Quantitative easing and nature loss:

Exploring nature-related financial risks and impacts in the European Central Bank's corporate bond portfolio

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Executive summary

The ongoing degradation of nature, ecosystems and planetary biodiversity poses major economic and financial risks (Dasgupta, 2021; CBD, 2021). Businesses are embedded within the environment via their dependencies and impacts upon the resources provided by nature. Through their lending, advisory and investing activities, financial institutions are exposed to business dependencies and responsible for facilitating negative impacts by those firms. In the financial sphere, several voluntary initiatives aiming to incorporate biodiversity considerations into financial institution decision-making have emerged (Finance for Biodiversity, 2021). Central banks are also beginning to examine how to address the impacts of biodiversity loss on financial stability, building on previous research on climate change (NGFS 2021b).

Central banks' own interventions in financial markets, including their large-scale asset purchase programmes (often referred to as Quantitative Easing or QE) are one channel via which they may be able to influence these nature-related financial risks (NRFR). By purchasing corporate bonds from a particular firm, central banks can increase the demand for its debt and drive down the interest rate on that debt, improving the firm's ability to finance its activities. Although QE is primarily a monetary policy operation aimed at stimulating general prices towards an inflation target, central banks also have financial stability mandates and secondary mandates relating to supporting wider government policies, including those relating to environmental sustainability. Recognising this, the Bank of England and European Central Bank (ECB) have both recently committed to incorporating climate change risk considerations into their respective corporate bond purchasing programmes (Bank of England, 2021; ECB, 2021). However, at present, these adjustments will not incorporate nature-related financial risks (NRFR).

In this report we examine the ECB's corporate bond purchase operations and their links to nature loss and NRFR. The ECB's Corporate Sector Purchase programme (CSPP) and more recent Pandemic Emergency Purchase Programme (PEPP) have now reached over €310 billion, representing 20% of the euro-denominated corporate bond market. As such, the ECB's approach to managing risks within its portfolio has considerable signalling power to financial markets and could have a material impact on the uptake of prudent risk management practices by the private sector relating to nature degradation.

The report draws on several data sources and methodologies to consider nature-related financial risks relating to the ECB's CSPP/PEPP portfolio at the aggregate level, the company-level and via global supply-chain impacts relating to deforestation.

Aggregate level results

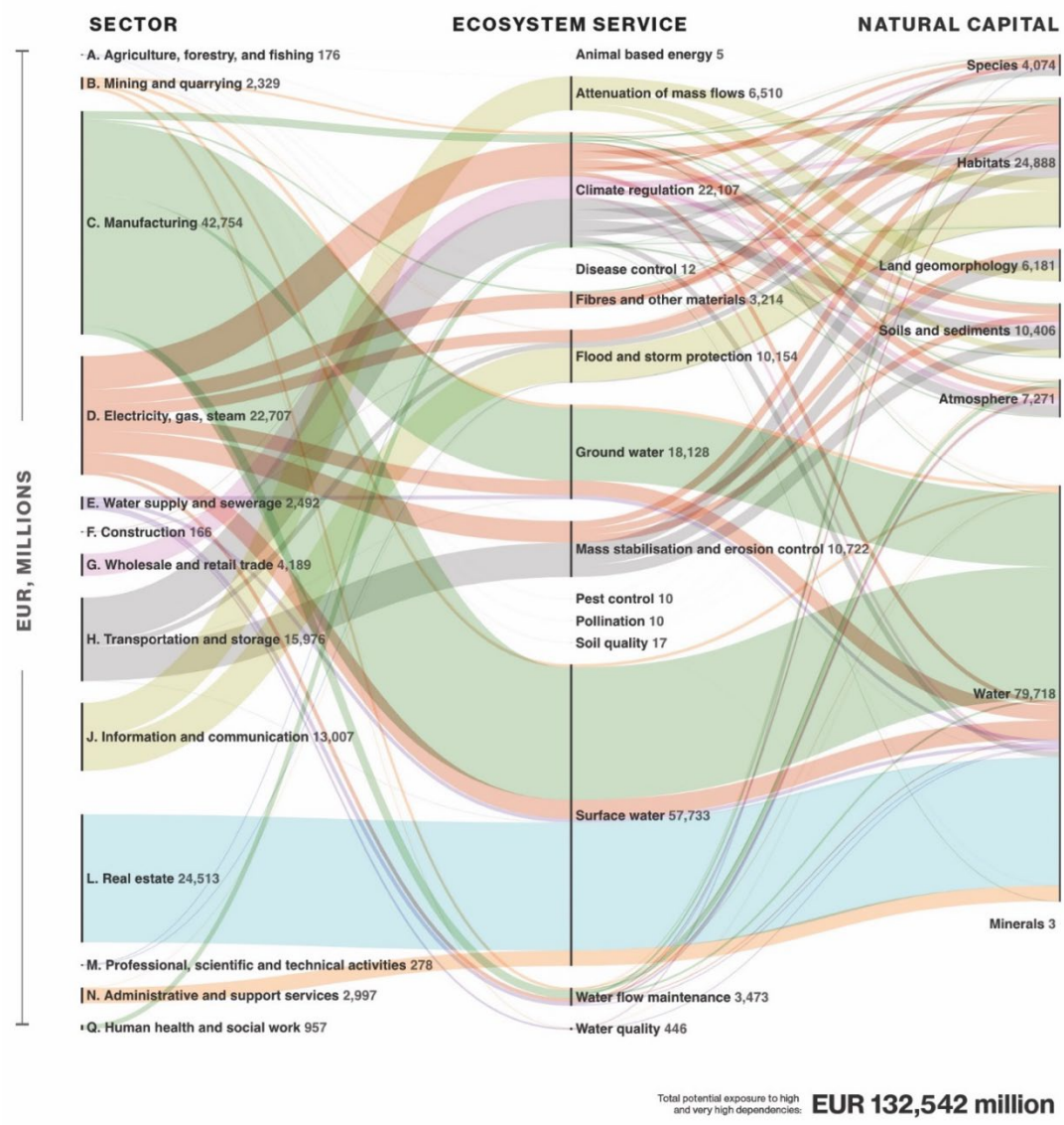
Using the Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)[1] framework, which maps financial dependencies and impacts on ecosystems services, we find that over **40% of the ECB's corporate bond portfolio is potentially exposed to high or very high dependencies**

[1] Developed by the Natural Capital Finance Alliance (Global Canopy, UNEP FI and UNEP-WCMC), 2021.

upon ecosystem services. This means that the loss of these ecosystem services would disrupt production and cause material financial losses (Figure A).

Within this, significant dependencies upon water-related ecosystem services are potentially associated with 25% of the ECB's exposures. This includes, first, physical risks due to the likelihood of future water scarcity making production impossible in specific locations and, second, transition and liability risks if new legislation and policies emerge around water use and pollution. The ECB's exposure to this high degree of water risk is linked to the size of its investments in real estate, processed food and drink manufacturing, pharmaceuticals and mining — all sectors associated with high water usage. In addition, the CSPP/PEPP portfolio is also potentially exposed to high dependencies upon ecosystem services that protect the production process from natural hazard disruption, particularly climate regulation, flood and storm protection, and mass erosion and stabilisation control.

Figure A. Flow diagram linking ECB exposure to NACE level 1 sectors to dependencies upon ecosystem services and natural capital assets



Source: Authors' calculations using the ENCORE framework

We also find that over **70% of the CSPP/PEPP portfolio is potentially contributing to key drivers of biodiversity loss**. Of this, negative impacts concerning land use and freshwater use are potentially associated with 29% of the ECB's portfolio, reflecting the size of the ECB's investments in real estate, infrastructure, mining and manufacturing. Land use change related to both terrestrial and freshwater ecosystems has had the biggest relative adverse impact on biodiversity since 1970.

A further **25% of the ECB's portfolio is potentially contributing to climate change and the emission of other biodiversity-negative pollutants**. Climate change exacerbates nature loss through increased frequency of extreme weather events, flooding, droughts and wildfires that place threatened biodiversity under additional stress. Pollutants from manufacturing, mining and agriculture, as well as poorly treated urban waste, toxic dumping and oil spills, have had significantly adverse effects on air, soil, freshwater and marine water quality, with negative impacts on local biodiversity.

Company-level results

To gain a more granular, company-level understanding of potential nature-related risk exposure, we use a database provided by Moody's ESG Solutions[2] to explore how many companies in the ECB's corporate asset purchase portfolio have production facilities located in: (1) areas of high water stress; and (2) areas associated with biodiversity loss.

We find that the **CSPP/PEPP is exposed to 67,991 business facilities associated with 'high' water stress, of which 12,921 facilities are associated with 'red flag' water stress, linked to 163 companies in the portfolio**. Measuring only companies whose total aggregated water stress scores represent the 'high' and 'red flag' categories, we estimate that the **ECB potentially has €38.6 billion in financial exposure** to high water risk in its corporate bond portfolio.

We also find that the **CSPP/PEPP is exposed to 3231 corporate facilities around the world that are associated with biodiversity loss, belonging to 94 companies in the portfolio**. Accounting only for companies that have over 100 biodiversity-negative production facilities, we estimate that the **ECB potentially has €17.2 billion in financial exposure to negative biodiversity impacts** in its corporate bond portfolio.

Impacts through the supply chain: deforestation

One limitation of the above analyses is that they only examine first-order impacts and dependencies of nature-related financial risks in specific sectors or firms. To address this, we consider how dependencies and impacts from deforestation — established as one of the most important drivers of biodiversity loss and environmental risk — might cascade throughout global supply chains to materialise within the ECB's corporate bond purchase portfolio.

We find that in total the ECB is **invested in 22 companies that are highly influential in forest risk commodity supply chains**, such as palm oil, soybeans, timber products and beef. Of these, only half have identified deforestation as a business risk and less than half have a company-wide

[2] See https://esg.moodys.io/climate-solutions.

commitment to remove deforestation from their operations and supply chains, or a commitment to remediate for damage caused, and less than a quarter conduct specific risk assessments for *all* the forest risk commodities they are active in. Lack of widespread implementation of deforestation risk management policies in this subset of companies indicates that the CSPP/PEPP portfolio could be exposed to transition risks, related to a tightening policy environment, and liability risk, including legal and reputational risk.

Policy options

Nature loss is characterised by a high degree of complexity and uncertainty with no single established anthropogenic activity or metric, such as carbon emissions, upon which to base risk-assessment. Yet many nature-related threats — such as deforestation and pollinator loss — are evolving over a shorter time horizon than climate risks and are subject to 'tipping points' whereby small changes in external drivers may lead to sudden and irreversible regime shifts. Such uncertainty means that mitigating actions may have to be taken on a precautionary basis with qualitative as well as quantitative assessments of risk, using the type of methodologies outlined in this report, even if precise probabilities of different outcomes are not available.

The ECB has traditionally determined its corporate bond purchase decisions using the principle of 'market neutrality'. This involves replicating the sectoral distribution of private bond markets to avoid price distortions that may result from large-scale asset purchases. As has been recognised for climate change, by mirroring the sectoral composition of the corporate bond market, the ECB's portfolio also mirrors the failure of credit rating agencies, as well as the broader failure of financial markets, to account for the financial risks associated with dependencies and impacts upon nature.

To deal with this challenge, the ECB could supplement its risk processes to account for NRFR in its corporate asset purchase operations. This could help to preserve its credibility as financial supervisor, fulfil its fiduciary duty with respect to prudent risk management, and ensure its monetary policy operations are aligned with existing and emerging biodiversity-related policy at the EU level. This includes the European Commission's Biodiversity Strategy for 2030, which proposes legally binding targets around ecosystem restoration and protection (European Commission, 2020).

A first step would be for the ECB to **promote the accelerated uptake of nature-related financial disclosures** amongst counterparties involved in monetary policy operations. Currently, the Task force on Nature Related Financial Disclosures (TNFD, 2021) is establishing voluntary guidelines, but by making this obligatory, a major central bank such as the ECB could significantly speed up the process of engagement. The ECB could also 'lead by example' by **disclosing its own assessment of the nature-related dependencies and impacts on its balance sheet,** including the CSPP/PEPP portfolio, as well as its pension fund and foreign exchange assets.

