Assessing nature-related risks in the Hungarian financial system: Charting the impact of nature's financial echo

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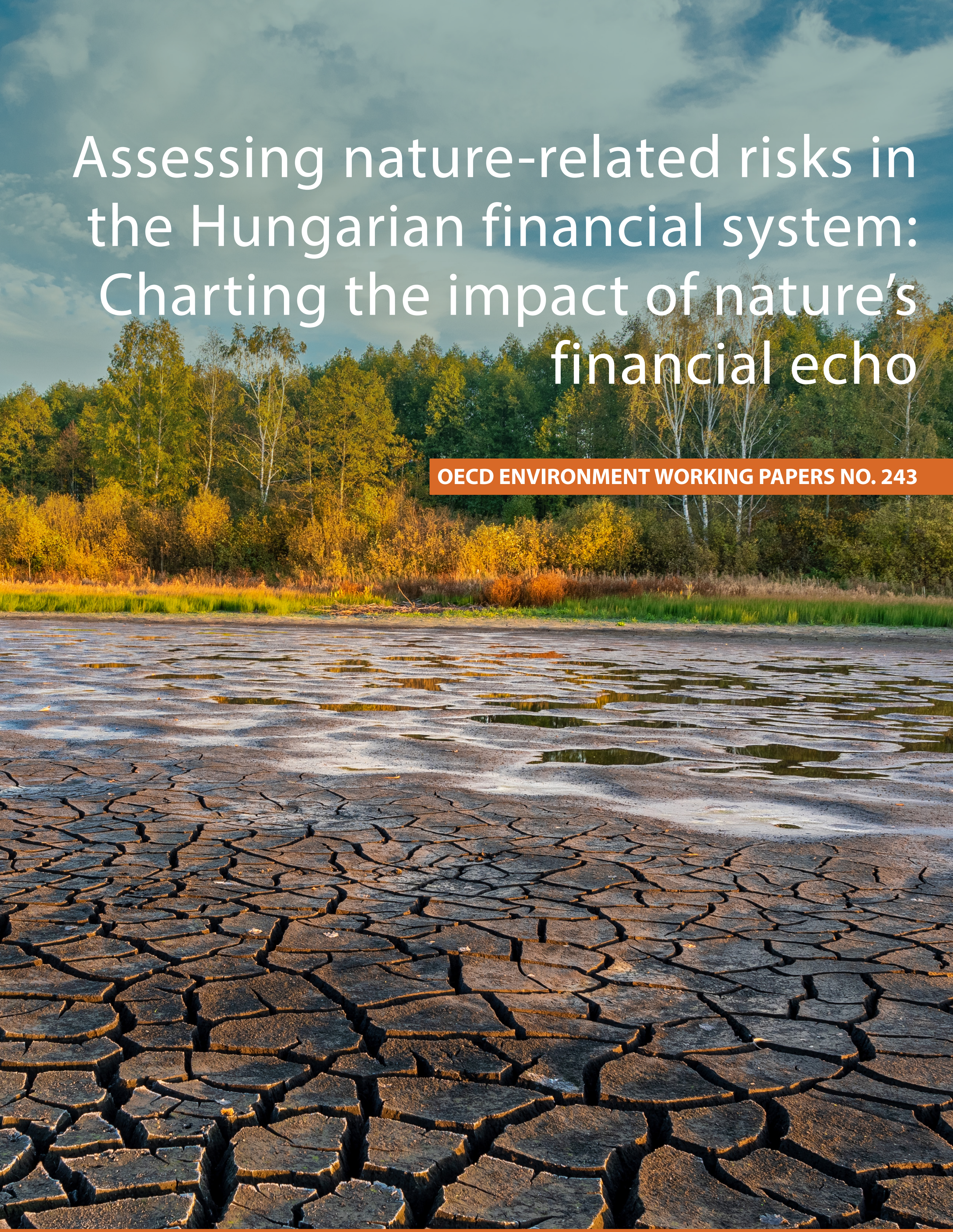

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Assessing nature-related risks in the Hungarian financial system

Charting the impact of nature's financial echo

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Keywords: Nature, biodiversity, nature-related risks, finance and investment, economics, financial materiality

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Abstract

This paper presents a technical assessment of nature-related risks within the Hungarian economy and financial system. The study draws upon the OECD Supervisory Framework to (i) prioritise various nature-related risks by conducting an impact and dependency assessment, identifying key economic sectors, and pinpointing the critical natural capital assets that are most crucial to the financial system; (ii) assess the direct and indirect economic impact of three exploratory scenarios on possible acute nature-related shocks using input-output analysis; (iii) explore the different financial risk channels through which economic risks stemming from nature-related losses may be transmitted within the Hungarian financial system; and (iv) provide supervisory recommendations based on the results.

Keywords: Nature, biodiversity, nature-related risks, finance and investment, economics, financial materiality

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Résumé

Ce document présente une évaluation technique des risques liés à la nature dans l'économie et le système financier hongrois. L'étude s'appuie sur le cadre de surveillance pour évaluer les risques financiers liés à la nature pour (i) hiérarchiser les différents risques liés à la nature en réalisant une évaluation de l'impact et de la dépendance, en identifiant les secteurs économiques clés et en repérant les actifs de capital naturel les plus importants pour le système financier ; (ii) évaluer l'impact économique direct et indirect de trois scénarios exploratoires sur d'éventuels chocs aigus liés à la nature en utilisant l'analyse des entrées-sorties ; (iii) explorer les différents canaux de risque financier par lesquels les risques économiques découlant des pertes liées à la nature peuvent être transmis au sein du système financier hongrois ; et (iv) fournir des recommandations en matière de surveillance sur la base des résultats obtenus.

Mots-clés : Nature, biodiversité, risques liés à la nature, finance et investissement, économie, matérialité financière

JEL classification : C67, E44, E58, G14, G21, G32, H63, Q20, Q57

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This report has been developed as a deliverable of the project on “Developing a Supervisory Framework for Financial Risks Stemming from Biodiversity Loss”, launched by the European Commission, together with the OECD as the implementing partner, to support the Magyar Nemzeti Bank (MNB). The project is carried out with funding by the European Union via the Technical Support Instrument and in co-operation with the European Commission's Directorate-General for Structural Reform Support (DG REFORM). DG REFORM co-ordinates and provides tailor-made technical support to EU Member States, in co-operation with the relevant Commission services. The support is primarily provided through the Technical Support Instrument (TSI). The goal is to support Member States’ efforts to design and implement resilience enhancing reforms, thereby contributing to the EU’s recovery from the COVID-19 crisis, improving the quality of public services and getting back on the path of sustainable and inclusive growth.

Table of contents

FIGURES

TABLES

Executive Summary

The loss of biodiversity and natural resources presents a pressing challenge to the global economy, with potential far-reaching implications for socioeconomic and financial stability. The rapid decline in biodiversity and natural resources threatens vital ecosystem services, thereby presenting physical (degradation or disruption of ecosystems on which economic sectors depend) and transition (misalignment between companies' business model and strategy, and actions related to the restoration, conservation, or sustainability of nature) risks to economic activities. In addition, economic impacts can create risks to financial assets and the financial institutions holding them, with possible implications for financial stability. Therefore, central banks and financial supervisors may need to identify, assess, and manage nature-related financial risks.

Recognising these needs, this paper provides a technical assessment of the impact of nature-related risks on the Hungarian economy and financial system. It is being developed as part of a project launched in 2022 by the European Commission together with the OECD as the implementing partner, at the initiative of the Central Bank of Hungary (MNB), and with funding from the European Union. This assessment builds on two reports published as part of the project, including a mapping of existing and emerging approaches for assessing biodiversity-related financial risks, impacts and dependencies and a Supervisory Framework for Assessing Nature-related Financial Risks.

The paper draws upon the Supervisory framework to implement a technical assessment of nature-related financial risks based on data of loans held by Hungarian banks at the end of 2022. The paper (i) undertakes an impact and dependency assessment, which considers impacts and dependencies as proxies for transition and physical risks, respectively; (ii) assesses the direct and indirect economic impact of three exploratory scenarios on possible acute nature-related shocks using input-output analysis; (iii) explores the different financial risk channels by which economic risks stemming from nature-related losses assessed previously may be transmitted in the Hungarian financial system; (iv) provides supervisory recommendations based on the results.

The assessment provides a preliminary analysis of the economic and financial risks that could stem from a nature-related event through a range of assumptions that have been developed looking at past events and studies. However, these assumptions can be adapted and tailored by central banks to better reflect their own assessments and needs.

The assessment indicates the Hungary's banking system is highly exposed to (i) transition risks from sectors significantly contributing to greenhouse gas (GHG) emissions (EUR 27 billion, 48% of corporate lending in the Hungarian banking system) **and (ii) nature-related physical risks from sectors heavily dependent on "surface water" and "ground water"** (EUR 24.4 billion, 43% and EUR 23.3 billion, 41% of corporate lending respectively), highlighting significant physical risks from water disruptions. The identification of key exposed sectors such as (a) Agriculture, Forestry, and Fishing, (b) Manufacturing and (c) Real Estate Activities underscores the areas where the financial system is most vulnerable to environmental changes and regulatory shifts.

The economic risk assessment examines three exploratory scenarios which focus on economic impacts from a severe drought in Hungary. The results of the economic assessment reveal a **reduction in output between EUR 6 to 11.3 billion, which equates to between a 4% and 7% shock to real GDP level**, over the course of a year. Most of the reduction in output is contained within the Agriculture, Forestry and Fishing sector (between 28% to 53% reduction in share of output) and the Manufacturing sector (3% to 9% reduction in share of output).

In these exploratory scenarios, the reduction in output has significant impact on trade, the accumulation of foreign currency, and relative price changes. The total net foreign currency generation loss of EUR 536 million, under the 2022 baseline, increases up to a EUR 5.3 billion loss, under the most severe scenario. This would reduce the demand for Hungarian forints and place depreciation pressures on the currency. **In this scenario, the Agriculture, Forestry and Fishing sector displays the greatest relative price increase, with a year-on-year increase of up to 24%**, whilst other sectors only display a modest increase in relative prices. These results suggest potential for cost-push inflationary pressures within the economy.

With regards to financial risks, the assessment reveals an increase in non-performing loans (NPLs) in the Hungarian banking system in the range of EUR 730 million (1%) up to 1,461 million (3%) of corporate loans in the Hungarian banking system. Although primary sectors such as Mining and Quarrying, and Agriculture, Forestry and Fishing are the ones that are most affected by a nature-related shocks given their proximity to natural resources, the high collateralisation of loans as well as the relatively low exposure of the financial system to primary sectors reduces the transmission of the shock.

In terms of market risk, Hungary could expect its general government sovereign debt to increase to a range between 77% and 80% due to the GDP shock from a baseline of 74%. The increase in debt to GDP ratio could raise the risk of sovereign rating downgrade as well as a degradation of fixed income prices if investors' confidence on the Hungarian economy deteriorated. Hungarian financial institutions holding significant amounts of Hungarian Government's sovereign bonds are exposed to fluctuations in the quality of Hungarian Government issuances. Moreover, the cost push inflationary pressures identified may have significant implications for interest rate risk in the financial system.

Based on the results of the assessment and building on MNB's Green Programme three pillars are assessed with respect to their applicability to nature: 1. Initiatives in the financial sector; 2. Development of MNB's social and international relations; and 3. Greening of MNB's own operations. Existing MNB climate-related risks considerations can be useful to understand what could be needed from the perspective of nature-related risks in terms of national supervision and international cooperation, data, and methodologies, noting possible limitations to the degree to which tools and analysis for climate can be applied to nature.

Additionally, a range of non-prescriptive short-, medium- and long-term nature-related considerations for MNB are provided. Short-term considerations include how the MNB could (i) leverage the resources provided by the OECD and TNFD, as well as by domestic institutions, to identify relevant available data and metrics; (ii) advance work on nature-related financial risks by further enhancement through the application of advanced methodologies; (iii) extended prudential approaches to address nature-related risks. **Medium-term considerations** include how the MNB could (i) develop supervisory expectations for credit institutions to identify, assess and manage nature-related risks into their governance structures, processes, and risk management controls; and (ii) start to assess how to refine its approach to nature scenario analysis and stress testing. **Long-term considerations** include how the MNB could (i) prioritize domestic nature-related risks to ensure that it can continue to meet its objectives in the long-term; and (ii) consider adjustments to monetary and prudential frameworks to reflect nature-related considerations.

Abbreviations

Abbreviation	Description
AUM	Assets Under Management
CMF	Committee on Financial Markets
CPRS	Climate Policy Relevant Sectors
EC	European Commission
DG REFORM	European Commission’s Directorate-General for Structural Reform Support
ECB	European Central Bank
ENCORE	Exploring Natural Capital Opportunities, Risks and Exposure
EPOC	Environment Policy Committee
FIGARO	Full International and Global Accounts for Research in Input-Output Analysis
G20 SFWG	G20 Sustainable Finance Working Group
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GICS	Global Industry Classification Standard
HICP	Harmonised index of consumer prices
IMF	International Monetary Fund
LSEG	London Stock Exchange Group
MNB	Magyar Nemzeti Bank (Central Bank of Hungary)
NACE	Nomenclature statistique des Activités économiques dans la Communauté Européenne
NGFS	Network of Central Banks and Supervisors for Greening the Financial System
NPLs	Non-Performing loans
OECD	Organisation for Economic Co-operation and Development
TNFD	Taskforce on Nature-related Financial Disclosures
UNEP FI	United Nations Environment Programme Finance Initiative
UNEP-WCMC	United Nation Environment Programme World Conservation Monitoring Centre

1. Introduction

Nature – considered as the nonhuman world, such as living organisms, their diversity, their interactions among themselves and with their abiotic environment, including biodiversity (Brondízio, Settele and Díaz, 2019[1]) – plays a fundamental role for human well-being and economic activities through the provision of a range of ecosystem services. Yet, biodiversity is currently declining at an unprecedented rate, with almost a 50 percent decline in natural ecosystems relative to their originally estimated state (IPBES, 2019[2]). Nature loss presents risks to economic activities through physical and transition risk channels. Subsequently, financial assets associated with these economic activities, and the financial institutions holding these assets, may in turn be subject to financial risks, with potential implications for financial stability.

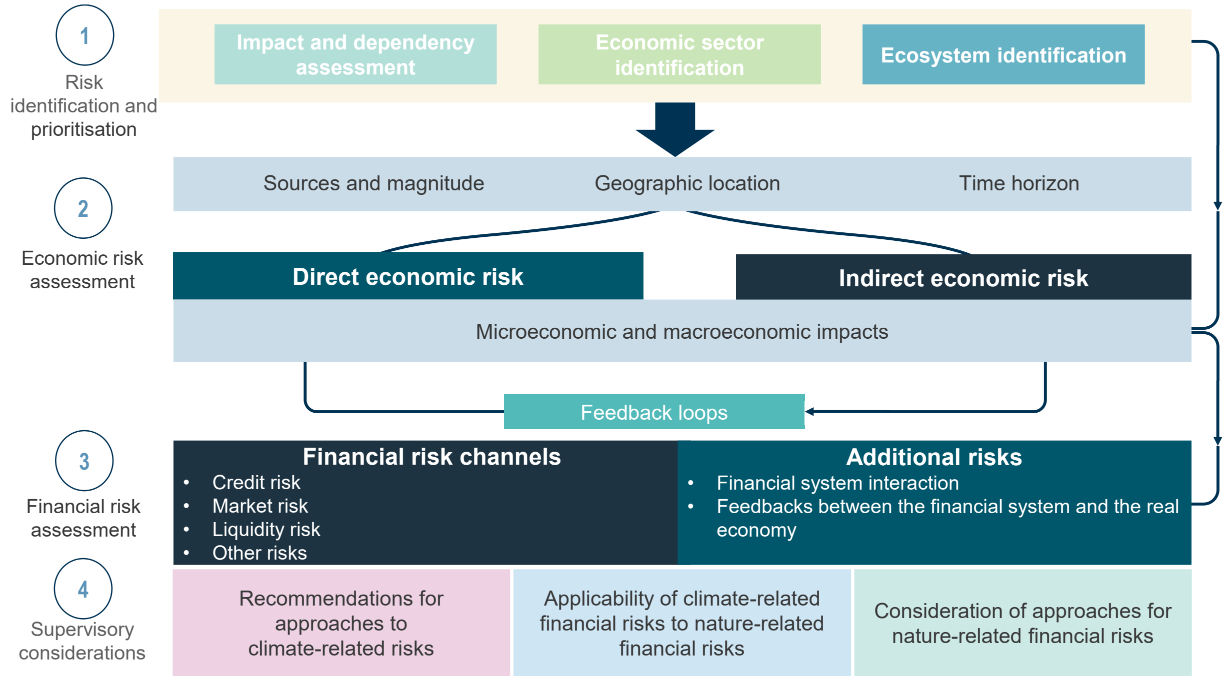
Recognising this need, the European Commission, together with the OECD as the implementing partner and at the initiative of the Central Bank of Hungary (MNB), launched in September 2022 a project on "Developing a Supervisory Framework for Financial Risks Stemming from Biodiversity-related Losses" with funding from the European Union. This project is financed by the European Union through the Technical Support Instrument (TSI) and implemented by the OECD, in cooperation with the European Commission's Directorate-General for Structural Reform Support (DG REFORM). As part of the Project, the OECD has developed a Supervisory Framework for Assessing Nature-related Financial Risks to help the Hungarian central bank (MNB) assess nature-related financial risks in the financial system. The Project aimed to help MNB and banks with retail activities in Hungary become more informed about their exposures, impacts and dependencies to biodiversity-related financial risks, to improve biodiversity-related risk management. The Project has been undertaken in two phases:

- Phase I has developed a Supervisory Framework for Assessing Nature-related Financial Risks: Identifying and navigating biodiversity risks (October 2023), drawing on a mapping of existing tools, practices, definitions, transmission channels, metrics and indicators in the report "Assessing biodiversity-related financial risks: Navigating the landscape of existing approaches" (April 2023).
- Phase II includes collection of available data, provide options to bridge data gaps, and the development of a software-based tool to implement the Supervisory Framework to analyse the nature-related financial risks in the context of the Hungarian financial system. The present paper provides key findings from Phase II implementation.

While recognising that national circumstances matter, including different mandates of financial authorities, the analysis assesses nature-related risks in the Hungarian financial system. The paper follows the four-step approach and technical guidance of the Supervisory Framework:

- Step 1: Risk identification and prioritisation, to identify and prioritise nature-related risks with the greatest relevance for financial materiality;
- Step 2: Economic risk assessment, to evaluate the direct and indirect economic impacts stemming from nature-related physical and transition risks;
- Step 3: Financial risk assessment, to explore the different financial risk channels by which economic risks may be transmitted in the financial system;
- Step 4: Considerations for supervisors to monitor the risks previously highlighted for the financial system, with respect to their objectives.

Figure 1. Overview of OECD supervisory framework steps

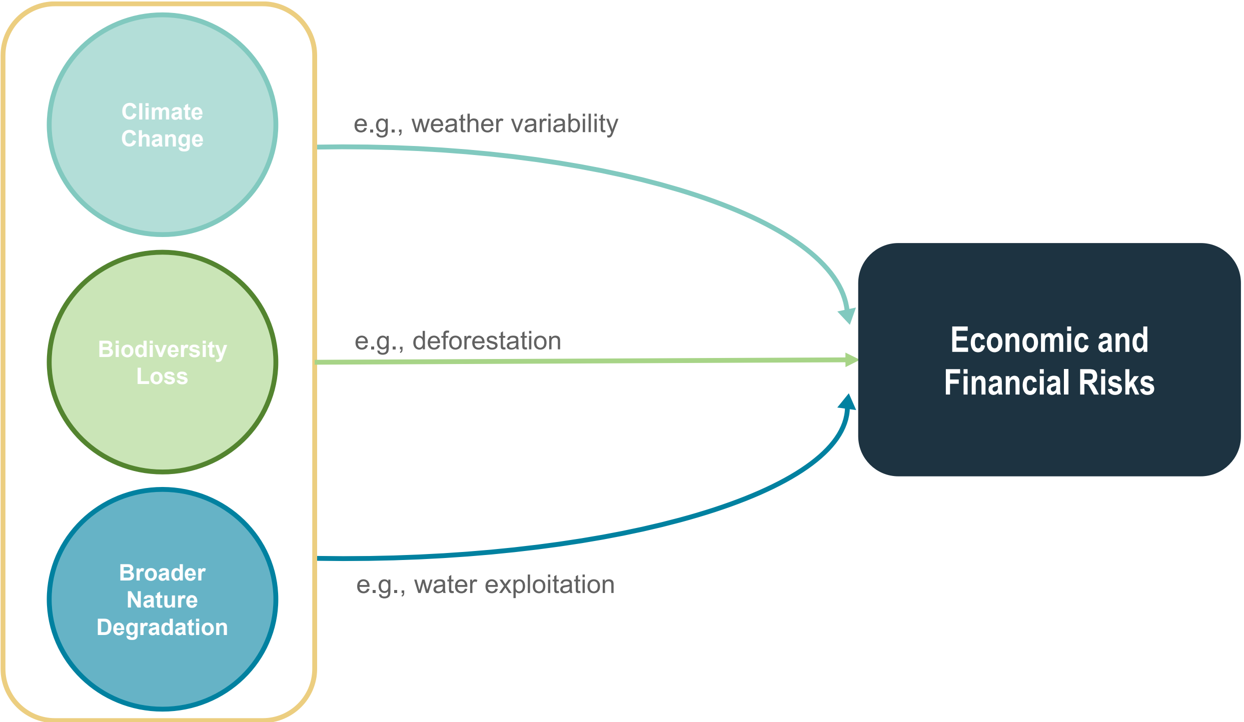


Source: OECD (2023), "A supervisory framework for assessing nature-related financial risks: Identifying and navigating biodiversity risks", *OECD Business and Finance Policy Papers*, No. 33, OECD Publishing, Paris, https://doi.org/10.1787/a8e4991f-en.

