodiversity-related financial risks could spread throughout the financial system, such as bank insolvency, market liquidity and fire sales, possibly affecting agents far from the source of the biodiversity loss. In addition, these transmission channels are likely to work in both directions: financial impacts could feed back into the real economy, through credit constraints and higher lending rates, further impacting production, investment and employment, and so on.

3.3. Potential next steps for central banks and financial supervisors

No matter what approach is taken, central bankers and financial supervisors are operating in the context of considerable uncertainty when it comes to assessing biodiversity-related financial risks, as we have highlighted. It may only be possible to make progress on our understanding and with policy actions in this area over the medium to long term but the timescale in which actions are needed is much shorter, given the increased scientific urgency to take action to reverse biodiversity

loss if we are to avoid potentially systemic risks (IPBES, 2019). Given the urgency of the challenge, some argue for a precautionary approach (e.g. Kedward et al., 2020), while others argue that this could fall outside of the mandates of most central banks and financial supervisors. In either case, central banks and financial supervisors will need to gain a better understanding of the next steps they could take to familiarise themselves with the materiality of the links between biodiversity, the macroeconomy and the financial system.

We have identified two potential avenues that central banks and financial supervisors could pursue in parallel to gain better understanding within their existing mandates:

i) Assessing domestic financial institutions' and system-wide dependencies and impacts on biodiversity

Central banks and financial supervisors could develop systematic measures of the dependencies of financial institutions on ecosystem services as well as their impacts on biodiversity. These would use similar methodologies to ensure comparability. While this is not the same as measuring risk, such measures can be an important prerequisite to deepening understanding of potential domestic vulnerabilities. Indeed, a business that is highly dependent on ecosystem services is more likely than one that is less dependent to be affected by a physical risk. Equally, a business with significant negative impacts on biodiversity is more likely than one with a low impact to be affected by biodiversity transition risk. In addition, a business or financial institution with highly negative impacts on biodiversity contributes to the build-up of both physical and transition risks. Developing measures in this way could at least partially compensate for the lack of standard scenarios of biodiversity-related physical risks and transmission channels.

Methodologies already exist to assess both dependencies and impacts, and they will certainly be improved with time. An overview can be found in Finance for Biodiversity (2021). Below, we describe some that have been used by central banks and financial supervisors.

The ENCORE database provides one means for estimating dependencies and therefore approximating physical risks.[5] Developed by the Natural Capital Finance Alliance and UNEP-WCMC (see Natural Capital Finance Alliance, 2021), ENCORE – short for Exploring Natural Capital Opportunities, Risks and Exposure – has already been used for assessments of biodiversity-related financial risks in the Netherlands (van Toor et al., 2020), France (Svartzman, Espagne et al., 2021) and Brazil (Calice et al., 2021). It links 21 ecosystem services, derived from eight types of natural capital asset, to 86 types of economic production processes. It then scores the dependency (or materiality) of each

5 ENCORE also covers impacts but those are not discussed here, given that central bankers and supervisors have not, to the best of our knowledge, used the database for that purpose.

economic production process to ecosystem services; for example, the functioning of the process 'large-scale irrigated arable crops' depends on 'water flow maintenance' among other services, with high materiality. Dependency is a function of the degree of disruption to productive processes if the ecosystem service were to disappear, and the expected resulting financial losses.

Using ENCORE, van Toor et al. (2020) find that 36 per cent of financial institution portfolios of listed shares in the Netherlands are highly or very highly dependent upon at least one ecosystem service. Calice et al. (2021) and Svartzman, Espagne et al. (2021) find similar results for, respectively, Brazil and France, although slightly different scopes prevent direct comparisons. Specific sectors and ecosystem services are identified in each case, thereby enabling a better understanding of the dependencies of these respective financial systems on biodiversity.