A second step would be to implement commitments and active risk management processes to ensure the **CSPP/PEPP is not directly or indirectly exposed to activities which scientific consensus or EU policy consider to be harmful to biodiversity and nature**, such as deforestation. An escalation strategy could be taken to encourage counterparties to align with rising standards, particularly where indirect exposures are at play. This approach would require the ECB to

implement robust processes for engaging and monitoring counterparties, with consequences for non-compliance.

Over time, the ECB could target or 'tilt' asset purchases towards companies directly contributing to nature restoration, ensuring targeted operations support the establishment of robust standards within new green financial instruments. It could also explore how to coordinate with central banks — mainly in low- or middle-income economies — operating in high biodiversity-value jurisdictions and with other relevant policy actors at the EU level, to proactively contribute to the greening of global financial standards in support of nature.

In its recent Strategy Review, the ECB (2021) has recommended the introduction of similar such policies to account for climate risks in its monetary policy operations. Given the interconnected nature of climate change and nature loss, the insights in this report suggest the ECB should also explore means to account for nature-related financial risks, as well as ensure its monetary policy operations are not inadvertently undermining emerging EU biodiversity policy.

1. Introduction

The increasing scale and intensity of human activity is pushing natural systems towards and beyond their functional limits, posing unprecedented threats to many human and non-human populations (IPBES, 2019). Policymakers and business leaders are recognising that environmental threats beyond climate change, including biodiversity loss, pose serious economic and financial risks (Responsible Investor and Credit Suisse, 2021; Dasgupta, 2021; NGFS, 2021b). Financial institutions face potentially significant exposures to nature-related financial risks (NRFR): both *physical risks* resulting from disruptions to business inputs, operating environments or consumer demand, and also *transition risks*, which include shifts in policy, regulation, technology, trade or consumer preferences (Kedward et al., 2020; Vivid Economics and Global Canopy, 2020).

A key challenge for central banks and financial supervisors in dealing with NRFR is that the conceptual framework for measuring and understanding them is far less advanced than that for climate-related financial risk. Yet many nature-related threats — such as deforestation and pollinator loss — are evolving over a shorter time horizon than climate risks. In addition, nature risks and climate risks intersect and interact with each other. Nature-depleting activities may increase climate-related risks given that habitats such as coastal floodplains, wetlands and mangroves provide critical ecosystem services in mitigating the weather disruption related to climate change.

On 12 July 2021, the Secretariat of the UN Convention on Biological Diversity (CBD, 2021) published the first draft of a new global biodiversity framework to 'guide actions worldwide to preserve and protect nature and its essential services to people.' The framework comprises 21 targets and 10 'milestones' proposed for 2030, including: ensuring 30% of land and sea areas globally are conserved; the prevention of invasive alien species by 50%; the reduction of nutrient loss by half, pesticides by two-thirds and the elimination of plastic waste; and the reduction of harmful financial incentives by $500bn per year. This framework will be further refined and finalised at the Council of the Parties (COP) 15 Biodiversity Summit, scheduled at the time of writing for October 2021.

The European Union is one of the jurisdictions leading the way on policy initiatives to support nature. The EU Green Deal acknowledges biodiversity loss as a major global risk and part of the roadmap for the transition to a sustainable economy (European Commission, 2019b). The European Commission's Biodiversity Strategy for 2030 proposes legally binding targets for ecosystem restoration, achieved through strict protections of 30% of the EU's land and sea area, and by the establishment of 'ecological corridors' (European Commission, 2020).

While these initiatives recognise that a biodiversity-positive economic transition is primarily a role for strategic industrial and fiscal policy, they also emphasise the important role to be played by private finance in both mobilising green investment funds and reallocating capital away from harmful activities.

Several voluntary initiatives aiming to incorporate biodiversity considerations into financial institution decision-making have emerged. These include a range of tools for quantitatively estimating NRFR (Finance for Biodiversity, 2021), although none are yet widely established. The

newly launched Taskforce on Nature-related Financial Disclosures (TNFD, 2021) aims to provide a harmonised framework for financial institutions to report and act upon NRFR, in order to incentivise sustainable capital reallocation, while recognising that financial regulators may have to step in to ensure systematic and consistent disclosure by financial institutions (Vivid Economics and Global Canopy, 2020).

Financial authorities are also turning their attention to NRFR. In France, new biodiversity reporting rules legally require financial institutions to align their investments to the 2030 biodiversity targets by reporting their biodiversity footprint and contributions made by their investments to reducing negative biodiversity impacts (Wheelan, 2021). The Dutch central bank, *De Nederlandsche Bank* (DNB), has quantitatively mapped the physical and transition risks of biodiversity loss for the Dutch financial system, estimating that 36% of financial institutions are highly dependent upon at least one ecosystem service (DNB, 2020). The Network for Greening the Financial System (NGFS) — a group of 92 central banks and financial supervisors — is now exploring the implications of biodiversity loss for financial stability (NGFS, 2021b).

This report contributes to this burgeoning research agenda by exploring the interactions between nature-related financial risks and monetary policy, specifically focusing on the European Central Bank's (ECB's) €310bn corporate bond purchase operations. The report has two main objectives.

First, we aim to provide a first-stage analysis of how current corporate asset-purchase operating procedures may give rise to nature-related financial risks on the ECB's balance sheet. At the same time, following the logic of double materiality,[3] this analysis constitutes an initial perspective on how corporate asset purchases may be enabling negative environmental impacts via providing financial support to certain sectors and firms. The exercise can also be understood as a case study investigating the potential transmission channels from nature loss through to the financial system.

Second, based on these findings, we explore some of the policy options the ECB could take to better account for NRFR in its monetary policy operations, acknowledging the complexity and uncertainty that characterise these risks.

The rationale for this focus on asset purchases is threefold. First, public finance, as well as private finance, needs to align with policies and commitments to restore nature (Smale and Zadek, 2020). Analysis in this area thus far has focused upon how public subsidies, stimulus funds and development banks are supporting biodiversity-harmful activities (Deutz et al., 2020; Dixon, 2020; Vivid Economics, 2021). Yet central banks too represent a significant source of public stimulus into the real economy: central bank balance sheets increased substantially in the wake of the financial crisis of 2007-8 and more recently in response to the economic crisis and financial

[3] Double materiality refers to the fact that companies and financial institutions are not only vulnerable to environmental (physical and transition) risks (i.e. financial materiality), they also contribute to the emergence of these risks through their corporate or financing activities (Oman and Svartzman, 2021). The concept has received some endorsement from European policymakers (European Commission, 2019c), including financial supervisors (ESMA, 2020).

instability brought about by the COVID-19 pandemic.[4] In major economies, asset purchases during the COVID-19 crisis have expanded to include support for the private sector in various ways, including via purchases of corporate bonds, exchange-traded funds and direct lending to firms (Cavallino and De Fiore, 2020).

The ECB's corporate bond purchases under the Corporate Sector Purchase Programme (CSPP) and Pandemic Emergency Purchase Programme (PEPP) have now reached over €310 billion, representing 20% of the euro-denominated corporate bond market.[5] The ECB's approach to managing risks within its portfolio will thus have considerable signalling power to financial markets and could have a material impact on the uptake of prudent risk management practices relating to nature (Svartzman et al., 2021a; Weidmann, 2021).

Central banks have traditionally relied upon the concept of 'market neutrality' to guide the allocation of QE programmes, whereby their purchases broadly replicate the sectoral distribution of private bond markets to avoid any price distortions that may result from large-scale asset purchases. Previous research has shown that relying on 'market neutrality' inadvertently leaves central banks exposed to climate-related financial risks, as well as potentially indirectly supporting activities that are incompatible with the net-zero carbon transition (Matikainen et al., 2017; van 't Klooster and Fontan, 2020; Dafermos et al., 2020; Dikau et al., 2021). It has been accepted by prominent European central bankers that the CSPP/PEPP may be reinforcing perceived market failures in relation to climate change and inadvertently conflicting with the wider EU net-zero carbon policy objective (Schnabel, 2020; Arnold, 2020). In response, in its recent Strategy Review for monetary policy, the ECB has committed to assess potential biases that may exist in market allocation and to recommend alternative benchmarks for the allocation of CSPP funds (ECB, 2021).

Second, and relatedly, there is potentially a legal dimension relating to the need to account for NRFR within European monetary policy. Should targets within the EU's Biodiversity Strategy for 2030 become legally binding, as the European Commission has proposed for the end of 2021, the ECB would in turn be bound to account for these objectives when designing and implementing monetary policy, as stipulated by Article 11 of the Treaty on the Functioning of the European Union (TFEU) (Solana, 2019). Regardless of if the targets become binding or not, the ECB already has a secondary mandate to support the broader goals of EU-level economic policy, which include the ecological transition (Elderson, 2021; Schnabel, 2021). Indeed, the ECB has recently acknowledged this issue in relation to climate change and has accordingly committed to ensure the companies in its CSPP are aligned with 'at a minimum, EU legislation implementing the Paris agreement through climate change-related metrics or commitments of the issuers to such goals' (ECB, 2021).

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[4] In 2007, the central banks in the US, euro area, UK and Japan had total assets ranging from 6% to 20% of nominal GDP. By the end of 2020, the Fed's balance sheet was 34% of GDP, the ECB's 59%, the Bank of England's 40% and the Bank of Japan's 127% (Cecchetti and Tucker, 2021).
[5] See https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html.

Third, the ECB — as banking supervisor for the euro area — has published supervisory guidance on the need for financial institutions to account for environmental financial risks, including those from biodiversity loss, in their operations (ECB, 2020). The ECB's own investment and monetary policy operations should be consistent with this guidance to ensure its credibility as a supervisor. In other words, the ECB — in its capacity as manager of a vast portfolio of assets ultimately representing public money – has a fiduciary duty to investigate and account for potential risks on its balance sheet.

Throughout this paper, we explicitly use a double materiality approach to gain a more comprehensive understanding of how aggregated NRFR may become material at the systemic level. On the one hand, negative impacts on nature are an indication of potential sources of transition risk as policy and regulation evolves to take mitigating action on nature-depleting activities. On the other hand, one firm's negative impact on nature may in turn adversely affect another firm which relies on that nature to enable production. Such reinforcing feedback loops suggest the presence of endogenous dynamics which may also interact with the financial system (Kedward et al., 2020).

The rest of this paper proceeds as follows: Section 2 outlines our methodological approach; Section 3 details the analysis and results; Section 4 reflects upon the implications of the results and considers policy options for the ECB to meet the challenge of NRFR; and Section 5 concludes.

2. Methods

The extent to which the loss of nature and biodiversity materialises into financial risk will be a function of:

1) the severity of the physical threat or transition risk factor;
2) the size of financial exposure to the hazard/risk;
3) the propensity of exposed firms to incur losses or adapt to cope with the hazard/risk (Svartzman et al., 2021b — forthcoming).

In our analysis, we focus first on the first two dimensions by exploring where sectoral exposures in the ECB CSPP/PEPP portfolio[6] may be associated with significant dependencies and impacts upon aspects of nature. Our chosen approach adapts and expands upon the Dutch central bank's exploration of biodiversity risks within the Dutch financial system, which used the ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure) framework (DNB, 2020). Second, we reflect upon the third dimension with qualitative analysis at the company level and through an examination of deforestation as a specific nature-related financial risk.

2.1 Explaining the ENCORE framework

ENCORE is a qualitative database that maps sectors and sub-industries onto their associated direct environmental dependencies and impacts, assigning to each a *materiality rating*. It was developed by the Natural Capital Finance Alliance in cooperation with UNEP-WCMC to help financial institutions improve their understanding and assessment of risks resulting from the decline in biodiversity and ecosystem services (Natural Capital Finance Alliance (Global Canopy, UNEP FI and UNEP-WCMC), 2021).[7] For dependencies, this rating reflects the degree to which production would be disrupted by the loss of the ecosystem service and the severity of associated financial losses. For impacts, the rating reflects the severity of the negative environmental impact, whether it occurs throughout the business life cycle and in all locations where production takes place, and whether it is operationally or financially feasible to redesign the production activity to avoid the impact.

In total, the ENCORE tool maps 86 production processes, representing 11 sectors and 138 sub-industries from the Global Industry Classification Standard (GICS) onto 21 ecosystem services, which in turn flow from eight types of natural capital assets. A recent extension of the ENCORE tool also maps connections to the most prominent impact drivers of biodiversity loss (UNEP-WCMC, 2020).[8] Appendix A provides more detail on the ecosystem services and natural capital assets included within the ENCORE framework.