This paper seeks to align with the Network for Greening the Financial System (NGFS) and the Taskforce on Nature-related Financial Disclosures (TNFD), with regards to the conceptualisation of risks. While specific assumptions are taken to perform this assessment, financial authorities may decide how best to undertake the assessment, with either a bottom-up or top-down approach, given the micro and macroeconomic risks, and financial institutions' capacity in their jurisdiction to participate in such exercises. The dataset used in the assessment includes EUR 56.5 billion in lending to both corporates as well as individuals identified as primary agricultural producers at the of 2022.

Nature loss and climate change interact and exacerbate each other, leading to greater overall impacts on the economy than the 'sum-of-the-parts' approach (IPCC-IPBES, 2021[3]). Hence, specific impacts of biodiversity loss on economic risks may not be considered in isolation, due to the close interlinkages with broader nature- or climate-related risks and their potentially compounding effects. An integrated perspective can better inform the sectoral and regional location of economic risk materialisation from biodiversity and broader nature-related risks. This does not entail quantitatively disaggregating their respective impacts on the economy, but rather ensuring current frameworks to capture environmental risks include each of these risk types and their interaction factors.

Figure 2. Integrated approach to biodiversity-, broader nature-, and climate-related risks



Note: Biodiversity loss, climate change, and broader nature degradation are presented to be distinct, but this is just to illustrate the additionality of each component in this conceptualisation. In reality, it may not be possible to quantitatively distinguish between the economic impacts stemming from each type of risk due to their strong interlinkages
Source: OECD authors' illustration.

2. Identification and prioritisation of nature-related financial risks

The identification and prioritisation process serves as the initial step in the analysis, allowing to pinpoint nature-related risks most relevant to financial materiality. Following the technical guidance from the *Supervisory Framework for Assessing Nature-related Financial Risks*, the risk identification and prioritisation process consists of a three-phase approach. Initially, this chapter provides an overview of the Hungarian banking system's exposure to physical and transition risks originating from its interactions with ecosystems. This is undertaken by linking financial assets to economic activities to assess their impacts and dependencies on ecosystem services[1], which are proxies for transition and physical risks.

Subsequently, the chapter identifies the most critical economic sectors for the Hungarian economy, concentrating on those with high and very high materiality ratings. This includes an assessment of the relevance and interconnectedness of different economic sectors. These ratings highlight the most significant relationships between industries and nature, pinpointing the key ecosystem services and impact drivers. Additionally, it evaluates the overlap between climate transition risk and nature-related transition risk, demonstrating the primary risks to which the Hungarian banking system is most exposed. Finally, the ecosystem assessment analyses the current and potential future state of ecosystems to identify the greatest vulnerabilities to possible risks.

2.1. Impacts and dependencies assessment

The assessment examines the interactions between sectors financed by the Hungarian banking system and natural capital. It evaluates how reliant sectors are on ecosystem services provided by different natural capital assets, and how they negatively affect them. Impacts and dependencies on natural capital serve as proxies for two distinct types of nature-related risks: sectors that are highly impacting the functioning of ecosystem services are more vulnerable to transition risks, while sectors that are heavily dependent on these services are exposed to higher physical risks.

Out of the total corporate lending by Hungarian banks to nonfinancial corporates and agricultural producers, EUR 43.7 billion, which represents 77% of this lending, highly impacts one or more drivers of ecosystem change. Meanwhile, EUR 22.1 billion, accounting for 39% of this lending, is highly dependent on one or more ecosystem services. Considering both direct and indirect impacts and dependencies through the upstream value chains, almost the entire lending portfolio appears to be linked to sectors which highly impact natural capital (more than 99% of corporate lending),[2] and 57% (EUR 32.3 billion) to those highly dependent on ecosystem services. This approach underscores a greater exposure of the Hungarian banking system to transition risks over physical risks due to a larger proportion of lending associated with industries that impact ecosystem services, compared to those that depend on them.[3]

The results of the identification and prioritisation step demonstrate that **Hungary's banking system is highly exposed to transition risks from sectors significantly contributing to "GHG emissions"** (EUR 27 billion, 48% of corporate lending) through a combination of direct and upstream channels. **For physical**

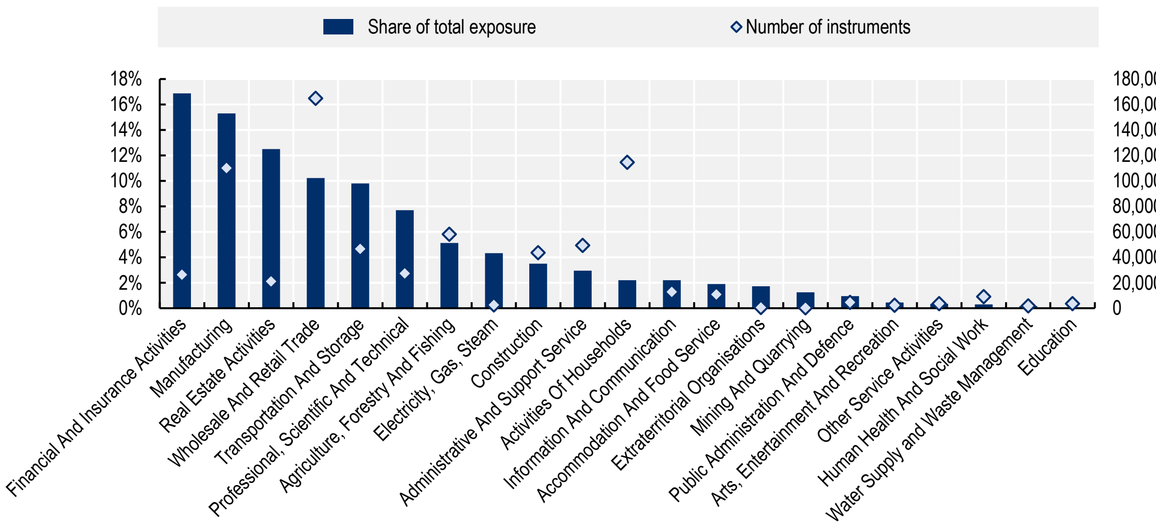
risks, the banking system is exposed to sectors heavily dependent on "surface water" and "ground water" (EUR 24.4 billion, 43% and EUR 23.3 billion, 41% of corporate lending respectively), highlighting significant physical risks from water disruptions.

The identification of key sectors such as Agriculture, Forestry, and Fishing, Manufacturing, and Real Estate Activities underscores the areas where the financial system is most vulnerable to environmental changes and regulatory shifts. Although Agriculture, Forestry and Fishing displays relatively low exposure to transition risks, the Manufacturing and Real Estate Activities sectors are among the most vulnerable to both physical and transition risks. This overlap between impacts and dependencies suggests that addressing physical and transition risks in conjunction necessitates an integrated approach due to their interrelated and cumulative effects, with the agricultural sector's pronounced reliance on ecosystem services directing attention towards physical risks primarily.

2.1.1. Scope of relevant financial assets and their link to economic activities

The assessment focuses on EUR 56.5 billion in lending at the end of 2022 to non-financial corporates and individuals identified as primary agricultural producers. These instruments represent about 70% of the value within the Hungarian banking system (EUR 81.2 billion). Most of this corporate lending is concentrated in Financial and Insurance Activities (EUR 9.5 billion), Manufacturing (EUR 8.6 billion), and Real Estate Activities (EUR 7.1 billion) as shown in Figure 3. Due to data constraints, the analysis is conducted at the instrument level rather than at the firm level, treating the Hungarian banking system as a single entity[4].

Figure 3. Sectoral breakdown of Hungary's banking system exposure

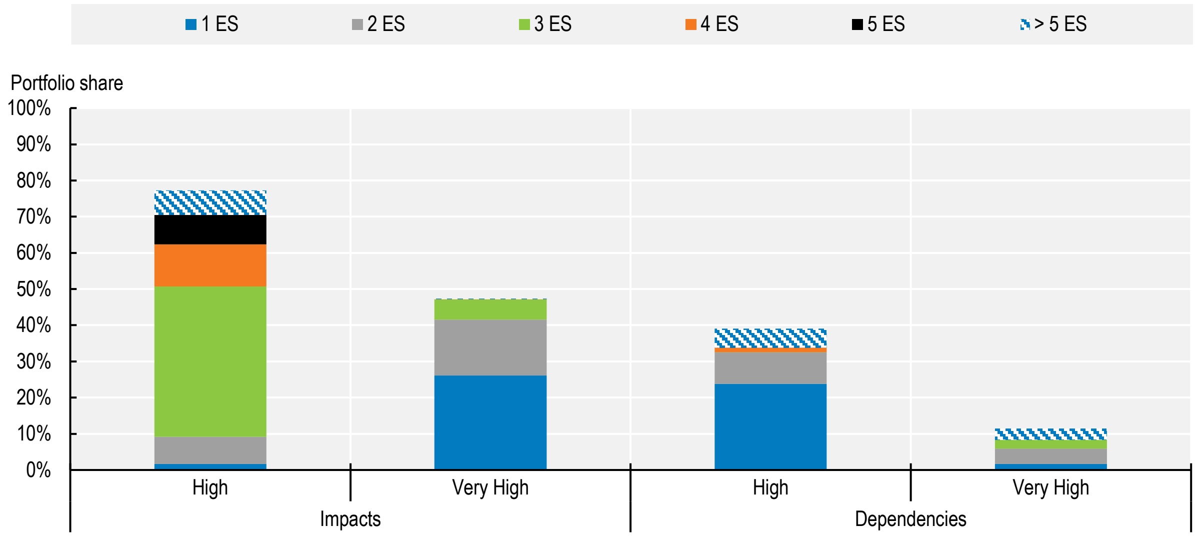


Note: The figure includes exposures of Hungarian banks to corporates and individuals identified as primary agricultural producers at the end of 2022, representing approximately 70% (EUR 81.2 billion).
Source: MNB, authors' calculations

2.1.2. Materiality of impacts and dependencies on ecosystem services

The assessment indicates that nearly all corporate lending from Hungarian banks is to companies that have a moderate or substantial direct impact on at least one driver and 57% to firms with a moderate or substantial direct dependency on at least one ecosystem service. As shown in Figure 4, 77% of lending (EUR 43.7 billion) is highly linked to an impact driver, and 47% (EUR 26.8 billion) is very high. Additionally, 39% of lending (EUR 22.1 billion) is linked to companies highly dependent on these services, with 12% (EUR 6.5 billion) tied to companies exhibiting very high dependency. This means 12% of the banking system's exposures are dependent on at least one ecosystem service (such as waterflow maintenance) at a very high degree of materiality.

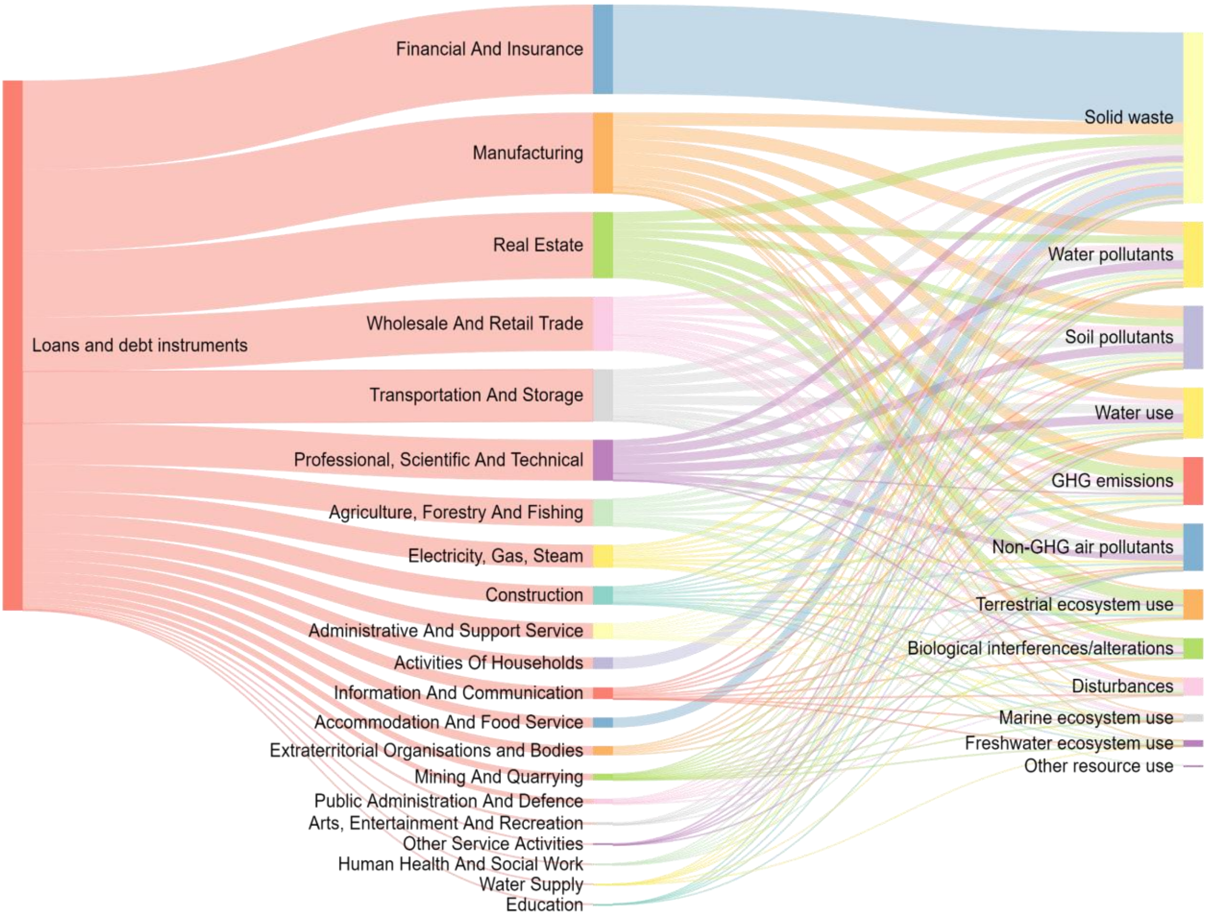
Figure 4. Portfolio share distribution by number of ecosystem services impacted and depended



Note: 'ES' in the key of the Figure refers to ecosystem services. The distribution of the total portfolio with a minimum impact / dependency rating of at least High (> 60%) to at least Very High (> 80%) on a number of ecosystem services and impact drivers, as defined by standard direct ratings. This reflect the brevity of different nature-related financial risks the banking system may be exposed to from ecosystem service degradation, such as climate regulation, waterflow maintenance, or ground water.
Source: ENCORE, MNB, authors' calculations

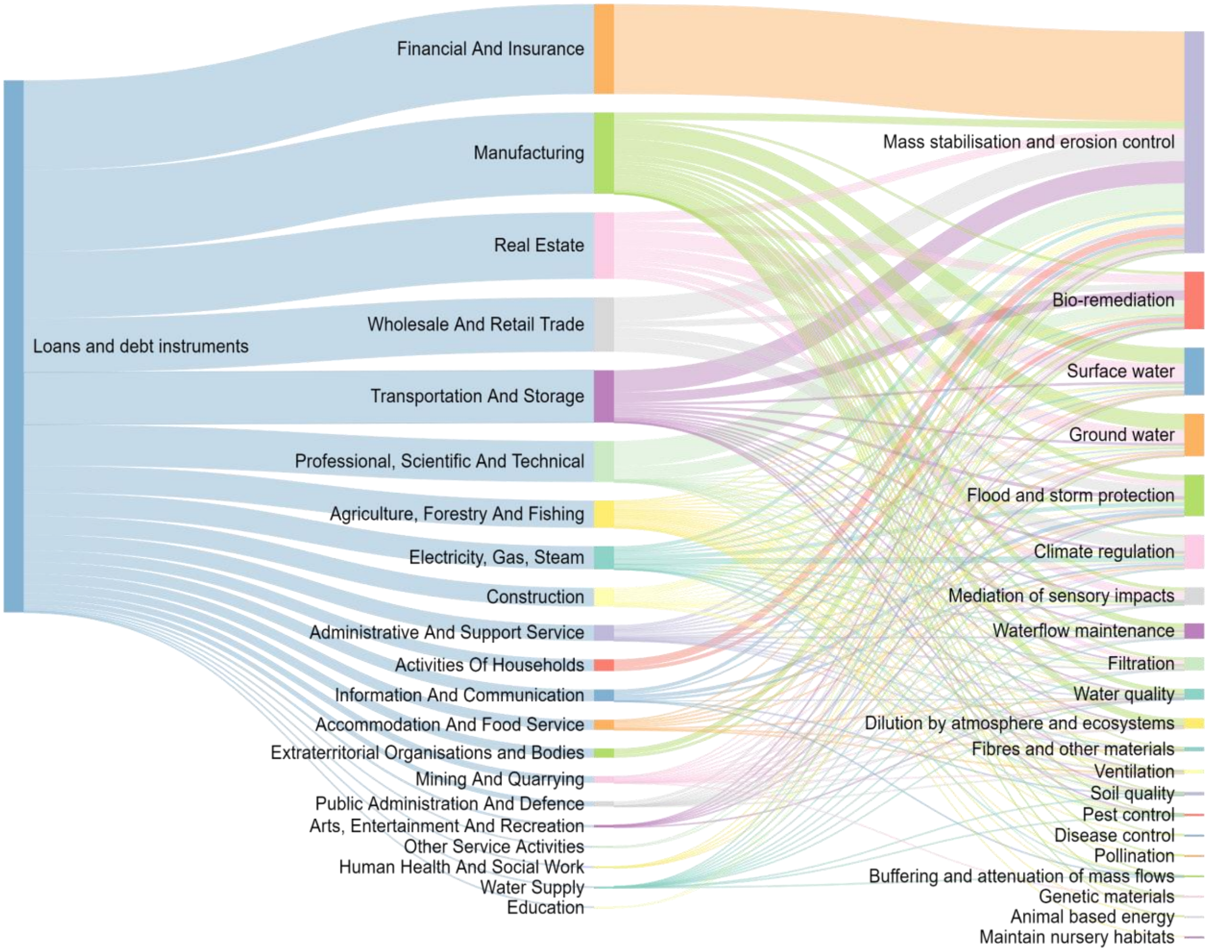
The assessment identifies vulnerabilities within sectors financed by the Hungarian banking system to nature-related risks. Sectors which are highly dependent on ecosystem services may incur increased physical risks and those negatively impacting these services may incur transition risks. The assessment of physical and transition risks relies on the ENCORE framework, which evaluates economic activities' dependencies on ecosystem services and their impacts on natural capital, providing materiality ratings through dependency and impact scores.[5] The ENCORE tool assigns one of five materiality levels to each pair of production process and ecosystem service. Dependency scores assess the significance of functional loss and financial impact from disruptions in a given ecosystem service, while impact scores evaluate the anticipated effects of that production process on natural capital. Figure 5 and Figure 6 below illustrate the Hungarian banking system's exposure to different economic activities and sectors, which in turn impact and depend on ecosystem services. For example, the red lines show the banking sector's exposure to different economic sectors, whereas the orange lines display the impacts of manufacturing activities in the real economy on different drivers of ecosystem degradation.