Meanwhile, existing models and tools can be used to calculate the biodiversity footprint of assets in a portfolio and to approximate the biodiversity impacts of a financial institution. Such 'biodiversity footprints' can be expressed, for instance, in Mean Species Abundance (MSA).km^2, which is defined as the average abundance of originally occurring species relative to their abundance in an ecosystem in a pristine state, undisturbed by human activity. A loss of x MSA.km^2 is equivalent to the conversion of x km^2 of undisturbed ecosystem (with an MSA of 100 per cent) into a totally artificialised area (MSA of 0 per cent). This loss can be expressed in static terms, which captures persistent effects that remain over time (or stocks of impacts), or dynamic terms, to include the changes (or flows) in biodiversity, namely new biodiversity consumption, restoration or conservation over the assessment period. Using such approaches, van Toor et al. (2020) and Svartzman, Espagne et al. (2021) find that the Dutch and French financial systems have, through their holding of equities and bonds, significant impacts on biodiversity loss. The latter suggests that they could be exposed to transition risks.[6]

ii) Developing scenario analysis in relation to biodiversity-related financial risks

It is necessary, in addition to the above approach, to conduct scenario analyses, as is the case for climate-related risks and learning from the NGFS work on climate scenarios (NGFS, 2019, 2020, 2021). At present, no standard scenarios have been designed to assess the resilience of the financial system to specific biodiversity-related physical or transition hazards or shocks – but this was, until very recently, also the case with climate scenarios. Forward-looking scenario analysis is necessary

6 It should be noted that footprinting approaches have methodological limitations. For example, their focus at the ecosystem level means they do not capture genetic diversity, and their dependence on globally modelled data means they can overlook local exposures. Other approaches, such as the Potentially Disappeared Fragment of Species Metric and lifecycle assessments, can address some of these drawbacks.

for biodiversity-related financial risks for the same reasons as for climate-related financial risks: both are far-reaching in breadth, scope and irreversibility; the risk is simultaneously uncertain yet totally foreseeable; and the size and balance of future risks will be determined by actions taken in the short to medium term (typically in the next decade at most).

One specific challenge would be to decide whether scenarios should be 'top-down', 'bottom-up'[7] or use a combined approach. The top-down approach sees biodiversity-related shocks generating an impact on macroeconomic variables such as GDP or interest rates, which then impact specific economic and financial agents. In a bottom-up approach, the biodiversity-related shock is assessed directly at the microeconomic (sector or firm) level, without factoring in the macroeconomic impacts of the shock. Combining the two approaches, meanwhile, could bring together an understanding of firm-level vulnerability and the vulnerability of the financial system and financial stability at large.

The scenarios could consider some the following narratives:

- **Specific policies, such as the extension of protected areas under consideration by the Convention on Biological Diversity at the upcoming COP 15, or national or regional biodiversity strategies, could be used to inform these scenarios.** Under the former, the proposed increase of terrestrial, freshwater and marine protected areas to 30 per cent by 2030, up from current commitments of 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, would likely strand some existing economic assets. For example, Van Toor et al. (2020) have estimated that under a scenario where 30 per cent of terrestrial and freshwater areas become protected, the Dutch financial system would face exposures of €28 billion, or 7 per cent of total lending.
- **Sector-specific scenarios could also be envisioned**. Van Toor et al. (2020) also assess the exposure of financial institutions to policy developments to reduce nitrogen emissions.
- **Narrative, qualitative discussions of sources of biodiversity risk also offer an important step in understanding exposure**. As a starting point, illustrative examples of biodiversity-related shocks and their transmission into the financial system can provide useful insights into possible risk hotspots and could help inform further analysis.

IPBES is working on scenarios and models of biodiversity and ecosystem functions and services. Potential exists for collaboration between IPBES and finance specialists to adapt or develop scenarios suitable for use by

7 The terms 'top-down' and 'bottom-up' are not used in the same way as for top-down and bottom-up stress tests (i.e. stress tests performed respectively by a public authority or by a bank).

finance sector actors, including central bankers and financial supervisors (IPBES, 2021). An additional consideration is whether scenarios might be developed that combine biodiversity- and climate-related financial risks, given the interrelationships between the two issues.

However, scenario building and modelling cannot be a substitute for preventing the crossing of tipping points. The speed of biodiversity loss and the potential for sudden regime changes and cascading impacts means that the central bankers and financial supervisors could face trade-offs between the need to measure precisely and the need to prevent tail risks.