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[6] We do not examine the ECB's public sector asset purchase programme, which mainly consists of purchases of sovereign bonds and bonds issued by public sector utilities or financial institutions.
[7] For an online visualisation of the ENCORE tool, see: https://encore.naturalcapital.finance/.
[8] As identified by IPBES (2019).

An advantage of the ENCORE framework is that it can act as a proxy for the multi-dimensionality of nature-related financial risks. Unlike climate change, which at its core concerns the impact of anthropogenic emissions upon atmospheric temperatures, loss of nature and biodiversity encompasses multiple interconnected threats (e.g. soil erosion, groundwater depletion, pollinator loss), which are the result of multiple human drivers (e.g. intensive agriculture, deforestation, chemical pollution) acting upon multiple scales, from local ecosystems to planetary processes. In its articulation of distinct ecosystem dependencies and impact drivers, the ENCORE framework offers a degree of granularity that is not captured by top-down macroeconomic modelling approaches.[9]

Furthermore, biodiversity-related threats are characterised by a high degree of uncertainty (Kedward et al., 2020). This is due in part to the fact that they are subject to 'tipping points' where relatively small shifts in external drivers lead to large and potentially irreversible regime shifts, rather than risks emerging in a more linear and predictable fashion. Examples include the degradation of coral reefs, the desertification of grasslands and shrub expansion in the Arctic (Lenton, 2013). Quantitative models may face inherent limitations in capturing all tail risks related to such environmental threats (Bolton et al., 2020; Chenet et al., 2021). Instead, it has been argued that exploratory analyses, encompassing qualitative as well as quantitative approaches, may also have to focus upon key risk transmission channels in order to proxy for such uncertainty and complexity (Kedward et al., 2020; Svartzman et al., 2021b — forthcoming).

In its focus upon dependencies and impacts, the ENCORE framework offers one approach to exploring potential risk transmission channels. Identifying dependencies upon ecosystem services will give an indication of which *physical risks* may be relevant within a portfolio; likewise, the identification of how a financial portfolio is contributing to negative biodiversity impacts can give a proxy for potential sources of *transition risk*, as well as pointing to where the financial system is undermining biodiversity targets by contributing to the materialisation of further physical risks.[10]

Thus, while ENCORE does not represent a comprehensive risk assessment of NRFR in quantitative terms, it does provide evidence of how financial materiality related to nature and biodiversity loss is likely to emerge within a portfolio. In particular, it can illustrate which sectors are most associated with risk, and which ecosystem services and negative impact drivers are most linked to financial exposures.

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[9] Such as World Bank's forthcoming Integrated Economic and Ecosystem Services Model (Johnson et al., 2021).

[10] Note that central banks have also utilised a dependencies and impacts approach in their early explorations of biodiversity-related financial risk (DNB, 2020; Svartzman et al., 2021 — forthcoming).

2.2 Estimating the ECB's financial exposure to ENCORE dependencies and impacts

The ECB purchases corporate bonds to help fulfil its monetary policy objective of price stability, defined as keeping inflation close to 2% over the medium term. With its traditional policy lever, the overnight — or 'policy-rate' — of interest reaching its effective lower bound, but inflation still below target, the ECB introduced its corporate sector purchase programme (CSPP) in June 2016 to improve financing conditions in the real economy, and stimulate inflation and growth. In March 2020, corporate sector purchases were increased once again as part of the Pandemic Emergency Purchase Programme (PEPP). By April 2021 corporate bond holdings under both the CSPP and the PEPP together amounted to €310.9 billion.[11]

Although the ECB publishes the bond issues which it holds in its portfolio, as well as the companies which issued the bonds, the volume of each issue held is not disclosed. For instance, we can know the number of bonds issued by BMW within the portfolio, but not the value in euros of the volume of those issues that the ECB has bought. The ECB also does not publish the sectoral breakdown of the CSPP/PEPP at the level of granularity required for the ENCORE analysis. To resolve this, we constructed a simulated investable universe that replicates the sectoral breakdown of the bonds eligible for ECB asset purchases, as per the principle of 'market neutrality'.[12] According to this principle, corporate bond purchases are allocated in such a way as to reflect the distribution of the existing euro-denominated bond market with respect to rating, country and, critically, sector. In reality, the CSPP/PEPP is not truly 'market neutral' as the ECB adds minimum eligibility criteria, such as minimum standards for credit ratings (Colesanti Senni and Monnin, 2020).[13]

In total, the simulated universe consists of 2460 bonds with a total outstanding value of €1,401.8 billion. The ECB's CSPP/PEPP holdings of €310.9 billion therefore represent approximately 20% of eligible euro-denominated corporate bonds.[14] We then scaled the distribution of two-digit NACE sectors[15] observed in the eligible universe to the size of the ECB's actual portfolio to approximate the value of the ECB portfolio exposed to each sector. In this way, the distribution of sectors by value in the CSPP/PEPP portfolio aligns with the distribution of sectors in the investable universe, as per the principle of market neutrality. Appendix B provides further detail on our calculations.

Figure 1 gives a stylised example of how the euro exposure to one two-digit NACE sector is then mapped to ecosystem dependencies and impacts using the ENCORE framework. First, we linked

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[11] CSPP holdings are disclosed here: www.ecb.europa.eu/mopo/implement/app/html/index.en.html#cspp. PEPP holdings are disclosed here: http://www.ecb.europa.eu/mopo/implement/pepp/html/index.en.html.
[12] This approach closely follows the method used by Dafermos et al. (2020) in their analysis of the climate-related risks on the ECB's balance sheet.
[13] Recognising the limitations of market neutrality, as discussed in Section 1, the ECB has committed to make concrete recommendations for alternative benchmarks for the CSPP in 2022 (ECB, 2021).
[14] This is in line with the ECB's published estimates of its holdings as a proportion of eligible bonds (De Santis et al., 2018).
[15] NACE stands for 'Nomenclature of Economic Activities' and is the European statistical classification of economic activities – see https://www.nace.org/standards/nace-standards/about-nace-standards.

each NACE sector within the ECB's portfolio to the multiple ENCORE production processes that each sector is associated with, assuming an equal weighting between all the production processes. So, for example, for every 1 euro invested into NACE sector *C13 – Manufacture of Textiles,* 0.5 euro each was allocated to natural fibre production and synthetic fibre production.[16] From assigning estimated euro value exposures to each ENCORE production process, we were then able to map exposures onto ecosystem service dependencies on the one hand, and exposures to biodiversity-negative impact drivers on the other, using the ENCORE database.

For this analysis, we only considered materiality ratings categorised as 'high' or 'very high' by ENCORE. Where multiple dependencies or impacts were associated with each production process, financial exposure was determined on a proportional distribution basis, but 'very high' ratings were given a heavier weighting to reflect the increased criticality of the dependency on the production process, or the increased severity and unavoidability of the impact upon biodiversity. The final outputs give an estimation in euros of the potential financial exposure to high and very high dependencies upon ecosystem services and negative drivers of biodiversity loss within the ECB's CSPP/PEPP portfolio.

Figure 1: Methodology for estimating financial exposure to dependencies and impacts using the ENCORE framework

Source: Authors' elaboration

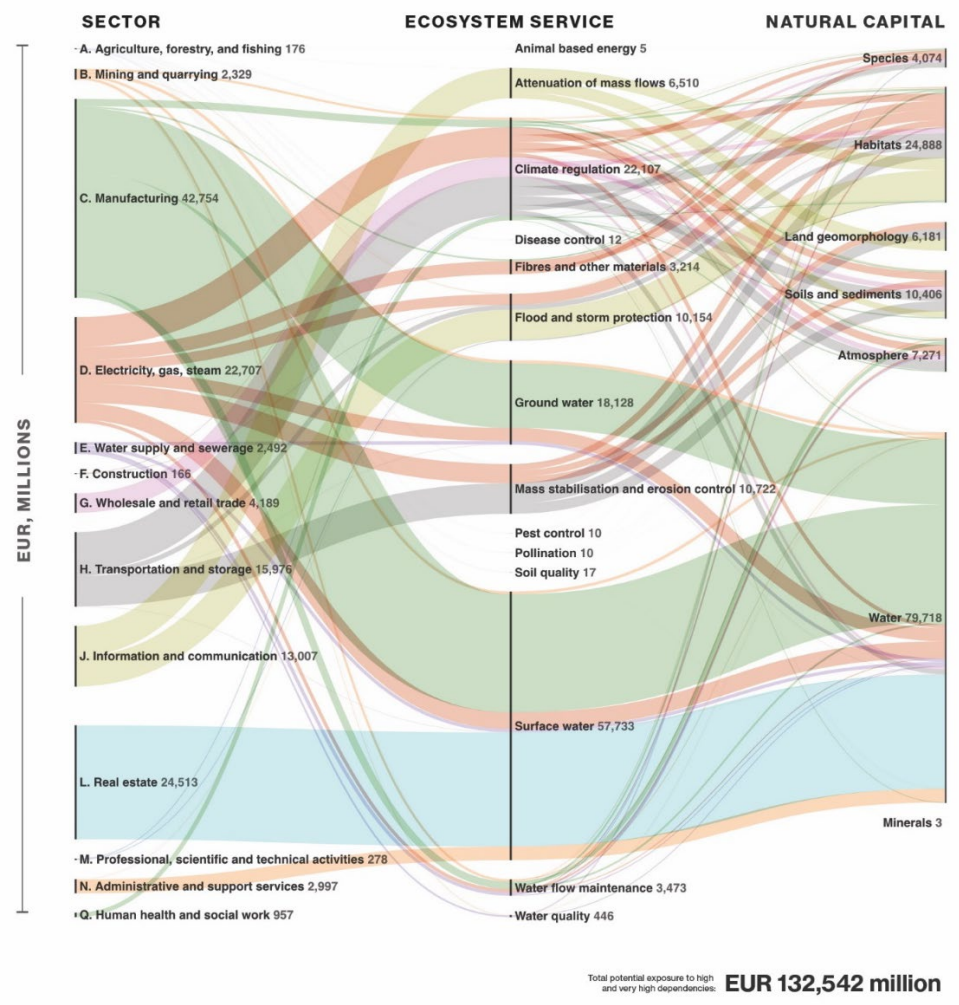
[16] Note that the ENCORE framework links its business processes to GICS sectors; this analysis required a manual remapping from GICS to NACE sectors.

3. Results

Mapping the sectoral breakdown of the ECB's eligible universe of bonds by outstanding volume to the ENCORE framework demonstrates that the CSPP/PEPP portfolio has potentially material exposures to nature-related financial risks. The sectors that the ECB is invested in are associated with **significantly high dependencies** upon nature to facilitate production, as well as causing **significantly negative impacts** upon nature which threaten the future provision of vital ecosystem services.