Figure 5. Hungarian banking system's impact on ecosystem services



Note: The distribution of the total portfolio amount across industries and the impacted drivers based on the standard materiality scores. The quantitative exposure to each activity is equally split between different impacts with the same materiality score. For example, approximately 15% of the Hungarian banking system is exposed to Manufacturing activities, which cause impacts through solid waste, water pollutants, soil pollutants, water use, as well as others. Given that Agriculture has multiple impacts, the impacts are thinly connected to each impact, including water use. For a complete definition of ecosystem services see ENCORE.
Source: ENCORE, MNB, authors' calculations

Figure 6. Hungarian banking system's dependencies on ecosystem services



Note: The distribution of the total portfolio amount across industries and the impacted drivers based on the standard materiality scores. For a complete definition of ecosystem services see ENCORE. For example, the purple lines display the links of Transportation and Storage activities' dependence on multiple ecosystem services, with mass stabilisation and erosion control, and bio-mediation at a higher materiality of dependence.
Source: ENCORE, MNB, authors' calculations

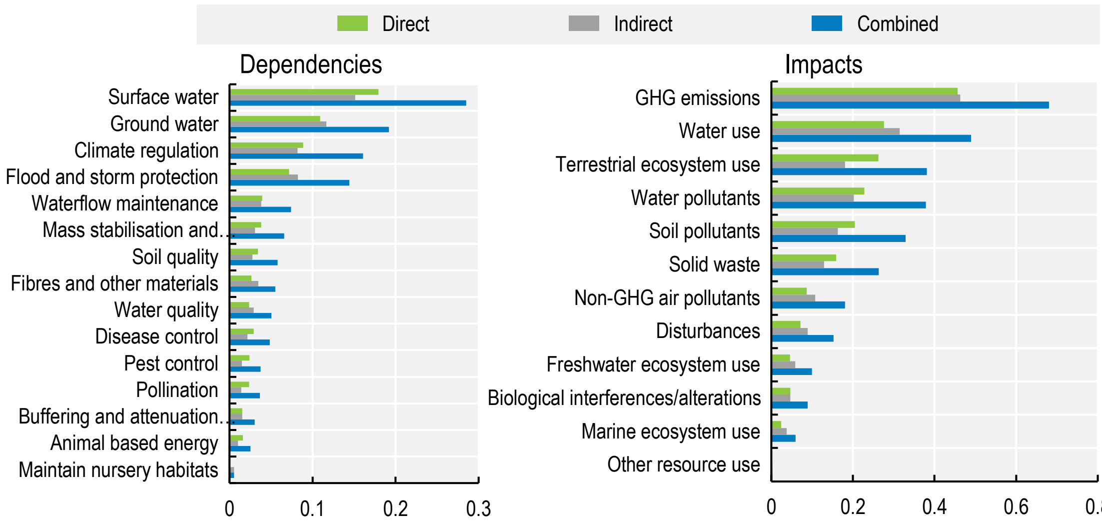
2.1.3. Direct and indirect materiality ratings

The assessment identifies "solid waste" as the main impact driver and "mass stabilization and erosion control[6]" as the main ecosystem service dependency as shown in Figure 5 and Figure 6. For each sector, the amount in the portfolio is distributed to the associated impacts / dependencies based on a weighting considering their relative materiality intensities. In other words, each sector is tied to all ecosystem services / impacts drivers for which it has a non-zero direct materiality rating, and the relative sizes of the links for that sector are based on the relative levels of those materiality ratings. **However, the results highlight the need for a more nuanced understanding of the relationship between sectors, materiality ratings, and natural capital** since this identification arises primarily because the Financial and Insurance Activities sector is marked by the materiality ratings as only impacting "solid waste", and only depending on "mass stabilisation and erosion control", therefore allocating the entire value of the largest exposed sector to these categories.

Therefore**, a "cautious" set of direct ratings, which focus only on High and Very High materiality impact and dependency links were computed** for the pre-selection of the relevant economic sectors, ecosystem services, and impact drivers[7]. This approach facilitates the identification of the most critical ecosystem services and impact drivers, thereby prioritising areas with significant risk or potential harm. It focuses on the dependencies and impact drivers that pose the highest risk of causing substantial operational, financial, or environmental harm. Additionally, both direct and indirect (upstream) materiality ratings are used in the final assessment. This allows to understand a sector's total indirect impact or dependency as a weighted average of the direct materiality ratings across its supply chain[8].

The results show that the largest impact according to this measure is attributed to "GHG emissions", followed by "water use", while the largest dependency is attributed to "surface water", followed by "ground water", as shown in Figure 7. The figure demonstrates the average impact and dependency scores of the sectors financed by Hungarian banks, weighted by their share in the portfolio. It considers therefore both the exposure amount for each sector, and its level of materiality ratings for each ecosystem service and impact driver. The impact and dependency scores of the portfolio are calculated for each factor based on the cautious ratings, facilitating the identification of the most critical ecosystem services and impact drivers.

Figure 7. Cautious impact and dependency scores of the Hungarian banking system



Note: "Cautious'' materiality ratings only include High and Very High materiality ratings. The x-axis represents the portfolio score, which is defined as the average of the impact and dependency scores of each industry, weighted by their share in the portfolio.
Source: ENCORE, MNB, authors' calculations

2.1.4. Sectoral disaggregation

At a sectoral level, Agriculture, Forestry and Fishing, Manufacturing, and Real Estate Activities emerge as the most dependent sectors, whereas Manufacturing, Real Estate Activities, and Transportation and Storage are the most impactful ones. Although Agriculture, Forestry and Fishing is the most dependent sector on ecosystem services, the Hungarian banking system is most exposed to physical and transition risks through Manufacturing and Real Estate Activities. This is due to a combination of both high materiality ratings and a high share of the portfolio, as shown in Figure 8.

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Figure 8. Sectoral breakdown of the Hungarian portfolio's impact and dependency scores

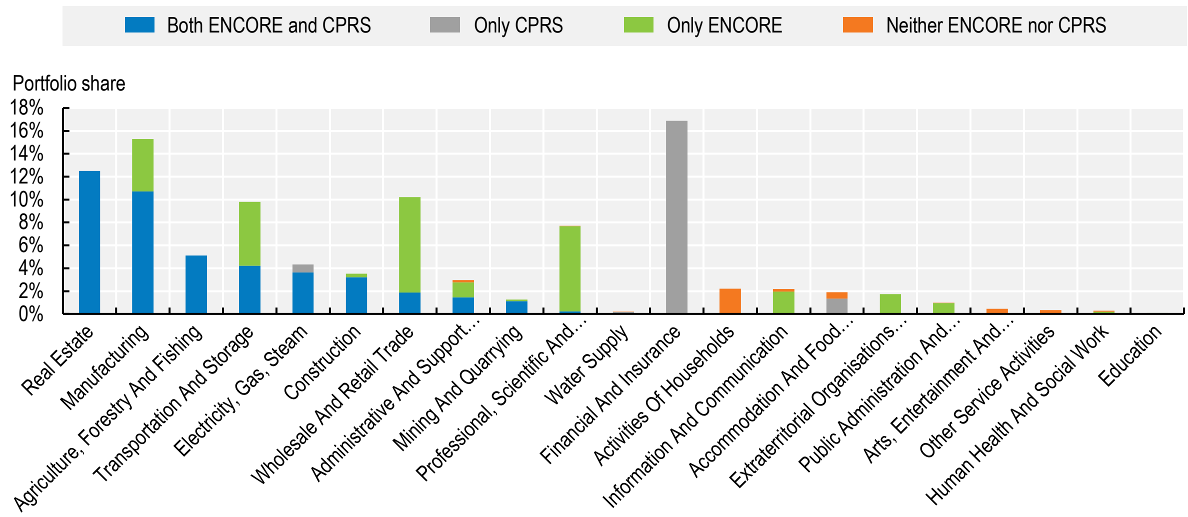
Note: Entries ranging from no materiality (0 - white) to very high materiality (1 - red).
Source: ENCORE, MNB, authors' calculations

2.1.5. Climate and nature nexus

The assessment subsequently evaluates the overlap between climate transition risks and broader nature-related transition risks. The assessment examines the relationship between the impact measures obtained from ENCORE for a given sector and its classification within the Climate Policy Relevant Sectors (CPRS) risk category.

Out of total corporate lending by Hungarian banks, 63% is tied to industries which are classified within a CPRS risk category, while 44% is tied to sectors which are both marked as risky by CPRS and are highly or very highly impacting at least one driver according to ENCORE. Among this 44%, the largest portfolio share is occupied by assets tied to Real Estate Activities (12%), Manufacturing (11%) and Agriculture, Forestry and Fishing (5%) as shown by Figure 9. In other words, it could be argued that the Hungarian financial system is most exposed to a combination of climate and nature-related transition risks through these sectors.

Figure 9. Share of portfolio exposed to both climate and nature-related transition risks



Note: "GHG emissions" were omitted as an ENCORE impact driver because these emissions and their associated impacts are thoroughly addressed within the CPRS framework. Including "GHG emissions" could lead to an inaccurate representation of the intersection between climate-related and nature-related transition risks.
Source: ENCORE, MNB, authors' calculations

2.2. Economic sector identification

The economic sector identification examines Hungary's economic structure to prioritise the most relevant sectors. This assessment is based on factors such as their proximity to natural capital, position within value chains, contribution to GDP, dependence on foreign resources, and geographic location.

The results highlight the importance of **the Agriculture, Forestry and Fishing, and Mining and Quarrying** sectors due to their closeness to natural capital within value chains. It further explores the centrality of sectors within the Hungarian production network and reveals Agriculture's crucial role in Hungary's economic resilience and sustainability. Additionally, the analysis includes a geographical breakdown of the financial landscape, indicating varied sectoral financial support and loan exposures across the country, with Budapest and surrounding counties playing a central role in the nation's economic activities.

2.2.1. Relevant direct and indirect economic activities

The second phase of the identification and prioritisation process starts with the selection of key economic sectors that financial authorities should prioritise to effectively address and comprehend nature-related risks. This is a process which involves distinguishing the “direct” and “indirect” sectors of the economy, with regards to nature-related impacts and dependencies.

A “direct sector” is defined as a sector whose interactions with impact drivers or ecosystem services are predominantly direct, while an “indirect sector” is defined as a sector whose impacts and dependencies are mediated through several layers of economic interlinkages. Hence, a direct sector’s average direct impact and dependency is greater than its average rating for indirect materiality. A positive score indicates that the sector's direct impacts or dependencies are stronger than its indirect effects. This suggests that the sector is closely and immediately connected with drivers of ecosystem services, influencing or being influenced by them directly as shown in Table 1.

Agriculture, Forestry and Fishing emerges as the sector with the most direct dependence on ecosystem services relative to indirect, while Construction has the highest relative direct impact. Looking at the opposite side of the spectrum, Activities of Households has the highest relative indirectness score both in terms of impacts and dependencies. This variance in dependency and impact underscores the importance of tailoring the approach to effectively gauge and manage nature-related risks across different sectors.

Table 1. Directness and indirectness ranking of one-digit NACE sectors in Hungary

Impacts		Dependencies	
NACE Sector Description	Directness score	NACE Sector Description	Directness score
Construction	0.322	Agriculture, Forestry And Fishing	0.413
Extraterritorial Organisations and Bodies	0.300	Mining And Quarrying	0.039
Mining And Quarrying	0.281	Real Estate	0.036
Real Estate	0.159	Extraterritorial Organisations and Bodies	0.029
Transportation And Storage	0.109	Transportation And Storage	0.026
Agriculture, Forestry And Fishing	0.062	Electricity, Gas, Steam	0.023
Wholesale And Retail Trade	0.054	Manufacturing	0.017
Manufacturing	0.049	Arts, Entertainment And Recreation	-0.030
Professional, Scientific And Technical	0.027	Administrative And Support Service	-0.044
Education	0.017	Water Supply	-0.045
Public Administration And Defence	0.008	Wholesale And Retail Trade	-0.059
Administrative And Support Service	-0.002	Financial And Insurance	-0.063
Information And Communication	-0.014	Public Administration And Defence	-0.070
Electricity, Gas, Steam	-0.020	Professional, Scientific And Technical	-0.070
Human Health And Social Work	-0.049	Accommodation And Food Service	-0.074
Other Service Activities	-0.073	Information And Communication	-0.075
Arts, Entertainment And Recreation	-0.139	Human Health And Social Work	-0.083
Financial And Insurance	-0.143	Education	-0.092
Water Supply	-0.219	Other Service Activities	-0.100
Accommodation And Food Service	-0.250	Construction	-0.114
Activities Of Households	-0.269	Activities Of Households	-0.120

Note: The scoring values in this table can range between -1 and 1. A score of -1 indicates a perfectly indirect sector, while a score of 1 indicates a perfectly direct sector. The focus is on the relative ranking of sectors, with absolute values mainly indicating whether a sector is more direct (positive scores) or more indirect (negative scores).
Source: ENCORE, EXIOBASE3, OECD calculations

To understand the broader economic consequences of changes in production levels due to nature-related risks, it is necessary to assess each sector's role and significance, and their upstream and downstream dependencies. Sectors influence the economy through backward and forward linkages. Backward linkages occur when increased sector output spurs demand for inputs from upstream sectors, while forward linkages involve supplying inputs to downstream sectors with increased output. These linkages help to identify key sectors with substantial economic interconnectedness, which guides the analysis to determine which sectors' expansion would most benefit the overall economy (Miller and Temurshoev, 2015[4]).

The assessment of both upstream and downstream linkages captures the sectors' dual significance in relation to both final demand and primary inputs. The metrics quantifying these two types of linkages show a positive correlation, suggesting that sectors close to final demand are also likely to be close to primary inputs. Building on this, a measure of relative importance was developed, calculated as the product of a sector's domestic upstreamness and downstreamness scores. This composite measure identifies sectors that play critical roles in the production network. Therefore, these sectors are more appropriate targets for economic stimulation, given that the initial positive shock can propagate widespread benefits throughout the entire production network. Conversely, a negative shock in these sectors might amplify the consequences of any disturbance due to their critical position within the network.

Agriculture's high connectedness score highlights its critical role in Hungary's economy, signalling both its vulnerability to disruptions from other sectors and its crucial role in propagating economic shocks as shown in Table 2. This dual importance suggests that policy measures or external shocks impacting this sector could have extensive effects, not only within the sector but across the entire economy. Furthermore, its deep ties to natural resources and ecosystems, emphasised by the high dependency scores, demonstrates its cruciality in mitigating the effects of nature-related economic and financial risks.

Table 2. Upstreamness, downstreamness, and connectedness measures of sectors in Hungary

NACE Sector Description	Upstreamness	Downstreamness	Connectedness
Administrative And Support Service	2.13	1.36	2.91
Agriculture, Forestry And Fishing	1.80	1.57	2.82
Financial And Insurance	1.92	1.45	2.79
Electricity, Gas, Steam	1.81	1.53	2.77
Mining And Quarrying	1.90	1.42	2.70
Water Supply	1.69	1.57	2.66
Professional, Scientific And Technical	1.71	1.37	2.34
Transportation And Storage	1.61	1.42	2.28
Information And Communication	1.61	1.35	2.16
Wholesale And Retail Trade	1.45	1.46	2.11
Construction	1.28	1.61	2.06
Accommodation And Food Service	1.16	1.66	1.93
Other Service Activities	1.35	1.41	1.90
Real Estate	1.43	1.29	1.85
Manufacturing	1.25	1.34	1.68
Arts, Entertainment And Recreation	1.08	1.47	1.59
Public Administration And Defence	1.11	1.31	1.46
Education	1.10	1.23	1.36
Human Health And Social Work	1.04	1.24	1.30

Note: The industries "Activities Of Extraterritorial Organisations And Bodies" and "Activities Of Households" were removed from the analysis. The scores are a relative measure, common in economic application.
Source: FIGARO 2023 edition for the year 2021, OECD calculations

2.2.2. Geographical scope of the financial exposure

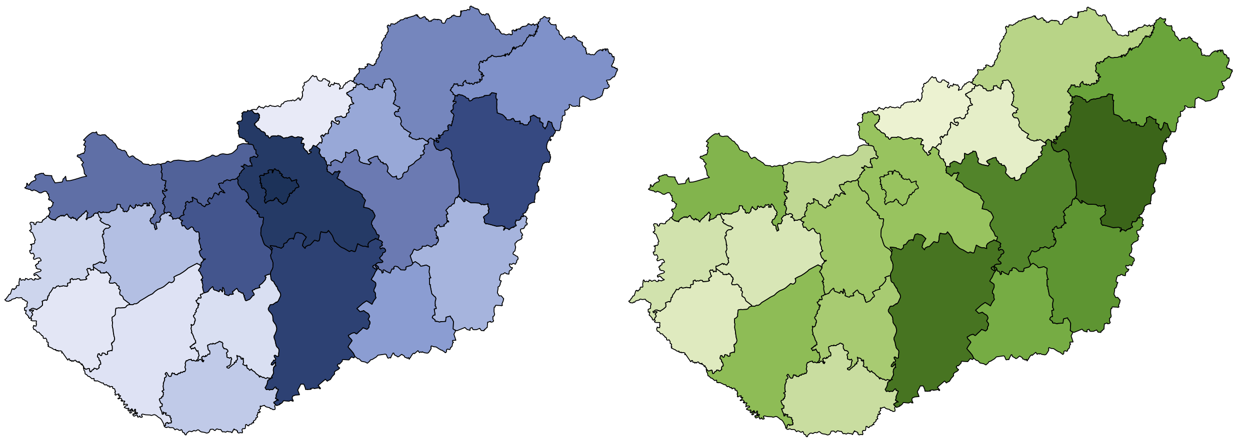
When considering loan volumes, the Hungarian banking system lending is heavily tilted towards Budapest, underscoring its central role in the nation's economy, serving as a hub for business and finance.[9] In Budapest, the loan composition is heavily skewed towards high-value sectors, with the majority of funds allocated to Financial and Insurance, Real Estate, and Professional, Scientific and Technical Activities, showcasing the city's robust service-oriented economic base. Following Budapest, Pest and Bács-Kiskun exhibit distinct sectoral compositions, with Pest focusing significantly on Transportation and Storage and Wholesale and Retail Trade, whereas Bács-Kiskun directs considerable financial support towards Manufacturing, highlighting their specialized economic activities within these key industries. The system's exposure shifts markedly in the realm of agricultural loans. Here, the focus moves to the southeastern counties of Hungary, including Hajdú-Bihar, Bács-Kiskun, Jász-Nagykun-Szolnok, and Békés. These regions, known for their rich agricultural lands and rural economies, are naturally prone to higher levels of agricultural lending, reflecting the local economic activities and the agrarian backbone of these counties.

Table 3. Top ten Hungarian counties and districts with the largest exposure

Rank	Counties		Districts (Járás)	
1	Budapest	22643.19	Dunakeszi district	3358.26
2	Pest	6919.88	11th district	2225.43
3	Bács-Kiskun	1610.61	13th district	1958.30
4	Hajdú-Bihar	1428.58	3rd district	1801.17
5	Fejér	1061.77	2nd district	1735.43
6	Komárom-Esztergom	1054.18	14th district	1490.19
7	Gyor-Moson-Sopron	1027.46	18th district	1484.59
8	Jász-Nagykun-Szolnok	932.93	4th district	1223.72
9	Borsod-Abaúj-Zemplén	912.81	Budakeszi district	1052.45
10	Szabolcs-Szatmár-Bereg	874.37	17th district	1010.47

Note: EUR millions
Source: MNB, authors' calculations

Figure 10. Total exposure amount (left) and exposure to loans in agriculture (right)



Note: The maps display the distribution of the lending to non-financial corporates and individuals classified as primary agricultural producers across counties. Each colour gradient represents a range of values sorted from low (light) to high (dark), indicating the relative financial activity in each county for the selected measures
Source: MNB

Table 4. Top 10 Hungarian counties and districts with the largest agricultural lending

Counties		Districts (Járás)	
Hajdú-Bihar	324.78	Debreceni district	84.91
Bács-Kiskun	208.86	Hajdúszoboszlói district	67.11
Jász-Nagykun-Szolnok	196.61	Szentesi district	54.41
Békés	190.23	Komáromi district	49.76
Szabolcs-Szatmár-Bereg	176.94	Győri district	49.32
Csongrád-Csanád	168.01	Jászapáti district	45.94
Győr-Moson-Sopron	153.06	Mosonmagyaróvári district	45.19
Somogy	151.29	Bajai district	44.82
Pest	149.39	Hódmezővásárhelyi district	41.72
Fejér	143.86	Nyiregyházi district	40.98

Note: EUR millions
Source: MNB, authors' calculations

2.3. Nature-related transition and physical risk drivers

This section provides an assessment of the transition and physical drivers which may lead to possible economic and financial risks for the Hungarian economy. The section adopts a sectoral approach to assess transition and physical risk drivers, in line with other sections of the assessment. For transition risks, the assessment focuses on upcoming policy developments, with forward-looking targets, as well as the current state of technology, and consumer and market sentiment drivers. For physical risks, the assessment focuses on the current and possible future state of ecosystems in Hungary and the surrounding region. Given the complexity and fragmentation of data, particularly for physical risks, the assessment provides a literature overview of the available historical records and research.

