Risk and Resilience: Quantifying the UK Investment Portfolio's Dependence on Nature

Final report –

UNEP-WCMC Dependencies Analysis

April 2024

UN environment programme

WCMC

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Contents

Executive Summary

In this report, we estimate the dependency of UK banks and insurers' financial assets (in this case loans, bonds and equities) on ecosystem services. Such dependencies on ecosystem services are currently neglected in policies and decision-making processes. This is despite them being vital for the normal functioning of all sectors, and, through supply chains and financial contagia, the entire economy. With the ongoing depletion of nature, the continued provision of ecosystem services cannot be taken for granted. Urgent steps are needed to protect and restore the natural systems on which the entire economy depends.

We estimate that the **£3.8 trillion in exposures from UK banks and insurers are dependent on £5.8 trillion of upstream economic activity through supply chains.** These upstream links create extensive exposure to physical nature-related risks.

Approximately £2.5 trillion (44%) of the upstream exposures are associated with NACE (Nomenclature of Economic Activities) **Divisions that have a high or very high dependency on nature and with areas of the world that have a high rate of natural capital depletion.** We calculated this by aligning the upstream financial exposures of NACE Sections and Divisions with their sectors' dependencies on ecosystem services from the Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE) knowledge base. We then overlayed this with estimates of rates of natural capital depletion using a global data layer. The co-location of high nature dependency and high rates of natural capital depletion exposes the 44% of the upstream economic activity to risk, as degradation of natural capital is likely to lead to the loss of ecosystem services that economic activity depends upon.

We find that at least **£751 billion (42% of the portfolio that could be examined) of UK bank and insurer financial assets are moderately *directly* dependent on ecosystem services. A further £179 billion (10%) are highly or very highly directly dependent. It is important to note that these figures were calculated after removing financial data on Section K** (*Financial and insurance activities,* amounting to 52.8% of total exposures, ~£2 trillion) from the analysis involving direct dependencies, due to a lack of data on exposure of and real-world impacts of investments in the financial sector. This means that these are likely to be underestimates of direct dependencies. When this analysis was repeated using upstream financial exposure, including Section K, high or very high dependencies on nature were found to be much higher (56% of upstream economic assets).

The most materially depended upon ecosystem services are related to the mass stabilisation and erosion control and the state of surface and ground water. *Mass stabilization and erosion control* is the ecosystem service upon which most financial assets depend. This ecosystem service is primarily provided by vegetation and soil that reduce the potential for landslides, subsidence and sedimentation of water bodies. Many sectors need erosion control to protect key infrastructure including manufacturing sites, warehouses and office buildings. Many financial assets also require *Surface water* and *Ground water* ecosystem services.

Electricity, gas, steam and air conditioning supply **(D35) is the NACE Division with the highest direct dependency materiality within the UK's financial investment portfolio.** It alone is dependent upon fourteen ecosystem services, six of which have a Very High dependency rating (*Flood and storm protection*, *Climate regulation*, *Surface water*, *Water flow maintenance*, *Fibres and other materials*, and

Ground water) meaning that processes in the sector will be disrupted should the ecosystem service supply be impacted. These combined material dependency scores were calculated by taking the score of each NACE Division (revealing how strongly dependent that Division was on ecosystem services) and summing this score with the Division's financial exposure.

Further analysis of the top ten NACE Divisions that are most materially dependent upon nature shows that dependencies on ecosystem services vary considerably between different Divisions. ***Surface water* is the most critical ecosystem service for 8 of the 10 top Divisions**, being the ecosystem service which the top ten Divisions are most dependent on regardless of financial exposure. ***Flood and storm protection* is the second most critical, followed by *Mass stabilization and erosion control***. We see this subset of ecosystem services coming through as important, but in slightly different rankings, in the different parts of our analysis, underlining that there is no one ecosystem service that is the most important for the UK financial investment portfolio, but rather a collection of key ecosystem services.

Urgent actions are required to protect and restore nature. If such action is not taken, ecosystem services in the UK will become increasingly damaged. This will disrupt both supply chains and economic production and lead to significant financial instability given the breadth of exposure that we identify in this report. To prevent this disruption, central banks, commercial banks, insurers and public policy makers must work together to understand their dependencies on nature and act to reduce threats to them. We outline key recommendations for each of these stakeholder groups at the end of the report.

Context

The Project: UK Nature Risk Quantification

The UK's financial investment portfolio is dependent upon nature and therefore at risk from its decline. This decline is itself driven by economic activity. However, the extent to which different sectors of the UK's financial investment portfolio are dependent on nature is unclear. Consequently, it is also unclear what volume of investments are exposed to risks associated with the nature crisis. In this six-month project, the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) have conducted an analysis on a subset of potential nature-related risks associated with the UK's financial investment portfolio. The analysis is based on the exposures of UK banks and insurers and examines their potential nature dependencies. The results of the analysis will contribute to increased action on nature by the UK and will complement global efforts to bring nature onto the agendas of key economic decision-makers.

This Document: Our findings

This document outlines the analysis that we have undertaken within this project and presents our key findings. We end with recommendations for the following key reader groups: staff at the Bank of England, policy makers within the UK government and staff working within commercial banks and insurers. A more detailed methodology and further contextual information can be found in the Annexes.

The analysis is discussed in two parts. First, it uses the ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure) knowledge base to assess where material dependencies lie in the exposures of UK banks and insurers. This first section is non-spatial and looks at the UK exposures as a whole. It then uses other datasets to add a spatial component and look at the nature risks arising from these dependencies on nature, based on the state of nature in countries where the UK has strong upstream financial exposures.

The analysis feeds into a final, combined summary document that has been compiled by the Green Finance Institute. That summary document summarizes the whole of this project, including work by the University of Oxford, University of Reading, and the National Institute of Economic and Social Research.

Inputs into the analysis

Main dataset: UK Banks and Insurers Financial Exposure by NACE Section

The financial dataset

In March 2023, a dataset was published by the Bank of England that includes around 90% of the UK banking and insurance system's total assets for the fourth Quarter of 2021[1] (the exact date of the dataset is 31 December 2021). The dataset includes sub-sectoral exposure of three types of assets in UK banks' and insurers' portfolios: loans, bonds and equities. The exposure coverage includes loans, bonds and equities for banks, and bonds and equities for insurers[2]. The sample of banks includes all UK-domiciled banks at the highest level of consolidation.

The sectoral classification used in the dataset follows the NACE 2 standard – the NACE Classification Code of Economic Activity with 2-digit codes. In the NACE 2 system[3], different levels of classification provide greater degrees of granularity – here we are interested in the first two levels:

- the first level consists of headings identified by an alphabetical code (referred to as Sections, which can broadly be considered 'sectors')
- the second level consists of headings identified by a two-digit numerical code (referred to as Divisions, which can broadly be considered 'sub-sectors')

For example, Section C refers to *Manufacturing*, and Division C11 refers to *Manufacturing of beverages*. This work provides a full list of NACE Codes in Annex 1. Due to confidentiality concerns, however, the dataset does not provide all data at the Division level, and this means that some exposures are just associated with the Section.

This dataset is not spatial. While it shows how much UK banks and insurers are exposed to each economic sector (by NACE Section or Division) it does not specify where in the world the related assets are held. Therefore, this work looked to other datasets and techniques to try to add a spatial element to this analysis. This was an important step to take as it was hard to fully assess exposure to nature dependency-based risks without understanding where key dependencies lie geographically and the state of nature in those areas.

[1] For details of the dataset, please refer to the published dataset and Appendix A of the published working paper. https://www.bankofengland.co.uk/working-paper/2022/measuring-capital-at-risk-in-the-uk-banking-sector-a-microstructural-network-approach

[2] Monetary financial institutions (MFI) security holdings of equity and debt are sourced from a sample of 33 MFIs with the sample target coverage of 90% of UK MFI equity and debt holdings. The sample of insurers includes the whole sample covered in Solvency II data. As for the asset types, loan exposures refer to Net Exposure Amount as described in the large exposure reporting standards, which is based on a risk-based capital framework. Securities – bond and equity – refer to banks' and insurers' asset holdings and are based on a financial accounting framework.

[3] Please refer to this website for further details on NACE: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Statistical_classification_of_economic_activities_in_the_European_Community_(NACE)

Summary of the data

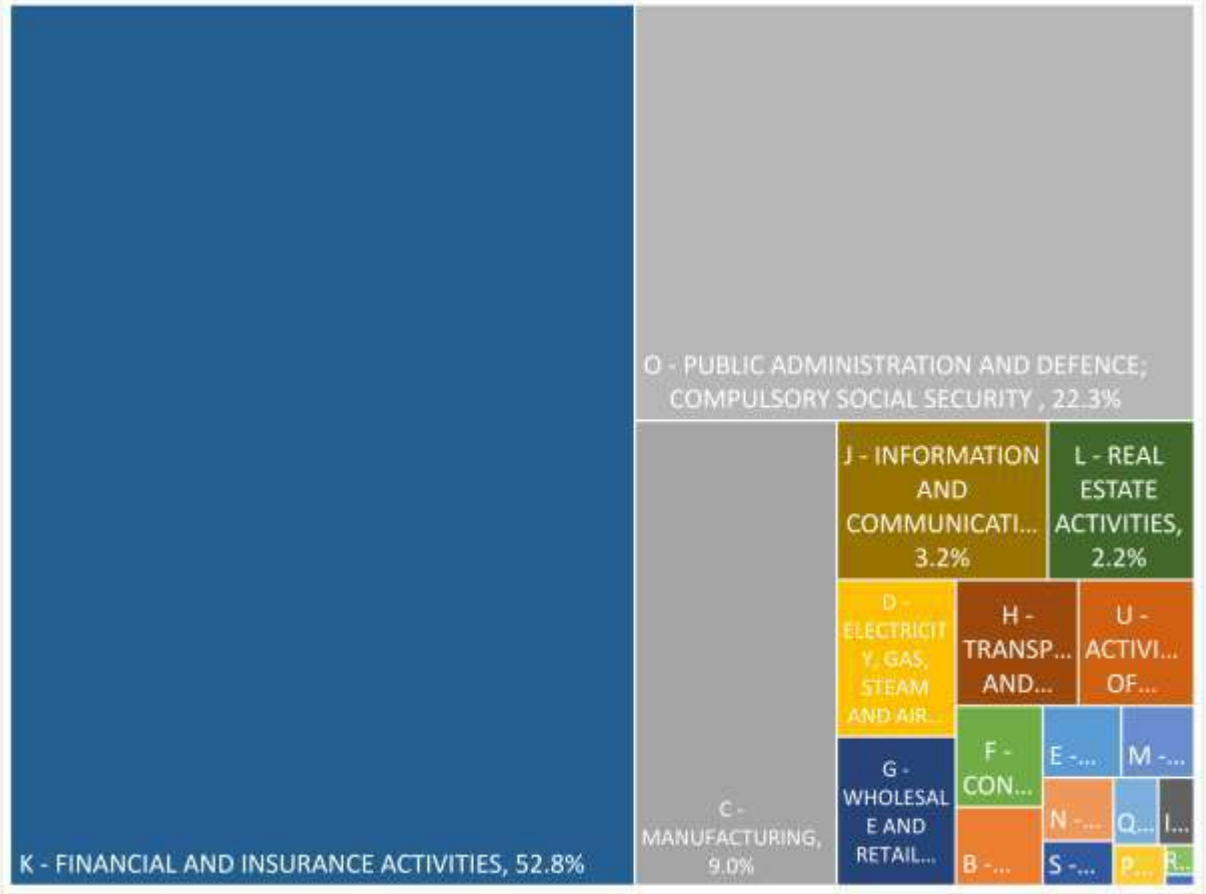

Figure 1: Financial exposures of UK banks and insurers, summed by NACE Section. Further detail on the names of NACE sections and their exposures by asset class (loans, bonds and equities) can be found in Annex 1.

Figure 1 shows the sectoral distribution of the sum of the three types of assets included in the dataset. Within the dataset, Section K (*Financial and Insurance Activities*) constitutes more than half of the overall asset exposure (52.8%, ~£2 trillion). As the assets within Section K (*Financial and Insurance Activities*) sit within the financial sector, without more context it is difficult to know what percentage constitutes onward financing to other sectors, and what percentage remains within the financial sector (e.g., through inter-bank transactions for liquidity purposes). As such, Section K (*Financial and Insurance Activities*) was excluded from the initial non-spatial dependency analysis that was conducted.

The second largest sector in the dataset is Section O (*Public administration and defence; compulsory social security*). From reviewing the detail of the dataset, it can be seen that a considerable amount of the finance flowing into Section O (*Public administration and defence; compulsory social security*) stems from bonds. Public bonds, like UK gilts, tend to be related to social security and public spending (Statista Research Department 2023). The total value of assets held in Section O (*Public administration and defence; compulsory social security*) in the dataset was £845 billion (22.32% of the total dataset, or 47.25% of the dataset once Section K (*Financial and Insurance Activities*) was removed).

ENCORE knowledge base

ENCORE was developed by Global Canopy, the UNEP Finance Initiative, and UNEP-WCMC with funding from the Swiss State Secretariat for Economic Affairs (SECO) and the MAVA Foundation. It is integral to this analysis.

The ENCORE dependency knowledge base outlines how different economic activities are potentially dependent on nature. It was applied within this analysis to assess how dependent the UK financial investment portfolio is on nature. Therefore, understanding the principles behind this knowledge base is important to understand the context of this work. It draws on scientific and grey literature, supplemented by expert reviews. Further detail on the methodology used for developing the ENCORE knowledge base can be found below and on the ENCORE website.