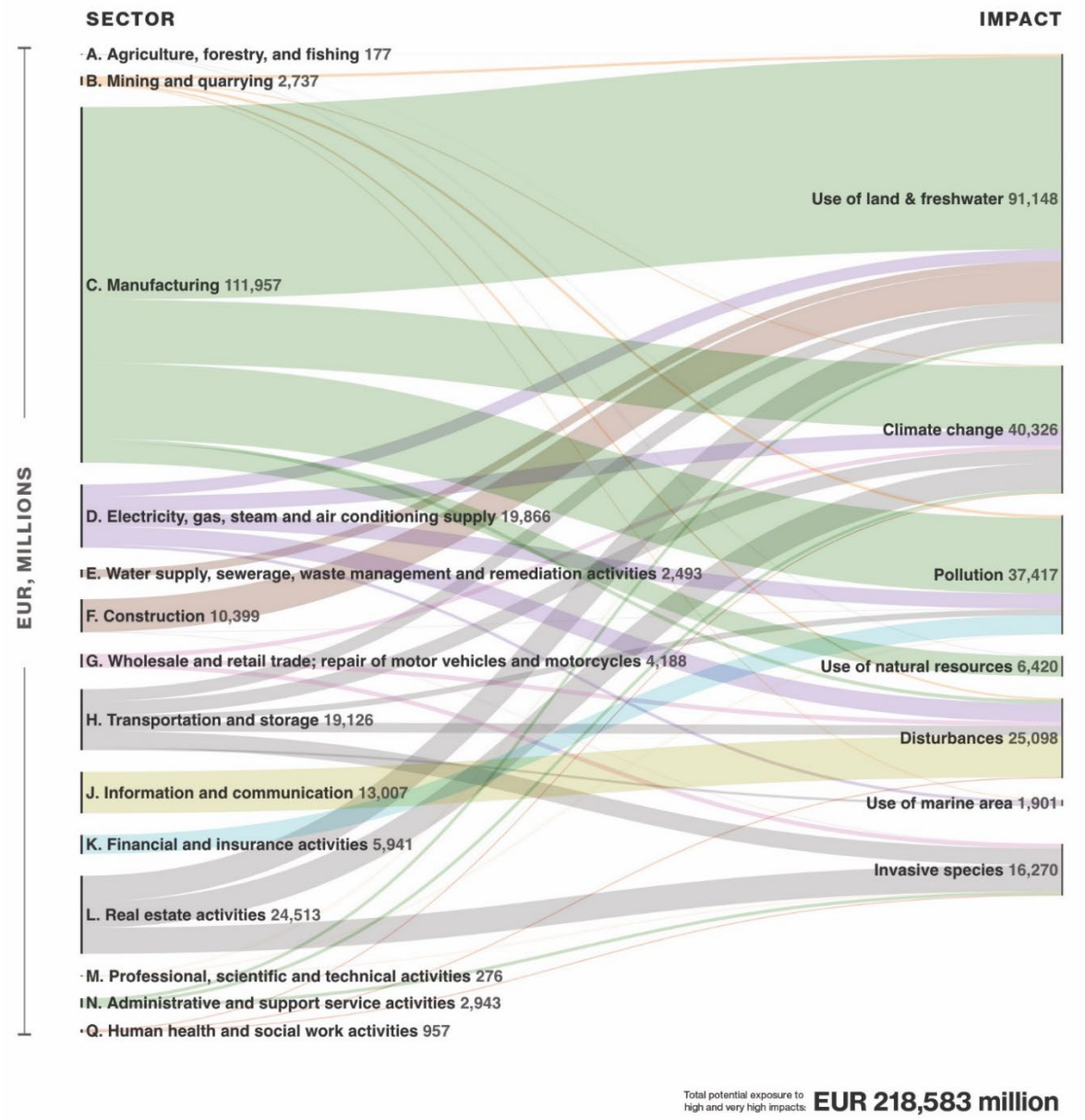
Figures 2a and 2b give an overview of which high-level sectors in the CSPP/PEPP are most associated with high and very high nature-related dependencies and impacts. Manufacturing, utilities, transportation and storage, and real estate together compromise 80% of the portfolio's high and very high dependencies on ecosystem services. The same sectors also account for 80% of the portfolio's potentially negative impacts upon biodiversity, most of which stems from the manufacturing sector. These findings suggest that the ECB should initially focus upon these sectors when considering how to manage nature-related risk exposure within its portfolio.

Figure 2a: Flow diagram linking ECB CSPP/PEPP NACE level 1 sectors to dependencies upon ecosystem services and natural capital assets



Source: Own calculations using the ENCORE framework

Figure 2b. Flow diagram linking ECB CSPP/PEPP NACE level 1 sectors to negative impacts driving biodiversity loss



Source: Own calculations using the ENCORE framework

3.1 Financial risks associated with dependencies upon nature

Over 40% of the ECB's corporate bond holdings, totalling to over €132 billion, potentially have high or very high dependencies upon the functioning of ecosystem services (Table 1). According to the materialities assigned within ENCORE, 'high or very high' dependency in this context means that the loss of these ecosystem services would disrupt production and cause moderate to severe financial loss.

Table 1: Nature-related dependencies associated with the ECB's CSPP/PEPP

Ecosystem service		% of portfolio
Direct physical input	Animal based energy	0.002%
	Fibres and other materials	1.036%
	Genetic materials	0.000%
	Ground water	5.842%
	Surface water	18.605%
Enabling production	Maintain nursery habitats	0.000%
	Pollination	0.003%
	Soil quality	0.005%
	Ventilation	0.000%
	Water flow maintenance	1.120%
	Water quality	0.144%
Mitigating direct impacts	Bio-remediation	0.000%
	Dilution by atmosphere and ecosystems	0.000%
	Filtration	0.000%
	Mediation of sensory impacts	0.000%
Protecting from disruption	Buffering and attenuation of mass flows	2.098%
	Climate regulation	7.124%
	Disease control	0.004%
	Flood and storm protection	3.272%
	Mass stabilisation and erosion control	3.455%
	Pest control	0.003%
Total high and very high dependencies		**42.714%**
Total portfolio size		**100.000%**

Source: Own calculations using the ENCORE framework

Most of the high and very high ecosystem dependencies potentially associated with the ECB's portfolio concern **direct physical inputs** to production. Of these inputs, water is the most important, with strong dependencies on ground water and surface water together associated with one quarter of the ECB's exposures.[17]

The ECB's exposure to this high degree of water risk is linked to the size of its investments in real estate, processed food and drink manufacturing, pharmaceuticals and mining – all sectors associated with high direct and/or indirect water usage (Hoekstra, 2015). For real estate, the direct water risk captured in these results refers to the water needed to operate and reside within properties. Indeed, there is emerging evidence linking areas of high water stress to negative effects on property values (Starkman, 2018; Foroudi, 2020; Farzanegan et al., 2020). However, real estate also has a significant indirect water footprint associated with the construction industry and the water embodied in the production of construction materials (McCormack et al., 2007).

[17] Groundwater is stored underground in aquifers comprised of permeable rocks, soil and sand. Surface water is sourced from collected precipitation and water flow from natural sources.

The CSPP/PEPP portfolio is also potentially associated with high or very high dependencies upon ecosystem services that **protect the production process from natural hazard disruption**, particularly climate regulation, flood and storm protection, and mass erosion and stabilisation control. The ECB's exposure to these risks is associated with its investments in sectors such as rail transport, and telecoms and wireless services, which rely on these ecosystem services to protect their critical infrastructure from damage and disruption. For example, landslides present serious hazards to humans, and road and rail infrastructure, across Europe (Jaedicke et al., 2014), causing an estimated US$ 300 million worth of infrastructure damage per year in Germany alone (Klose et al., 2016). One of the vital ecosystem services provided by functioning habitats and ecosystems is mass stabilisation and erosion control, where terrestrial vegetation cover protects against landslides and avalanches, and healthy coastal and wetland ecosystems provide protection against coastal and sediment erosion (Natural Capital Finance Alliance (Global Canopy, UNEP FI and UNEP-WCMC), 2021).

The results suggest that the ECB's portfolio has only negligible exposure to ecosystem services **enabling production** and **mitigating direct impacts**, which include critical services such as pollination and soil quality (see Table 1). Yet these findings are likely to be a significant underestimation of true exposure to these risks, reflecting the portfolio's small exposure to the primary production sectors (such as agriculture and forestry) where these dependencies are more relevant. We consider the limitations of the ENCORE framework in accounting for supply-chain linkages in sections 3.4 and 3.5.

An important consideration with this analysis is that ecosystem services cannot be isolated from the natural capital assets which provide them. As depicted in Figure 2a, habitats and species play a key role in providing both climate regulation and water-related ecosystem services. Habitats provide carbon sequestration and help to regulate local climates through water retention and shade provision. Ecosystems also affect how water flows through landscapes and widespread habitat loss can adversely affect the hydrological cycle. Certain species also provide important water services, such as filtration and nutrient cycling, that help to manage water quality (Natural Capital Finance Alliance (Global Canopy, UNEP FI and UNEP-WCMC), 2021). A key conclusion from the ENCORE framework, therefore, is that key dependencies associated with water and climate regulation are interconnected with broader biodiversity factors.

3.2 Financial risks associated with negative impacts upon nature

Over 70% of the ECB's corporate bond portfolio, totalling over €218 billion, is in sectors associated with high or very high impacts upon nature (Table 2). The seven negative impacts assessed in this analysis correspond with the major drivers of biodiversity loss identified by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019).[18] The ENCORE framework classifies an impact as 'high or very high' when it is expected to

[18] The IPBES drivers used in this analysis do not yet feature in the online ENCORE tool, but are available upon request from UNEP-WCMC, who integrated the drivers into the ENCORE framework separately for a previous report (UNEP-WCMC, 2020).

occur in large volumes/areas continuously throughout production, and/or in all locations where production takes place, and/or it would be operationally and financially impossible to redesign the production process to avoid the impact.

Table 2: Nature-related impacts associated with the ECB's CSPP/PEPP

Drivers of biodiversity loss	% of portfolio
1. Use of land and freshwater	29%
2. Use of marine area	1%
3. Use of natural resources	2%
4. Pollution	12%
5. Climate change	13%
6. Invasive species	5%
7. Disturbances	8%
Total high and very high impacts	71%
Total portfolio	100%

Source: Own calculations using the ENCORE framework

Negative impacts concerning land use and freshwater use are potentially associated with 29% of the ECB's portfolio. Land use change related to both terrestrial and freshwater ecosystems has had the biggest relative adverse impact on biodiversity since 1970 (IPBES, 2019). The CSPP/PEPP portfolio's potential contribution to such impacts reflects the size of its investments in real estate, infrastructure, mining and manufacturing. While agricultural expansion is the most pervasive form of land use change, the doubling of urban areas since 1992, alongside the rapid expansion of infrastructure related to increased consumption and population growth, has also been a significant driver – occurring largely at the expense of old-growth forests, grasslands and wetlands (IPBES, 2019). It has been estimated that 190,000 km^2 or 16% of total natural habitat loss between 1992 and 2000 was attributable to urban expansion; and that 1.5 times that habitat loss is expected again from urban growth between 2000 and 2030 (McDonald et al., 2020).

Mining is also a significant contributor to habitat loss: bad practices severely degrade habitats through use of heavy machinery, seismic activities, explosives and other chemicals, which result in pollution of groundwater and surface water systems, as well as the depletion of these water sources (Hoekstra, 2015; Sonter et al., 2018). Additionally, although mines occupy a very small proportion of the planet's land surface, mining activities often venture onto pristine habitat, establishing infrastructure and facilitating future access to previously under-developed ecosystems, which can fuel further land use change (Siqueira-Gay et al., 2020).

The ECB's portfolio exposures are also associated with climate change and the emission of other pollutants. Climate change exacerbates nature loss through increased frequency of extreme weather events, flooding, droughts and wildfires that place threatened biodiversity under additional

stress.[19] Pollutants from manufacturing, mining and agriculture, as well as poorly treated urban waste, toxic dumping and oil spills have had significantly adverse effects on air, soil, freshwater and marine water quality, with negative impacts on local biodiversity (IPBES, 2019). The CSPP/PEPP portfolio's association with these drivers of biodiversity loss reflects its exposure to manufacturing, pharmaceuticals, mining, and oil and gas refining.

Overall, exposure to negative impacts upon nature may result in financial materiality for the CSPP/PEPP through exposure to potential transition risks, as policy and regulations on habitat loss, pollution and resource use is tightened to support a transition to an ecologically sustainable economy. Moreover, the ECB's exposure to negative impacts may indirectly undermine the aims of the EU's Biodiversity Strategy for 2030 and could potentially put it in contravention of its secondary mandate to support the policies of the European Union.

3.3 Limitations of the ENCORE framework

The findings above represent a 'first port of call' in exploring how the ECB's corporate bond holdings are both exposed to and potentially contributing to the loss of nature and biodiversity. Yet it is important to emphasise that the exposures identified above represent only estimations of *potential* risk. Actual risk exposure will be dependent upon where production processes in each firm are located, and any actions taken by the firm to mitigate its dependencies and impacts. As such, substantial heterogeneity in risk exposure will materialise within companies operating in the same sector.

In addition, the ENCORE mapping framework currently considers only first order dependencies and impacts; in other words, those directly related to each sector, rather than indirect exposures reflecting supply-chain effects. As a result, there is an important caveat to our findings: they are likely to be an underestimation of true exposures to nature-related financial risks. The significantly material dependencies and impacts of primary production sectors, such as agriculture and mining, are not accounted for in the numerous secondary sectors, such as manufacturing and construction, that also indirectly rely on these dependencies for their inputs, or whose demand indirectly contributes to negative impacts. This limitation is also evident in the negligible dependencies and impacts assigned to the finance and insurance sectors. In reality, as has been now widely recognised for climate change, financial institutions and insurers are exposed to the economic risks associated with nature-related threats through their financing and underwriting of real economic activity (Bassen et al., 2019; Vivid Economics and Global Canopy, 2020; NGFS, 2021b).