Box D | Estimating finance sector dependencies and impacts – examples from the Netherlands, France and Brazil

For central banks and financial supervisors, an assessment of the dependencies and impacts of their own financial sectors on biodiversity is an important first step in understanding biodiversity-related financial risk. As of September 2021, the central banks of the Netherlands and France had undertaken such an assessment, while the World Bank had estimated the biodiversity exposure of Brazil's financial system. Their findings are summarised below.

- **De Nederlandsche Bank** was the first central bank to undertake this work, published in its *Indebted to Nature* report (van Toor et al., 2020). It found that 36 per cent of investments by Dutch financial institutions, totalling €510 billion, is highly or very highly dependent upon at least one ecosystem service. It calculates that Dutch financial institutions have a 'biodiversity footprint' equivalent to the loss of 58,000km^2 of pristine nature, an area 1.7 times the size of the Netherlands.
- In August 2021, **Banque de France** published similar analysis (Svartzman, Espagne et al., 2021), although the slightly different hypotheses and methodologies used prevent direct comparison with the Dutch study. The Banque sets out an analytical framework to understand biodiversity-related financial risks – which emphasises the complexities involved and the limited substitutability of natural capital – and the dependencies and impacts of France's financial sector. It finds that 42 per cent of French financial institutions' portfolios comprise securities from issuers that are highly or very highly dependent on one or more ecosystem service, and the biodiversity footprint of these securities, through the firms and activities that are financed, equates to 130,000km^2 of pristine nature, or 24 per cent of the area of metropolitan France.
- Similarly, the **World Bank** found that 46 per cent of Brazilian banks' non-financial corporate loan portfolios, equal to 20 per cent of their total credit portfolios, are concentrated in sectors highly or very highly dependent on one or more ecosystem service (Calice et al., 2021). The Bank also looked at the impact of collapsing ecosystem services on non-performing loan (NPL) ratios, estimating a long-term increase in corporate NPLs of nine percentage points. In addition, it found that 15 per cent of banks' corporate loans are to companies operating in protected areas, a figure that could rise to 38 per cent if all priority areas became protected. This represents a source of transition risk.

4. Emerging financial sector practices

The financial sector is beginning to consider biodiversity loss in products and risk management practices. As well as the assessment exercises discussed in the previous chapter, central banks are starting to signal the importance of biodiversity. However, few tools currently exist that are well-tailored for the needs of central banks and financial supervisors.

4.1. Central banks and financial supervisors

Assessment is a core first step to understanding the financial stability implications of biodiversity loss. Central banks and financial supervisors are also starting to take a range of initial actions based on the growing evidence of the materiality of biodiversity-related financial risk. Examples are presented in Figure 4.1 on the next page.

Most of these actions are at an early stage, but they demonstrate how biodiversity loss is rising up the agendas of central banks and financial supervisors. As well as the assessment examples discussed in the previous chapter, examples include:

The **European Central Bank**, which has identified biodiversity loss as a source of environmental risk and has elaborated supervisory expectations covering risk management and disclosure, while the **European Banking Authority** has recommended how biodiversity loss might be included in regulatory frameworks.