Principles behind ENCORE

In ENCORE, each sector's main production processes are linked to a series of ecosystem services on which they potentially depend for their continued operation. A full list of ecosystem services included in ENCORE can be found in Annex 2. Each production process-ecosystem service link has a materiality rating, which can be Very High, High, Medium, Low or Very Low (as seen in **Figure 2**, below). These materiality ratings are based on available peer-reviewed and grey literature and expert input from sector practitioners. Therefore, each sector has its own 'dependencies profile' (i.e., the list of ecosystem services it potentially depends on and their associated materiality ratings).

It should be noted that the ENCORE knowledge base was developed using the Global Industry Classification Standard (GICS) sector classification, whereas the data on UK banks and insurers exposures is split by NACE sector codes. As such, a conversion process needed to be conducted to be able to run this analysis, which is described further in Annex 3A.

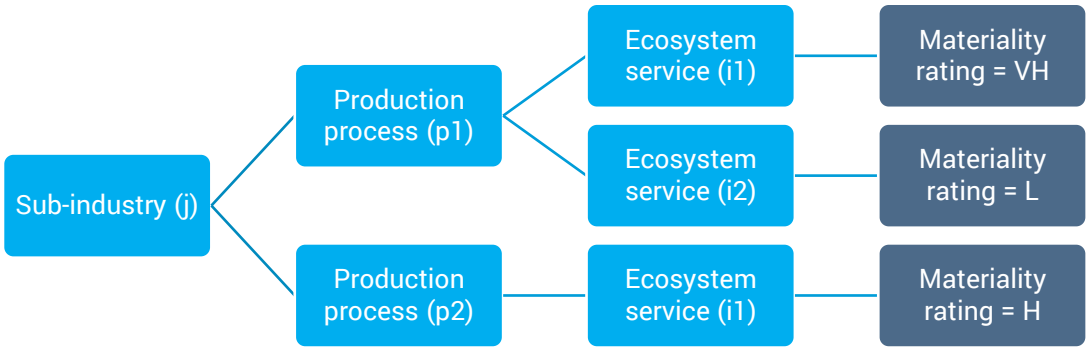

Figure 2: The structure of relationships in the ENCORE knowledge base. Each sub-industry is associated with several different production processes, which in turn are associated with one or more ecosystem services. VH = Very High; H = High; M = Medium; L = Low; and VL = Very Low.

The dependencies of economic activities on nature are often overlooked. ENCORE helps make these links explicit. For example, in the NACE Division of *Electricity, gas, steam and air conditioning supply* (D35), the required equipment and infrastructure need stable ground. Therefore, soil erosion and instability negatively impact the function of the whole energy generation sector.

In ENCORE, not all sectors are given the same dependency materiality rating for the same ecosystem service. For example, while both *Oil & Gas Production* in the energy sector and *Brewers* in *Consumer Staples* are dependent on the *Flood and Storm Protection* ecosystem service, the former has a very low

(VL: Very Low) materiality rating for its dependence on the ecosystem service, whereas the latter has a medium (M: Medium) materiality rating for the same ecosystem service. This is accounted for in the analysis and means that when the combination is made with the financial data on exposures to different sectors from the dataset, the 'importance' of each ecosystem service will be weighted based on: 1) the materiality of the ecosystem services for all relevant sectors (using ENCORE); and 2) the amount invested by UK banks and insurers in those sectors.

Spatial datasets

In order to add a spatial dimension to this analysis, a number of other datasets were used, which are discussed further in the Results section (page 18 onwards). These datasets are outlined in brief below.

Foreign Direct Investment

This dataset ('Foreign direct investment involving UK companies (directional): outward'), held by the Office for National Statistics, shows the flows of investment directed to other countries from the UK, by sector. In this analysis, it was used to take the financial dataset from exposure by sector, to exposure by sector and region, in order to input it to EXIOBASE.

EXIOBASE MRIO

EXIOBASE is a multi-regional input-output table. It relates the financial flows that connect sectors and regions in the production of goods and services. In this analysis it was used to approximate where upstream financial exposures of the UK investment portfolio are held.

Hotspots of Natural Capital Depletion

As a proxy for the state of nature, the Hotspots of Natural Capital Depletion Layers, developed by UNEP-WCMC (UNEP-WCMC 2021) were used. This layer assesses how fast natural capital is being depleted globally. Within this data layer, the depletion rates of four different natural capital assets were assessed: atmosphere, biodiversity, soils and sediments, and water[4]. Hotspots of depletion are defined as areas within the top 20% of relative depletion values for natural capital assets globally. Due to time constraints with this analysis, just the terrestrial, and not marine, layer was used.

[4] More information on calculation of these layers can be found in the briefing note for the Hotspots of Natural Capital Depletion dataset, at https://s3.eu-west-2.amazonaws.com/ncfa.documents/resources/hotspots_methodology.pdf

Results

Non-spatial ENCORE dependencies analysis

Material dependencies of the UK's financial investment portfolio on nature

The first part of this analysis uses the ENCORE knowledge base to calculate how dependent the exposures of UK banks and insurers are on nature. This method is in line with other similar reports by central banks - see Box 1 below for a comparison. This phase of the analysis is non-spatial. This means that it takes the whole of the UK's financial exposure and is agnostic to where those exposures are situated in the world and what the state of nature may be in those areas. This first part looks at the strength of dependencies on nature on a sector-by-sector basis. However, given that the analysis does not assess the state of nature, it was impossible to directly link these dependencies to risks (associated with the declining state of nature). That is estimated in the second part of this analysis, where spatial elements are considered.

To calculate the material dependency scores, the analysis first used a crosswalk to map the NACE Sections from the dataset onto the GICS codes used in ENCORE. Once this mapping was complete, the dependency score for each NACE Division was then calculated by dividing the materiality rating for each unique *Division* x *ecosystem service* combination by the sum of all ecosystem service materiality ratings associated with the Division. It then multiplied this proportion by the financial value associated with the Division. A full methodology is found in Annex 3A.

In each Sankey diagram (see Figure 3 and Figure 4 below), financial investments enter the economy on the left as either a bond, equity or loan, then flow rightwards and redistribute across NACE Sections. The size of the node of each NACE Section is proportional to the financial value (exposure) associated with it, with the biggest sectors located at the top of the diagram and the smallest at the bottom. Traveling rightwards, investments are again subdivided through production processes into ecosystem services. Similarly, the ecosystem services that underpin the highest financial value are located at the top of diagram. The sum of the heights of the diagram represents the total amount of exposures held in the portfolio.

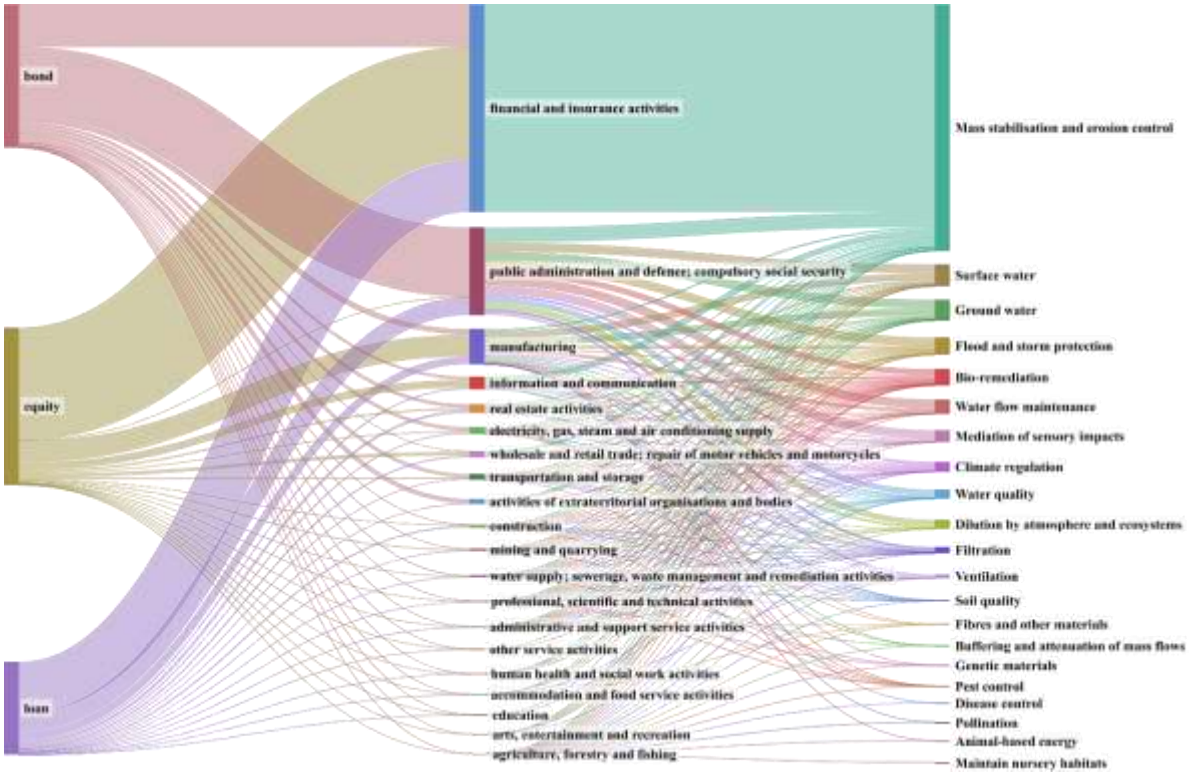

Figure 3: Sankey diagram showing how the financial exposures of UK banks and insurers, by asset class, are dependent of ecosystem services. The left-hand column shows asset classes from the dataset, and the size of the left-hand flows show financial flows to NACE Sections (centre column). The right-hand flow uses the ENCORE knowledge base to identify dependencies between NACE Sections and ecosystem services (in the right-hand column), and the size of the relationship is proportional to the strength of the dependency, weighted by the financial value attached with it.

Figure 3 is a Sankey diagram that shows the relationship between the whole of the financial dataset and ecosystem services. From this, it is clear, again, that Section K (*Financial and insurance activities*) is by far the largest Section of financial exposure, in particular for equities.

NACE section K and the apparent importance of *Mass Stabilisation and Erosion Control*

A strong material dependence (combination of financial exposure and ecosystem service dependence from ENCORE) is seen between Section K (*Financial and insurance activities*) and the *Mass stabilization and erosion control* ecosystem service[5], making it by far the most depended upon ecosystem service within the UK banks and insurers exposures. However, this strong material dependence on the *Mass stabilization and erosion control* ecosystem service is underpinned by just three weak dependency links in ENCORE for three processes: *Financial services* (Low dependency rating), *Real estate investment* (Low dependency) and *Managed health care* (Very Low dependency). It is the very large financial exposure from Section K (more than half of the financial exposure of the whole dataset) that skews this material dependency.

It should be noted that the *only* direct dependence on ecosystem services for Section K in the ENCORE knowledge base is upon *Mass stabilization and erosion control* – this is due to direct operations of the financial and insurance sector primarily being office-based activities. It should also be noted that this

[5] Mass stabilization and erosion control is delivered through vegetation cover protected 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.

sector typically finances multiple other sectors, which will have varying degrees of dependence on ecosystem services. With the data available, it was not possible to capture this, as discussed below.

Removing Section K (*Financial and insurance activities*) from further analysis

NACE Section K (*Financial and insurance activities*) is a very large sector, constituting more than half of the overall asset exposure (52.8%, ~£2 trillion) in the financial dataset. It is unclear from the data available where the finances within Section K (*Financial and insurance activities*) are spent in the real economy. This makes it very difficult to estimate the true dependencies on nature associated with this sector. Therefore, financial exposures within Section K were removed from the analysis from this point onwards in order to make the outputs of the analysis as actionable as possible.

⚠ **Decision made:** It is unknown where the finances within Section K are held in the real economy, and therefore it is not possible to accurately link processes within Section K to ecosystem services on which they depend. Given this, Section K data were taken out of the analysis from this point forward.

Improvement that the Bank of England could make: Use internal data on where financial exposure lies to run this analysis more accurately, including Section K.

Figure 4 shows a Sankey diagram formatted with the same method as Figure 3, but where Section K (*Financial and insurance activities*) has been removed from the dataset. The left-hand linkages within Figure 4 show how financial exposures vary between assets classes for different NACE sections. For example, more than half of the bond exposures in the dataset (£670 billion out of £970 billion in total bond exposures) flow to NACE Section O (*Public administration and defence; compulsory social security*), which as discussed previously, include many government bonds, or gilts. Most equity exposures (£210 billion out of £424 billion total), by comparison, are in NACE Section C (*Manufacturing*), with a smaller but still sizable flow (£74 billion) to Section J (*Information and communication*). The majority of loan exposures go to Section O (£175 billion, *Public administration and defence; compulsory social security*), followed by Section C (£75 billion, *Manufacturing*).