Throughout the analysis, the most exposed sector is the Agriculture Forestry and Fishing sector, followed by Manufacturing. For physical risks, the available evidence presents a mixed assessment of the state of ecosystems; however, a few clear risks are still identifiable, particularly water-related risks. **95% of Hungary's surface water is from beyond its borders, which leaves it exposed to transboundary risks**. The Agriculture, Forestry and Fishing, as well as the Manufacturing sectors, are particularly dependent on surface and groundwater. The manufacturing sector in Hungary is particularly water-intensive, which exposes the sector to potential future regulation and physical risks related to water extraction. Hungary has already experienced droughts with significant impacts on agricultural production; however, changes in precipitation patterns due to climate change and nature loss may further exacerbate these impacts in future. Moreover, the change in precipitation patterns, which include direr summers and high frequency of extreme rain events has decreased the water retention capacity of soil, leading to erosion, soil degradation, and reduced soil fertility (OECD, 2023a[5]).

Both international and domestic policies primarily focus on land-use change and chemical use, particularly of pesticides and fertilisers. Land use change is the primary driver of nature degradation in Hungary and there are clear quantitative policy targets at the national level to restore habitats. This may particularly affect the Agriculture, Forestry and Fishing sector, given the expanse of agroecosystems in the territory. These policies may present transition risks to the agricultural sector and lead to reduced crop yields, which underscores the overlap between physical and transition risk drivers, and their impact particularly on the agricultural sector. However, beyond policy-induced transition risks, there is little evidence of material transition risks in the Hungarian economy.

Agriculture, Forestry and Fishing and Manufacturing sectors represent 5.1% and 15.3% of the Hungarian banking system's lending portfolio to nonfinancial corporates, see Figure 3. Hence, the risks to these sectors may lead to financial as well as economic risks. Moreover, most banks' exposures to Agriculture, Forestry and Fishing are within the Hungarian Great Plains, and a significant number of Manufacturing exposures are located in Bács-Kiskun, which are identified to be particularly at risk to drought.

2.3.1. Nature-related transition risks

Policy transition drivers

The following assessment examines domestic and international policy developments which aim to protect and restore biodiversity and broader dimensions of nature. This assessment focuses on policies which are most relevant to the Hungarian sectors exposed to transition risks.

Hungary already has several relevant policy instruments related to environmental protection and restoration. There are 35 active national policy instruments and one supranational policy instruments in Hungary which relate to environmental protection (OECD, 2023b[6]). Whilst most instruments address climate change mitigation (15.7%), a significant proportion are aimed at addressing other environmental objectives, including: solid waste (13%), chemicals management (9.3%), air pollution (9.3%), biodiversity (7.4%), and water pollution (3.7%) (Ibid). These instruments indicate that there is at least a baseline for policy and regulation as a potential driver of transition risks in Hungary. Moreover, these policies are primarily aimed at the manufacturing sector, followed by water supply and waste management, and agriculture, forestry, and fishing.

Several key policy developments have occurred in recent years at the domestic, EU, and global level. The following table provides an overview of recent international and domestic policies developments:

Table 5. Overview of relevant agreements, policies and strategies related to nature restoration

Governance	Name	Example of Main Relevant Policies and Targets	Sectors Affected	Targets and Goals
Global	Montreal-Kunming Global Biodiversity Framework	- Ensure at least 30% of degraded areas are under effective restoration by 2030, - Reduce pollution risks from all sources by 2030, including reducing excess nutrient loss by at least half, reducing risk from pesticides and hazardous chemicals by at least half, and work towards eliminating plastic pollution, - Ensure areas under agriculture, aquaculture, fisheries, and forestry are managed sustainably, with biodiversity friendly practices, - Ensure large corporations and financial institutions disclose risks, impacts and dependencies, - By 2025 identify harmful incentives, including subsidies, to biodiversity, and progressively reducing them by $500 billion per year by 2030, - Mobilise at least $200 billion per year by 2030 in public and private financial resources. - Align all public and private activities, fiscal and financial flows with the goals and targets of the framework.	Cross-cutting	Goals for 2050, with 2030 targets
European Union	EU 2030 Biodiversity Strategy	- Place 30% of EU land into protected areas, - Restore degraded ecosystems, - Restore 25,000km of rivers to be free flowing, - Reduce the use and risk of pesticides by 50%, - Plant 3 billion biodiversity-rich trees, - Manage 25% of agricultural land under organic farming and promote agro-ecological practices, - Establish biodiversity-rich landscape features on at least 10% of farmland, - Reverse decline in pollinators.	Cross-cutting, with focus on land-intensive and agricultural sectors	2030 targets
European Union	From Farm to Fork Strategy	- Reduce the use and risk of chemical pesticides by 2030, - Reduce the use of more hazardous pesticides by 2030, - Reduce nutrient losses by at least 50%, - Reduce fertilizer use by at least 20%, - Reduce the sales of antimicrobials for farmed animals and in aquaculture by 50%, - Increase organic farming to 25% of total farmland by 2030, - Mandatory sustainable food labelling framework.	Agriculture	2030 targets
Hungary	National Biodiversity Strategy	- Ensure at least 34,000 hectares of wetlands, 35,000 hectares of grasslands, and 136,000 hectares of forest are affected by restoration activities, - Measures to reduce harmful pesticides, including limits on amounts used per hectare, and absolute bans on certain chemicals, reducing nutrient leaching by 50%, - Halt the decline in pollinators, maintain and restore pollination as an ecosystem service, - Ensure a coherent network of highly biodiverse landscape elements covering at least 10% of the national territory, - Increase share of areas under organic farming to 15%, - Achieve protection of surface and groundwater as defined in the Water Framework Directive.	Cross-cutting, agriculture, land-intensive sectors	2030 targets

Note: Non-exhaustive list of policy frameworks at different levels of governance which may present relevant transition risks to the Hungarian economy. There is overlap between policies at the EU and national level as many national policies are derived from EU legislation. However, both are included to highlight the domestic and international policies which may be relevant for transition risks.
Source: (CBD, 2022[7]), 'The Kunming-Montreal Global Biodiversity Framework', (European Commission, 2020a[8]), 'The EU 2030 Biodiversity Strategy', (European Commission, 2020b[9]), 'From Farm to Fork Strategy', (The Hungarian Government, 2023[10]), 'The National Biodiversity Conservation Strategy for 2030'.

All these international agreements and regional strategies include quantitative targets related to biodiversity and broader nature by 2030, which evidences a potential increase in policy-induced transition risks in the short-to-medium term, both in the international and domestic context. A significant proportion of these policy frameworks focus on land-use and the impacts of activities related to agriculture.

At the international-, EU-, and domestic- levels, there are quantitative targets to restore and protect land areas by 2030. Currently, 22.2% of Hungary's territory is covered by protected areas, so only an additional 7.8% is required by 2030 to meet the international and EU targets on protected area extent (European Commission, 2019a[11]). However, this is below the EU average of 26%, and of the habitats within Hungary, only 13.3% are assessed to have a good conservation status (European Environment Agency, 2023c[12]) (European Commission, 2019a[11]). Hence, Hungary may need to adopt more rigorous policy measures to ensure the 2030 targets for land cover and restoration are achieved, see. This may induce transition risks for land-intensive sectors, such as agriculture and forestry, through greater regulatory stringency and possible increase in land prices. Additionally, given the low natural forest and land cover, see Figure 11, Hungarian sectors may be particularly exposed to policies which aim to achieve the quantitative national targets for wetland, grassland, and forest restoration, see Table 5.

The Kunming-Montreal Global Biodiversity Framework (GBF) requires countries to identify harmful subsidies by 2025 and progressively start reducing them by 2030 (CBD, 2022[7]). In Hungary, harmful subsidies exist in the form of direct support or preferential tax treatment, and are primarily directed at the energy, transport, agriculture, and fishing sectors (OECD, 2018[13]). Moreover, at the domestic, EU, and international level, there are quantitative targets to reduce both chemical pesticides and fertilizer use, as well as adopt organic farming practices. Hence, Hungarian agriculture may face transition risks from restrictions on pesticides and chemical usage, as well as from the removal of harmful subsidies. The reduction in pesticide and fertilisers may lead to a decline in crop yield for farmers and reduce overall profitability.

Hungary faces challenges related to the impact of climate change on water availability and aquatic ecosystems, as well as natural water nutrient and pollutant loads, and the degradation of riverbeds (The Hungarian Government, 2023[10]). Currently, only 9% of surface water bodies in Hungary are assessed to be in at least good ecological condition, with most of the land area in the Danube sub-basin examined to be moderate-to-poor condition (Barreto et al., 2017[14]). The amendments under the EU Water Framework Directive includes expanding the list of pollutants to be monitored (European Commission, 2022[15]). In Hungary, agriculture land use is responsible for a significant load of pollution (Barreto et al., 2017[14]). In terms of the distribution of water use, the energy industry, particularly the atomic power industry is the largest consumer, followed by irrigation and fish farming (Barreto et al., 2017[14]). Hence, these sectors may be exposed to regulations which reduce sectors' impact on the quality and availability of ground and surface waters.

Technological, consumer and market sentiment, and litigation drivers

There is limited evidence to assess the technological, consumer and market sentiment drivers of nature-related transition risks. A 2018 survey of European attitudes towards biodiversity suggests only 33% of Hungarian respondents had heard of the term "biodiversity" and knew its meaning, compared to an EU average of 41% (European Commission, 2018[16]). Hungary respondents scored below the EU average for considering drivers as "very much" a threat towards biodiversity, except for conversion of natural lands (Ibid). For example, 62% of Hungarian respondents perceive the pollution of air, soil and water to "very much" be a threat to biodiversity, compared to the 67% average across the EU (Ibid). Despite being below the EU average for most questions, Hungarian responses for considering drivers as "very much" a threat to biodiversity increased across all questions compared to the previous 2015 survey (Ibid). This may offer an initial indicator that transition risks from consumer sentiment may gradually be increasing, although they seem to remain relatively low.

Separately, the European Commission has published a disclosure standard as part of the Corporate Sustainability Reporting Directive (CSRD), which includes specific reporting standards on biodiversity and ecosystems (European Commission, 2023[17]). This includes specific information on the resilience of corporate strategy and business models to biodiversity and ecosystem-related physical and transition risks (EFRAG, 2022[18]). Nearly 50,000 companies across the EU are expected to report against CSRD, which will greatly increase the availability of information related to companies' dependencies and impacts on nature. Greater availability of information may increase awareness and affect market sentiment and awareness of nature-related financial risks, which may lead to sentiment-driven transition risks. However, in the context of Hungary, 99.8% of companies are classified as SMEs, with 94.1% considered as micro businesses (European Commission, 2019b[19]). Hence, most Hungarian companies are not subject to reporting in the scope of CSRD, so there may be limited increase in information on nature-related risks for investors and market participants.

With respect to litigation-related risks, there are only two Hungarian litigation cases related to environmental issues documented in the OECD National Contact Points (NCPs) and Columbia Global Climate Change Litigation databases (OECD, 2024[20]; Sabine Center for Climate Change Law, 2024[21]). Hence, the limited evidence suggests minimal litigation on nature-related risks in the context of Hungary. Although, recent years have documented an increase in nature-related litigation cases globally (Ibid). Regarding technology associated transition risks, there is no available evidence of substantial risks from technological advancement in Hungary, specific to nature-related considerations. Overall, **nature-related transition risks driven by technology, litigation, and sentiment remain limited in Hungary**. While there is some public awareness of the threats, this does not currently translate into material risks relevant for financial institutions.

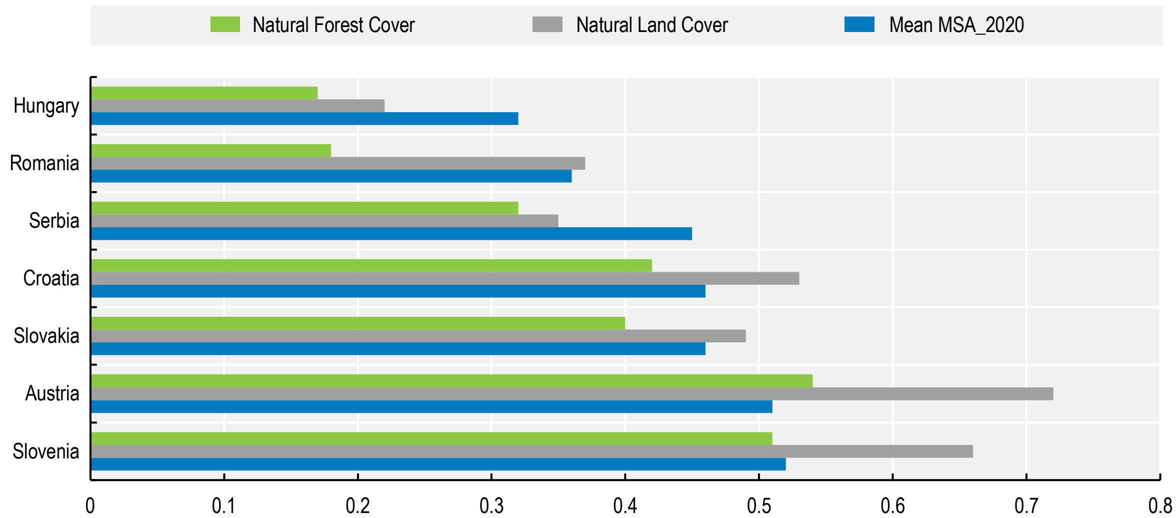
2.3.2. Nature-related physical risks

Ecosystem assessment

The following assessment analyses the estimated current and future state of ecosystems within Hungary and in neighbouring countries. The focus is on ecosystems that are associated with most important ecosystem services identified through the impacts and dependencies assessment. The analysis below provides a summary of the assessment. For a comprehensive evaluation, please see Current state of domestic and regional ecosystems in Annex 2.

Comparative to other European and neighbouring countries, Hungary has significantly lower levels of biodiversity and natural land cover, primarily driven by historical land use change. Hungary's mean species abundance[10] (MSA) score is 32%, in contrast to the neighbouring countries' average of 46%, see Figure 11. Loss of ecosystem habitats may lead to disruption of ecosystem services which highly depend on these assets, including local "climate regulation", "flood and storm protection", and "soil quality" (ENCORE, 2024[22]). According to the WWF biodiversity risk filter, the physical risks from biodiversity loss in Hungary are scored at 4.64 out of 5.0. At the regional-level, both Hajdú-Bihar and Jász-Nagykun-Szolnok have a score of 5.0, which is particularly relevant given the concentration of financial exposures towards agriculture and manufacturing in these regions.

Figure 11. Comparative assessment of biodiversity indicators in Hungary and neighbouring countries



Note: Percentage scores for MSA, natural land cover, and forest cover are for 2020. Graph shows comparative scores of Hungary and all neighbouring countries, excluding Ukraine due to data restrictions.
Source: GLOBIO 4, 2019.

The primary driver for biodiversity loss in Hungary in 2020 is land use change, responsible for -0.417 and -0.633 (out of 1.0) of MSA loss for birds and mammals, and plants, respectively. Land use change in Hungary is driven, to a significant extent, by agriculture. 64.7% of Hungary's land is dedicated to agricultural land, which is the third highest in the EEA38+UK, whist having the 7th lowest coverage of forests and semi-natural areas at 26%. Despite the reduction in forests and grasslands stabilising in recent years, Hungary remains vulnerable to risks stemming from biodiversity and broader nature degradation, given the low scores for MSA and natural land cover, see Biodiversity and terrestrial ecosystems. The loss of biodiversity and nature degradation undermines the resilience of nature to environmental pressures, such as those expected from climate change.

Hungary is particularly exposed to negative transboundary risks related to water supply, as 95% of surface water is received from neighbouring countries (CBD, 2024[23]). Whilst overall water-related physical risks are not estimated to be particularly extreme, changes in seasonal dynamics of precipitation patterns may present material risks, exacerbated in future by climate change. Moreover, the status of ecosystem services related to water are estimated to be the most at risk. Similarly, the Hungarian National Biodiversity Strategy states that 85% of freshwater habitats have disappeared in the territory (The Hungarian Government, 2023[10]). This highlights the limited ability of ecosystems to mitigate the potential risks from changes to seasonal precipitation rates and ensure the continuous provision of supporting and regulating services, specifically water regulation, supply, and pollution control (WWF, 2023[24]). The reduction in freshwater habitats reflects estimates of reduced precipitation, both in comparison to historical as well as expected future rates. A reduction in regular precipitation may have significant implications for agriculture as the Great Plains are identified as key region at risk from drought, where substantial agricultural activity occurs. Moreover, most agricultural land in Hungary is rainfed, with a ratio of 1:1.78 rainfed to irrigated agriculture, which underlines the dependency of regular precipitation patterns for agricultural output (FAO, 2020[25]).

Whilst climate change is identified as a primary driver of changes to seasonal precipitation dynamics, the loss of natural forest and land cover plays an important role. The absence of natural land cover, including forests, naturalised riverbanks, and trees in agriculture fields, increases the vulnerability of the Hungarian economy to drought and diminishes its resilience. Specifically, the lack of natural land cover reduces the availability of green water[11] and lowers the level of evapotranspiration in the region.

Future estimates on the state of ecosystems are highly uncertain, with different scenarios offering substantially different outcomes, see Future state of ecosystems in Annex 2. The data present a mixed overview on the state of ecosystems; however, it does indicate a continuous decline in MSA and an increase in risks from the declining status of water-related ecosystems. Hence, the resilience of biodiversity and water ecosystems may be further reduced in future, which may leave the Hungarian economy vulnerable to associated risks, particularly from less reliable precipitation patterns.

Beyond freshwater ecosystems, the evidence on the physical risks provides a mixed picture. However, certain other risks which are identified include the rise in invasive (alien) species, and habitat loss and degradation, all contributing to notable declines in ecosystem services, see Current state of domestic and regional ecosystems in Annex 2.

Additionally, it is important to acknowledge global-local trade-off as outlined in the NGFS technical document on nature-related scenarios (NGFS, 2023[26]). While it is necessary to consider how locally specific ecosystems, sectors, and corporates interact to understand transmission channels and financial risks, nature loss dynamics outside Hungary may also be important drivers of risks.

3. Economic risk assessment

The economic risk assessment entails a domestic "case study" shock scenario to examine the economic risks which may materialise from the occurrence of nature-related risks. The domestic scenario focuses on a severe drought in Hungary and the direct and indirect impacts for the Hungarian economy. The scenario is selected based on the exposure of the Hungarian banking system to economic activities which are heavily dependent on specific ecosystem services and the assessment of ecosystems in Hungary. The exploratory scenario is supported by evidence-driven assumptions. Subsequently, the section provides exposure analysis of potential risks from abroad, which may translate into economic risks for the Hungarian economy via trade linkages.