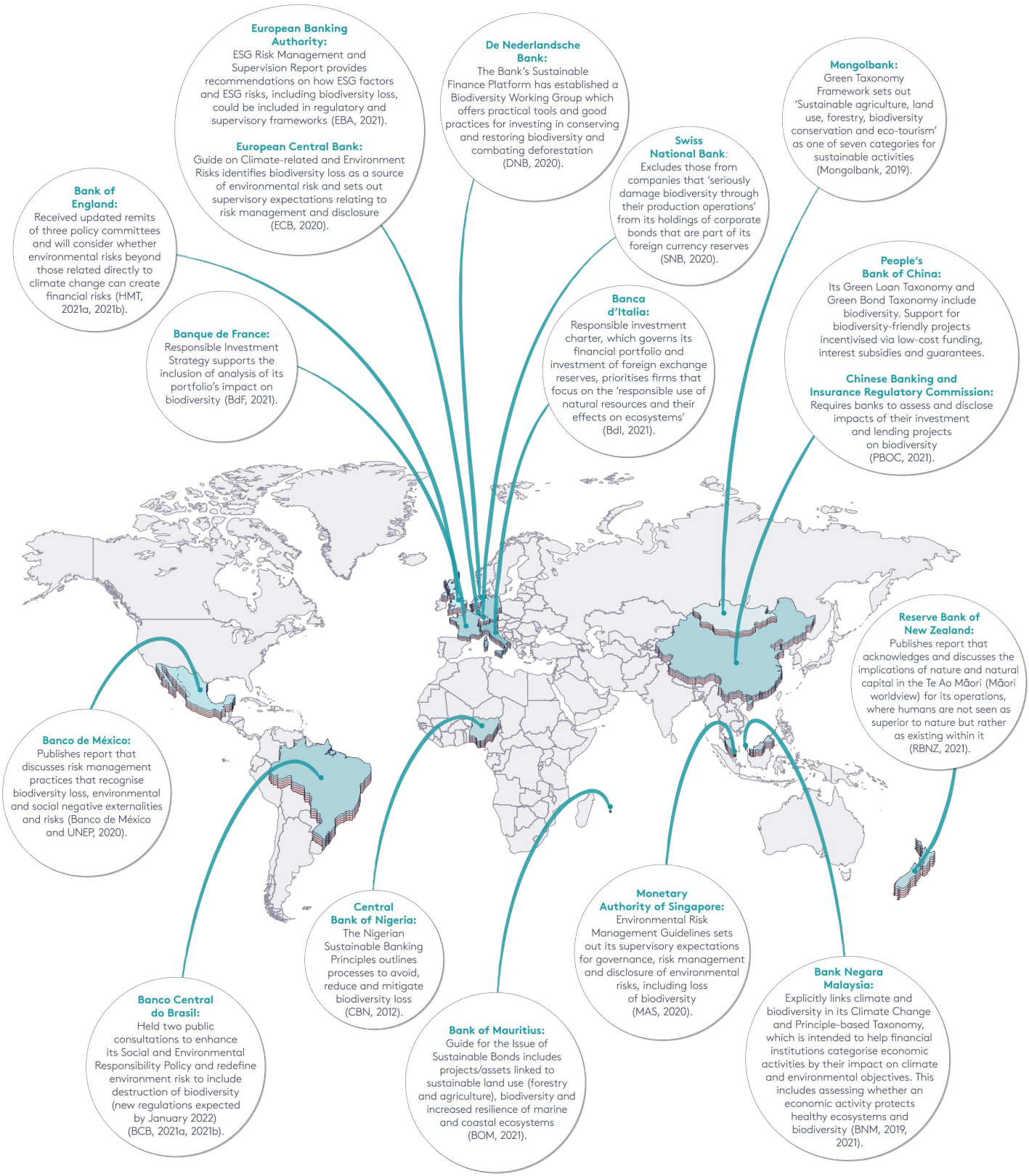
Similarly, the **China Banking Regulator** requires banks to assess and disclose the impacts of their lending and investments on biodiversity, the **Monetary Authority of Singapore** has included biodiversity loss in its supervisory expectations for governance, risks management and disclosure, while Morocco's **Bank Al-Maghrib** has included environmental conversation in its recent directive on financial risk management. **Banco Central do Brasil** has consulted on broadening its definition of environmental risk to include destruction of biodiversity.

Bank Negara Malaysia explicitly links climate and biodiversity in its recently published Climate Change and Principle-based Taxonomy, which is intended to help financial institutions categorise economic activities by environmental impact.

The **Swiss National Bank** excludes from its bond portfolio issues from companies with high biodiversity impacts, and **Banque de France** has started to explore some biodiversity-related impacts of its own portfolios.

The **Bank of England** will explore the potential relevance of other environmental risks to its primary financial stability objective. This work will consider whether environmental risks beyond those related directly to climate change can create financial risks that, left unaddressed, could pose a threat to UK financial stability.

Figure 4.1. High-level summary of biodiversity-related actions taken by central banks and financial supervisors



Source: compiled by authors

4.2. Private sector financial institutions

To date, private financial institutions, alongside think tanks, non-governmental organisations and UN bodies, have led the way on financial sector engagement with the issue of biodiversity loss. This includes through producing the Principles for Responsible Banking, which has issued guidance on biodiversity target-setting for banks, as well as commitments to protect biodiversity, such as the Finance for Biodiversity pledge by 78 financial institutions, managing €10 trillion in assets, to set and report on targets to reduce significant negative impacts and increase significant positive impacts of their financing activities on biodiversity. Several institutions have launched biodiversity-linked investment products. Examples of these products include Mirova's Land Degradation Neutrality Fund, BNP Paribas' Blue Economy Exchange Traded Fund and the natural capital investment joint venture between HSBC Global Asset Management and Pollination Group.