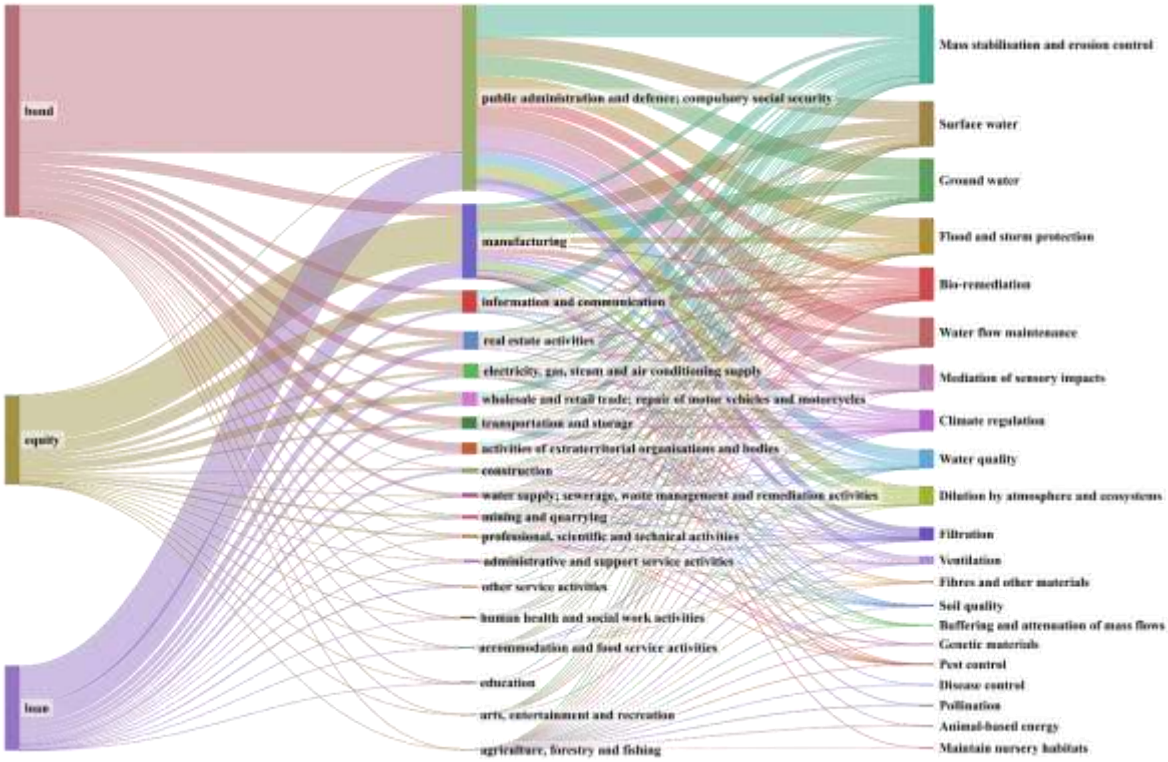

Figure 4: Sankey diagram of UK's financial exposures excluding Section K (*Financial and insurance activities*) and their dependencies on ecosystems services. The left-hand column shows asset classes from the dataset, and the size of the left hand flows show financial flows to NACE Sections (centre column). The right-hand flow uses the ENCORE knowledge base to identify dependencies between NACE Sections and ecosystem services (in the right hand column), and the size of the relationship is proportional to the strength of the dependency, weighted by the financial value attached with it.

The right-hand linkages within Figure 4 show how the financial flows from each NACE Section correspond to ecosystem services upon which that NACE Section is dependent. The strength of the connection is weighted by the materiality of the dependency and the size of the financial flow.

***Mass stabilization and erosion control* is the ecosystem service with highest material dependency** (combination of dependency score and financial exposure), **and is the most frequently occurring ecosystem service**, being directly depended upon by every analyzed NACE Section. This ecosystem service is primarily provided by vegetation and soil, which reduces the potential for landslides, subsidence and sedimentation of water bodies. Alignment between the results of this analysis and previous analyses of central bank's portfolios are discussed in Box 1 below.

NACE Section O (*Public administration and defence; compulsory social security*) has the highest material dependency on *Mass stabilization and erosion control*. This is due to a combination of the large financial exposure within this sector, combined with the sector's dependencies on three processes provided by the *Mass stabilization and erosion control* ecosystem service: *Infrastructure holdings* (Low dependency), *Manufacture of machinery, parts and equipment* (Very Low dependency), and *Specialized consumer services* (Low dependency). These processes cover erosion control to protect key infrastructure such as manufacturing sites, warehouses, other industrial locations and their associated office buildings. Therefore, while the dependencies on the *Mass stabilization and erosion control* ecosystem service are Low and Very Low respectively, the major importance of Section O (*Public administration and defence;*

compulsory social security) from a financial exposure perspective makes for a strong overall weighted dependency.

The provisioning ecosystem service of *Surface water*[6] is the second most materially dependent ecosystem service and is directly depended upon by 14 NACE Sections. Of these Sections, the strongest material dependencies are to NACE Section O (*Public administration and defence; compulsory social security*) and NACE Section C (*Manufacturing*). Within Section O, the key process with dependence on *Surface water* is *Manufacture of machinery, parts and equipment*, with a Medium (M) materiality dependency and high financial exposure. With Section C (*Manufacturing*), these key processes are more varied (as would be expected from a sector that encompasses many kinds of manufacturing) and include the following processes with Very High dependencies: *Processed food and drink production*, *Alcoholic fermentation and distilling*, *Tobacco production*, *Natural fibre production*, *Synthetic fibre production*, and *Large-scale forestry*.

Given that a large proportion of the financial dataset is invested in Section O (*Public administration and defence; compulsory social security*), which has very strong dependencies upon the *Mass stabilization and erosion control* ecosystem service, a Sankey diagram where both Section O and Section K are removed from the dataset was also generated. This can be seen in Annex 4.

[6] *Surface water* is provided through freshwater resources from collected precipitation and water flow from natural sources. While surface water would be available in the absence of a stable, functioning ecosystem, the regulation of its quantity and quality is an important ecosystem service.

Box 1. Comparing results to previous analyses

The above results differ slightly from previous analyses (Svartzman *et al.* 2021; Martinez-Jaramillo *et al*. 2023; DNB and PBL Netherlands Assessment Agency 2020; Nikuradze and Tvalodze 2023; Calice, Diaz Kalan and Miguel 2021; World Bank and Bank Negara Malaysia 2022; Kedward, Buller and Ryan-Collins 2021), which have most often cited *Surface water* as the ecosystem service with the highest share of High or Very High materiality. Across all of the above references, the top five most frequently cited highest materiality ecosystem services are (in order from highest to lowest): 1) *Surface water*, 2) *Climate regulation*, 3) *Ground water*, 4) *Flood and storm protection*, and 5) *Mass stabilization and erosion control*. This is largely consistent with the top five ecosystem services identified in Figure 4 and Table 2.

There are two main explanations for the differences in the results of this analysis compared to those of previous analyses, as detailed below.

1. Methodology – The methodology used here focused on direct dependencies and considered all levels of ecosystem service dependency materiality (Very Low through to Very High). These were then combined with financial values to identify the ecosystem services with the highest weighted materiality (i.e., dependency materiality ratings and financial value). This is different from previous analyses, which have often only split financial flows across ecosystem services with a High or Very High materiality rating. Including the full range of dependency materialities helps to avoid potential oversight of ecosystem services that are critical to a large number of sectors/sub-sectors (here, Sections and Divisions) and have a high associated financial value. This does, however, lead to certain ecosystem services showing as more critical when their materiality ratings are lower, but the associated financial values are very high.

2. Data input – Because the input data on financial flows to sectors is unique to this analysis, it is to be expected that the list of most material ecosystem services would be different as well. Additionally, the data used in this analysis had: i) a major skew towards a small number of NACE Sections with a large financial exposure but Very Low or Low materiality dependencies; and ii) several NACE Sections that were at a coarser level of granularity, meaning that their financial values had to be split evenly across sub-sectors.

Next, the percentage of the total portfolio value (the financial exposures of UK banks and insurers, with Section K excluded) associated with each materiality category is calculated, and displayed in Figure 5 (a full methodology can be found in Annex 3A). This is an alternative way of visualizing the same relationships as are within the Sankey.

In this non-spatial analysis, it can be seen that **£751 billion (42% of the portfolio that could be examined) of UK bank and insurer financial assets are moderately directly dependent on ecosystem services. A further £179 billion (10%) are highly or very highly directly dependent**. Of all the asset types, **equities have the highest dependence on ecosystem services, with 19% of equity exposures associated with high or very high dependencies**. It is important to note that these figures were calculated after removing financial data on Section K (*Financial and insurance activities,* amounting to 52.8% of total exposures, ~£2 trillion) from the analysis involving direct dependencies, due to unworkable data uncertainties.

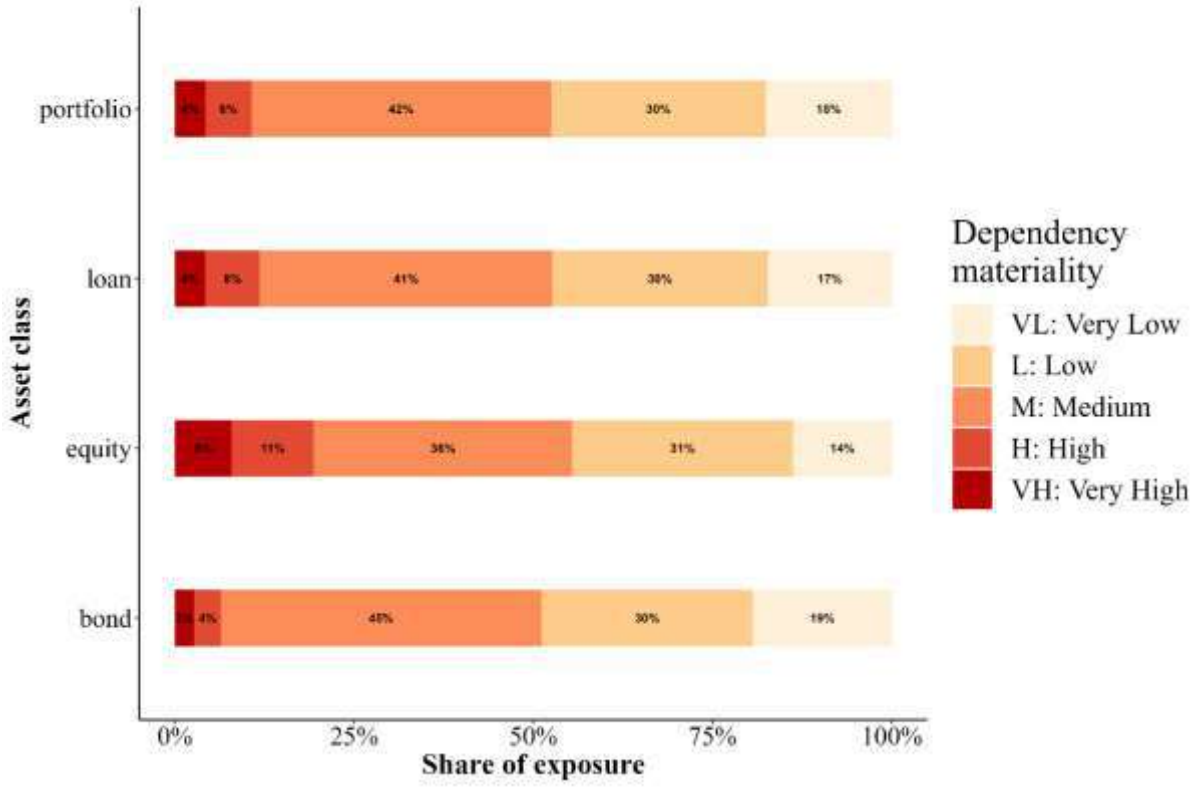

Figure 5: Percentage of the total portfolio value (the financial exposures of UK banks and insurers, excluding Section K) associated with each materiality category, showing the range of strengths of dependencies on nature in the portfolio.

Top 10 sectors that are most materially dependent on nature

Using the ENCORE knowledge base and the financial exposure data, it was possible to identify the top 10 NACE Divisions that are most materially dependent upon nature (combining the dependency rating and the financial exposure) in the UK's financial investment portfolio. This can be seen in Table 1.

This ranking is created by summing a normalized dependency score[7] for each NACE Division and the normalized financial exposure to the Division for UK banks and insurers. There were very disproportionate amounts of exposure invested across NACE Divisions, with very large amounts of exposure invested into very few Divisions. This skewed the overall material dependency scores. Therefore, to reduce the effect of large investments, financial exposure values were log-transformed. These can be seen in Table 1, and a full methodology is found in Annex 3A. We discuss the top three Divisions in further detail below.

⚠ **Decision made:** Dependency rating was normalized with the log-transformed, normalized financial exposure to create an overall material dependency score. This sum was used, and not a multiplication, to avoid further skewing the nature dependency score with large discrepancies in financial value.

[7] In short, the normalization process assigns a value of 0 to the lowest dependency score and a value of 1 to the highest dependency score. The same process is applied to the financial exposure values, with 0 representing the lowest and 1 representing the high exposure score. More detail on this process is provided in Annex 3A.

Table 1: Top 10 NACE Divisions with the highest material dependency scores, considering the ecosystem service dependency materiality ratings and the financial value associated with each Division. Normalized values range between 1 and 0, which indicate the highest and the lowest value observed respectively. The overall score equates the sum of the dependency rating and financial exposure for a given NACE Division. Section K is excluded here again.