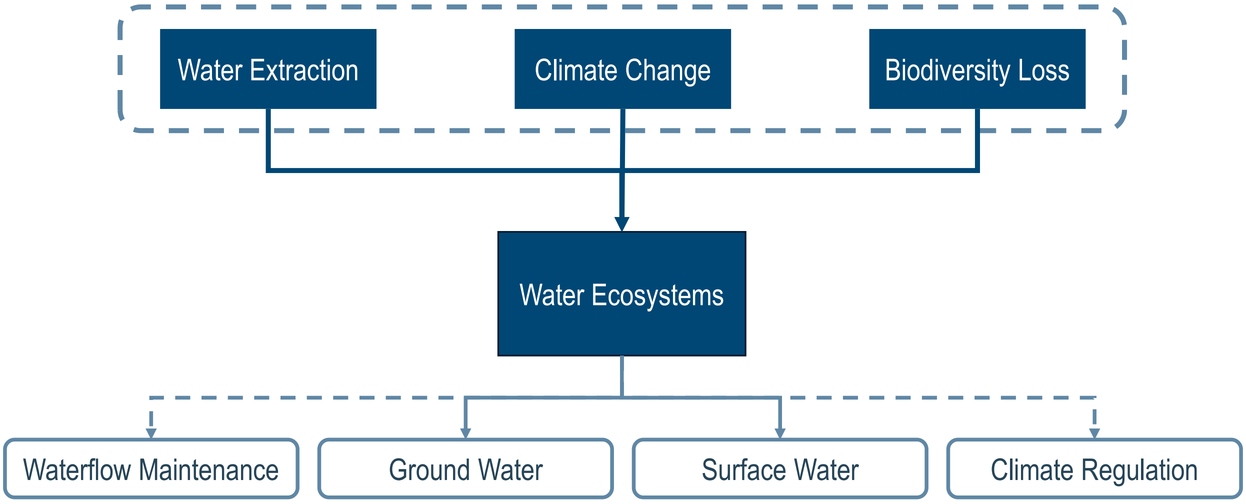
3.1. Domestic Scenario

As previously highlighted, the Hungarian economy and banking system are exposed to physical nature-related risks stemming from disruptions to "ground water", "surface water", "waterflow maintenance" and "climate regulation", see Figure 7. Furthermore, the review of the state of ecosystems identified that ecosystems in Hungary are comparatively more degraded than in the surrounding region, see Current state of domestic and regional ecosystems in Annex 2.

Three drivers contribute towards future drought-related risks in Hungary: (i) climate change; (ii) loss of natural land cover; and (iii) demands on water extraction. A review of studies in Hungary and the surrounding region identifies the historical decline in precipitation levels and the rise in temperatures. Across several studies the historical increase in drought indexes, which account not only for precipitation but also for evapotranspiration[12], indicates the effect of climate change as well as nature loss on precipitation levels. Similarly, studies project future declines in precipitation levels, particularly in summer months, accompanied with further increases in average mean temperatures, and potentially greater demand on water extraction. These studies reveal agriculture to be particularly at risk from drought, with significant impacts on crop yields, see Domestic scenario supportive evidence in Annex 2.

Hence, the following exploratory scenario examines the economic impact of a severe drought in Hungary. The shock is applied at the ecosystem-level, affecting the flow of ecosystem services related to water ecosystems. The scenario focuses on water ecosystems, which directly include surface and ground water ecosystem services, according to ENCORE's classification (ENCORE, 2024[22]). Waterflow maintenance and climate regulation are also partially included because they are closely connected to and depend on water ecosystems but are not directly included under the ENCORE classification.

Figure 12. Illustration of initial shock from drivers to ecosystem services



Source: OECD authors' illustration

The analysis examines three sub-scenarios which focus on economic impacts from a severe drought in Hungary. For all scenarios the initial shock distribution is closely aligned to historical studies which assess drought in Hungary, see Literature review of historical studies and forward-looking scenarios in Annex 2. The shock distribution is dispersed amongst sectors based on their green and blue water consumption per unit of output. The data on water consumption is taken from the satellite accounts of EXIOBASE 3, which is first used to compute the shock, and then the indirect impacts in the economy.

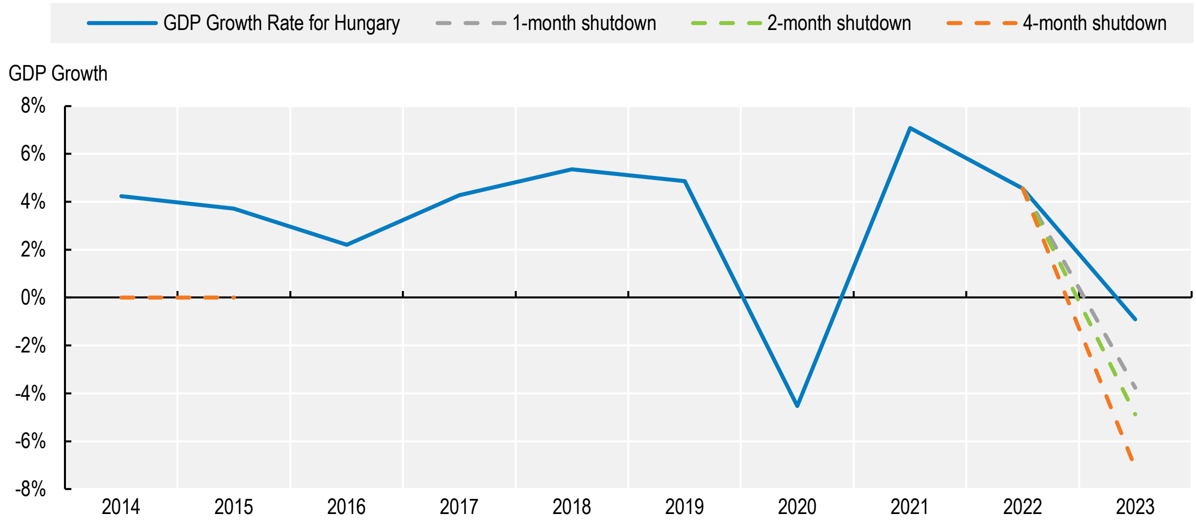
Additionally, the ENCORE materiality ratings are employed to determine the size of the shock, because these ratings reflect the level of potential disruption to production processes due to a reduction or disruption in the flow of ecosystem services. A weighted average between the four ecosystem services (highlighted in Figure 12) is used to determine which sectors are affected and how much their output is reduced. This additional impact reflects the non-linear relationship between sectors' water usage and production, see Sector-specific transmission channels in Annex 2. Under these scenarios, a partial or full shutdown point for sectors is assumed due to a lack of necessary water availability. The shutdown is assumed based on the ENCORE materiality ratings and their indication of potential business disruption. A partial shutdown assumes a 50% reduction in output and a full shutdown assumes a 100% reduction in output for the stated period[13]. The three scenarios assume different lengths of a shutdown period, with 1-, 2- and 4-month periods.

The analysis describes the potential impact on GDP, sectoral output, trade, and relative cost-push inflationary pressures from a drought under the three scenarios. The results for output reduction versus relative price change use different models with varying assumptions. Hence, these results should not be interpreted as equivalent, please see Economic risk assessment in Annex 1 for further details on the methodology and assumptions.

3.1.1. Impact on GDP and sectoral output

Overall GDP reduces between EUR 6 billion to EUR 11.3 billion from the least to most severe scenario, which would equate to a fall in the GDP level between 3.8% and 7.1%, see Figure 13. All three scenarios applied have a significant impact on sectoral output, particularly for Manufacturing and Agriculture, Forestry, and Fishing. Whilst the shock to the economy under the various scenarios spans 1-to-4 months, the results are communicated in the loss of output on an annual basis. This is a substantial impact on the Hungarian economy, with the least severe scenario equating to a shock which is akin to the negative GDP growth experienced during the COVID-19 pandemic.

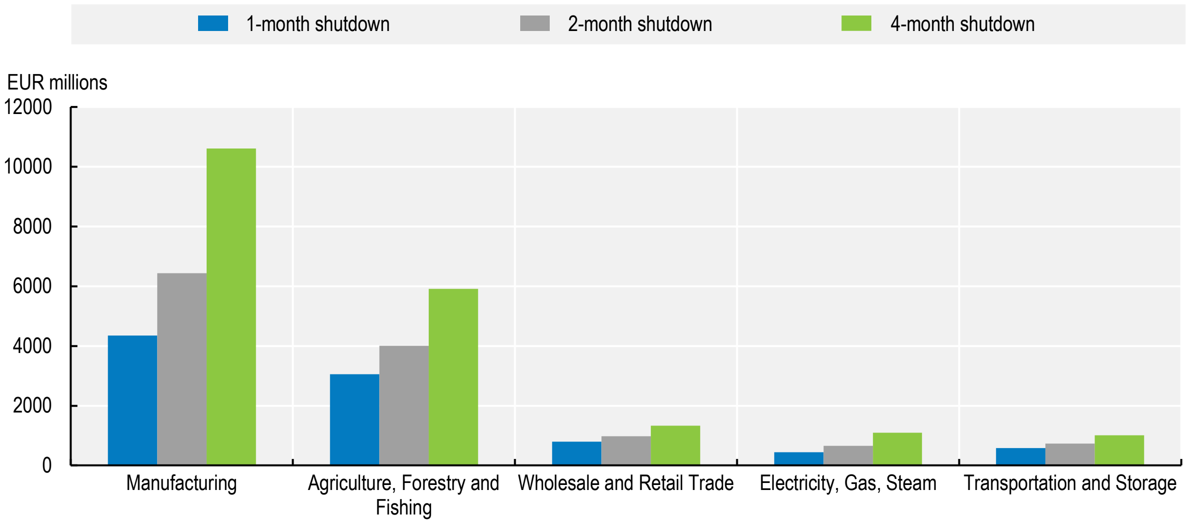
Figure 13. Percentage reduction in GDP growth under three drought scenarios



Note: This figure charts the historical GDP growth of Hungary, with the shock under the three scenarios compared to the 2023 actual growth rate, which was -0.9%. The shocks to GDP are calculated using EXIOBASE figure for Hungarian GDP, which use forecasted figures. Whilst, the historical GDP growth is from the OECD data explorer, which uses actual historical data. Hence, there might be small discrepancies in the exact figures, but the relative impact on GDP growth is the same.
Source: EXIOBASE 3, OECD Database Explorer, authors' calculations

The shock, in absolute terms, is primarily contained with the Manufacturing and Agriculture, Forestry and Fishing sectors, with sectoral output under the most severe scenario reduced by EUR 10.6 billion and EUR 5.9 billion, respectively. The next most affected sector, Wholesale and Retail Trade, only incurs a EUR 1.3 billion reduction in output under the most severe 4-month scenario. Hence, the distribution of the shock is highly correlated to economic activities which are highly dependent on water ecosystem services but does not significantly permeate other areas of the economy. However, this partially reflects the structure of the Hungarian economy and the size of the Manufacturing sector. Other sectors which incur a reduction in output over EUR 1 billion under the most severe scenario include the Transportation and Storage, and Electricity, Gas and Steam sectors.

Figure 14. Absolute total reduction in selected sectoral output under three drought scenarios



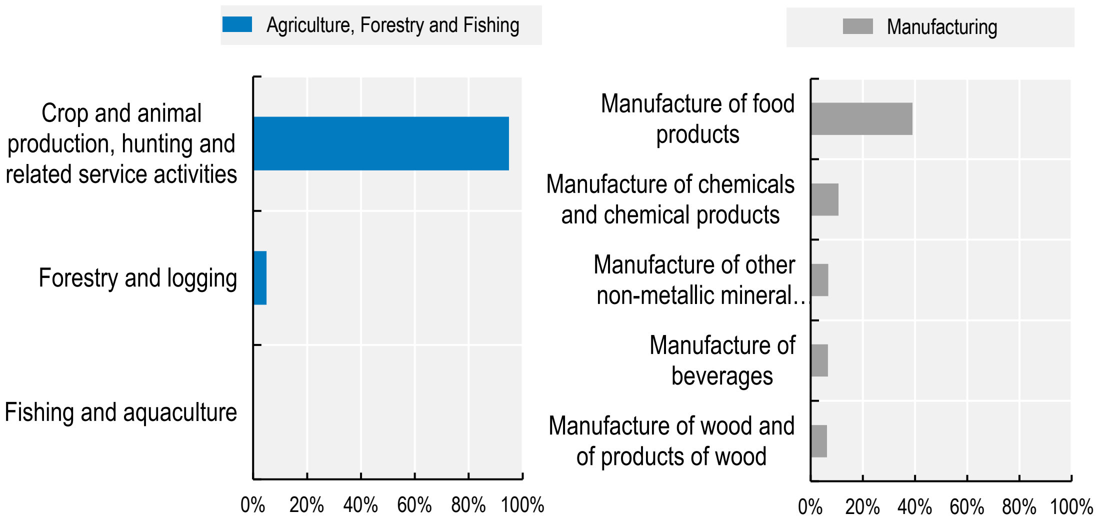
Note: NACE sectors T (Activities of Households as Employers) and U (Activities of Extraterritorial Organisations and Bodies) are excluded due to being reported as not having produced any output for the year 2022 in the Hungarian economy according to EXIOBASE data.
Source: EXIOBASE 3, authors' calculations

For less severely affected sectors, most of the impact is transmitted through upstream indirect impacts. For example, EUR 386 million out of EUR 426 million of output reduction for Financial and Insurance Activities stems from upstream indirect impacts, equating to 91% of the total sectoral output reduction, under the most severe scenario. This is because Finance and Insurance Activities are in an upstream position compared to the sectors which are mostly directly affected by the shock, see Table 1. Directness and indirectness ranking of one-digit NACE sectors in Hungary. Therefore, the backward linkages in the economy are a more prominent transmitter of economic impact, leading to strong upstream indirect impact for other sectors. However, overall, most impact stems from direct effects due to the relatively greater impact in the Manufacturing and Agriculture, Forestry and Fishing sectors.

There are significant differences in distribution of the shock between different sub-sectors within the most affected sectors. Sub-sectors related to food production receive a substantially greater share of the total shock, see Figure 15. For example, Crop and Animal Production incurs 95% of the total reduction in Agriculture, Forestry and Fishing, under the most severe scenario. Similarly, the Manufacturing of Food Products incurs the greatest share within the Manufacturing sector, with 39% of the total reduction in output, followed by the Manufacturing of Chemicals. This underscores the substantial impact on food supply chains and related input sectors, the potential ramifications for corporate profitability in these sectors. Given the concentration of incurred loss of output in these sub-sectors, firms undertaking these economic activities may suffer significant stress on their cash flows due to the level of disruption. Moreover, for cropland and animal farmers, they may also incur a depreciation in the value of their assets, particularly if more severe droughts and reduction in output are anticipated to become more regular in future.

These results reflect the impact experienced during the 2022 drought in Hungary, with crop production experiencing the largest reduction on output due to drought. In 2022, the total volume of output in crop production decreased by 25% due to extreme weather, with maize, rape, sunflower and apple experiencing the largest falls in production (Hungarian Central Statistical Office, 2022[27]). In 2022, cereals, followed by industrial crops, constituted the greatest change in the volume of output (Ibid).

Figure 15. Relative output reduction for agriculture and manufacturing subsectors under 4-month scenario

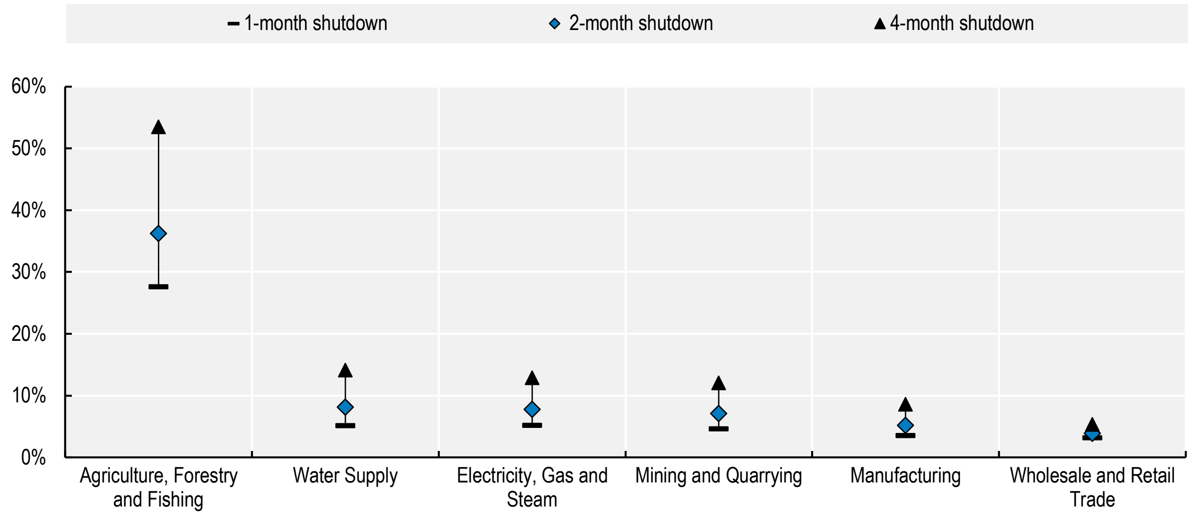


Note: Only top 5 subsectors most affected sub-sectors, by greatest relative distribution of impact, are included in the charts.
Source: EXIOBASE 3, authors' calculations

On a relative basis, as a share of total sector output, Agriculture, Forestry, and Fishing incurs a relative reduction between 27.6% and 53.5% in output, whereas Manufacturing only incurs between 3.5% and 8.6% reduction, under the different scenarios, see Figure 16. This is because Manufacturing constitutes a significantly greater total value output compared with the Agriculture, Forestry, and Fishing sector, with approximately 11 times the value output for the Manufacturing sector. Additionally, as a share of output, both the Mining and Quarrying, and Electricity, Gas, and Steam incur a greater decrease in output compared to Manufacturing. For sectors where the share of reduction in output is minimal, the sector may have a greater capacity to absorb the adverse impacts and maintain profitability. However, this also dependent on firm concentration within a sector, with sectors which are less concentrated with many firms more likely to incur solvency issues. For example, most agricultural activities in Hungary are undertaken by small-scale farmers, with 196,000 farms using an average agricultural area of 22.8 hectares (Hungarian Central Statistical Office, 2023[28]). Hence, even though the Manufacturing sectors has the greatest absolute decline in output, Agriculture, Forestry, and Fishing may suffer a more significant disruption to activities and greater challenges to maintain solvency.

Moreover, those sectors which are relatively more affected under the scenarios, in terms of output reduction, are also more sensitive to the intensity of the shock. For example, Agriculture, Forestry, and Fishing has a 25.9% spread in relative sectoral output reduction under the different scenarios, compared to an average spread of 3.7%, see Figure 16. These sectors are more sensitive to the severity of the shock and will display a proportionally greater output loss compared to other sectors. Hence, under more severe scenarios, there will be a greater than proportional reduction in the relative sectoral output of Agriculture, Forestry, and Fishing compared to other sectors.

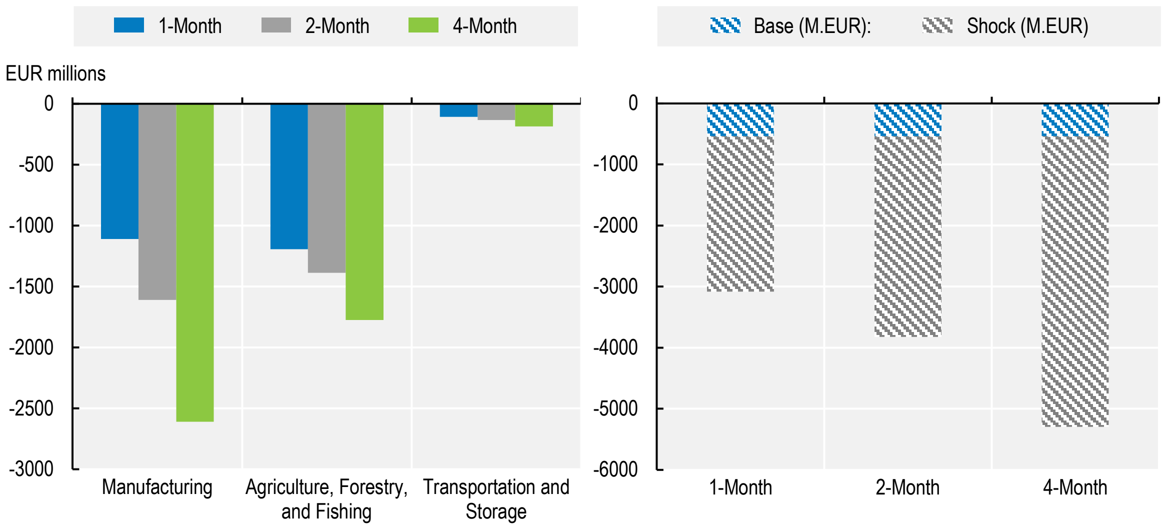
Figure 16. Share of relative output reduction by sector under three scenarios



Note: NACE sectors T (Activities of Households as Employers) and U (Activities of Extraterritorial Organisations and Bodies) are excluded due to being reported as not having produced any output for the year 2022 in the Hungarian economy according to EXIOBASE data.
Source: EXIOBASE 3, authors' calculations

3.1.2. Changes to trade and foreign exchange generation

Figure 17. Value loss in foreign currency generation by sector and total



Note: Lefthand side chart shows the loss of foreign currency generation by sector under the three scenarios, compared with 2022 EXIOBASE data. Only the six sectors with the three largest positive and negative changes in foreign currency generation are included. Righthand side chart shows total net foreign currency generation, including the base loss of currency generation (which is taken from EXIOBASE and refers to Hungary's current balance of payments), and the additional loss under the three scenarios.
Source: EXIOBASE 3, authors' calculations

The total net foreign currency generation declines, ranging from a loss of EUR 3.08 billion under the least severe scenario to EUR 5.3 billion under the most severe scenario, see Figure 17. 86% of the net foreign currency loss stems from Hungary's trade with EU economies, and 14% from trade with the rest of the world. Manufacturing and Agriculture, Forestry and Fishing incur the greatest loss in foreign currency generation, with approximate losses of EUR 2.6 billion and EUR 1.8 billion, respectively under the most severe scenario. Conversely, the Electricity, Gas, and Steam, Construction, and Financial and Insurance Activities sectors incur the greatest gains in foreign currency generation, comparative to the 2022 baseline, albeit rather modest gains. This is because these sectors reduce their demand for imports, which in turn reduces their loss in foreign currency generation. These changes in trade and foreign currency generation may lead substantial deterioration in Hungary's balance-of-payments, with a significant reduction in demand for Hungarian forints and potential depreciation pressures on Hungarian currency.