Of most relevance for central banks and financial supervisors, these efforts have resulted in a diverse landscape of biodiversity-related metrics, tools and databases that capture various dimensions of impacts and dependencies (see e.g. Lammerant et al., 2021).

Initiatives recently launched to attempt to bring some standardisation to the field include:

- The Taskforce on Nature-related Financial Disclosures (TNFD), which aims to develop a comprehensive framework for nature-related financial disclosures (see Box E on the next page).
- The Align project, which seeks to harmonise biodiversity-related accounting and measurement approaches.
- The consortium of AXA Investment Managers, BNP Paribas Asset Management, Sycomore Asset Management and Mirova, which is developing, with Iceberg Data Lab and I Care & Consult, a biodiversity impact measurement tool for investors.
- Global Forest Watch Pro and Global Fishing Watch's real-time database and geospatial tools on forest and ocean ecosystems respectively.
- The Science Based Targets Network's plan to encourage companies to set credible targets for both nature and climate, along the lines of the Science Based Targets initiative's work on climate targets.

These initiatives are set to bring more convergence in the range of metrics, tools and databases, pointing towards the potential for a monitoring and assessment dashboard. First experiences from the private sector show that there is no single metric or indicator that sufficiently captures either biodiversity-related impacts or dependencies of a financial asset. The complexity of biodiversity needs to be matched with a set of complementary metrics and tools (Lammerant et al., 2021; UN Environment Programme et al., 2020). Neither comprehensiveness nor exact accuracy is attainable at this stage of market development and

scientific insight. However, the current state of biodiversity-related metrics and tools allows a targeted, function-driven screening to build monitoring and assessment dashboard. This dashboard could provide a high-level understanding of impacts and dependencies relevant to assessing biodiversity-related physical transition and systemic risks.

Some of the main challenges faced by the financial sector in the adoption of such instruments relate to the fragmentation and partially inaccessible nature of biodiversity-related business-useful data. This problem refers not only to the lack of data, but also to data fragmentation, lack of public access and/or cost. First, relevant biodiversity-related data might exist but might be held by government agencies, universities or other third parties. Cooperation, such as between the DNB and the Netherlands Environmental Assessment Agency (PBL) (van Toor et al., 2020), is needed to overcome such data fragmentation. Second, some assessment tools are proprietary, preventing the more widespread testing and enhancement of biodiversity-related metrics, tools and databases.

Another challenge is that existing metrics, tools and databases were not designed for central banking or supervisory purposes, particularly in terms of being used in forward-looking analysis. While this does not render them irrelevant for such purposes, these tools will need to be adapted to serve the needs of central banks and financial supervisors.

Lastly, profound uncertainty about the future extent of biodiversity loss has inhibited forward-looking assessment. Whereas transition pathways such as the NGFS's climate scenarios allow a forward-looking analysis of climate-related transition risks, such future scenarios are virtually absent from the biodiversity space (see Chapter 3). This encourages a focus on the past and present, which is problematic in the context of the non-linearity that characterises the trajectory of the state of biodiversity.

Box E | The Taskforce on Nature-related Financial Disclosures

The Taskforce on Nature-related Financial Disclosures (TNFD) is a market-led global initiative that aims to support financial institutions and companies in assessing nature-related risks and opportunities. Its stated goal is to "support a shift away from nature-negative impacts and toward nature-positive global financial flows, by providing a framework for organisations to report and act on nature-related risks, including impacts and dependencies". It is co-chaired by Elizabeth Maruma Mrema, Executive Secretary of the CBD, and David Craig, CEO of Refinitiv.