NACE Division		Dependency rating (normalized)	Financial exposure (normalized)	Overall materiality score
D35	Electricity, gas, steam and air conditioning supply	0.459	0.722	1.181
A01	Crop and animal production, hunting and related service activities	0.838	0.260	1.099
O84	Public administration and defence; compulsory social security	0.040	1.000	1.041
C20	Manufacture of chemicals and chemical products	0.393	0.617	1.010
A02	Forestry and logging	1.000	0.000	1.000
C24	Manufacture of basic metals	0.286	0.565	0.851
L68	Real estate activities	0.065	0.747	0.812
A03	Fishing and aquaculture	0.795	0.007	0.802
C26	Manufacture of computer, electronic and optical products	0.117	0.680	0.797
C28	Manufacture of machinery and equipment n.e.c.	0.143	0.619	0.763

NACE Division D35 (*Electricity, gas, steam and air conditioning supply*) is the Division with the highest material dependency score within the UK's financial investment portfolio, when considering both the combined dependency rating and financial exposure. The *Electricity, gas, steam and air conditioning supply* Division corresponds to 12 production processes within ENCORE[8], and is dependent on 14 ecosystem services, six with a Very High dependency rating (*Flood and storm protection*, *Climate regulation*, *Surface water*, *Water flow maintenance*, *Fibres and other materials*, and *Ground water*[9]).

The dependencies of the *Electricity, gas, steam and air conditioning supply* Division (D35) are a good example of how many of the key services upon which the country relies to maintain a well-functioning economy are – in multiple ways – dependent upon the natural world, despite not necessarily being primary sectors. Ecosystems provide many services that are taken for granted, such as storm protection and regular water provisioning, which would cause large disruptions to the economy if lost or disrupted.

[8] These production processes are: *Electric/nuclear power transmission and distribution*, *Hydropower production*, *Gas distribution*, *Infrastructure holdings*, *Nuclear and thermal power stations*, *Biomass energy production*, *Geothermal energy production*, *Oil and gas exploration surveys*, *Water services* (e.g. waste water, treatment and distribution), *Solar energy provision*, *Wind energy provision* and *Gas retail*.

[9] *Surface water* and *Ground water* are provisioning ecosystem services. While surface and ground water would be available in the absence of a stable, functioning ecosystem, the regulation of their quantity and quality are important ecosystem services.

NACE Division A01 (*Crop and animal production, hunting and related service activities*) is the Division with the second highest material dependency score, when considering both the combined dependency rating and financial exposure. This Division corresponds to 10 ENCORE production processes[10], and has a Very High dependency on 15 ecosystem services. However, there is relatively low financial exposure to this Division in the financial dataset. A01 (*Crop and animal production, hunting and related service activities*) can be considered a primary economic sector. Therefore, it is not surprising to find such a high dependency on nature. While this NACE Division has a relatively low financial exposure, the risks associated with losing related ecosystem services should not be underestimated, due to the large societal impacts of such losses. A01 (*Crop and animal production, hunting and related service activities*) underpins the food system, which is fundamental to a well-functioning economy.

The NACE Division with the third highest material dependency score is O84 (*Public administration and defence; compulsory social security*). This Division has the highest financial exposure (after the removal of Section K (*Financial and insurance activities*)), and due to the financial exposure in Table 1 being logged and normalized, it is represented by a value of 1. O84 (*Public administration and defence; compulsory social security*) is dependent on 12 ecosystem services, with an equal potential dependency on *Flood and storm protection, Ground water, Surface water, Water flow maintenance* and *Mediation of sensory impacts*. The ENCORE production process *Manufacture of machinery, parts and equipment* has a Medium potential material dependency on each ecosystem service and a high financial exposure to the ecosystem service from bonds.

Ecosystem services upon which the UK's portfolio of financial investments is most dependent

After identifying the top 10 NACE Divisions with the highest material dependency scores, a closer look was given to each ecosystem service that these sectors are most dependent on. Financial exposure was left aside in this part of the analysis in favour of just focusing on the nature dependency ratings derived from ENCORE. A full methodology can be found in Annex 3B.

Table 2 shows the ranked dependency of each NACE Division on the ecosystem services on which it is dependent. This was calculated by summing the dependency ratings across all processes within each Division, and then converting this figure into a ranking for each Division. A ranking was used here as ENCORE's qualitative dependency scores (VL to VH) for processes within each sector are not designed to be compared directly between sectors. By ranking, it was possible to compare the relative importance of the ecosystem services to each Division. In each column, a value of 1 represents the ecosystem service upon which the NACE Division is most dependent (i.e. it has the highest dependency rating).

[10] These production processes are: *Aquaculture*, *Freshwater wild-caught fish*, *Large-scale or small-scale irrigated or rainfed arable crops*, *Large-scale or small-scale livestock (beef and dairy)*, *Saltwater wild-caught fish* and *Processed food and drink production*.

Table 2: Ranked dependency of each top 10 NACE Division on each ecosystem service. Full methodology can be found in Annex 3B.

Ecosystem Service	NACE Division										
	Forestry and logging	Crop and animal production, hunting and related service activities	Fishing and aquaculture	Electricity, gas, steam and air conditioning supply	Manufacture of chemicals and chemical products	Manufacture of basic metals	Manufacture of machinery and equipment n.e.c.	Manufacture of computer, electronic and optical products	Real estate activities	Public administration and defence; compulsory social security	**Average of Ranks**
Surface water	1	1	1	4	1	1	1	1	1	2	1.4
Flood and storm protection	3	3	4	1	2		1		4	2	2.5
Mass stabilization and erosion control	4	5	6	2	3	4	3		3	1	3.4
Climate regulation	2	4	2	3	7	3	4	4		4	3.7
Water flow maintenance	5	5	7	5	5	2	1			2	4.0
Ground water	8	9	9	6	1	1	1	1	2	2	4.0
Water quality	9	2	3	7	6		2			3	4.6
Disease control	6	7	6								6.3
Soil quality	6	5	5	11							6.8
Dilution by atmosphere and ecosystems	14	10	9		8		2	2		3	6.9
Bio-remediation	12	10	9	9	9		5	5	3	3	7.2
Filtration	13	11	10	8	8		4	4	4	4	7.3
Fibres and other materials	7	8	8	10	10			3			7.7
Pest control	6	7	6	12							7.8
Buffering and attenuation of mass flows	10	6	5	12							8.3
Mediation of sensory impacts	18	17	14	12	4		1		3	2	8.9
Ventilation	16	14	11		9		4			4	9.7
Pollination	11	13	10								11.3
Genetic materials	14	12	9		11						11.5
Animal-based energy	15	16	13								14.7
Maintain nursery habitats	17	15	12								14.7

Table 2 reveals how dependencies on ecosystem services vary considerably between the top 10 Divisions. **The provision of *Surface water* is the most critical ecosystem service for 8 of the 10 top Divisions. *Flood and storm protection*[11] is the second most critical, and this service is particularly**

[11] Flood and storm protection is provided by the sheltering, buffering and attenuating effects of natural and planted vegetation.

important for the *Electricity, gas, steam and air conditioning supply* Division (D35) due to the risk of the various processes involved in power production and transmission being undermined by storm and flood damage. *Flood and storm protection* is also the most important ecosystem service for the *Manufacture of machinery and equipment n.e.c.* Division (C28) due to the Medium-rated dependency on the process *Manufacture of machinery, parts and equipment* on the *Flood and storm protection*. *Mass stabilization and erosion control* is the third most critical ecosystem service in Table 2, and is relied upon by all but one of the top 10 Divisions.

Table 2 also clearly shows that not all Divisions are dependent on all ecosystem services. For example, while *Forestry and Logging* (A2) has a potential dependence on all 21 ecosystem services, *Manufacture of basic metals* (C24) is only dependent on four ecosystem services. This is important to note as it means that the loss of certain ecosystem services will affect some industries more than others.

Comparing these findings to the wider literature reveals that strategic investment in the protection of ecosystem services has long term benefits to the economy. *Surface water* and *Ground water* provision are ecosystem services that are vital to water provisioning within the UK, for both homes and businesses. The ONS (Office for National Statistics (ONS) 2023) estimated the value of their equivalent 'water abstraction' ecosystem service to the UK at £5.4 billion in 2021 prices. Increasing pressure on water provisioning is already being seen in the UK, with rainfall patterns becoming increasingly unreliable. The Environment Agency says 'projections show that, by 2050, some rivers could have between 50 and 80 percent less water during the summer' (Environment Agency 2022), and already in February of this year (2023), a number of record-breaking low flows were recorded in rivers across the UK (Horton 2023). Plans are being considered for a large new pipeline to redirect water from Powys in Wales to the Thames basin in England to help the South East cope with increasingly likely drought conditions (Forgrave 2023). Averting stresses in water provisioning systems, if ecosystem services are lost, will not only cost the government and associated agencies, but also the many businesses that depend upon water to function.

The ONS does not yet calculate a natural capital monetary estimate for benefits of flood protection from natural resources in the UK, but some relevant estimates from the literature are as follows:

- Fitch *et al.* (2022) estimate that, in the absence of vegetation providing flood protection ecosystem services in the UK, 'an extra 8.5 billion m^3 (10-year average) of water would have travelled downstream into flood risk zones each year'. By their calculations, flood protection from vegetation provides annualized value of £4 billion per year (2021 prices) to the UK.
- Swinton Insurance (Swinton Insurance n.d.) reports a 320% increase in major UK storms from the years 2010-2014 (10 storms) to 2015-2020 (42 storms), and put the total costs of damage to the UK in the last 10 years at £4.8 billion.

Not all of this flood and storm damage can be alleviated by more robust 'green infrastructure'. However, as storm intensities are expected to continue to grow as the climate warms, investments need to be made in protecting ecosystems that provide free flood and storm protection rather than allowing them to decline.

Mass stabilization and erosion control is the third most critical ecosystem service in Table 2, and has the highest material dependency in Figures 3 and 4. This is an ecosystem service, primarily provided by vegetation and soil, which reduces the potential for landslides, subsidence and sedimentation of water bodies. While many sectors are dependent on this service, the likelihood of it disappearing as a service could be considered lower than some others. However, there are already examples of where

the subsidence of private properties, in quite large areas, has become more likely due to climate change impacting this ecosystem service. For example, the British Geological Survey (2022) state "Shrink–swell ground movement, typically reported as subsidence, is one of the most damaging geohazards in Britain today, costing the economy an estimated £3 billion over the past decade." London's clay soils are particularly prone to this risk, with "nearly half of the capital's homes at increased risk in 2030 and 57% in 2070" (Carrington 2021).

Adding a spatial dimension using EXIOBASE

The analysis discussed so far has been conducted in an entirely spatially agnostic manner. Nature dependency ratings derived from the ENCORE knowledge base were applied across the financial exposures for UK banks and insurers with no reference to the physical location of the assets that these financial exposures are associated with. While this was a useful screening exercise to identify key Divisions that are particularly dependent on nature, it was also important to take a step further and look to locate these nature dependencies spatially. This helps to start estimating associated risks – i.e. the potential loss of ecosystem services upon which different sectors are reliant. This is what is done in the second half of the analysis.

One way to add a spatial proxy to this analysis is by looking at data from the Office for National Statistics (ONS) on where investments from the UK are held overseas. This is available in the form of the Foreign Direct Investment dataset from the ONS[12]. Another complementary method is to use multi-regional input-output models (MRIOs)[13] to look at which upstream sectors contribute to the financial exposure of sectors within the UK's financial investment portfolio. With help from the Stockholm Environment Institute at York (SEI York), it was possible to bring these two elements together.

Section K (*Financial and insurance activities*) is included in this second part of the analysis, as it is possible to look to upstream indirect dependencies. This Section had to be removed from the first part of the analysis due to the difficulties in assessing direct dependencies on nature from the financial sector. This is likely to mean that dependencies on nature in the first part of the analysis were underestimated, due to this large portion of financial assets being set aside.

Identifying overseas upstream exposures of key sectors

MRIO experts from SEI York helped to approximate a spatial upstream distribution of financial exposures from the financial dataset. This upstream exposure refers to where there are financial links from the sector in question from the financial dataset (e.g. agriculture) to another sector upon which it is reliant for inputs (e.g. manufacturing of agricultural machinery).

SEI York first estimated regionally and sectorally disaggregated financial exposures by combining the Bank of England dataset with the ONS Foreign Direct Investment data. An assumption was made here that 87.5% of the UK exposures are held in the UK, and the remaining 12.5% is held overseas. This was

[12] 'Foreign direct investment involving UK companies (directional): outward'. This dataset shows the flows of investment directed to other countries from the UK, by sector.

[13] Multi-regional input-output models, or MRIOs, are used to track financial flows between countries' major economic sectors. They are large matrices that can be used to track back upstream dependencies in a supply chain, even across many countries and steps. The EXIOBASE MRIO was used by Svartzman *et al*. 2021 in the Banque de France analysis, along with other tools, to identify the value of output produced by each sector in each region, and the value chains associated with each production sector in each region.

an informed estimate based on two data sources[14], which was necessary to make given the lack of spatially explicit information in the primary dataset.

SEI York then ran this disaggregated input data (financial exposures by sector and region) through the EXIOBASE MRIO (Stadler *et al.* 2018) to provide an estimate of where financial exposures lie in the sectors upstream of those in the data published by the Bank of England. A simplified methodology is seen in Figure 6 below and is detailed further in Annex 3C.