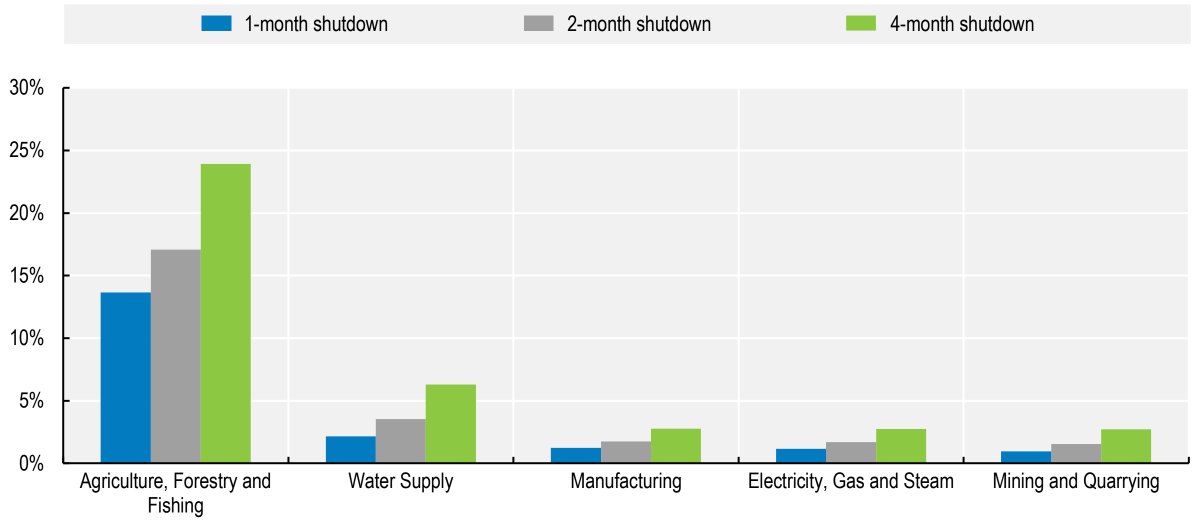
3.1.3. Relative price change and inflationary pressures

Agriculture, Forestry, and Fishing exhibit the greatest relative price increases, between 13.6% to 23.9% under the three scenarios, see Figure 18. **This can be an indicator of cost-push inflationary pressures in the economy.** Hungary experienced the highest HICP inflation in the European Union in 2022, with 24.5% year-on-year inflation in December 2022 (Bech, Foda and Roitman, 2023[29]). Moreover, food prices where the primary driver of inflation in Hungary in the second half of 2022 and start of 2023 because of the severe drought in 2022 which significant reduced agricultural output (European Commission, 2023[30]; OECD, n.d.[31]). Elsewhere in the economy, relative price changes are comparably modest, with prices in most sectors increasing less than 5% under the most severe scenario, except for Water Supply and Waste Management, which incurs a 6.29% relative price increase. Hence, the majority of cost-push inflationary pressures stem only from the Agriculture, Forestry, and Fishing sector; however, this may still have a material impact on headline inflation in the economy.

Within the Agriculture, Forestry, and Fishing sector, there are significant differences in the relative price changes, most increases occurring in the Crops and Animal Production, and Forestry sub-sectors. Crop and Animal Production and Forestry exhibit between a 14%-24% and 6%-21% relative price increase under the scenarios, respectively. Conversely, only minor relative price changes are seen for Fishing Activities, which only incur a 2.5% relative price increase under the most severe scenario. At the most granular level, the growing of Cereals, Leguminous Crops and Oil Seeds display the greatest increase out of different crops, with a 35.9% relative price increase under the most severe scenario.

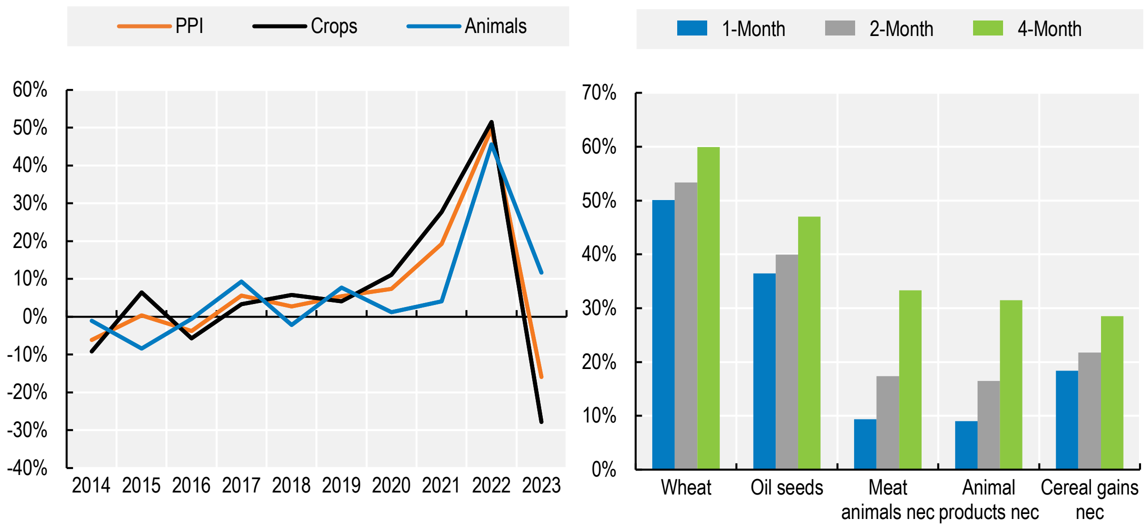
The relative price changes under the scenarios reflect those recorded during the severe drought in 2022 for agricultural products. In 2022, the year-on-year relative price change for the producer price index for agricultural output was 49.7%, with a relative change of 51.5 and 45.6% for crops and animals, respectively, see Figure 19. Similarly, the most affected agricultural commodities within our scenarios display a range of relative price changes between 31.5% and 59.9%, under the most severe scenario. However, the relative price change in 2022 was affected by the broader macroeconomic environment, which included other drivers of high inflation including, labour tightness, the energy crisis, and high inflation globally (Bech, Foda and Roitman, 2023[29]). The results under this scenario analysis only consider severe drought as a driver for relative price change. Hence, in this context, these results are more extreme than those recorded in 2022.

Figure 18. Average relative price increase of outputs by sector under three drought scenarios



Note: The relative price increases are compared to modelled data in EXIOBASE of average prices for each sector in 2022.
Source: EXIOBASE 3, authors' calculations

Figure 19. Year-on-year historical relative price change for agricultural commodities, and relative price change under three drought scenarios



Note: Lefthand side chart displays the actual historical relative price change of agricultural produce, with change benchmarked to previous year equating to 0. PPI refers to the producer price index of total agricultural output, crops refer to crops and horticultural products, and animals refers to live animals and animal products. The righthand side displays the modelled relative price change for the most affected agricultural commodities under the three scenarios, with prices baselined to 2022 data in EXIOBASE.
Source: Hungarian Central Statistical Office, EXIOBASE 3, authors' calculations

Output loss versus relative price increases

These results should be interpreted with a relative degree of caution, particularly when comparing the results related to output loss versus relative price increases. These results are calculated using different methodologies and underlying assumptions, see The Cost-Push Input-Output Price Model for Inflationary Pressures. Moreover, it should be noted that the effects from relative price increases may offset the impacts from output loss for certain sectors. For example, during the severe drought in 2022, total crop production fell by 25%, but the value of agricultural output was 19% higher than in 2021. This was due to a 44% increase in prices, which offset the loss in output for the agricultural sector (Hungarian Central Statistical Office, 2022[27]). In the results presented above, either the sectoral output or the prices are held constant to examine the impact to the economy under the three drought scenarios, rather than examining the price and output effects together due to modelling limitations. Hence, price and output impacts may partially or fully offset one another for certain sectors, and so caution should be adopted when interpreting the results.

Mitigating actions and long-term risks

The results presented above do not account for government mitigation actions, which may reduce corporate credit and liquidity stress. During historical droughts, government interventions have previously focused on highly vulnerable sectors, particularly agriculture, to help mitigate the effects of the drought. For example, during the severe drought in 2022, the Hungarian Government created a Drought Emergency Operational Taskforce with a five-point action plan to help farmers. These measures included an optional moratorium on investment and working capital loans for agricultural businesses from September 2022 to the end of 2023; HUF 3 billion for the transport of fodder for livestock farmers; HUF 1.4 billion to support the increased energy costs for public irrigation of agricultural land; assistance for farmers to resubmit applications for exceptional water use for automatic authorisation; and to speed up the procedure for insurance companies to assess and pay for drought damage to farmers to 14 days (Kovács, 2022[32]). Moreover, the government has provided longer-term funding to increase the resilience of agriculture to drought, farmers have already received HUF 45 billion to support the development of irrigation farming, with a further HUF 70 billion earmarked for this purpose (Ibid). These measures can significantly insulate the agricultural sector from the economic and financial ramifications of a severe drought.

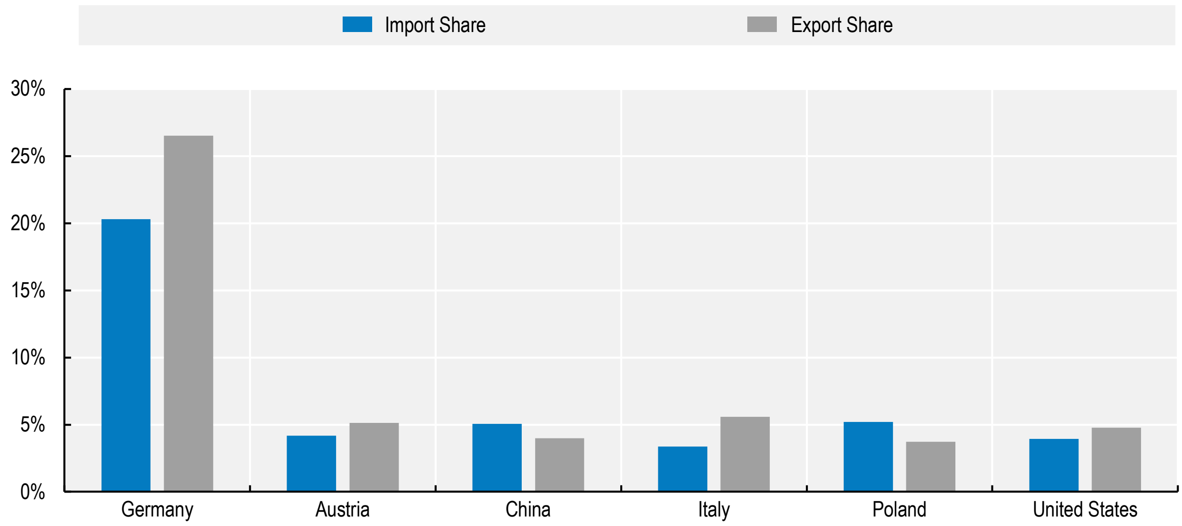
The domestic scenario focuses on economic impacts of an acute nature-related physical shock; however, several highly impacted sectors may also be adversely affected by chronic risks. The results above highlight the substantial impact on agricultural activities and manufacturing. These sectors are also exposed to more chronic nature-related risks, which may lead to gradual declines in profitability and an erosion in the value of assets. For example, the 2030 targets at both the domestic and international level on pesticide and fertiliser use may lead to reduced crops yields for farmers and affect the sales of chemical production companies. Hence, over a longer-term perspective, sectors such as agriculture may face due pressures on their business model from the materialisation of physical and transition risks.

3.2. Foreign exposure assessment

The Hungarian economy may be affected by risks originating beyond its borders, via economic ties in trading partners' economies and financial ties where the financial system is exposed to other countries. The analysis below presents the main economic linkages between the Hungarian economy and foreign economies.

The analysis focuses on exports and imports given that these are the two fundamental economic transmission channels for foreign risks. For instance, the occurrence of a nature-related shock in a country importing from Hungary may result in a reduction of demand for Hungarian inputs, which generates direct and indirect impact losses in the upstream chain located domestically in Hungary. Likewise, a shock affecting a country exporting to Hungary may result in lower inputs, output reduction, and inflationary pressures for domestic sectors. Figure 20 indicates Hungary's largest trade partners and their share in each transmission channel for foreign risks.

Figure 20. Share of total Hungarian imports and exports by top six trading partners

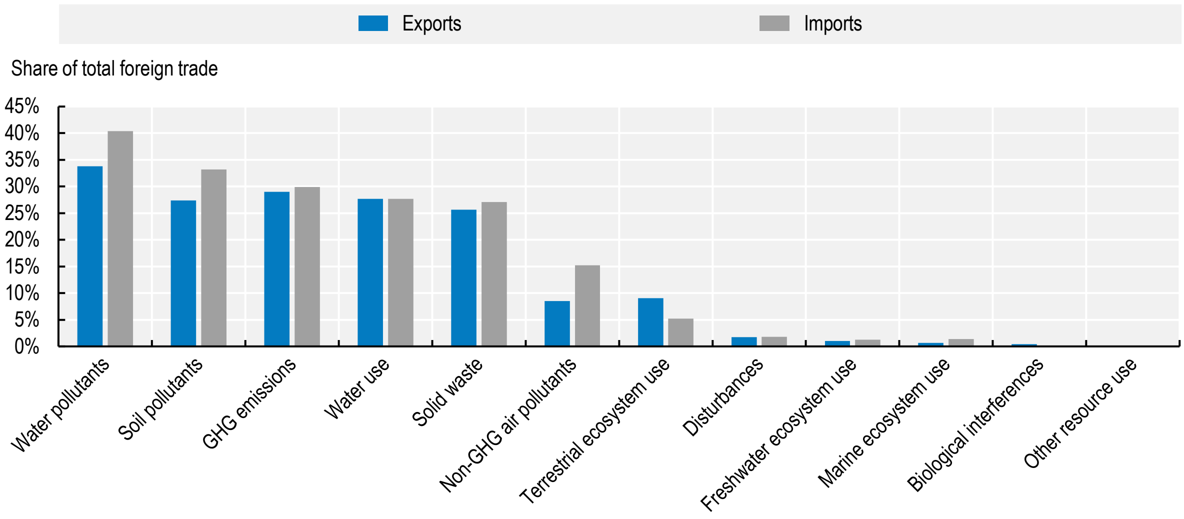


Notes: The figure shows the percentage share of total Hungarian import and exports for the six largest trading partners, broken down by country.
Source: EXIOBASE 3, authors' calculations

The Hungarian economy has the greatest trade ties with other European economies, accounting for 75.4% and 79.4% of Hungarian imports and exports, respectively. In particular, the Hungarian and German economies are closely tied through the trade in manufacturing. After European economies, Hungary has significant trade ties with Asian economies, which constitutes 15.2% of imports and 9.6% of exports. Hence, the greatest exposure to risks imported from abroad is heavily concentrated in regional European economies. This is particularly pertinent given that most European economies are part of the European Union and so will face the same policy environment regarding policies to mitigate nature loss or increase nature restoration, which may induce transition risks.

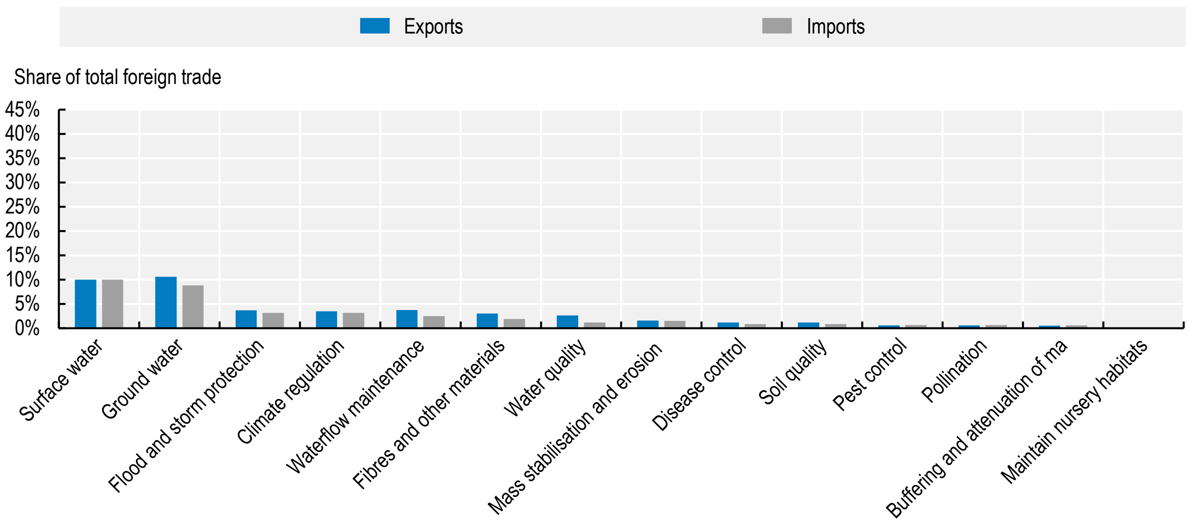
Similar to the domestic analysis, results display a greater susceptibility of the Hungarian economy to foreign transition risks over physical risks, see Figure 21 & Figure 22[14]. The shares of Hungarian exports and imports exposed to high and very high materiality impacts, hence, a proxy for transition risks, see Exploring Foreign Exposure. The results indicate around 40% of Hungarian imports and 35% of its exports are composed of activities that are highly intensive in "water pollutants". Moreover, at least 25% of Hungarian foreign trade is exposed to transition risks stemming from activities that impact nature in the form of "GHG emissions", "soil pollutants", "solid waste", and "water use". Conversely for physical risks, the results indicate that around 10% of Hungarian foreign trade activity is dependent on "ground water" and "surface water". Besides, activities dependent on "climate regulation", "fibres and other materials", "flood and storm protection", "waterflow maintenance" and "water quality" also comprise between 2% and 4% of Hungarian foreign trade.

Figure 21. Share of Hungarian foreign trade exposed to different nature-related impact drivers



Note: The chart displays the share of Hungarian foreign trade directly associated with foreign sectors that are classified with high and very high impact materiality ratings by the ENCORE classification. Taking GHG emissions as an example, the chart shows that around 29% of Hungarian exports is purchased by foreign sectors whose activities are associated with high or very high impacts in terms of GHG emissions. Likewise, 30% of Hungarian imports are purchased from foreign sectors whose activities are associated with high or very high impacts in terms of GHG emissions.
Source: ENCORE, EXIOBASE 3, authors' calculations.

Figure 22. Share of Hungarian foreign trade exposed to dependencies on ecosystem services



Note: The chart displays the share of Hungarian foreign trade directly associated with foreign sectors that are classified as having high and very high dependencies based on the materiality ratings by the ENCORE classification. Taking flood and storm protection as an example, the chart shows that around 3.68% of Hungarian exports is purchased by foreign sectors whose activities are highly or very highly dependent on flood and storm protection. Likewise, 3.14% of Hungarian imports are purchased from foreign sectors whose activities depend highly or very highly on flood and storm protection.
Source: ENCORE, EXIOBASE 3, authors' calculations

3.2.1. Materialisation and propagation of a foreign nature-related transition risk

Nature-related risks affect the economy through direct and indirect impacts, and by means of cross-market and cross-sector propagation. In the case of foreign risks, direct economic impacts take place in foreign jurisdictions while indirect and cross-propagation effects affect the domestic economy. The analysis below explores the exposure of foreign trade to the materialisation of a transition risk related to "Soil pollutants". 'First wave'[15] of indirect effects are expected to impact Hungarian sectors that directly export to the soil polluting foreign sectors. This is followed by indirect and cross-propagation effects that take place upstream inside the domestic Hungarian economy.