To overcome these limitations, we supplement the findings from the ENCORE framework with additional qualitative analysis into location-specific risks and supply-chain linkages.

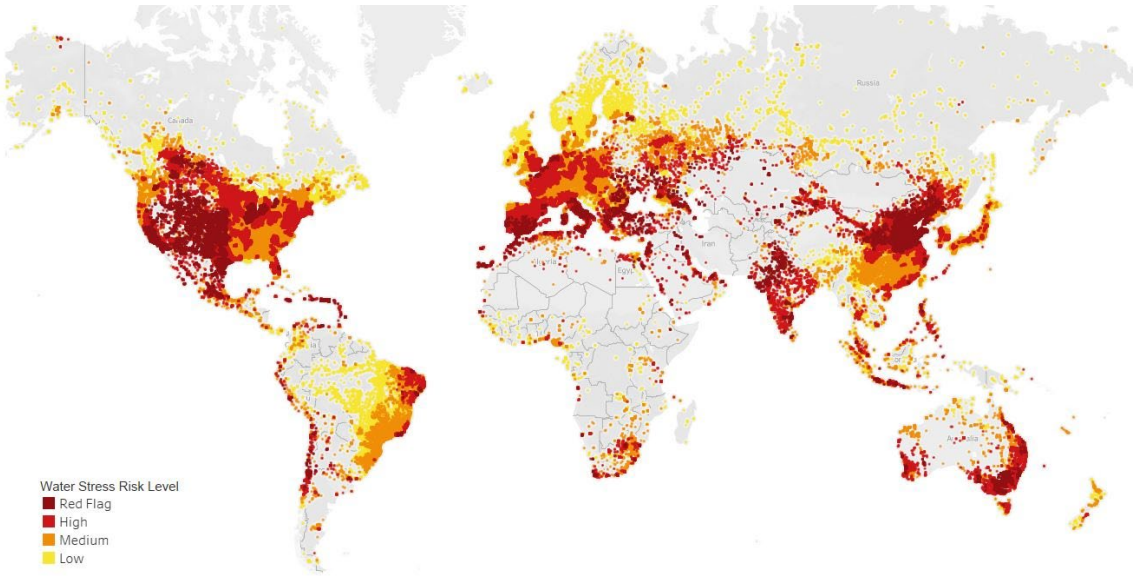
[19] The contribution of the CSPP/PEPP to drivers of climate change has been extensively analysed by Dafermos et al. (2020).

3.4 Company-level exposure to water stress and biodiversity loss

Risk analysis based on location-specific data can give additional insights into how risks will materialise between different countries in the same sector. We use a database provided by Moody's ESG Solutions to assess how many companies in the CSPP/PEPP portfolio have production facilities located in (1) areas of high water stress; and (2) areas associated with habitat loss.[20] Using the assumption that the ECB is invested in 20% of the total outstanding amount of each bond in its portfolio,[21] we then estimate the approximate financial exposure the ECB may have to the risks associated with these companies.

The Moody's ESG Solutions database assesses 173,512 corporate facilities belonging to 173 companies in the ECB's portfolio. The water stress score assigned to each corporate facility encompasses several indicators measuring current water stress, water availability, projected future water supply and demand, and projected changes in future water availability. Therefore the total score, aggregating all corporate facility scores up to the company level, only measures physical water scarcity, rather than broader measures of water quality and regulatory risk. Figure 3 shows shows the total facilities in Moody's ESG Solutions' database (approximately two million) coloured based on their exposure to water stress.

Figure 3: Corporate facilities according to exposure to water stress



Source: Moody's ESG solutions: https://esg.moodys.io/climate-solutions

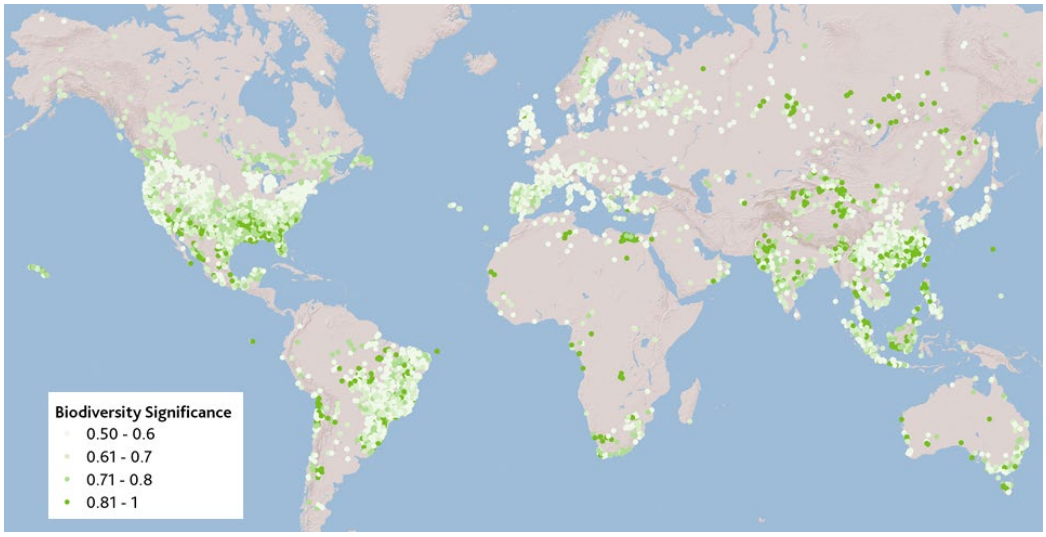
[20] See https://esg.moodys.io/solutions#solutions. The Moody's ESG Solutions database scores over 2.1 million corporate facilities worldwide, belonging to nearly 5300 multinational companies, on exposures to physical climate and biodiversity risks, utilising climate and environmental data from a number of public and private datasets.

[21] This proportion is in line with published estimates of the ECB's holdings as a proportion of the total eligible euro-denominated bond market (De Santis et al., 2018).

In total, the CSPP/PEPP is exposed to 67,991 business facilities associated with 'high' water stress, of which 12,921 facilities are associated with 'red flag' water stress.[22] These business facilities are linked to 163 companies in the portfolio. Measuring only companies whose total aggregated water stress scores represent the 'high' and 'red flag' categories, we estimate that the ECB potentially has €38.6 billion in financial exposure to high water risk in its corporate bond portfolio.

Moody's ESG Solutions identifies each corporate facility as being associated with habitat loss and thus potentially contributing to negative impacts on biodiversity if it meets three criteria: (1) it is located in or near an area of high biodiversity value; (2) there has been significant forest disturbance in the surrounding area; and (3) the facility is associated with an industry that has negative impacts on the surrounding environment through resource use or pollution. Figure 4 depicts the corporate facilities associated with biodiversity loss coloured according to biodiversity significance of their location.[23] In total, the analysis revealed that the CSPP/PEPP is exposed to 3231 corporate facilities that are associated with habitat loss, belonging to 94 companies in the portfolio. Accounting only for companies that have over 100 facilities associated with habitat loss, we estimate that the ECB potentially has €17.2 billion in financial exposure to negative biodiversity impacts in its corporate bond portfolio.

Figure 4: Corporate facilities associated with biodiversity loss according to biodiversity significance of their location.[23]



Source: Moody's ESG solutions: https://esg.moodys.io/climate-solutions

[22] Under the Moody's ESG Solutions methodology, 'high' is defined as current water stress likely already being high with water supplies already diminishing; 'red flag' is defined as competition for water resources being extreme, with future water supply failure possible.

[23] Darker green facilities are those in locations with higher biodiversity significance, based on species composition and habitat quality. Lighter facilities are in areas of lower, although still high, levels of biodiversity significance. Biodiversity significant values range from 0-1, signifying the share of similar habitats that are in poorer condition based on human interference. For example, locations with a value greater than 0.5 are in better condition than over half of similar habitats. Values above 0.5 are considered high value biodiversity habitat.

3.5 NRFR and global supply chains: a focus on deforestation risk

The question of how financial risks associated with nature-related dependencies and impacts might cascade throughout global supply chains and propagate throughout the financial system represents a prominent research gap. To supplement our findings above, we now consider a preliminary qualitative exploration of how NRFR may cascade through supply-chain linkages to materialise within the ECB's CSPP/PEPP portfolio, focusing on deforestation as a key transmission channel.

Deforestation is a major direct driver of biodiversity loss (FAO, 2018; IPBES, 2019; European Commission, 2019a). As such, the interaction between deforestation, real economic activity and the financial system represents a key transmission mechanism of relevance (Green et al., 2019). Most deforestation is linked to expansion in commercial cropland, pastures and tree plantations; and is particularly associated with the key 'forest-risk commodities': palm oil, soy, beef and timber products (Curtis et al., 2018; Pendrill et al., 2019).

Given that ENCORE does not yet account for indirect exposures, the findings above initially suggest that the CSPP/PEPP is not materially exposed to deforestation risk, with agriculture and forestry together accounting for only 0.1% of highly material dependencies and impacts in the portfolio (Table 1). Yet, within the European context, exposures to deforestation through supply-chain linkages are far more relevant. The EU is one of the world's largest markets for agricultural commodities linked to deforestation, second only to China (European Commission, 2019a; Trase, 2020; Wedeux and Schulmeister-Oldenhove, 2021). It is estimated that EU demand indirectly contributed to nearly 300,000 hectares of deforestation each year between 2005 and 2013, an area over three times the size of Berlin (Pendrill et al., 2019).

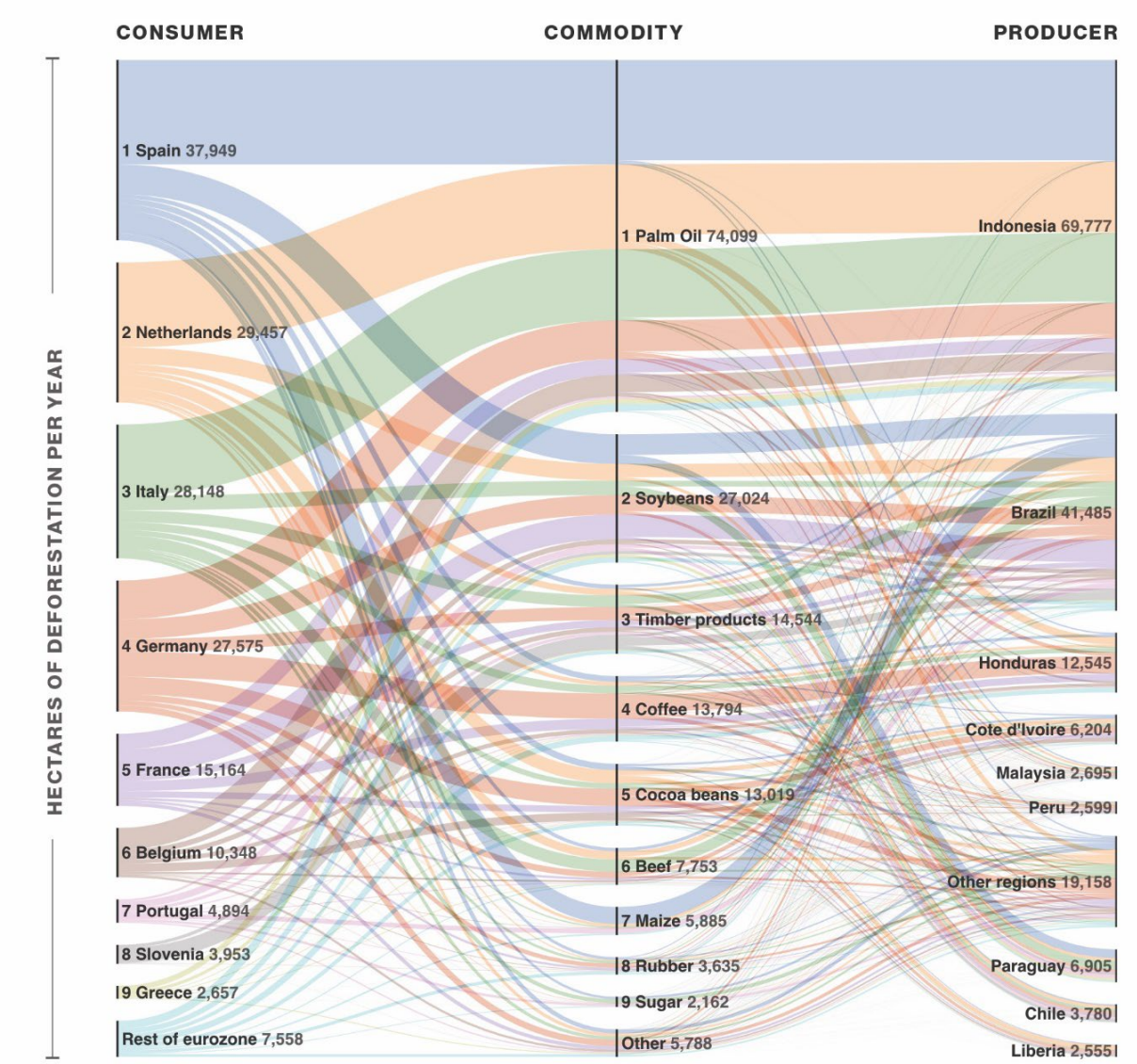
In the EU, deforestation is also increasingly subject to a tightening policy environment. The EU's Biodiversity Strategy for 2030 has identified deforestation as a key driver of biodiversity loss and has stipulated a need to 'ensure that EU actions do not result in deforestation in other regions of the world' (European Commission, 2020, p.4). In October 2020, the European Parliament adopted a resolution for the Commission to establish a legal framework for the mandatory due diligence of deforestation, habitat loss and related human rights abuses within forest-risk commodity supply chains and financing practices (European Parliament, 2020).