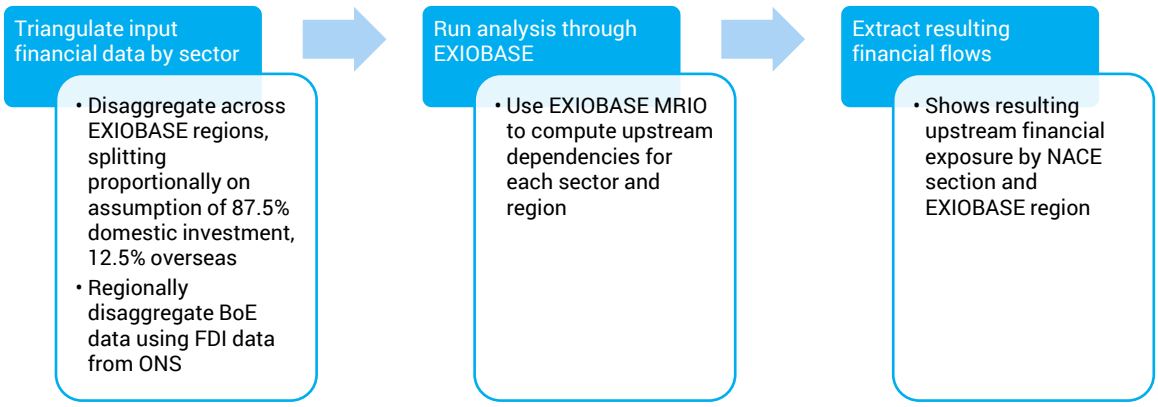

Figure 6: Simplified methodology for assessing upstream financial exposures from the Bank of England dataset, using EXIOBASE. Full methodology can be found in Annex 3C.

⚠ **Assumption made:** The input data for EXIOBASE needs to show financial exposures by sector and region. However, the dataset used here only reveals which NACE Sections UK banks and insurers have exposure to, and not where the investments are actually held. To estimate where the financial exposure is by sector and region, two assumptions had to be made:

1. The BoE exposure data was split on the basis that 87.5% of the investment was held domestically, and the remaining 12.5% overseas.
2. The distribution of that 12.5% overseas element was assumed to be split across sectors in the same proportions as found in the ONS Foreign Direct Investment dataset.

Improvement that the Bank of England could make: Greater access to data regarding financial exposure by sector and region would ensure a more accurate analysis using an MRIO like EXIOBASE of upstream financial exposures.

The total exposure within the results from the SEI York analysis is £5.8 trillion. However, the total exposure of UK banks and insurers from the Bank of England dataset is £3.8 trillion. This discrepancy

[14] This estimate is based on two data sources. The level of investment in the UK, recorded as gross domestic fixed capital formation in GDP calculated through the expenditure approach (https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/grossfixedcapitalformationbysectorandasset) and data on Foreign Direct Investment, both into and from within the UK (https://commonslibrary.parliament.uk/research-briefings/cbp-8534/). Subtracting the flow of investment from outside the UK from the amount of investment in the UK (as recorded in GDP statistics) gives a proxy of investment in the UK from within the UK, data on foreign investment from within the UK gives a proxy of the level of investment the UK as a whole directs overseas. Both data sets were looked at for 2021, the same year as the data for bonds, loans and equities. Therefore assuming these financial assets follow a similar pattern to the investments recorded in GDP and FDI data, we can approximate the share of investment that will be domestic and international.

in totals is a function of how MRIOs work and is not an error. It should be noted that MRIOs are based on the financial flows that connect sectors and regions in the production of goods and services, so while the connections and dependencies recorded are correct, the value of connected assets has to be estimated. Using the relationships in EXIOBASE it is estimated that **the £3.8 trillion in assets from UK banks and insurers are dependent on a wider set of assets through supply chains, which may represent approximately £5.8 trillion of assets**. This assumes that the wider set of assets that are relied upon through supply chains have a value that is proportionate to the inputs required in production processes. Further explanation of this can be found in Annex 3C.

Next, the upstream financial exposures for key NACE Divisions are visualized. This gives an indication of where overseas dependencies are for these Divisions, and therefore where in the overseas value chain UK sectors are exposed to the loss of nature and associated ecosystem services. Here, the UK has been excluded from the visualisations, as the financial split of domestic vs. overseas spending was set at 87.5 vs. 12.5% respectively, and so the split in exposure between the UK and overseas is not a finding *per se*. In the figures below, the focus is on the differences in financial exposures of the UK in different overseas regions.

In Figure 7 below, it can be seen that **for Division D35 (*Electricity, gas steam and air conditioning supply*), the UK has particularly strong financial exposures in France, Germany, Spain, the United States and China - mainly arising from loans**.

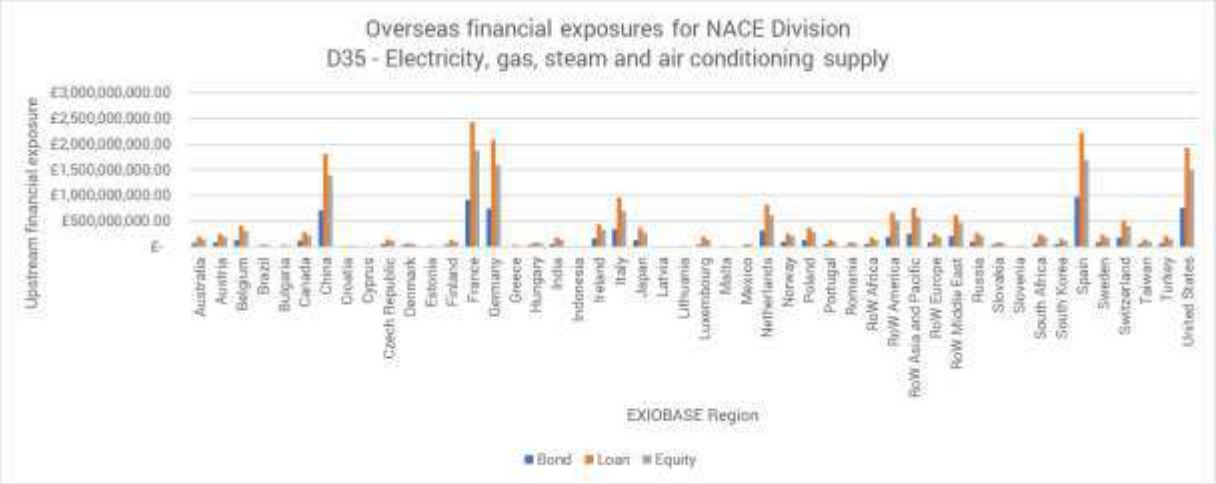

Figure 7: Overseas financial exposures, by EXIOBASE region, for NACE Division D35, where the UK has been excluded.

This exercise was repeated for the second of the top 10 Divisions, A01 *(Crop and animal production, hunting and related service activities*), which can be seen in Figure 8 below. Interestingly, **the overseas financial exposure distribution was strikingly different for this Division (A01 *Crop and animal production, hunting and related service activities*). China and the United States still come out highly (but not France, Germany or Spain), but so do some 'rest of world' EXIOBASE regions, particularly *RoW Asia and Pacific*, *RoW Africa* and *RoW Middle East***. These regions are groupings of countries. It can be assumed that they would come out more highly than individual countries, but the difference with Division D35 (*Electricity, gas steam and air conditioning supply*) was still clear.

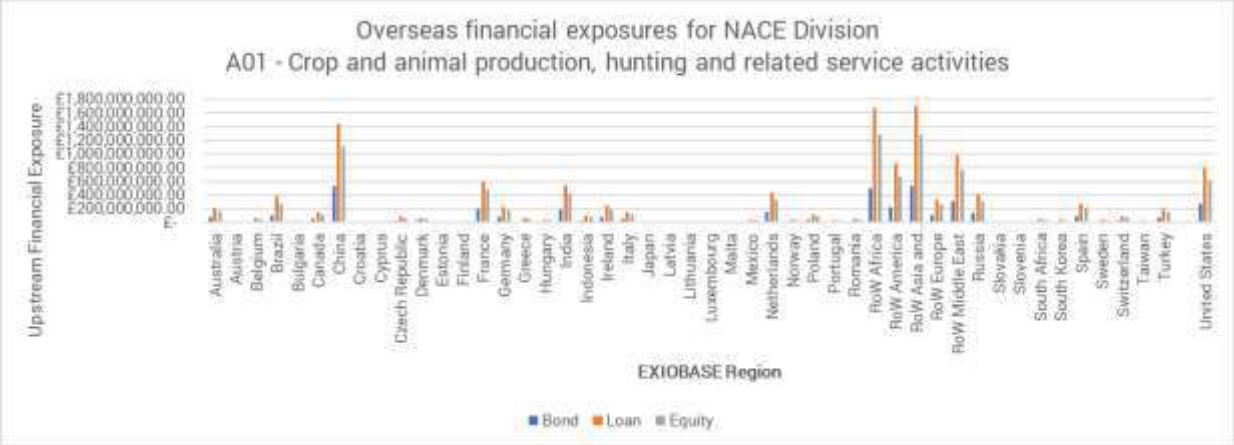

Figure 8: Overseas financial exposures, by EXIOBASE region, for NACE Division A01, where the UK has been excluded.

Consolidating upstream financial exposure with nature dependency

The upstream financial exposures from the SEI York data (by EXIOBASE region and NACE Division) were combined with the nature dependency ratings from the ENCORE knowledge base. From this, the **upstream financial exposures associated with NACE Divisions with a High or Very High dependency on nature were calculated. This came to £3.2 trillion, or 56% of the total upstream exposure**. This shows that, while 10% of the UK's first order (direct) dependencies from the ENCORE knowledge base are very highly dependent on nature (excluding Section K, as seen in Figure 5), a much larger proportion is highly or very highly dependent on nature within the sectors that supply the UK's financial investment portfolio.

Next, this combined data (upstream financial exposure and nature dependency) was visualized in a Sankey diagram, as was done previously for the primary dataset.

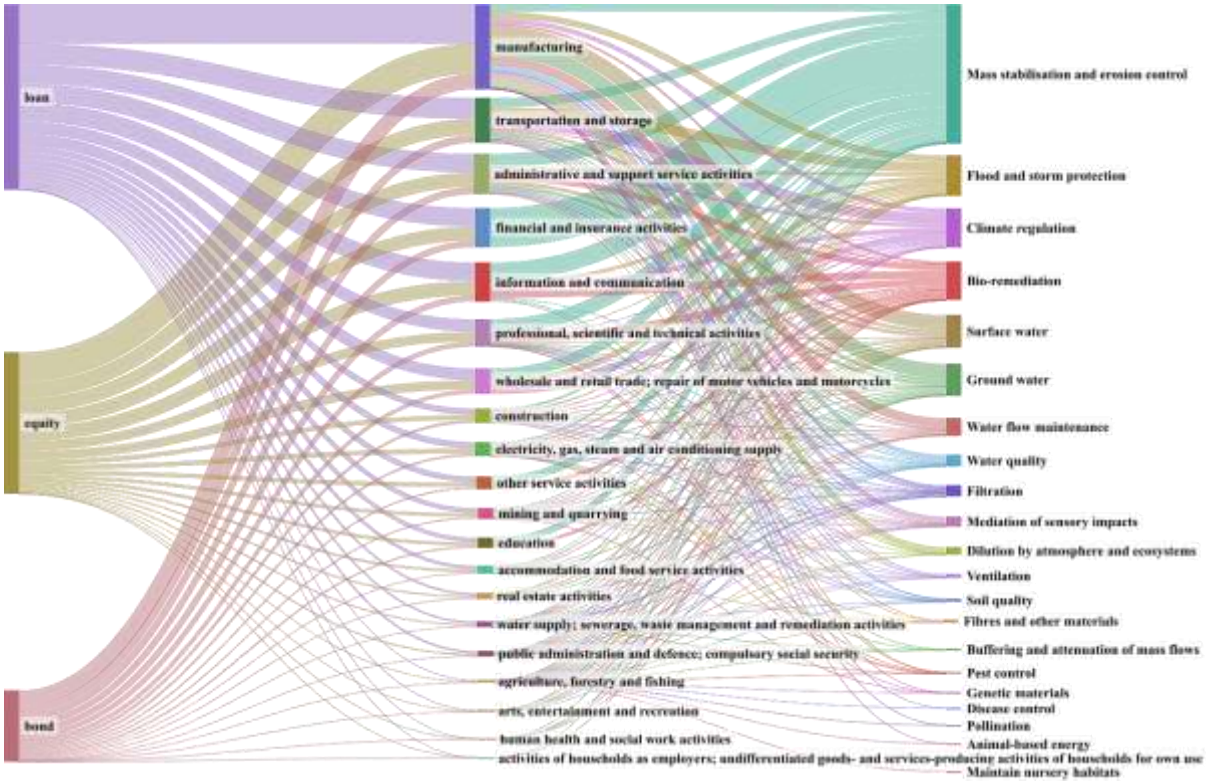

Figure 9: Sankey diagram based on the upstream financial exposure data calculated by SEI York, including Section K, showing the NACE Sections (centre) on which the UK banks' and insurers' exposures depend upstream in the value chain, and the ecosystem services (right) upon which those NACE Sections themselves depend upon. The left-hand flows represent financial flows from the three asset classes (loans, bonds and equities) to NACE Sections. The right-hand flows show the dependence on ecosystem services, weighted by financial flows.