The total Hungarian output exposed to a foreign transition risk related to "soil pollutants" amounts to EUR 46.7 billion, as of modelled 2022 data in EXIOBASE. EUR 33.8 billion are first wave of impacts in exports and EUR 12.9 billion are the result of upstream domestic indirect and cross-propagation effects. The total exposed output represents 27.3% of Hungarian exports and 14% of Hungarian total output. The top 5 most exposed Hungarian sectors in terms of volume of the shock are presented in Table 6 together with the share of exposed total output of each sector. The exposure values for the first wave and domestic upstream exposures are presented separately and their sum add to the total output exposure.

Table 6. Hungarian economic exposure to foreign transition risk affecting soil polluting sectors

NACE Sector Description	First wave exposure (B. EUR)	Upstream exposure (B.EUR)	Total output exposure (B.EUR)	Share of sector's total output exposed
Manufacturing	27.37	5.22	32.58	26%
Wholesale And Retail Trade	1.60	1.89	3.49	14%
Transportation And Storage	1.56	0.98	2.54	11%
Administrative And Support Service	0.65	1.00	1.64	12%
Professional, Scientific And Technical	0.48	0.62	1.09	12%

Note: The table displays the Top 5 most exposed Hungarian sectors to foreign transition risks affecting foreign sectors with high and very high impact in terms of soil pollutants. The first wave exposure column indicates the total value of Hungarian exports that are sold to highly impacting foreign sectors. The column of upstream exposure indicates the value of the upstream Hungarian production that is needed for producing the exported products and, hence, is also exposed to risk. The total output exposure column is the sum of the first wave exposure and the upstream exposure. The last column on the right displays the share of each sector's total output that is exposed to the transition risk.
Source: EXIOBASE 3, ENCORE, authors' calculations

The same sectors are also most exposed for "solid waste", "water use", and "water pollutants", at a similar level of exposure. For "solid waste", the total Hungarian output that is exposed to a foreign transition risk ranges from EUR 44.1 billion to EUR 57.9 billion for the different impacts. From these, first wave effects account for between EUR 31.7 billion up to EUR 41.9 billion. Whilst upstream domestic indirect and cross-border propagation effects account for between EUR 12.3 billion to EUR 16.0 billion.

4. Financial risk assessment

The financial risk assessment is a continuation of the economic risk assessment, examining the financial risks that may materialise following an economic shock due to nature-related risks. The assessment focuses on the financial risks that could materialise because of a nature-related shock, and the consequent possibilities of contagion to the Hungarian financial sector. The analysis is based on the results of the exploratory scenario developed in the economic risk assessment.

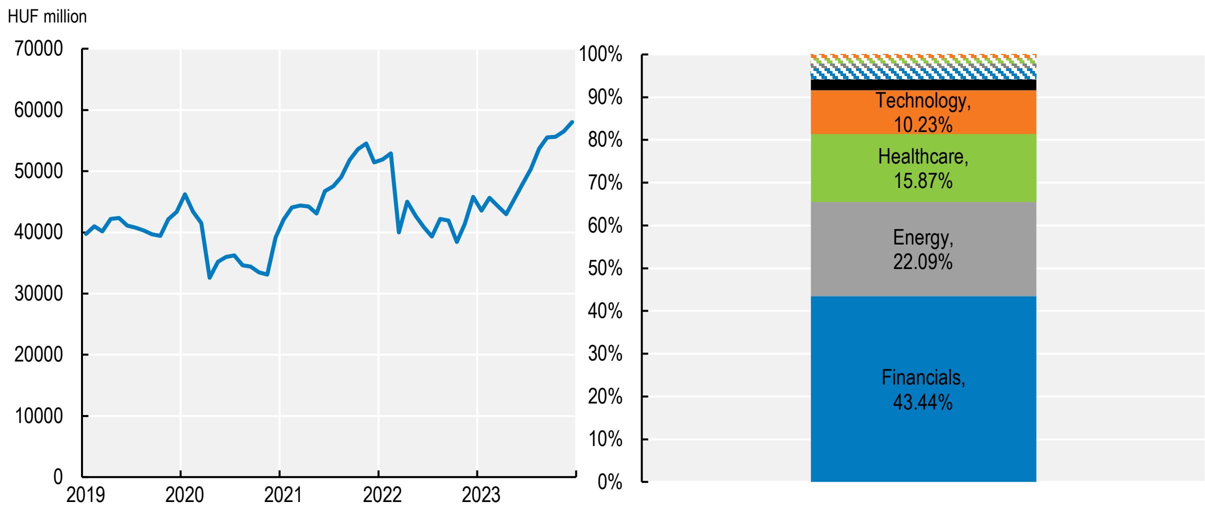
The assessment focuses on fours risks: (i) credit risk; (ii) market risk; (iii) interest rate risk; and (iv) financial system contagion. The assessment aligns with historical studies on impacts on the financial system of an economic shock and uses the results from Domestic Scenario as a basis for the analysis, see Financial risk assessment in Annex 1.

4.1. Overview of the Hungarian financial system

Following its integration into the European Union in 2004, the Hungarian financial system has undergone significant transformations. Today, it comprises banks, capital markets, insurance companies, and regulatory authorities.

The BUX (Budapest Stock Exchange Index) is the primary stock market index in Hungary. The index comprises the 17 largest and most actively traded companies listed on the Budapest Stock Exchange, representing mostly financials, energy, healthcare, and technology companies. Other sectors include consumer non-cyclicals and cyclicals, real estate, industrials, and utilities.

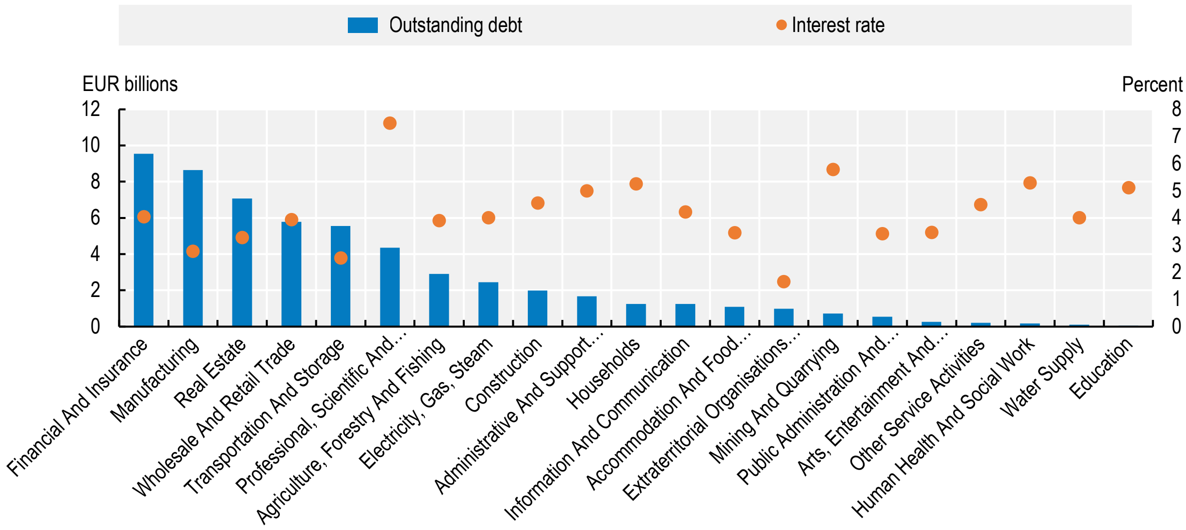
Figure 23. Budapest Stock Exchange Index and constituents



Source: LSEG, authors' calculations

The Hungarian banking sector, which is well-developed, capitalised, profitable, and liquid, plays a crucial role in financing the real economy (IMF, 2023[33]). As of the end of 2022, the largest portions of outstanding debt were held by the Financial and Insurance Activities and Manufacturing sectors. The Agricultural, Forestry and Fishing sector and the Mining and Quarrying sector represent a smaller share of the total, at around 6%. Financing costs vary depending on the sector, with an average interest rate of around 4% (calculated as a weighted average by industry).

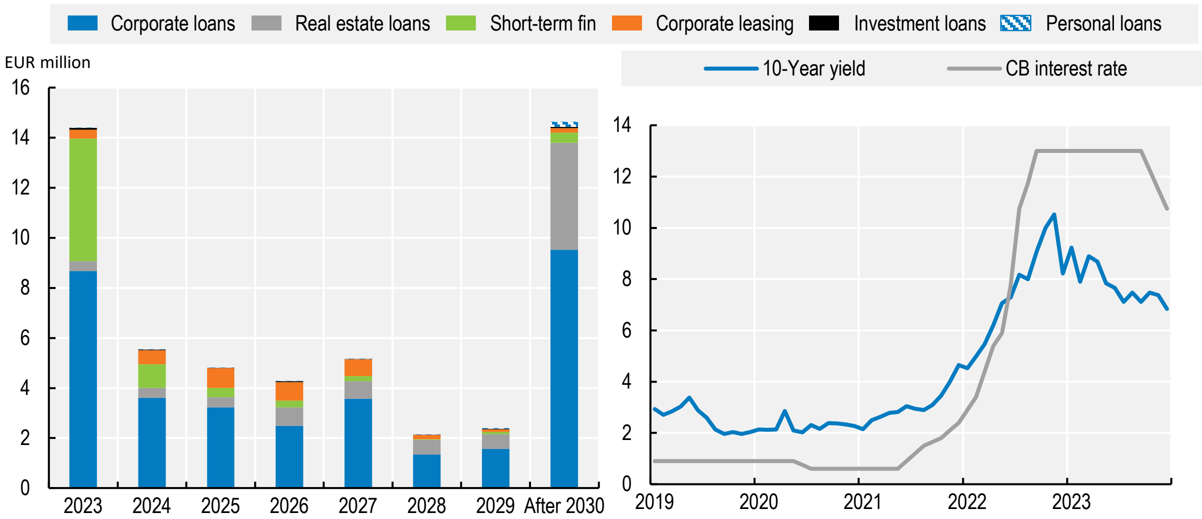
Figure 24. Outstanding debt and interest rate by sector in Hungarian banking system



Note: The interest rates shown above correspond to the average interest rate of each instrument in a given industry, weighted by the amount of outstanding debt for that instrument.
Source: MNB, authors' calculations

A stronger presence of short-term financing at the end of 2022 could increase the exposure to acute nature-related shocks in the short term. Risks could be exacerbated by continued tight financing conditions, despite easing in 2023. Nonetheless, interest rate volatility remains at historically high levels, owing to uncertainty about the speed with which inflation is set to slow.

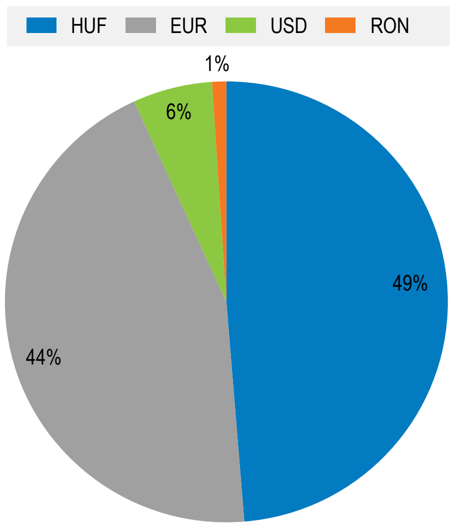
Figure 25. Maturity structure of Hungarian banking system's debt outstanding



Note: Debt outstanding as of year-end 2022. Excluding instruments with missing expiry dates, amounting to about 5.4% of the portfolio. The 10-year yield refers to the Hungarian 10-year yield on government bonds.
Source: MNB, authors' calculations

Foreign currency loans were typically taken out by companies with natural collateral in 2022 (MNB, 2023a[34]). The foreign currency financing is mainly done in euro, with a smaller presence of USD and RON.

Figure 26. Outstanding debt by currency of the Hungarian banking system



Source: MNB, authors' calculations

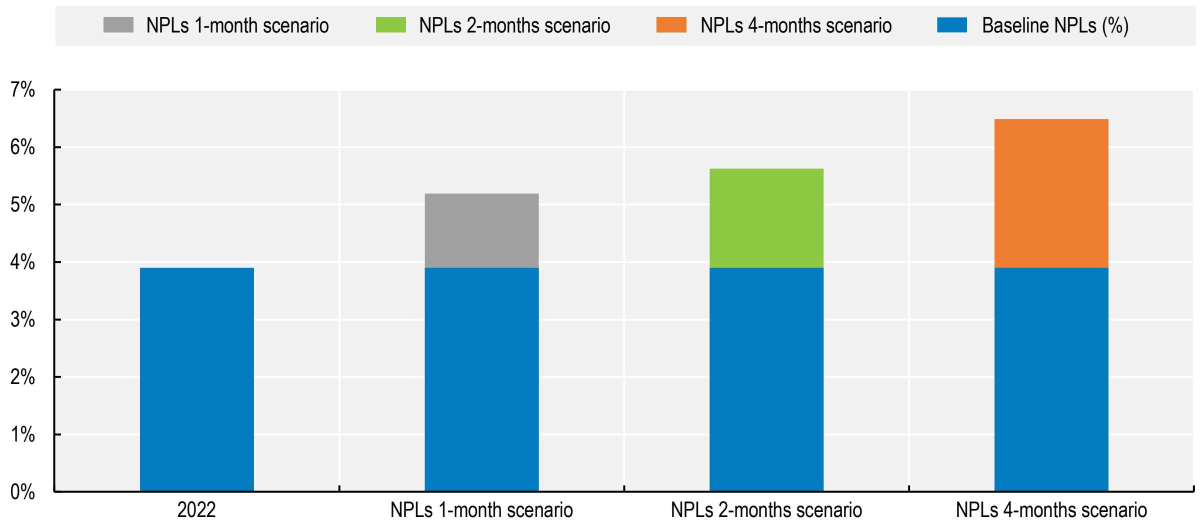
4.2. Credit risk

Nature risk drivers may lead to credit risks for the financial system via the ability of borrowers (public sector, corporates, or households) to repay debts. Additionally, domestic and foreign financial market vulnerabilities could amplify the transmission of shocks. Transition or physical risk drivers may negatively impact debt servicing capacity or the ability of banks to react to an increase in non-performing loans, particularly if the value of the collateral decreases.

At the end of 2022, the non-performing loan ratio (NPL ratio) for the corporate sector was 3.9%. This followed a steady downturn in recent years. However, the NPL ratio slightly increased after the phase-out of the general payment moratorium in October 2021, mainly due to those who remained in the moratorium (MNB, 2023a[34]).

Under the scenarios developed in the economic section, NPLs in the Hungarian banking system could incur increases in the range of EUR 730 (1.3%) up to 1461 (2.6%) millions of the total debt outstanding (see Figure 27). The assessment considers the GDP loss under the three scenarios and uses it as a proxy for the probability of default of the different sectors, after accounting for collateralisation.

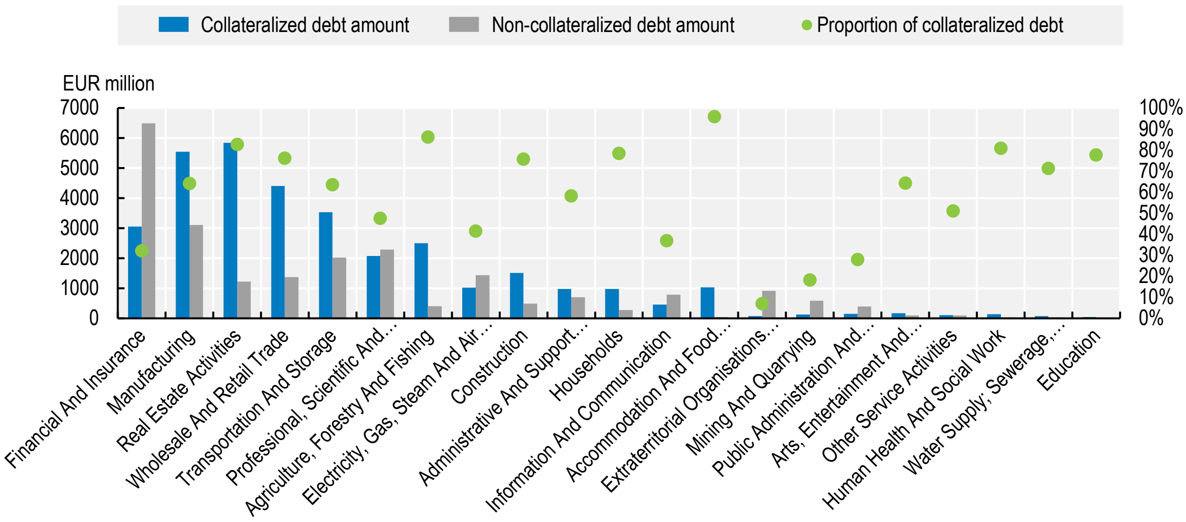
Figure 27. Ratio of non-performing loans in the Hungarian banking system under three drought scenarios



Note: The grey, green and orange bars represent the growth in NPLs, e.g. NPLs growth under one month scenario.
Source: MNB, authors' calculations

The assessment assumes that banks would be able to fully recover any losses from NPLs that are collateralised and does not account for difficulties of recovering the full amount as well as possible depreciation of collateral in an economic downturn. This assumption is particularly relevant for sectors such as Agriculture, Forestry and Fishing, and Electricity, Gas, and Steam (see Figure 28), which are heavily collateralised by real assets that could suffer from loss in value in the case of a physical risk event.

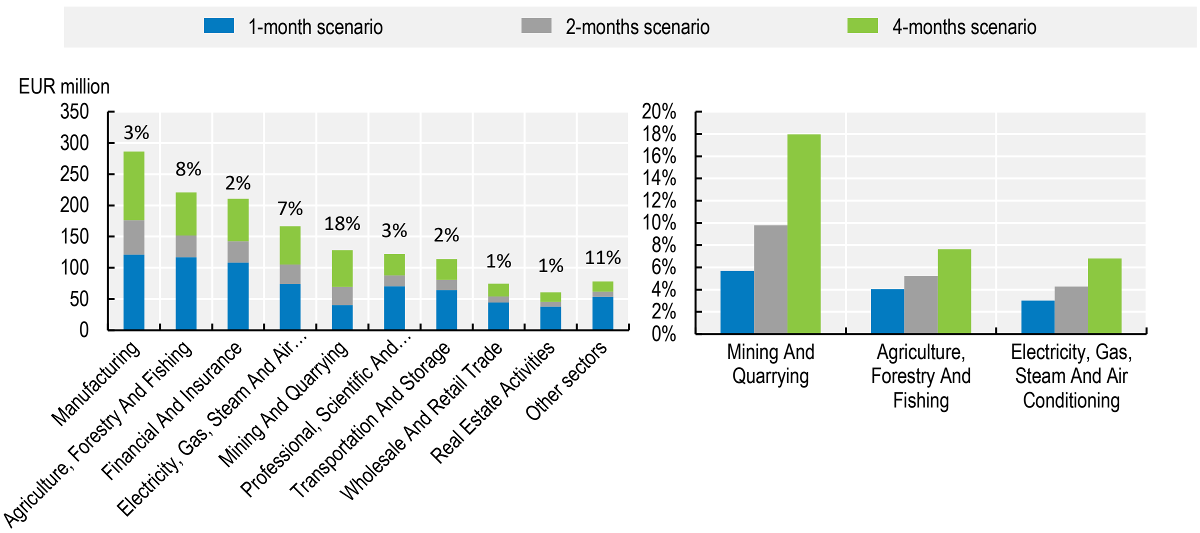
Figure 28. Amount of collateralised and uncollateralised debt by sector in the Hungarian banking system



Source: MNB, authors' calculations

Primary sectors are the ones that are most affected by a nature-related shocks given their proximity to natural resources. While Manufacturing is the sector with the largest loss in absolute terms, it still represents about 3% of the total debt, see Figure 29. The sectors suffering the most as a percentage of total debt outstanding are Mining and Quarrying, Agriculture, Forestry and Fishing, and Electricity, Gas, and Steam. Despite Agriculture, Forestry and Fishing being the most affected sector in economic terms, the high collateralisation of loans as well as the relatively low exposure of the banking system to the overall sector reduces the transmission of the financial shock.