Figure 5 provides a visualisation of how deforestation is embodied in European supply chains. Using data from Pendrill et al. (2020),[24] we show that imports by the 19 eurozone countries in 2017 were linked to deforestation in Indonesia, Brazil and Honduras, as well as other tropical frontier regions where biodiversity loss is particularly acute (Kehoe et al., 2017). The imported products most associated with deforestation include palm oil, soybeans, timber products, coffee and cocoa beans, and beef. Given that investments in the CSPP/PEPP portfolio are allocated

[24] Pendrill et al. (2020) use a land-balance model to attribute tropical deforestation across 135 countries to expansion of cropland, pastures and forest plantation, and then onto the commodities produced on this land. Their model then traces these commodities to final consumption demand using a physical trade model.

according to the market neutrality principle, such indirect deforestation risk is also likely to be embodied in the ECB's corporate bond holdings.

Figure 5: Deforestation embodied in Eurozone trade



Source: Own visualisation using data from Pendrill et al. (2020)

Forest 500, an initiative of civil society organisation Global Canopy, has identified 350 companies which are most influential in global forest risk commodity supply chains, 101 of which are headquartered in Europe.[25] To understand how potential financial risks associated with deforestation may materialise in the ECB's portfolio from a supply-chain perspective, we compared the 1658 unique bond ISINs in the CSPP/PEPP, which represent 344 unique issuers, to

[25] The Forest 500 database also assesses the 150 financial institutions that provide the most finance to the 350-list firms. As the CSPP/PEPP portfolio is not substantially invested in financial institutions, we have not included them in this particular analysis.

companies featured in the Forest 500 database of corporates.[26] Assessing each firm on more than 20 indicators per commodity, the database also evaluates corporations on the strength of their voluntary processes and commitments to manage deforestation impacts within their operations and supply chains (Thomson, 2020).[27]

In total, the ECB is invested in 22 companies that are highly influential in forest risk commodity supply chains. Table 3 demonstrates that there is a high degree of heterogeneity in how well these companies are assessed to be managing deforestation risks. Of concern from a portfolio risk management perspective is that only half have identified deforestation as a business risk; less than half have a company-wide commitment to remove deforestation from their operations and supply chains or a commitment to remediate for damage caused; and less than a quarter conduct specific risk assessments for *all* the forest risk commodities they are active in. Lack of widespread implementation of deforestation risk management policies in this subset of companies indicates that the CSPP/PEPP portfolio could be exposed to transition risks, related to a tightening policy environment, and liability risk, including legal and reputational risk.

Yet even the presence of voluntary commitments cannot proxy for adequate risk management. In practice, even where such commitments exist, they can be weak and lack robust enforcement. Data from Trase (a deforestation data provider) has shown there is no observed difference in deforestation risk between companies with a voluntary commitment and those without, suggesting a need for mandatory requirements to set robust standards (Wedeux and Schulmeister-Oldenhove, 2021; Trase, 2021).

Within the ECB's bond portfolio, Bunge Ltd and Glencore – multinationals which are prominent in agri-commodity processing and trading – provide two salient examples of poor risk management. Despite the presence of a commodity-specific risk assessment for soy, Bunge Ltd is known to source soy from the 'MATOPIBA' region of Brazil,[28] a deforestation frontier in the Cerrado biome that is responsible for 90% of deforestation risk in Brazil's soy exports (Trase, 2020). Trase Finance estimates that Bunge's exports of Brazilian soy alone are associated with 11,197 hectares of absolute deforestation in 2018, making it the global corporation most implicated in soy-related deforestation in Brazil.[29] Glencore also features as one of the largest contributors to Brazilian soy-related forest loss, despite its company-wide deforestation-free commitment.

The gap between commitment and implementation also extends to the financial sector: Forest 500 research has estimated that the top financial institutions have up to $2.7 trillion invested in activities linked to deforestation activities. Their survey data has also shown that many financial institutions continue to finance companies linked to deforestation in contravention of their own deforestation policies (Thomson, 2020). This suggests that, in the absence of legal liability or

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[26] Bond ISINs are published on the ECB's website; where the individual bond issuer was a special purpose vehicle or finance subsidiary, we considered the parent company.
[27] The score assigned to each company reflects an assessment of their company-wide and commodity-specific commitments on deforestation, the strength of the implementation of commitments, and reporting on progress achieved, as well as how well social considerations are integrated into deforestation policies.
[28] A region intersecting the states of Maranhão, Tocantins, Piauí and Bahia.
[29] See https://trase.finance/entities/b7c1989f-8a2f-34ea-80e8-d5baa06291fb.

regulatory oversight, voluntary commitments will be insufficient to ensure sufficient management of deforestation-related risks in financial institutions.[30]

In summary, the qualitative assessment in this section has shown that the CSPP/PEPP may be exposed to deforestation risk through bond issuers who are highly active in forest-risk commodities. Not only are these firms facing transition risks related to tighter deforestation policy, but they are also indirectly exposed to the loss of vital ecosystem services needed to enable production of these agricultural inputs. While many of these firms do have procedures in place to manage deforestation risk, financial institutions invested in these companies face challenges assessing the effectiveness of such processes, especially given the gap between commitment and implementation observed in some companies. Evaluating the degree of deforestation risk that may emerge across a financial portfolio implies a greater role for due diligence and counterparty engagement. In the next section we consider how the ECB could play a leading role in establishing robust procedures to account for NRFR in its CSPP/PEPP portfolio, thereby setting a 'gold standard' in biodiversity risk management for other financial institutions to follow.

[30] The Finance for Biodiversity Initiative is working towards creating legal liability for nature loss for financial institutions. See https://www.f4b-initiative.net/legalaction.

Table 3: Evaluation of company commitments to and processes for managing deforestation risk in operations and supply chains

Company	Relevant forest risk commodities company is active in	Relevant sectors	Forest 500 score	Company identifies deforestation as a business risk	Commodity-specific risk assessments for the forest risk commodities it is active in	Company-wide commitment to achieve deforestation/conversion-free production and/or procurement	Commitment to free, prior and informed consent of affected communities	Commitment to provide remediation for deforestation/ conversion- related harm
Unilever PLC	Palm oil, soy, beef, paper	Personal and home care products, packaged food	70%	✓	✓	✓	✓	✓
Danone	Palm oil, soy, paper	Dairy, packaged food	55%		Palm oil and soy only	✓	✓	
Mondi Group	Paper	Paper and packaging, forestry	52%	✓	✓	✓		
BASF SE	Palm oil, paper	Ingredients, chemicals	51%		Palm oil only	✓	✓	✓
Kering S.A.	Leather, paper	Apparel, accessories	48%	✓			✓	✓
Reckitt Benckiser Group PLC	Palm oil, leather, paper	Personal and home care products	48%	✓	Palm oil only		✓	
UPM	Paper, timber	Paper and packaging, forestry	48%	✓	✓	✓		✓
Mondelez International Inc.	Palm oil, pulp and paper, soy	Packaged food	47%	✓	✓		✓	✓
Bunge Ltd.	Palm oil, soy, paper	Agri commodities, oils and fats	45%		Palm oil and soy only		✓	
Henkel AG & Co. KGaA	Palm oil, soy, paper	Cosmetics and personal care, home care	45%			Net deforestation only		
Carrefour S.A.	Palm oil, soy, beef, paper	Food retail	44%	✓	Beef only	✓		
Stora Enso	Paper, timber	Paper and packaging, forestry	44%				✓	✓
LVMH Moet Hennessy Louis Vuitton S.A.	Palm oil, leather, paper	Apparel, accessories and footwear	37%	✓	✓			
Ahold Delhaize	Palm oil, soy, beef, paper	Food retail, furniture and flooring	36%			Net deforestation only		✓
Royal Dutch Shell	Palm oil, soy	Biofuel, chemicals	36%				✓	
Bertelsmann SE & Co. KGaA	Paper	Printing and publishing	32%	✓				

Company	Relevant forest risk commodities company is active in	Relevant sectors	Forest 500 score	Company identifies deforestation as a business risk	Commodity-specific risk assessments for the forest risk commodities it is active in	Company-wide commitment to achieve deforestation/conversion-free production and/or procurement	Commitment to free, prior and informed consent of affected communities	Commitment to provide remediation for deforestation/ conversion- related harm
Glencore	Palm oil, soy	Agri commodities	30%			✓	✓	
Metro AG	Palm oil, soy, beef, paper	Food retail	30%	✓		✓	✓	
Koninklijke DSM N.V.	Palm oil, soy, paper	Ingredients	29%					
RELX Group	Pulp and paper	Printing and publishing	28%	✓				✓
H & M Hennes & Mauritz AB	Leather, palm oil, pulp and paper, soy	Apparel, accessories	27%					
Adidas Group	Leather, paper	Apparel, accessories	24%					

Source: Forest 500 data

4. Discussion and policy recommendations

4.1 Key insights from the results

The results in the previous section show the types of nature-related financial risks that may materialise within the ECB's €310 billion corporate bond purchase portfolio. We find significant dependencies upon water and ecosystem services providing protection from natural hazard disruption. Loss of these aspects of nature will adversely impact company performance and may feed through to financial impacts within the CSPP/PEPP portfolio. We also find that the sectors the ECB is invested in are associated with significant negative impacts upon nature, especially with regards to use of land and freshwater, pollution and climate change – all of which are key drivers of biodiversity loss. These particular dependencies and impacts reflect the ECB's significant exposures to the manufacturing, real estate, utilities and transportation/distribution sectors.

The fact that a large portion of the portfolio (over 70%) is potentially associated with drivers of biodiversity loss, most notably relating to land and freshwater use, demonstrates the importance of considering the double materiality of nature-related financial risks. While damage inflicted by businesses upon the natural world is undoubtedly problematic from an ethical perspective,[31] as discussed in Section 1, it also threatens to give rise to further financial risk. One related example is how biodiversity-depleting activities may ultimately increase climate-related risks, given that habitats such as coastal floodplains, wetlands and mangroves provide critical ecosystem services in mitigating the weather disruption related to climate change.

Indeed, our results emphasise the strong interlinkages between nature-related dependencies and impacts, and those related to climate change. The water risks we identify, for example, are exacerbated by climate change, and water scarcity in turn may undermine the ability of both ecosystems and business activities to remain resilient to the physical climate impacts. Similarly, negative impacts associated with deforestation are not only major drivers of biodiversity loss, but they also undermine climate mitigation efforts through the loss of carbon sequestration ecosystem services. A key insight from our findings, then, is that nature loss and climate change cannot be assessed in silos. Indeed, current attempts by central banks to evaluate climate-related financial risks may in fact be underestimating true exposures without taking into consideration the interconnected dynamics of nature and biodiversity loss.