Comparing Figure 9 above to Figure 3, reveals some interesting differences. Figure 3 uses the dataset of UK banks' and insurers' direct exposures (including Section K) and shows the direct dependencies calculated from ENCORE between these financial exposures and ecosystem services. Figure 9, by comparison, shows upstream financial exposures as calculated by SEI York using EXIOBASE (also including Section K). This means that it shows exposure of UK banks and insurers not to the NACE Sections in which they are directly invested, but the NACE Sections that supply those Sections to which UK banks and insurers are directly exposed. This is calculated using the sector relationships in the EXIOBASE MRIO and makes it possible to get a better idea of where second and third order dependencies on nature may lie within the value chain.

In Figure 9, looking upstream, *Manufacturing* (NACE Section C) represents the Section with the highest financial exposure, followed by *Transportation and storage* (NACE Section H). *Financial and insurance activities* (NACE Section K) and *Public administration and defence* (NACE Section O), the two Sections with the highest financial exposure in Figure 4 (using direct exposures of banks and insurers) represent a much smaller financial exposure in the upstream Sankey. This is likely due to their reliance on other sectors for inputs (e.g., manufacturing of office supplies).

When comparing Figure 9 with Figure 3, we can see that the *Mass stabilization and erosion control* ecosystem service still comes out as the most depended upon ecosystem service. However, the importance of the provision of *Surface water* and *Ground water* drops between Figure 3 and Figure 9 (from second to fifth most material ecosystem service for the former and from third to sixth most material for the latter). *Flood and storm protection* (fourth to second) and *Climate regulation* (eighth to

third) increase in importance. This further underlines **that there is no one ecosystem service that is the most important for the UK financial investment portfolio, but rather a collection of key ecosystem services**.

This exercise shows the importance of considering the relationships within value chains when considering dependencies on nature. Looking just at the direct dependencies of the immediate sector is the most straightforward way to start to assess dependencies, but this leaves out the ecosystem services from other sectors that are needed to support inputs to the sector in question. For example, by considering just the nature dependencies of the agriculture sector, the importance of ecosystem services that underpin the manufacturing of the equipment needed to sow and harvest crops would not be taken into account.

Assessing the state of nature

The analysis run by SEI York, using EXIOBASE, reveals where upstream financial exposures of the UK's financial investment portfolio are, by NACE Division and EXIOBASE region (geographical spread at the country or region level). This can then be matched with the ENCORE nature dependency ratings for each NACE Division. However, to discuss the potential *risk* associated with these dependencies, it is important to assess the state of nature in these regions.

As a proxy for the state of nature, the Hotspots of Natural Capital Depletion Layers, developed by UNEP-WCMC (UNEP-WCMC 2021) were used, specifically the combined terrestrial layer for natural capital depletion. This layer assesses how fast natural capital is being depleted globally. Within this data layer, four different elements of natural capital depletion were assessed: atmosphere, water, soil and sediments, and biodiversity[15]. Hotspots of depletion are defined as areas within the top 20% of relative depletion values for natural capital assets globally. Where multiple different hotspots overlap, the risk of ecosystem services being disrupted increases and a wider range of business activities will be affected.

The percentage of each country that is exposed to one or more, two or more, three or more, or all four depletion hotspots was calculated. Due to time constraints, only terrestrial natural capital was considered; future analysis should include marine elements so that the blue economy is not forgotten. In an ideal world, the state of nature relating to the location of the actual assets would have been assessed. However, as it was only possible to calculate financial exposure to a country level, the analysis for the state of nature was also limited to a national level.

75% of the United Kingdom is covered by at least one hotspot of natural capital depletion, and 25% is covered by two or more hotspots of natural capital depletion[16]. This is due to high depletion rates for biodiversity and soil and sediments in the UK. This indicates that the state of natural capital in much of the UK is depleting fast. As such, future provisioning of ecosystem services is at risk.

Given that the ONS estimate the total annual value of ecosystem services (limited to only those ecosystem services that they were able to value) in England alone at £35.7 billion in 2020, this fast rate of depletion of natural capital should be a cause for concern (ONS 2023). Without keeping natural capital assets intact, it is not possible to rely on the ecosystem services that these assets currently provide.

[15] More information on calculation of these layers can be found in the briefing note for the Hotspots of Natural Capital Depletion dataset, at https://s3.eu-west-2.amazonaws.com/ncfa.documents/resources/hotspots_methodology.pdf
[16] This can be further explored in an interactive map available at: https://encore.naturalcapital.finance/en/map?view=hotspots

The UK is not alone in these fast-depleting rates of natural capital – 101 countries have >75% of their land area covered by one or more hotspots of natural capital depletion, and 100 countries have >25% of their land area covered by 2 or more hotspots of depletion. Policymakers and financiers globally should be concerned by the potential loss of ecosystem services going forward if natural capital continues to decline.

⚠ **Assumption made:** It is not known where in the UK financial exposure is distributed, nor where in the UK different sectors are more strongly represented. Therefore, a high level statement about the rate of natural capital depletion across the UK as a whole had to be made. Only terrestrial natural capital was considered, not marine.

Improvement that the Bank of England could make: With data on where financial exposure in different sectors is physically situated across the UK, the Bank of England could make a more accurate assessment of nature risks. Focusing on sectors that have a High or Very High dependence on nature to begin with and assessing the state of nature in geographies in which these key sectors are clustered is recommended. Additionally, including marine natural capital in future analyses would ensure that the blue economy is fully considered.

Overlaying dependencies and exposure with hotspots of depletion

Finally, to look at risk that is introduced into exposures of UK banks and insurers from overseas dependencies, all the data generated in this analysis were combined. The depletion of natural capital hotspots data (aligned to EXIOBASE regions) was combined with ENCORE dependency ratings by NACE Division, and the upstream financial exposure (by EXIOBASE region) calculated by SEI York, as seen in Figure 10.

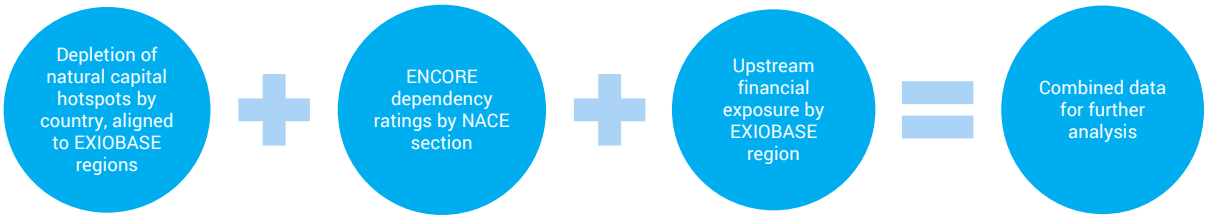

Figure 10: Combining three key pieces of analysis allows us to discuss risk arising from investments overseas from sectors that are highly dependent on nature and that are situated in regions where nature is fast depleting.

This spreadsheet was then interpreted to assess the financial exposure associated with NACE Divisions with a High or Very High dependency on nature in areas of the world that have a fast rate of natural capital depletion[17]. This reveals that **£2.5 trillion or 44%[18] of the portfolio is at risk in this manner.** This co-location of high nature dependency and high rates of natural capital depletion puts this 44% of the upstream economic activity at particular risk, as the degradation of natural capital is highly likely to lead to the loss of ecosystem services on which that economic activity depends.

<u>High nature depletion in 'Rest of World' regions</u>

[17] We set this boundary as any EXIOBASE region (excluding 'Rest of World' regions) which had >10% of land classified as covered by 2 or more hotspots of natural capital depletion.
[18] Proportional to the total exposure in the upstream financial exposure database calculated by SEI York, £5.8 trillion. For further details on why this figure is larger than the total exposure from the Bank of England dataset (£3.8 trillion), please see Annex 3C.

EXIOBASE regions are a mix of individual countries and 'Rest of World' regions (*RoW Asia and Pacific*, *RoW America*, *RoW Europe*, *RoW Africa*, and *RoW Middle East*). EXIOBASE does not provide the upstream financial exposure data at the country level for the countries within these 'rest of world' groupings, and therefore it was impossible to properly include these countries in this combined analysis.

However, it should be noted that **all of the countries with more than 10% of their land area covered by all four hotspots of natural capital depletion fall into these 'Rest of World' groupings**, as seen in Table 3. Further, nine of the top ten most depleted countries from the natural capital depletion hotspots analysis fall into 'rest of world' regions – with India being the exception. Particular care should be taken for further analysis that considers these highly nature-depleted countries. The widespread and high rates of nature depletion in these countries is likely already leading to disruption in ecosystem service provision.

Table 2: Top 10 countries with the greatest area of hotspots of natural capital depletion, with corresponding EXIOBASE Region.

EXIOBASE region		Country	% of land area covered by X hotspots of natural capital depletion			
			X ≥ 1	X ≥ 2	X ≥ 3	X ≥ 4
48	RoW Africa	Burundi	100.0%	97.1%	62.9%	**31.4%**
45	RoW Asia and Pacific	Pakistan	95.0%	63.4%	41.6%	**17.0%**
48	RoW Africa	Uganda	94.2%	74.6%	44.7%	**16.1%**
45	RoW Asia and Pacific	Nepal	100.0%	83.8%	39.5%	**13.0%**
48	RoW Africa	Nigeria	99.1%	87.1%	44.7%	**10.1%**
48	RoW Africa	Rwanda	100.0%	97.2%	47.2%	8.3%
35	India	India	98.7%	84.2%	42.0%	7.5%
48	RoW Africa	Ethiopia	92.9%	66.1%	32.3%	7.1%
48	RoW Africa	Kenya	98.0%	54.2%	23.9%	6.2%
48	RoW Africa	Tanzania	97.8%	62.5%	27.5%	5.5%
45	RoW Asia and Pacific	Bangladesh	98.8%	91.3%	59.9%	5.2%

Recommendations

There are obvious material dependencies upon nature found throughout the UK's financial investment portfolio. The ecosystem services that natural capital assets provide have, so far, not been costed into balance sheets, and this means they are often overlooked. However, **at least 10% of the UK's portfolio of bonds, equities and loans is directly Very Highly or Highly dependent on nature and its services, and £2.5 trillion or 44% of upstream financial exposures are associated with NACE Divisions with a High or Very High dependency on nature and areas of the world with a fast rate of natural capital depletion – exposing this 44% to considerable potential nature-related risk.**

This should be a wake-up call for financial institutions and policy makers to take steps to more fully understand the UK economy's dependencies on the natural world and the risks arising from these. We suggest tailored recommendations for action for three key audiences, below.

Recommendations for the Bank of England

We strongly recommend that the Bank of England's teams **take the analysis steps that we have laid out here as a starting point for a deeper investigation**. Throughout the report we have highlighted (in blue boxes) where we have had to make assumptions in order to move this analysis forward. We also point out where the Bank of England might have the potential to **further develop this analysis with more refined data**. In particular, there are two key elements of this analysis where better data would make for more actionable results:

- Greater granularity on the **exposures within NACE Section K** (*Financial and Insurance Activities*), including what onward sectors those investments will affect. Without this, it is very hard to accurately discuss the nature dependencies arising from the Financials sector, which represents a very large proportion of exposure for UK banks and insurers.
- **Spatial data on where investments are located**, both within the UK and overseas, would help make this analysis much more actionable.

Additionally, we recommend that the Bank of England **conduct an ENCORE-based analysis to identify where nature-related impacts lie within the UK's financial investment portfolio**. Dependencies (as discussed here) are just one side of the coin. It is also important to understand how the UK financial sector leads to negative impacts on nature. It is particularly important to identify sectors that have both a high dependency on nature, but also a high impact on nature, as these sectors could be undermining the ecosystem services on which they, and others, depend.

Finally, we recommend that the Bank of England **address the twin risks of climate change and nature loss as the interlinked crises that they are**. As Kedward *et al.* (2022) state, "Neglecting their interconnections […] may lead to 'blind spots' and misestimations of systemic financial risk, potentially undermining progress on both climate finance policy and emerging policy on biodiversity-related financial risks (BRFR)." The bank should take a joined-up approach when addressing nature and climate risks, and ensure that proposed solutions to address one crisis do not exacerbate the other.

Recommendations for national policy makers

Given the striking dependencies within the UK's financial investment portfolio on nature, **we strongly recommend that national policy makers take steps to protect and restore nature. They must also push financial institutions to understand and disclose their nature-related dependencies and impacts**.

Following the historic agreement on the Kunming-Montreal Global Biodiversity Framework in Montreal in December 2022, 196 countries have a written commitment to step up action on biodiversity. Among many others, these national governments have committed to close the current biodiversity finance gap – estimated at US$ 700 billion per year – and to align financial flows with the Kunming-Montreal Global Biodiversity Framework.

The UK Government should ensure that there are viable plans in place to align with the Kunming-Montreal Global Biodiversity Framework within the UK, and there are two Targets that are particularly pertinent here:

- Target 11: *'Restore, maintain and enhance nature's contributions to people, including ecosystem functions and services, such as regulation of air, water, and climate, soil health, pollination and reduction of disease risk, as well as protection from natural hazards and disasters, through nature-based solutions and ecosystem-based approaches for the benefit of all people and nature'.*
- Target 15: *'Take legal, administrative or policy measures to encourage and enable business, and in particular to ensure that large and transnational companies and financial institutions: (a) Regularly monitor, assess, and transparently disclose their risks, dependencies and impacts on biodiversity…'.*

To align with Target 15, **we recommend that reporting in line with the Taskforce on Nature-related Financial Disclosures (TNFD) is made mandatory** for large businesses and financial institutions. A key element of the LEAP (Locate, Evaluate, Assess, Prepare) approach within TNFD is the Locate phase, where businesses are encouraged to identify where key assets are situated in their portfolio or supply chain. These data are currently often missing but are vital for evaluating a business' dependencies and impacts on nature. By introducing a legal requirement to disclose against TNFD, policy makers can ensure a level playing field for businesses. This will help ensure that good actors who would have disclosed against TNFD regardless are not put at a financial disadvantage against competitors who would not have volunteered to invest in this process.