Following work by its Informal Working Group, the TNFD was formally launched in June 2021 and intends to deliver a reporting framework by 2023, with initial compliance with its recommendations being voluntary (TNFD, 2021). The TNFD does not intend to develop a disclosure standard itself. Rather, it intends for its outputs to be integrated into existing frameworks and standards, such as those published by the Global Reporting Initiative, the Sustainability Accounting Standards Board, the Climate Disclosure Standards Board and the forthcoming International Financial Reporting Standards Sustainability Board. The proposed work of the TNFD was referenced by the G7 finance ministers and central bank governors (HM Treasury, 2021c).

5. The international policy context

Central bankers and financial supervisors face a landscape of growing biodiversity-related economic and financial risk. In the years ahead, government policy to conserve biodiversity is expected to be tightened at the international and national levels, generating important implications for financial authorities.

The current focus of policy activity is at the international level, with negotiations ongoing for a post-2020 global biodiversity framework under the auspices of the Convention on Biological Diversity. The first draft of the framework has a number of potential implications that could be relevant for the mandates of central banks and financial supervisors (Secretariat of the CBD et al., 2021). These stem from the Framework's three pillars: reducing threats to biodiversity, meeting people's needs through sustainable use and benefit sharing, and developing tools and solutions for implementation and mainstreaming.

To achieve the goals set out in the draft framework, a whole-of-government and whole-of-financial-system approach will be needed. This approach should connect financial policymakers, financial institutions, business and household consumers of financial services, and civil society. Article 2.1(c) of the Paris Agreement, which sets a goal of "making financial flows consistent" with decarbonisation and resilience objectives, has been an important stimulus for climate action across the financial system. The similar language proposed in the draft post-2020 global biodiversity framework on "ensuring that all activities and financial flows are aligned with biodiversity values" could help to mainstream biodiversity considerations into all financial decision-making.

The core aim of the framework is to initiate a transition to a 'nature-positive' economy by reducing threats to biodiversity. Currently, many economic activities have a negative impact on biodiversity. Harmful government subsidies alone amount to around US$500 billion annually (OECD, 2020), and will likely have profound impacts on sectors and companies when redirected and eliminated. The Framework's goal of reducing negative impacts on biodiversity could lead to transition risks for financial assets, institutions and, potentially, for the system as a whole.

Central banks and financial supervisors need to understand which assets and institutions could be exposed to transition risk to draw conclusions for microprudential and macroprudential policy. A first effort by a central bank in this context has been undertaken by the DNB (van Toor et al., 2020). It found that the Dutch financial sector had €15 billion in exposure to companies that are active in already protected areas, rising to €28 billion in a scenario where protected areas are increased to 30 per cent of land and inland waters by 2030. Scenario analysis and stress testing will be instrumental to the assessment of transition risk.

To address the draft framework's second pillar, focused on addressing the socioeconomic dimension of biodiversity, central banks and financial supervisors could help by connecting biodiversity with their broader strategies around financial inclusion, particularly in developing countries. The Alliance for Financial Inclusion (2021) has set out an agenda for 'inclusive green finance' focusing on climate change; this could also apply to biodiversity and nature.

Central banks and financial supervisors could also play a role in supporting the development of tools and solutions to support the implementation of the Framework's 2030 target to put biodiversity on a path to recovery, particularly with regard to policy dialogue. Those with appropriate mandates could provide governments with independent assessments of the financial implementation related to the Framework. These could cover both real economy aspects, such as the reform of harmful subsidies, and financial system aspects, including financial regulation.

More broadly, agreement on the post-2020 Global Biodiversity Framework is likely to elevate biodiversity as a strategic priority for government, business and finance, as well as civil society. As a consequence, it is set to catalyse broader reflection in the central banking and supervisory community of the role that they could play across their mandates. One area in which the Framework is likely to spur action is disclosure, reflected in the target in the draft for all businesses to "assess and report on their dependencies and impacts on biodiversity" by 2030. The TNFD will play a shaping role in providing a reporting framework that will allow for consistent and comparable reporting. The reporting framework will be designed to complement the Task Force on Climate-related Financial Disclosure (TCFD)'s framework and is expected to be launched in 2023. Central banks and financial supervisors could use the framework once it is published to spur disclosure beyond dependencies and impacts, reflecting the financial risks connected to biodiversity-related physical and transition risks.