Our analysis also adds further to calls to rethink market neutrality as the primary operating principle guiding the allocation of funds within monetary policy portfolios. As has been argued for climate change (van 't Klooster and Fontan, 2020; Dafermos et al., 2020; Colesanti Senni and Monnin, 2020), by mirroring the sectoral composition of the corporate bond market, the ECB's portfolio also mirrors the failure of credit rating agencies, as well as the broader failure of financial markets, to account for the financial risks associated with dependencies and impacts upon nature. In its recent Strategy Review, the ECB announced a detailed roadmap to incorporate climate change considerations into its monetary policy framework (ECB, 2021). As we argued in Section 1, there is also a strong rationale for the ECB to supplement its risk

[31] Given it may threaten the existence of certain societies or the intrinsic right of nature to exist on its own terms.

processes to account for nature-related financial risks too. This is all the more warranted given the interconnected and potentially reinforcing dynamics between climate change and nature loss.

Many prominent sustainable finance initiatives have proposed that the measurement and disclosure of environmental-financial risks is the best means to manage these risks (TCFD, 2017; HLEG, 2018; BEIS, 2019; Paulson, 2020). This perspective is grounded in a 'market failure' understanding of environmental problems whereby lack of information is assumed to hold back efficient market pricing of risk (Christophers, 2017; Ryan-Collins, 2019). Yet nature loss is characterised by a high degree of complexity and radical uncertainty, which presents considerable challenges for the conventional financial risk management tools utilised by central banks and financial institutions, such as stress testing and scenario-based modelling designed to support risk disclosure (Kedward et al., 2020). Given the presence of radical uncertainty, it is increasingly recognised that the meaningful quantification of all relevant environment-financial interactions is not likely to be methodologically feasible (Bolton et al., 2020; Chenet et al., 2021; Svartzman et al., 2021a).

Under such circumstances, it may be advisable to take mitigating actions on a precautionary basis, justified primarily by qualitative assessments of system-wide risk, with quantitative exercises focusing instead on key transmission channels between sources and drivers of nature loss, the real economy and the financial system (Kedward et al., 2020; Chenet et al., 2021). Indeed, the need to take precautionary action sooner rather than later to avoid the worst risks is increasingly recognised by central bankers in the context of climate-related uncertainty. The NGFS, for example, has noted that:

> When balancing the need for robust and comprehensive data against the opportunity cost of inaction, central banks should be cognisant of the risk that acting early with imperfect information could be less costly than acting only once stronger data standards have emerged.
>
> (NGFS, 2021a, p.7)

The findings in this report represent a preliminary attempt to qualitatively assess the extent of NRFR within the CSPP/PEPP portfolio, identifying potential sources of risk and the sectors where key transmission mechanisms may be particularly relevant. We now consider the policy options that could be explored by the ECB to account for NRFR in the risk management processes of its monetary policy operations.

4.2 Policy options

Central banks have started to consider how to manage climate-related financial risk in monetary policy operations, identifying a variety of policy options for adjusting credit operations, collateral policy and asset purchases – including positive and negative screening, counterparty eligibility requirements, tilting operations to align with climate-related metrics or targets and margin haircut adjustments (NGFS, 2021a; Bank of England, 2021; ECB, 2021).[32] Most notably, the Bank of England's recent (2021) proposal suggests a new precedent for the active management of monetary policy portfolios in relation to climate

[32] The NGFS has noted, however, that the suitability and operational feasibility of some of the more proactive measures may vary depending on the jurisdiction.

risks, emphasising an important role for the central bank to engage with bond issuers to incentivise an acceleration of progress towards sustainable practices.

One key challenge relating to NRFR, in contrast to climate change, is the lack of metrics regarding the biodiversity properties or 'performance' of individual assets, where establishing such indicators is complicated considerably by the multiplicity of nature risks, their high dimensionality (i.e. multiple drivers) and the need for location-specific data (Kedward et al., 2021). For the same reasons, the identification of credible transition plans using company-level indicators is also less simple for NRFR; there is no clear biodiversity equivalent to emissions reductions pathways, for example.

Another key challenge, demonstrated within our results, is that all economic sectors are implicated in the emergence of NRFR and must variously transition their business practices to mitigate such risks. Unlike with climate change, where whole sectors can easily be identified as incompatible with a net-zero carbon trajectory (e.g. coal-fired power generation), the management of NRFR cannot be reduced to the exclusion of certain business sectors. Indeed, as discussed in the previous section, the considerable heterogeneity in risk management approaches between companies within the same sector implies a greater role for counterparty engagement and due diligence.

Taking into account these challenges, we now consider some policy options that the ECB could implement as part of a broader strategy for managing NRFR in its monetary policy operations.

Option 1: Promote the accelerated uptake of nature-related financial disclosures amongst counterparties involved in monetary policy operations

The ECB has recently committed to making the disclosures of climate-related information an eligibility requirement for asset purchases and collateral operations, recognising that such a policy can promote more consistent market disclosure practices (ECB, 2021). While disclosures alone will not be sufficient to ensure the management of nature-related financial risks, they can serve as an important first step for financial institutions and corporates to explore and acknowledge NRFR within their operations and activities. A key challenge faced by central banks is that knowledge and understanding of NRFR lags far behind climate risks, yet many nature-related threats are evolving over a shorter time horizon than longer term climate risks. There is a risk that some NRFR may become financially material, potentially systemically so, before initiatives such as the Taskforce for Nature-related Financial Disclosures (TNFD) have been fully implemented by firms. Such a trade-off provides further rationale for a precautionary policy approach to be taken with regards to managing the systemic potential of NRFR, as discussed in Section 4.1. But it also means that it is in the ECB's interests to reinforce a far more rapid uptake of the eventual TNFD's recommendations than has been seen for the TCFD, as well as promoting NRFR disclosures based upon qualitative risk assessments that can proxy for the increased complexity and data challenges that surround biodiversity loss. Policy options to operationalise this could include:

- A commitment to disclose early assessments of nature-related risks on the ECB's balance sheet, as a means of leading by example;
- A commitment to link eligibility criteria for credit operations, the collateral framework and asset purchases to criteria which reinforce the mandatory uptake of the TNFD recommendations, once published.

Option 2: Implement commitments and active risk management processes to ensure CSPP/PEPP is not directly or indirectly exposed to activities which scientific consensus or EU policy consider to be harmful to biodiversity and nature

This recommendation focuses upon key nature risk transmission channels where scientific consensus or existing EU policies provide a justification for precautionary action in advance of having full certainty about the magnitude of risk. As discussed in Section 3, deforestation is one such transmission channel where there is both robust scientific evidence for harm and legislative action taking place at the EU level. In the near term, actionable steps the ECB could take include:

- A portfolio-wide assessment of where exposure to deforestation is likely to materialise;
- Engagement with relevant counterparties to understand how they are managing potential sources and drivers of deforestation within their activities and supply chains, and to encourage alignment of risk management practices with emerging EU policy;
- Divestment from counterparties associated with significant deforestation who also fail to provide a credible response to engagement efforts.

In the medium term, as EU policy accelerates deforestation-related disclosure and due diligence, the ECB could also explore the potential to implement:

- A strategic commitment to ensure that there is no deforestation or high biodiversity-value habitat loss associated with any of its investment or financing activities, including both direct and indirect exposures;
- Additional specific investment policies covering key forest-risk commodities (palm oil, cattle products, soy and timber products), which are applied to ECB monetary policy operations and other relevant investment activities of the ECB;
- For relevant sectors, counterparty eligibility for asset purchases, collateral frameworks and credit operations could become contingent upon compliance with the ECB's deforestation commitment and commodity-specific policies.
- An escalation strategy could be taken initially to encourage counterparties to align with rising standards, particularly where indirect exposures are at play. This approach would require the ECB to implement robust processes for engaging and monitoring counterparties, with consequences for non-compliance.

Beyond monetary policy, the ECB could also set supervisory expectations for financial institutions to implement similar risk management policies related to deforestation. Indeed, greening the financial system must involve not just incorporating aspects of nature into financial frameworks, but also promoting a shift in financial institution behaviours and practices to support the needs of the ecological transition (Svartzman et al., 2021a). By aligning monetary and prudential policy, the implementation of portfolio-wide commitments and investment policies to manage NRFR within the CSPP/PEPP is likely to have a strong signalling effect in terms of incentivising financial markets to accelerate the implementation of robust risk management processes.[33]

[33] Indeed, in announcing the ECB's plans to incorporate climate risk considerations into its CSPP, ECB President Christine Lagarde noted that the ECB could 'play a bit of a catalyst role so that other purchasers, other investors, also follow suit' (Lagarde, 2021).

Other potential policy options

It is important to note that accounting for NRFR within monetary policy operations, as well as within the broader financial system, will be a dynamic process in policy design and implementation, evolving as EU level biodiversity policy becomes more established following the COP15 biodiversity conference. Looking ahead, the ECB could explore the scope for additional actions as policy and understanding on NRFR becomes more established, including:

- Targeting or 'tilting' asset purchases towards companies directly contributing to nature restoration, ensuring that targeted operations support the establishment of robust standards within new green financial instruments;
- Collaborative engagement with central banks located in jurisdictions of high biodiversity value, for example those operating at the tropical frontier, in order to coordinate the tightening of global financial standards related to nature loss;
- Contributing more broadly to policy coordination with regards to NRFR, including a commitment to escalate its risk management strategy over time as EU policy on biodiversity is expanded and updated.

Some of the policy options proposed in this section represent a more proactive, market-shaping approach to effectively manage NRFR, justified by the need for precautionary action amidst significant uncertainty on how these risks interact with the financial system. Yet such precautionary financial policymaking does not have to infringe upon central bank independence. As discussed in Section 1, the ECB already has a secondary mandate to support the broader goals of economic policy, which includes the ecological transition.

Having said this, as has recently been argued for the net-zero carbon transition, some degree of policy coordination with broader EU strategy may also be the most effective approach to minimise risks to the financial system (Barkawi and Zadek, 2021; Dikau et al., 2021). In particular, EU governments and the European Commission need to be more proactive in establishing environmental regulation that supports nature, cognisant of the huge economic costs of not acting.

At the same time, while it is true that central banks cannot prevent nature loss without broader policy interventions from the EU and member states, it is also true that such policy interventions are unlikely to be successful if the financial system remains blind to nature-related risks. Importantly, policy coordination does not just mean aligning to existing EU policy, but also actively contributing to the development of new policy mixes (Bolton et al., 2020; Svartzman et al., 2021a). This institutional role is perhaps even more relevant for the ECB, given its macroeconomic and institutional significance within the Eurozone. At its most basic, such active policy involvement could include the identification of where particular transmission channels of nature-related financial risk need to be acted on by EU-level or other government policy. The ECB could also use its considerable research capacity to contribute substantively to the development of the biodiversity components of the EU Sustainable Taxonomy and the financial regulatory provisions of the Biodiversity Strategy for 2030, where relevant to its mandate.

5. Conclusion

This report contributes to the emerging biodiversity-finance research agenda by exploring the interactions between nature-related financial risks and monetary policy, focusing on the ECB's asset purchase operations. We find that the sectors the ECB is invested in are associated with **significantly high dependencies** upon nature to facilitate production, as well as contributing to **significantly negative impacts** upon nature which threaten the future provision of vital ecosystem services.

In particular, we find that the CSPP/PEPP potentially has material dependencies upon water and ecosystem services providing protection from natural hazard disruption. It is also potentially contributing to significant negative impacts upon nature, especially with regards to use of land and freshwater, pollution and climate change – all of which are key drivers of biodiversity loss. Our supplementary qualitative assessment showed that potential indirect financial exposures are also potentially relevant, with the CSPP/PEPP exposed to deforestation risk through bond issuers who are highly influential within forest-risk commodity supply chains.

The findings in this paper also represent an exploratory case study into the relevant channels through which nature loss may transmit to financial risk, focusing on the European context. Future research could extend our analysis beyond corporate bonds to focus on the broader European financial system and its interactions with nature-related tipping points.[34] Indeed, as a supervisory institution with access to confidential loan-level data, the ECB itself could significantly contribute to this research effort.