Additionally, **government-led data sharing initiatives may be required to facilitate the sharing of location data up and down a value chain**, given concerns over privacy. We recommend that policy makers investigate this further and discuss with business and financial institutions within key supply chains what would be required to facilitate secure and controlled location data sharing.

Finally, it should not be forgotten that the nature and climate crises are intertwined and mutually reinforcing (Pörtner *et al*. 2021). This is reflected in the UK government's The 10 Point Plan for financing biodiversity, which reflects both the need to increase finance for biodiversity (domestically and internationally) from all sources, and to ensure that synergies with climate finance are exploited. Recent independent assessments of the UK's progress towards meeting both climate (e.g., Climate Change Committee 2023) and biodiversity (e.g., House of Commons Environmental Audit Committee 2021) objectives has been slow. This means there are growing biophysical risks around the capacity of the natural environment to support current and future generations in the ways we are accustomed to that will have ramifications for economic and financial stability. As well as biophysical risks, litigation risks are growing e.g., there is an increasing trend for climate litigation where governments are held to account by citizens (United Nations Environment Programme 2023).

Recommendations for commercial banks and insurers

We recommend that commercial banks and insurers **assess their readiness to report in line with the Taskforce of Nature-related Financial Disclosure**. Banks and insurers should **invest in the necessary internal capacity** needed to collect and analyze the relevant data required to assess their nature-related dependencies, impacts, risks and opportunities.

Commercial banks and insurers should **follow the steps laid out in this report to run an initial screen of the nature dependencies within their portfolios using ENCORE and should also repeat the exercise to look at nature-related impacts**, as we discuss above for the Bank of England. Again, **collating location data on key assets and supply chains** will be critical for properly understanding nature risk. Without knowing the location of key assets, banks and insurers will be unable to assess the state of nature at relevant locations. This will render them blind to nature risk and the threats that it presents to those assets. Investees should be able to disclose on the location of their operations. If they are not able to do so, then pressure should be applied to ensure they reach this level of granularity.

Once key nature risks within the portfolio have been identified, banks and insurers should engage with investees to manage these risks. **Active engagement should be employed in order to support investees as they manage their own nature-related risks** and future proof their businesses.

If we do not take action to protect ecosystem services, we are at risk of losing them. Without action to protect and restore nature, we will face economic impacts. As Johnson *et al.* (2021) say, "Not acting is not an option: there are no winners under business-as-usual. Conventional economic models do not account for the declining trends in nature's services and thus provide an overly optimistic scenario of economic growth." Further, the cost of meeting our biodiversity protection and restoration goals doubles if we continue to delay action for another 10 years (Natural History Museum 2021).

Therefore, it is imperative that we act now to protect and restore nature. By acting we will continue to benefit from the ecosystem services that natural capital provides and prevent the threats to economic growth that inaction would present. Action now also ensures we avoid the need to spend more money on nature protection and restoration in the future, with a smaller benefit.

The protection and restoration of nature will ensure that the current ecosystem services, which we benefit from, continue to support businesses and enhance individuals' wellbeing, as well as mitigating risks from climate change. Climate change and nature loss should not be seen as siloed – and while these two crises threaten to spiral into a vicious circle, if we protect and restore nature we can reverse the current losses of biodiversity, protect ecosystem services, draw down carbon dioxide, and benefit from the many opportunities of a nature-based economy.

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Annexes

Annex 1 – Summary exposures from Bank of England dataset

This table provides a summarized view of the data contained in the dataset on UK Banks' and UK Insurers' Exposures by Asset Class and NACE Code in Q4-2021 (available here). NACE codes are listed verbatim in line with the official NACE Rev. 2 classification. Further details on NACE can be found here.

NACE2 Section	Bond	Equity	Loan	Total
A - Agriculture, Forestry and Fishing	£179,497,394.62	£1,034,522,706.13	£ -	**£1,214,020,100.75**
B - Mining and Quarrying	£5,331,017,922.34	£15,160,760,657.10	£4,261,434,620.66	**£24,753,213,200.10**
C - Manufacturing	£55,372,182,784.48	£209,881,371,328.90	£75,437,374,661.88	**£340,690,928,775.26**
D - Electricity, Gas, Steam and Air Conditioning Supply	£36,815,591,202.23	£14,599,351,896.33	£16,206,981,920.35	**£67,621,925,018.91**
E - Water Supply; Sewerage, Waste Management and Remediation Activities	£15,229,613,229.32	£2,589,398,588.89	£2,591,013,615.78	**£20,410,025,433.99**
F - Construction	£4,046,639,696.40	£8,685,031,870.14	£19,163,307,443.95	**£31,894,979,010.49**
G - Wholesale and Retail Trade; Repair Of Motor Vehicles And Motorcycles	£10,039,965,968.86	£35,318,686,314.25	£19,101,404,929.64	**£64,460,057,212.75**
H - Transportation and Storage	£35,311,115,238.37	£13,095,136,390.96	£7,327,702,624.74	**£55,733,954,254.07**
I - Accommodation and Food Service Activities	£2,457,251,786.76	£5,448,410,249.79	£962,311,772.16	**£8,867,973,808.71**
J - Information and Communication	£30,631,728,019.24	£73,869,326,208.60	£17,237,721,303.81	**£121,738,775,531.65**
K - Financial and Insurance Activities	£407,601,502,829.73	£1,088,578,946,866.45	£501,187,872,517.37	**£1,997,368,322,213.55**
L - Real Estate Activities	£35,985,525,024.50	£21,249,762,649.83	£27,405,422,060.89	**£84,640,709,735.22**
M - Professional, Scientific and Technical Activities	£2,583,587,350.52	£11,901,686,528.64	£4,597,628,361.82	**£19,082,902,240.98**
N - Administrative and Support Service Activities	£4,016,316,675.14	£5,295,391,172.91	£6,965,209,915.15	**£16,276,917,763.20**
O - Public Administration and Defence; Compulsory Social Security	£669,859,519,769.96	£181,667,292.16	£175,059,521,786.76	**£845,100,708,848.88**
P - Education	£7,053,573,371.27	£264,280,273.92	£384,464,981.25	**£7,702,318,626.44**
Q - Human Health and Social Work Activities	£7,173,706,431.24	£3,324,508,636.01	£463,403,750.83	**£10,961,618,818.08**
R - Arts, Entertainment and Recreation	£830,324,161.15	£2,281,806,389.04	£ -	**£3,112,130,550.19**

S - Other Service Activities	£2,597,841,668.30	£239,760,808.40	£8,598,789,793.46	**£11,436,392,270.16**
U - Activities of Extraterritorial Organisations and Bodies	£44,648,761,421.57	£ -	£8,378,293,934.44	**£53,027,055,356.01**
Total	**£1,377,765,261,946.00**	**£1,512,999,806,828.45**	**£895,329,859,994.94**	**£3,786,094,928,769.39**

Annex 2 – Ecosystem services in ENCORE

In ENCORE, ecosystem services are the links between nature and business. Each of these services represent a benefit that nature provides to enable or facilitate business production processes. 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 included in the first iteration of ENCORE as they were not considered to be direct inputs or to enable production processes. The CICES framework has been simplified as below for use in ENCORE:

Ecosystem Services listed in Encore	Explanation
Animal-based energy	Physical labour is provided by domesticated or commercial species, including oxen, horses, donkeys, goats and elephants. These can be grouped as draught animals, pack animals and mounts.
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.
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	Global climate regulation is 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.
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.
Disease control	Ecosystems play important roles in regulation of diseases for human populations as well as for wild and domesticated flora and fauna.
Fibres and other materials	Fibres and other materials from plants, algae and animals are directly used or processed for a variety of purposes. This includes wood, timber, and fibres which are not further processed, as well as material for production, such as cellulose, cotton, and dyes, and plant, animal and algal material for fodder and fertilizer use.
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.
Flood and storm protection	Flood and storm protection is provided by the sheltering, buffering and attenuating effects of natural and planted vegetation.
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.
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.

Mass stabilisation and erosion control	Mass stabilisation and erosion control is delivered through vegetation cover protected 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.
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.
Pest control	Pest control and invasive alien species management is 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 to pests.
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.
Surface water	Surface water is provided through freshwater resources from collected precipitation and water flow from natural sources.
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 circulation of water through the Earth's atmosphere, land, and oceans. The hydrological cycle is responsible for recharge of groundwater sources (i.e., aquifers) and maintenance of surface water flows.
Water quality	Water quality is 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.

Annex 3 – Full Methodology

A. ENCORE Analysis

The steps outlined below were used to conduct the first part of the dependencies analysis. Further detail on this process can be found in supplementary information that is available on request.

1. Use a crosswalk table to identify the GICS codes corresponding to the NACE coded economic activities in the Bank of England dataset (see notes below on method for resolving GICS and NACE data).
2. Use the GICS codes identified in step 1 to match all relevant sub-industries in ENCORE, and their associated dependencies and materiality ratings.
3. Map ENCORE's knowledge base on dependencies back with the Bank of England dataset.
4. Calculate, for each sub-industry *j*, the dependency score (i.e. the value invested) in ecosystem service *i* associated with process *p* using the following formulae:

$$Dependency\ Score_{jpi} = \frac{MRpi}{SMRj} \times ICj$$

$$SMRj = \sum_{p=1}^{np} \sum_{i=1}^{ni} MRpi$$

Where:

- *MRpi* = Materiality rating of ecosystem services *i* associated with process *p*
- *SMRj* = Sum of materiality ratings of all unique combinations - process/ecosystem service - found in sub-industry *j*
- *ICj* = Currency invested in the sub-industry *j*
- *np* and *ni* represent the number of processes in sub-industry *j*, and the number of ecosystem services associated with process *p*, respectively.

5. Identify percentage of portfolio value associated with each materiality category.
6. Present data in Sankey diagram format, to show the dependency score associated with each ecosystem service for each economic activity in the NACE classification.
7. Identify top 10 NACE economic activities according to their combined dependency materiality ratings and reported associated exposure in GBP.
    a. The total unique combinations of dependency materiality ratings and ecosystem services is counted per GICS sub-industry, and each materiality rating is converted to a numerical score from 1-5.
    b. These unique combinations of dependency materiality ratings and ecosystem services are summed per GICS sub-industry (as seen in calculation for *SMRj*, above) and the resulting scores are normalized to values between 0 and 1.

c. Subsequently, the financial exposures for each sub-industry are normalized to values between 0 and 1. This means the two normalized values (dependency materiality ratings and financial exposure) can be summed per sub-industry and a weighted materiality ranking can be assigned for the GICS sub-industry based on this.

d. Convert results from GICS sub-industries into NACE economic activities and present accordingly.

Annotated scripts in the programming software R have been developed to help streamline ENCORE dependency analyses, improve transparency, and enable reproducibility in future work.

Method for resolving GICS and NACE data

In the analysis, GICS codes for each individual data item (i.e., each security) are required to enable analysis of the total exposure of the portfolio divided by each GICS sub-industry. However, the Bank of England dataset provides sectors using NACE codes. As such, a translation process was required to convert NACE codes into associated GICS codes. For this, a NACE code to GICS code crosswalk table was used, which was based on the information available in the European Commission's *Handbook of Climate Transition Benchmarks, Paris-Aligned Benchmark and Benchmarks' ESG Disclosures* (available here).

There are two 'scenarios' in the industry classification data provided by Bank of England. In scenario one, the NACE codes provided by the Bank of England are directly matched to unique GICS codes through the crosswalk for the dependencies analysis. In scenario two, the NACE codes matched multiple GICS codes, so the exposure for each of these NACE codes was divided equally across all relevant GICS codes. These steps help to ensure that: 1) all NACE code data can be translated into a GICS code accurately; and 2) we avoid double counting data.

B. Heatmaps

In Table 2, a heatmap is shown that ranks the summary of the dependency ratings across all processes within each sector. Ranks were calculated within each column, for each of the top 10 NACE Divisions taken from the non-spatial ENCORE analysis, where 1 indicates the ecosystem service upon which that sector is most dependent. The financial exposures of each sector were not considered here, as this heatmap was designed to highlight key dependencies on ecosystem services.

To calculate the dependency score for each ecosystem service for each NACE Division, the dependency score for each process was summed within that ecosystem service and Division, where 1 = Very Low (VL) and 5 = Very High (VH). To take a concrete example, the Division *Public administration and defence; compulsory social security* (O84) has a summed dependency score of 9 for the sector's dependency on the ecosystem service of *Surface Water*. This is because it has three medium dependencies on surface water (M = 3), through the process of '*Manufacture of machinery, parts and equipment*' sitting within the sub-industry of '*Aerospace & Defence*', within bonds, loans and equities, respectively.

The summed dependency scores were then converted to ranks within each Division, as they should not be directly compared between Division. This is because the data that underpins the ENCORE materiality ratings are not suited to comparisons across sectors. Therefore, the score of 9 for *Surface water* for O84 (*Public administration and defence; compulsory social security*) becomes 2, as it is the second highest dependency after *Mass stabilisation and erosion control*. When the scores are tied within a Division, they are given the same rank.