There is also growing recognition of the links between biodiversity loss that flows from illegal activity, notably money laundering, and other areas of financial regulation. The Financial Action Task Force is working on the money laundering risks resulting from environmental crimes and, at the 2021 G20 Summit, leaders recognised "the links between climate and biodiversity threats and other serious crimes" (US Department of the Treasury, 2021). This could translate into transition risks (including liability and reputational risks for individual financial institutions involved in such practices) and therefore warrants consideration by central bankers and financial supervisors.

Policy to address biodiversity loss will also likely advance at regional, national and sub-national levels. Policy efforts to address biodiversity loss are expected to accelerate in other forums, with the EU's biodiversity strategy, the UK's Environment Bill and plans to include measures to conserve marine biodiversity in China's 14th Five Year plan as cases in point.

6. Proposed next steps for central banks and financial supervisors

As central bankers and financial supervisors develop their responses to the physical and transition risks related to biodiversity loss, there are a number of actions they can take now that will help lay the foundations for more comprehensive measures.

The Study Group's Final Report, to be published in early 2022, will more comprehensively consider options for central banks and financial supervisors to address the micro- and macroprudential risks that biodiversity loss poses.

However, the options below provide suggestions for work by NGFS members to both directly address those risks, as well as contributing, where mandates allow, to wider efforts to address the global biodiversity crisis. They are proposed as 'no regrets' options that do not close off potential for further action in the future.

These options are based on examples of existing practice by central banks and financial supervisors. They should be considered as part of an integrated approach to biodiversity loss and climate change, which recognises the synergies, tensions and distinctions between the two. Some of these actions are best undertaken by individual central banks, recognising their specific mandates and contexts. However, there is also considerable advantage in working together on some elements, such as scenario building. The collaborative work of the NGFS on climate risk led to substantial advances in the understanding of central banks on the subject, and similar advances on nature might be expected.

Central banks and financial supervision authorities could:

- **Build** the skills, capacities, tools and cooperation to address biodiversity-related economic and financial risks. For example, the NGFS has played an important role in developing climate change scenarios for use by financial supervisors and the institutions they oversee, while the Bank for International Settlements has recently co-founded the Climate Training Alliance, which will provide training resources to help financial authorities respond to climate risk (BIS, 2021). Central Banks and financial supervisors could play similar roles in building capacity around measurement, assessment and disclosure of biodiversity-related risks. Moreover, as financial activity in one jurisdiction can have impacts on biodiversity-related risks in another, international cooperation between central banks and financial supervisors is an important lever for strengthening financial stability.
- **Assess** domestic financial system dependencies and impacts on biodiversity. As discussed in Chapter 3, these assessments could be quantitative, where accessible and business-relevant data exists,

or qualitative. They could draw on biodiversity–economy modelling (recognising its current limitations discussed in Chapter 2), scenario analysis, or new systematic measures of financial institution dependencies and impacts. Assessments need to consider the interrelationships between biodiversity loss and climate change, the endogeneity of such risks (e.g. through a double-materiality framework) and the complexity and non-linearity of biodiversity-related financial risks, which can translate into cascading and contagion effects.

- **Signal** to the financial institutions that they supervise, other economic actors and policymakers the importance of understanding the risks arising from their dependencies and impacts on biodiversity. Simply by publicly expressing their concerns about the physical and transition risks posed by biodiversity loss, central banks and financial supervisors can send a powerful message to banks and other financial institutions to work to understand their exposures and those of their clients. This signal can be strengthened by including biodiversity in central bank and supervisory policy statements, as a number of authorities are starting to do. In addition, central banks and financial supervisors could encourage financial institutions to seek information from borrowers on their biodiversity plans, exposure and performance. Finally, central banks and financial supervisors can lead by example through the integration of biodiversity factors into the responsible investment policies for their own portfolios.
- **Support**, to the extent possible within their mandates, governments' efforts to reverse biodiversity loss, in particular regarding the implementation of the post-2020 Global Biodiversity Framework, by addressing financial risks and preparing the financial infrastructure required for nature-positive financing. With growing recognition of the need to align financial flows with national and international biodiversity goals, central banks and financial supervisors can play an important role in translating this ambition into the operational language of risk and financial stability. This could extend to working with governments and the private sector to support the scaling-up of conservation finance in a manner similar to efforts to address climate change.

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