There is a strong rationale for the ECB to supplement its prudential policy by accounting for NRFR in its monetary policy operations, in order to preserve its credibility as financial supervisor, fulfil its fiduciary duty with respect to prudent risk management, and to ensure that the ECB's monetary policy is aligned with existing and emerging environmental policy at the EU level.

Given that NRFR are characterised by a high degree of complexity and uncertainty, but may become material over short-term time horizons, mitigating actions may have to be taken on a precautionary basis with qualitative as well as quantitative assessments of risk. The policy options we explore reflect this precautionary approach and emphasise the active role that the ECB can play in accelerating understanding and management of NRFR.

Ultimately, greening the financial system must involve not just incorporating aspects of nature into financial frameworks, but also promoting a shift in financial institution behaviours and practices to support the needs of the ecological transition. By leading the way in developing robust and effective risk management processes within its own monetary policy and investment operations, the ECB can use its strong signalling power to accelerate the uptake of sustainable risk management practices within financial institutions.

[34] Galaz et al. (2018) have developed a relevant methodology here, linking the equity exposures of large financial institutions to industries modifying critical biomes in the Amazon rainforest and the boreal forests of Canada and Russia.

Appendix A: The ENCORE framework

Table A1: Natural capital assets in ENCORE

Asset	Description
Atmosphere	The atmosphere is the mass of air surrounding the earth. Its components (such as oxygen) and its processes (such as temperature regulation) support a number of essential ecosystem services.
Habitats	Habitats refer to the conditions of the environment necessary for life to prosper. These conditions vary widely between species but can include such elements as water and food availability, temperature range or absence of predators. Habitats can be defined very narrowly for one population of a particular species or more widely by type, such as forests or coastal habitats, that host many different species.
Land geomorphology	Land geomorphology describes the structure of the land, such as mountains and valleys. Land geomorphology supports the provision of regulatory services, like erosion control.
Minerals	Minerals are naturally occurring compounds not produced by living beings. They can be metallic or non-metallic and play an important supporting role in the provision of services like soil quality.
Ocean geomorphology	Ocean geomorphology describes the structure of the marine environment, such as shelfs and slopes. Ocean geomorphology supports the provision of regulatory services, like dilution by ecosystems.
Soils and sediments	Soils and sediments are the layers of the earth's surface that support life. They comprise top-soil, sub-soil and ocean sediments, and support a number of regulatory services.
Species	Species includes plants, animals, fungi, algae and genetic resources, which can be wild or domestic/commercial, for example livestock. Like habitats, species underpin a wide range of ecosystem services.
Water	Water includes surface water, ground water, ocean water, fossil water and soil water. Water is essential for a wide range of ecosystem services.

Source: Natural Capital Finance Alliance (Global Canopy, UNEP FI and UNEP-WCMC) 2021

Note: UNEP-WCMC have developed a hierarchical natural capital asset classification to support the identification of natural capital assets which underpin ecosystem services (Leach et al., 2019). It comprises a four-level hierarchical structure, allowing aggregation or disaggregation depending on the level of complexity required in decision making. ENCORE adopts Level 3 of the framework as above.

Table A2: Ecosystem services in ENCORE

Category	Ecosystem service	Description
Direct physical input	Animal-based energy	Physical labour is provided by domesticated or commercial species, including oxen, horses, donkeys, goats and elephants.
	Fibres and other materials	Fibres and other materials from plants, algae and animals are directly used or processed for a variety of purposes.
	Genetic materials	Genetic material is understood to be deoxyribonucleic acid (DNA) and all biota, including plants, animals and algae.
	Ground water	Groundwater is water stored underground in aquifers made of permeable rocks, soil and sand. The water that contributes to groundwater sources originates from rainfall, snow melts and water flow from natural freshwater resources.
	Surface water	Surface water is provided through freshwater resources from collected precipitation and water flow from natural sources.
Enables production process	Maintain nursery habitats	Nurseries are habitats that make a significantly high contribution to the reproduction of individuals from a particular species, where juveniles occur at higher densities, avoid predation more successfully or grow faster than in other habitats.
	Pollination	Pollination services are provided by three main mechanisms: animals, water and wind. The majority of plants depend to some extent on animals that act as vectors, or pollinators, to perform the transfer of pollen.
	Soil quality	Soil quality is provided through weathering processes, which maintain bio-geochemical conditions of soils, including fertility and soil structure, and decomposition and fixing processes, which enables nitrogen fixing, nitrification and mineralisation of dead organic material.
	Ventilation	Ventilation provided by natural or planted vegetation is vital for good indoor air quality and without it there are long-term health implications for building occupants due to the build-up of volatile organic compounds (VOCs), airborne bacteria and moulds.
	Water flow maintenance	The hydrological cycle, also called water cycle or hydrologic cycle, is the system that enables the circulation of water through the Earth's atmosphere, land and oceans. It is responsible for the recharge of groundwater sources (i.e. aquifers) and maintenance of surface water flows.
	Water quality	Provided by maintaining the chemical condition of freshwaters, including rivers, streams, lakes and ground water sources, and salt waters to ensure favourable living conditions for biota.
Mitigates direct impacts	Bio-remediation	Bio-remediation is a natural process whereby living organisms, such as micro-organisms, plants, algae and some animals, degrade, reduce and/or detoxify contaminants.
	Dilution by atmosphere and ecosystems	Water, both fresh and saline, and the atmosphere can dilute the gases, fluids and solid waste produced by human activity.
	Filtration	Filtering, sequestering, storing and accumulating pollutants is carried out by a range of organisms, including, algae, animals, microorganisms, and vascular and non-vascular plants.
	Mediation of sensory impacts	Vegetation is the main (natural) barrier used to reduce noise and light pollution, limiting the impact it can have on human health and the environment.

Category	Ecosystem service	Description
Protection from disruption	Buffering and attenuation of mass flows	Buffering and attenuation of mass flows allows the transport and storage of sediment by rivers, lakes and seas.
	Climate regulation	Provided by nature through the long-term storage of carbon dioxide in soils, vegetable biomass and the oceans. At a regional level, the climate is regulated by ocean currents and winds, while, at local and micro-levels, vegetation can modify temperatures, humidity and wind speeds.
	Disease control	Ecosystems play important roles in regulation of diseases for human populations, as well as for wild and domesticated flora and fauna.
	Flood and storm protection	Provided by the sheltering, buffering and attenuating effects of natural and planted vegetation.
	Mass stabilisation and erosion control	Delivered through vegetation cover protecting and stabilising terrestrial, coastal and marine ecosystems, coastal wetlands and dunes. Vegetation on slopes also prevents avalanches and landslides, and mangroves, sea grass and macroalgae provide erosion protection of coasts and sediments.
	Pest control	Provided through direct introduction and maintenance of populations of the predators of the pest or the invasive species, landscaping areas to encourage habitats for pest reduction, and the manufacture of a family of natural biocides based on natural toxins for pests.

Source: Natural Capital Finance Alliance (Global Canopy, UNEP FI and UNEP-WCMC), 2021

Note: Ecosystem services were classified according to the Common International Classification of Ecosystem Services (CICES) which comprises a five-level hierarchical structure, for example: section (e.g. provisioning), division (e.g. nutrition), group (e.g. terrestrial plants and animals for food), class (e.g. crops) and class type (e.g. wheat). Cultural ecosystem services were not considered in this project as they are not considered to be direct inputs or to enable production processes. The CICES framework has been simplified for the purposes of this tool.

Table A3: Negative impacts driving biodiversity loss

Drivers of biodiversity loss	Description
Use of land and freshwater	Direct use of habitats throughout operations. Terrestrial ecosystem use includes area of agriculture by type, area of forest plantation by type, area of open cast mine by type, etc. Freshwater ecosystem use includes the use of wetland, ponds, lakes, streams, rivers or peatland necessary to provide ecosystem services such as water purification, fish spawning, areas of infrastructure necessary to use rivers and lakes such as bridges, dams, and flood barriers, etc.
Use of marine area	Examples include area of aquaculture by type, area of seabed mining by type, etc.
Use of natural resources	The over-exploitation of resources directly used in production, such as volume of mineral extracted, volume of wild-caught fish by species, number of wild-caught mammals by species, etc.
Pollution	Threats arising from the introduction of contaminants into the natural environment, including non-greenhouse gas air pollutants, water and soil pollutants, and solid waste.
Climate change	Emission of greenhouse gases from vehicles and vessels
Invasive species	Harmful plants, animals, pathogens and other microbes not originally found within the ecosystem(s) in question, and directly or indirectly introduced and spread into it by human activities.
Disturbances	Examples include decibels and duration of noise, lumens and duration of light at site of impact.

Source: IPBES (2019), UNEP-WCMC (2020), Natural Capital Finance Alliance (Global Canopy, UNEP FI and UNEP-WCMC) (2021)

Appendix B: Constructing the simulated bond universe eligible for ECB asset purchases

First, we established the investable universe of corporate bonds that are eligible for ECB asset purchases according to the CSPP/PEPP criteria. We applied several screens to the total bond universe available in the Thomson Reuters Refinitiv system, beginning with all bonds issued by corporate entities domiciled in the European Union and denominated in euros. The following additional screens were applied:

- Investment grade
- Maturity of at least 28 days if the bond is less than one year in duration OR between six months and 31 years if the bond is greater than one year in duration.
- Issuer is a non-bank institution

Subsequently, the issuers of these bonds were matched to their respective NACE two-digit sectors. In several instances, the immediate issuer of the bond was a special purpose vehicle or holding company established for the purpose of issuing and carrying a corporation's debt; in these instances, issuers were manually re-categorised under the NACE system according to their parent corporation's industry. For example, BMW Finance N.V. was originally categorised within the NACE system as belonging to the financial sector; it was manually recoded to fall within the automotive sector. In line with the rules for investment set out by the ECB, financial institutions whose primary operations involve financial intermediation (asset management) were also excluded. Diversified financial companies who have significant asset management operations, but who primarily operate within the insurance sector, such as AXA, were included. Once this investable universe was established (n = 2460 bonds), relative allocations of value in each sector were established by summing the total outstanding value of all bonds within a given sector (original amount issued in euros) and dividing this value by the total outstanding value of all bonds within the universe.

Table B1: Comparing the sectoral breakdown of the simulated eligible bond universe and the actual CSPP/PEPP

NACE sector	ECB published list of bonds under CSPP/PEPP %	Eligible bond universe %
A – Agriculture, forestry and fishing	0.07%	0.06%
B – Mining and quarrying	0.76%	1.01%
C – Manufacturing	40.48%	42.09%
D – Electricity, gas, steam and air conditioning supply	15.34%	13.69%
E – Water supply; sewerage, waste management and remediation	0.74%	0.80%
F – Construction	3.50%	3.35%
G – Wholesale and retail trade; repair of motor vehicles	2.19%	2.69%
H – Transportation and storage	9.13%	7.25%
I – Accommodation and food service activities	0.51%	0.42%
J – Information and communication	10.01%	8.84%
K – Financial and insurance activities	3.29%	8.69%
L – Real estate activities	5.86%	7.88%
M – Professional, scientific and technical activities	1.10%	1.01%
N – Administrative and support service activities	0.36%	1.27%
Q – Human health and social work activities	0.98%	0.92%
Blank	5.70%	–
Total	100.00%	100.00%

Source: Thomson Reuters Refinitiv database; European Central Bank

Table A2 demonstrates that the sectoral breakdown simulated eligible universe of bonds (aggregated to the NACE one-digit level) is broadly consistent with that of the CSPP/PEPP, as published by the ECB. Certain sectors with larger discrepancies (e.g. finance and insurance activities) may be partially accounted for by the roughly 6% of bonds in the ECB list which did not return a NACE sector from the Refinitiv system, as well as by our inclusion of companies with diversified financial operations, as outlined above, which may have been excluded by the ECB.

This established distribution of sectors was then scaled to the size of the ECB's actual portfolio (EUR 311 billion, as of 30 April 2021) in order to approximate the value of the ECB portfolio exposed to each sector based on the principle of market neutrality, such that the distribution of sectors in the investable universe aligned with the distribution of sectors by value in the CSPP/PEPP portfolio.

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