The rows of the table, representing ecosystem services, are ordered by the average of the ranked scores for each ecosystem service, from lowest to highest. This means that the ecosystem services that the Divisions are most highly dependent on, on average, appear at the top of the table.

C. SEI York MRIO analysis

Input-output modelling experts at SEI York were commissioned to help approximate a spatial upstream distribution of financial exposures from the Bank of England dataset. They first estimated regionally and sectorally disaggregated financial exposures by combining the Bank of England dataset with the ONS Foreign Direct Investment data. They then ran this through EXIOBASE to provide an estimate of where financial exposures lie in the sectors upstream of those in the data from the Bank of England. This step was important in order to understand the true dependencies of the UK economy on nature, as using ENCORE alone would only allow us to see direct dependencies, which are only one part of the picture.

The input data and methodology used by SEI York to estimate upstream dependencies of UK investments is summarized, as well as the outputs of the implementation of this methodology.

Input data

The following datasets were used in this analysis:

Name	Description	Details	Use
uk-banks-and-uk-insurers-exposures-by-asset-class-and-nace-code-in-q4-2021.xlsx	Bank of England investment data	Exposure given for Level 2 NACE sectors where possible. Exposure given for Level 1 NACE sectors is residual. Negative investment values are zeroed-out.	Input data for calibrating the analysis
foreign_direct_investment_UK_outward_2021.xlsx	Outward FDI international investment positions by area, main country, and industrial activity of foreign affiliates (directional)	Investment given for 18 large sectors, countries, and some residual regions	Regional disaggregation of foreign BoE exposure, by proportion
Z_2021	EXIOBASE Intermediate Demand matrix	Expenditure by every EXIOBASE regional sector on every other.	Sectoral disaggregation of BoE exposure, by proportion
L_2021	EXIOBASE Leontief matrix	Inputs from each regional sector required per unit output by each regional sector	Links upstream

Methodology

1. Compute upstream supply chain links, assuming all Bank of England data corresponds to UK outward foreign investments.

    1.1. Regionally disaggregate Bank of England investment data, which is given at sector level only, using Foreign Direct Investment (FDI) data, which is given by sector and region.

        1.1.1. Concord FDI data to EXIOBASE regions.

        1.1.2. For each NACE Division for which there is exposure listed in the Bank of England data, regionally disaggregate this exposure across EXIOBASE regions according to proportions for the corresponding FDI sector. Note that some values in the FDI table are negative, indicating net disinvestment from the UK. Negative values are set to zero before the disaggregation is carried out.

    1.2. Disaggregate regionally-disaggregated Bank of England investment data across EXIOBASE sectors.

        1.2.1. For each NACE Division for which there is exposure listed in the Bank of England data, find the corresponding EXIOBASE sectors, and compute the proportional split of total non-domestic UK intermediate demand across these sectors.

        1.2.2. Multiply the exposure by the proportions to give sectoral disaggregation.

    1.3. For each NACE Division for which there is exposure listed in the BoE data, apply a modified Leontief Inverse Matrix (specifically, the standard Leontief Inverse Matrix with its diagonal entries removed) to the vector of exposure values to obtain upstream expenditure.

2. Compute upstream dependencies assuming all BoE data corresponds to UK domestic investments.

    2.1. Disaggregate Bank of England investment data across EXIOBASE sectors.

        2.1.1. For each NACE Division for which there is exposure listed in the BoE data, find the corresponding EXIOBASE sectors, and compute the proportional split of total domestic UK intermediate demand across these sectors.

        2.1.2. Multiply the exposure by the proportions to give sectoral disaggregation within the UK. Set investment in all non-UK sectors to zero.

    2.2. For each NACE Division for which there is exposure listed in the BoE data, apply a modified Leontief Inverse Matrix (specifically, the standard Leontief Inverse Matrix with its diagonal entries removed) to the vector of exposure values to obtain upstream expenditure.

3. Estimate upstream dependencies that are due to combined foreign and domestic investments:

    3.1. Assume that the UK's investment profile across sectors is the same whether within or outside the UK, and set a percentage of investments that are domestic (this was taken to be 87.5%[19]).

[19] This estimate is based on two data sources. The level of investment in the UK, recorded as gross domestic fixed capital formation in GDP calculated through the expenditure approach (https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/grossfixedcapitalformationbysectorandasset) and

3.2. Take the corresponding convex combination of upstream dependencies that are due to foreign and domestic investments (i.e., 0.875 times the dependencies due to domestic investments plus 0.125 times the dependencies due to foreign investments).

Note that the method is linear with respect to the investment data. Data for (a) different asset types, (b) different NACE sector levels, and (c) foreign and domestic investments, are therefore treated separately, and results can be summed if desired.

A note on total exposure

The sum of upstream financial exposures from the SEI York analysis (£5.8 trillion) is greater than the total exposures in the dataset from the Bank of England (£3.8 trillion). This is not an error – rather, the fact that total upstream connections are not equal to the total investments is inherent in the method laid out above.

To recall how the method works:

1. Investments are distributed over sectors and regions to give a vector of investments that is compatible with EXIOBASE regions and sectors. *(At this stage the total investments will be conserved.)*
2. The vector of investments is multiplied by the EXIOBASE Leontief matrix with its diagonal elements removed – also referred to as the 'modified Leontief matrix'. *(This step does not conserve total investments.)*

For a sector *j*, the *j*-th column of the modified Leontief Inverse Matrix gives the units of input required from sectors other than sector *j* per unit output by sector *j*. In many cases, the total units of input exceeds the total units of output. This is because the units of input account for all upstream expenditure. Effectively, this leads to double-counting of upstream expenditure. In reality, the purchase by a sector A from a sector B includes already the costs of sector B purchasing from sector C, which already includes the costs of sector C purchasing from sector D, etc. However, to understand the exposure of an investment to a wider set of assets that may also be at risk from the decline in nature, we need to consider all different steps along the chain and can approximate the value of this broader stock of assets based on the magnitude of financial activity connecting sectors, even if (in expenditure terms) we are effectively "double counting" the same expenditure across multiple steps in a supply chain.

The results from this MRIO analysis show us that the £3.8 trillion investments of UK banks and insurers are dependent on a wider portfolio of assets, which if valued in proportion to the financial relationships through supply chains equates to around £5.8 trillion of total upstream assets.

D. Hotspots of Natural Capital Depletion

Data was extracted from the existing Hotspots of Natural Capital Depletion dataset, developed by UNEP-WCMC[20]. An analysis was run to extract the proportion of the land area per country with at least

data on Foreign Direct Investment, both into and from within the UK (https://commonslibrary.parliament.uk/research-briefings/cbp-8534/). Subtracting the flow of investment from outside the UK from the amount of investment in the UK (as recorded in GDP statistics) gives a proxy of investment in the UK from within the UK, data on foreign investment from within the UK gives a proxy of the level of investment the UK as a whole directs overseas. Both data sets were looked at for 2021, the same year as the data for bonds, loans and equities. Therefore assuming these financial assets follow a similar pattern to the investments recorded in GDP and FDI data, we can approximate the share of investment that will be domestic and international.

[20] More information on calculation of these layers can be found in the briefing note for the Hotspots of Natural Capital Depletion dataset, at https://s3.eu-west-2.amazonaws.com/ncfa.documents/resources/hotspots_methodology.pdf

X hotspots depleted, i.e. the proportion of grid cells within the country with number of hotspots depleted ≥ X. This conversion from spatial data to a numerical proportion allowed this dataset to be combined with the financial exposure and ENCORE dependency rankings for further analysis.

The spatial resolution of the depletion map was 0.25x0.25 degree, i.e. ~ 28km at the Equator, and countries' boundaries were taken from the GADM database version 3.6[21].

E. Combining upstream exposures, dependencies and state of nature

All three datasets (as discussed in Annexes 3A, 3C and 3D) were combined into one large dataset for final analysis, with the following column names:

- NACE_Section
- Code_level1 – numerical code for the NACE Section
- NACE2_code – the alphanumerical NACE Division code
- EXIOBASE_region_code
- Country
- Asset – loan, bond or equity
- Exposure – upstream financial exposure, as taken from SEI York dataset
- land_depleted_by_min_1htspt – extracted from Hotspots of Natural Capital Depletion dataset
- land_depleted_by_min_2htspt– extracted from Hotspots of Natural Capital Depletion dataset
- land_depleted_by_min_3htspt– extracted from Hotspots of Natural Capital Depletion dataset
- land_depleted_by_min_4htspt– extracted from Hotspots of Natural Capital Depletion dataset
- Process – ENCORE process for which nature dependency rating is given
- Ecosystem Service– ecosystem service for which nature dependency rating is given, for the ENCORE process in question
- Rating – ENCORE dependency rating (Very Low (VL) to Very High (VH))
- Rating_num– ENCORE dependency rating (where VL = 1 and VH = 5)

This made a large spreadsheet of 306,223 rows, where every combination of NACE Division, Asset and country was included, with duplicates to ensure all dependency scores for all processes were covered.

This combined dataset was interrogated as follows using filters in Excel:

- land_depleted_by_min_2htspt column - filtered out NA for value to be >0.1, so that only countries with more that 10% of their land covered by up to 2 hotspots of natural capital depletion were included.
- Rating column – filtered for dependency to be H or VH.

Next the columns for the filtered data for exposure, NACE Division and Country were copied into a new sheet, and duplicates were removed. The remaining exposures (without duplicates) were then summed. This gave a value for the financial exposure associated with NACE Divisions with a High or Very High dependency on nature in areas of the world that have a fast rate of natural capital depletion.

[21] Global Administrative Areas, GADM database of Global Administrative Areas version 3.6 [2018-05-06], available online at: http://www.gadm.org

Annex 4 – Sankey diagram where Sections O and K are removed

Figure 11 below shows a Sankey diagram formatted with the same method as Figures 3 and 4, but where both Section K (*Financial and insurance activities*) and Section O (*Public administration and defence; compulsory social security*) have been removed from the dataset. The left-hand linkages within Figure 11 show how financial exposures vary between assets classes for different NACE sections.

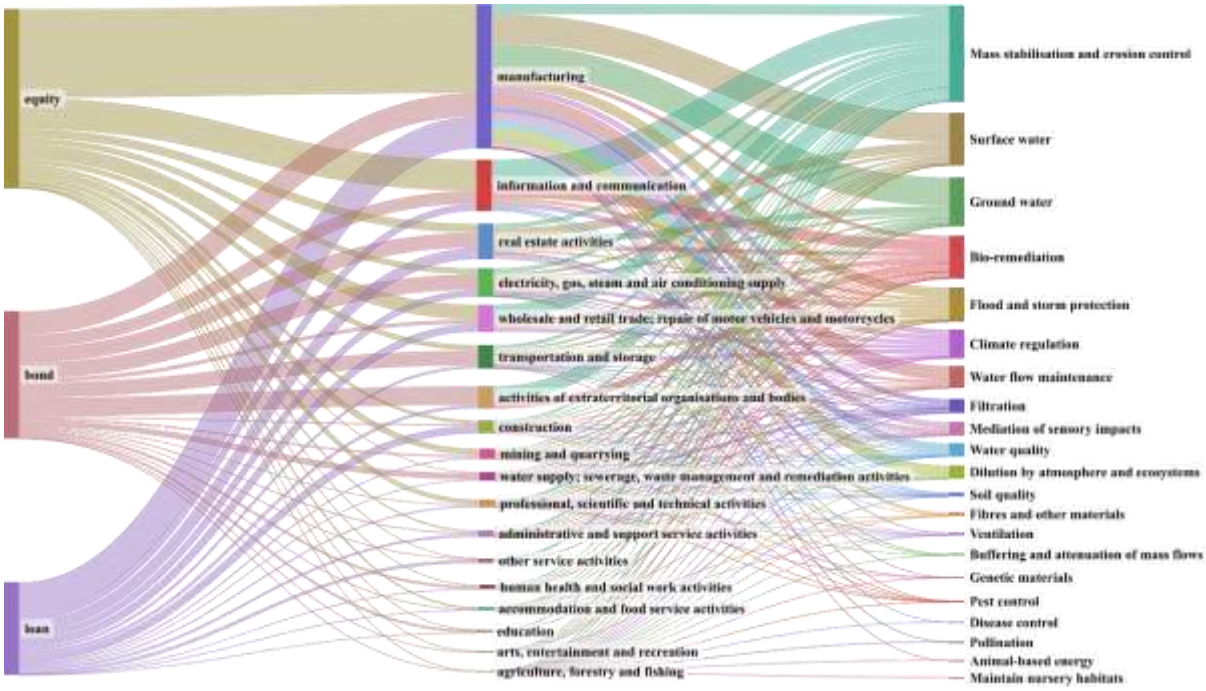

Figure 11: Sankey diagram of UK's financial exposures - excluding Section K (*Financial and insurance activities*) and Section O (*Public administration and defence; compulsory social security*) - and their dependencies on ecosystems services. The left-hand column shows asset classes from the dataset, and the size of the left-hand flows show financial flows to NACE Sections (centre column). The right-hand flow uses the ENCORE knowledge base to identify dependencies between NACE Sections and ecosystem services (in the right-hand column), and the size of the relationship is proportional to the strength of the dependency, weighted by the financial value attached with it.

When compared to Figure 4 (where only Section K is removed from the financial dataset), Figure 11 is broadly similar. However, the ecosystem service of *Bio-remediation* increases slightly in importance, as compared to Figure 4, moving ahead of *Flood and storm protection*.