Figure 29. Selected sectoral non-performing loans increases under three scenarios



Note: On the lefthand figure, percentages indicate the increase of NPLs under the most severe scenario on the corporate lending for each industry. The righthand figure shows the aggregated % increase in NPLs for the three most relatively affected sectors under three scenarios.
Source: MNB, authors' calculations

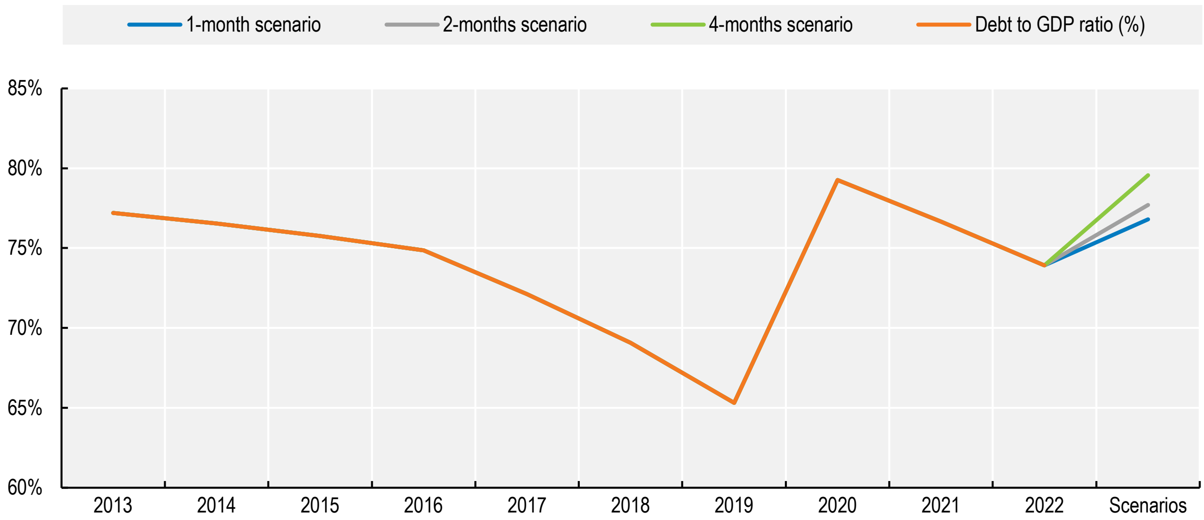
4.3. Market risk

Nature risk drivers may also lead to market risks for the financial system through volatility in market prices, including for example equity or fixed income prices. This may result in the degradation of earnings or the economic value of capital for financial institutions. However, given the limited presence of primary sector companies in the Hungarian stock market, the analysis will mainly focus on fixed income effects.

Using the aforementioned scenarios, Hungary could expect its sovereign debt to increase to a range between 76.8% and 79.6% of GDP due to the output shock. However, the assessment does not consider an increase in public spending which could result from government interventions to help the most affected sectors during the drought.

The increase in debt to GDP ratio could raise the risk of sovereign rating downgrade as well as a degradation of fixed income prices, should investor confidence on the Hungarian economy deteriorated. A downgrade in sovereign credit ratings could lead to a decline in the value of these holdings, potentially resulting in losses for financial institutions.

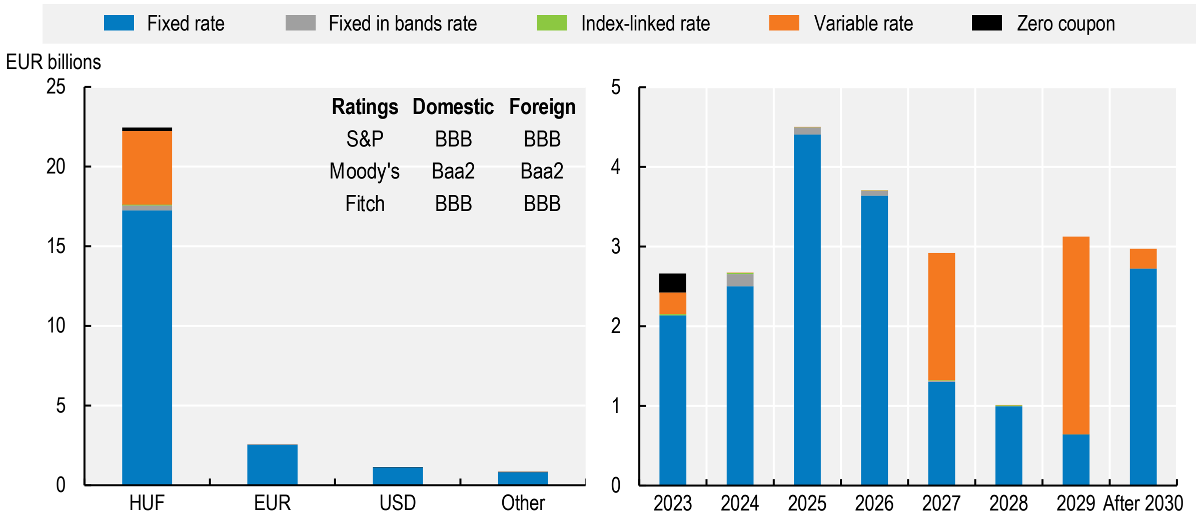
Figure 30. Public debt to GDP ratio under different scenarios



Note: General government debt
Source: NBH, KELER, Hungarian Central Statistical Office, authors' calculations

Hungarian financial institutions holding significant amounts of Hungarian Government bonds are exposed to fluctuations in the quality of Hungarian Government issuances. Additionally, foreign-currency-denominated debt holdings stand at about 20% of total debt, showing possible vulnerabilities in the event of a shock which could affect the balance of payment and the exchange rate, making these loans more expensive to repay.

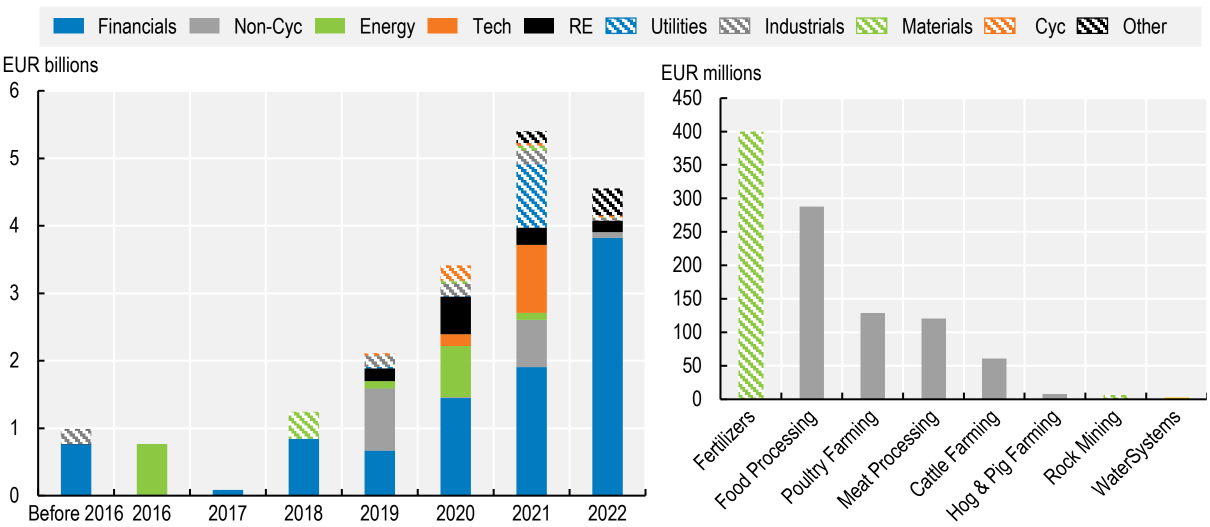
Figure 31. Amount and maturity of sovereign debt held by Hungarian banks



Note: Data as of year-end 2022.
Source: MNB, authors' calculations

The Hungarian corporate bond market could also be affected through a reduction in credit quality, particularly in sectors closely related to the shock. At the end of 2022, more than 250 corporate bonds were outstanding in the Hungarian market, most of which from financial institutions. About EUR one billion of total debt was outstanding at the end of 2022 for primary sectors engaged in agriculture, farming, and mining (see right side of Figure 32).

Figure 32. Hungarian corporate bond market issuances



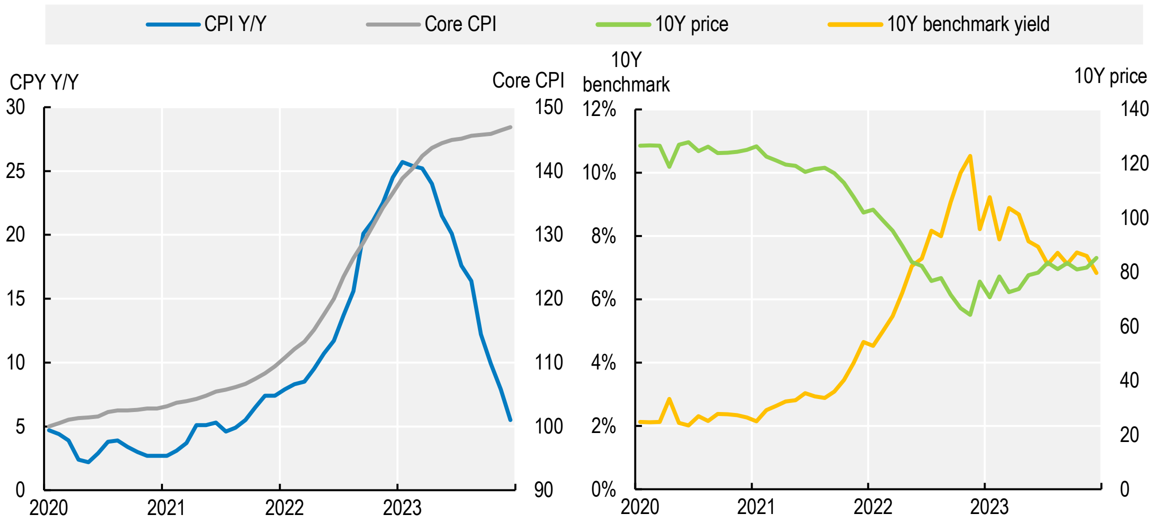
Note: Data as of year-end 2022; Cyc: Consumer cyclicals; Non-Cyc: Consumer non-cyclicals; RE: Real Estate; Other includes Government Activity, Healthcare, and Institutions, Associations & Organizations
Source: LSEG, authors' calculations

4.4. Interest rate risk

The relative price changes and inflationary pressures observed in the economic assessment, particularly within the Agriculture, Forestry, and Fishing sector, have significant implications for interest rate risk in the financial system. The relative price increases in these sectors, ranging from 13.6% to 23.9%, suggest the potential for cost-push inflationary pressures within the economy.

As a response to inflationary pressures the MNB may adjust interest rates to maintain price stability and manage inflation expectations. In the context of interest rate risk, such adjustments can influence the yields and market values of fixed-income securities, including holdings of Hungarian financial institutions as shown in Figure 33. Declines in the market value of existing fixed-income securities may lead to potential liquidity concerns and capital losses for financial institutions.

Figure 33. Core and year over year consumer price index and 10Y benchmark



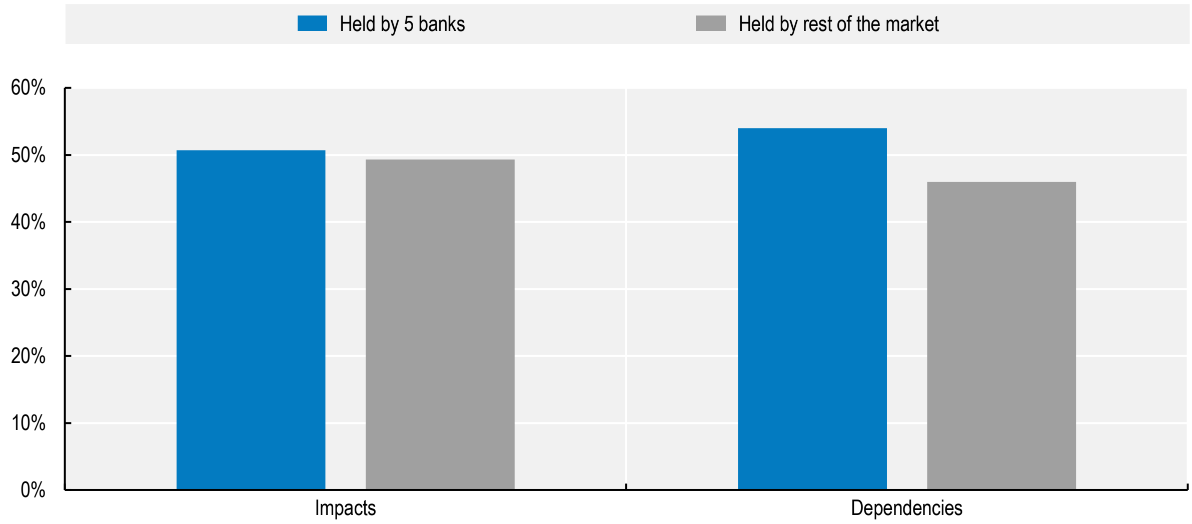
Note: Base year (100): 2020
Source: LSEG, authors' calculations

4.5. Financial system interaction and real economy feedback

Concentration risk could pose a significant concern for Hungarian financial institutions, given the potential for adverse effects on portfolio stability and resilience. This risk arises when institutions have a high level of exposure to physical and/or transition risks, making them more vulnerable to disruptions.

In the Hungarian context, concentration risk can manifest in various forms, such as excessive exposure to specific industries like Agriculture, Forestry and Fishing, or reliance on a small number of counterparties for a substantial portion of lending or investment activities. As shown in Figure 34, more than 50% of all instruments directly related to a high or very high-risk sector are held by five banks.

Figure 34. Share of direct exposure to high-risk sectors



Note: Exposure to at least one ecosystem service for impacts and one for dependencies. The final calculation is the share of high and very high materiality instruments owed by banks, as a share of all high and very high instruments in the entire financial system. Figure considers number of banks which hold 50% of the exposure to impacts.
Source: MNB, authors' calculations

In the event of a nature-related shock, if a financial institution has a large portion of its portfolio concentrated in a particular sector that experiences a downturn, such as Agriculture, Forestry and Fishing, the institution's overall financial health could be jeopardised. Similarly, if a significant portion of the institution's investments is concentrated in sovereign bonds issued by the Hungarian Government, any adverse developments in the sovereign's credit quality could have a disproportionate impact on the institution's asset value and profitability.

4.5.1. Feedback between the financial system and the real economy

The Hungarian financial system plays a crucial role in the economic infrastructure of the country, supporting the flow of capital between savers and borrowers and supporting economic growth and stability. However, this relationship also means that vulnerabilities in one sector can quickly transmit to the other, exemplified by the feedback loop between the financial system and the real economy.

Information asymmetries within the financial sector or the real economy can exacerbate these vulnerabilities, particularly concerning the financial risks stemming from nature loss. For instance, the lack of clear data on the impacts and dependency of financial institutions on ecosystem services can mask the true extent of exposure to nature-related financial risks. Similarly, the concentration of cross-border exposures and dependencies within the financial system could amplify these risks, as a shock in one country can lead to significant repercussions globally.

Furthermore, there could be overlap between sectors identified as high-risk for nature-related financial risks and those for climate-related risks, such as Agriculture, Forestry and Fishing, Electricity, Gas, and Steam, and Manufacturing. This overlap suggests a potential amplification of financial risks due to the interaction between climate change and nature loss. For example, climate change can exacerbate the degradation of natural habitats and biodiversity, leading to more pronounced impacts on sectors that rely on ecosystem services, thereby amplifying the financial risks associated with nature loss.

5. Supervisory considerations

Building on key results from the assessment, this chapter presents high-level considerations for the Central Bank of Hungary (MNB) to incorporate nature-related financial risks into its monitoring and assessment activities, as part of MNB Green Programme and under MNB's green mandate. The goal is to explore how these risks can be integrated into the activities and operations of the MNB. Additionally, collaboration with the government on nature-related risks could be beneficial in considering governmental agencies' perspectives.

This chapter should be viewed as **non-prescriptive considerations** for MNB to manage nature-related financial risks, and not as recommendations. These suggestions outline possible avenues for MNB to consider these risks in their operations, but do not recommend any single approach to be undertaken. This reflects the evolving understanding of nature-related financial risks in the context of the broader policy context such as the Global Biodiversity Framework, the evolving European legislation and broader financial sector policies. The considerations outlined provide the flexibility to explore alternative interpretations and methods for integrating these risks into supervisory practices. It is also important to note that this chapter is tailored to MNB, under its Green Programme. It builds on non-prescriptive supervisory considerations provided by the Supervisory Framework for Assessing Nature-related Financial Risks, which recognises that country circumstances and mandates differ.

5.1. Applicability of existing MNB policies to nature-related financial risks

MNB has increasingly acknowledged the critical importance of environmental sustainability and the risks climate change poses to financial stability. In response to this and its "green mandate", the MNB's is undertaking a strategic shift towards integrating environmental considerations into its core functions.

The MNB's Green Programme was adopted and published in January 2019. MNB's Green Programme strives to ensure that both the MNB's own activities and the operation of domestic financial markets and the financial intermediary system contribute to the detection, assessment, prevention and management of environmental risks and to Hungary's climate policy objectives, while also meeting prudential requirements to the maximum extent possible (MNB, 2021a[35]). As part of this shift, in 2022 MNB also issued a recommendation in relation to the identification, measurement, management, control, and disclosure of climate-related and environmental risks and the integration of environmental sustainability considerations into the business activities of credit institutions (MNB, 2022[36]).

Building on MNB's Green Programme, three pillars are assessed with respect to their applicability to nature: 1. Initiatives in the financial sector; 2. Development of MNB's social and international relations; and 3. Greening of MNB's own operations. Existing climate-related risks considerations can be useful to understand what could be needed from the perspective of nature-related risks in terms of national supervision and international cooperation, data, and methodologies, noting possible limitations to the degree to which tools and analysis for climate can be applied to nature (ECB, 2024[37]) (OECD, 2023[38]):

5.1.1. Pillar 1: Initiatives in the financial sector

- **Analysis of ecological and financial risks**: Despite the increased complexity of nature-related risks with respect to climate due to its multifaceted characteristics, existing green policies can be useful to tailor the assessment of financial risks. Understanding short-term risks as well as capturing the long-term consequences of nature losses is essential as a widespread loss of biodiversity and ecosystems would have impacts extending beyond countries' borders. As such, climate scenarios can help inform the development of nature scenarios, such as those being developed by the NGFS (NGFS, 2023[26]), and move towards an integrated assessment of climate- and nature-related risks. This approach would allow the MNB to proactively assess potential future nature-related financial risks and implement necessary mitigation and adaptation measures in line with its mandate.
- **Greening financial services, mobilising funds for green goals**: While "green" markets, instruments and products are already becoming mainstream for climate, nature-related financial markets' instruments and products may take more time to develop and become widely adopted particularly given the complexity of nature. Initially, the MNB may analyse the 'green' products offered by financial institutions and take stock of the inclusion of key performance indicators (KPIs)[16] which explicitly account for broader nature-related issues beyond climate, such as biodiversity loss, pollution, or water use. The analysis may serve as a basis to engage with financial institutions to understand the 'environmental usefulness' of the KPI indicators and help establish best practices, referring to external standards, such as the TNFD framework, where relevant. This foundation may identify relevant KPIs and support instruments, such as indices and funds, to tilt towards products (such as equity and fixed income) that are in line with global biodiversity goals. Additionally, the MNB can take a leading role by including similar tilting methodologies within its asset purchase programmes.
- Moreover, existing green products' frameworks, roadmaps, and guidelines, primarily aimed at climate objectives, can be further expanded to include biodiversity and broader nature objectives. Again, the initial analysis and identification of useful KPIs can help support the broadening of these frameworks to consider biodiversity and broader nature. An example would be the Hungarian Green Bond Framework, which already includes biodiversity considerations (The Hungarian Government, 2023[39]). However, the inclusion of nature-related criteria could be expanded to cover broader nature-related issues, aligned with the objectives in the National Hungarian Biodiversity Strategy. For instance, broadening the environmental impact reporting criteria beyond greenhouse gas emissions to consider progress towards the goals in the National Biodiversity Strategy to restore wetlands, grasslands, and forests, or reduce nutrient leaching.
- Beyond financial product development, just as has been done for climate issues, prudential frameworks could integrate nature-related considerations to provide capital incentives (such as more favourable capital requirements existing in Hungary). This would guide banks, insurance companies, and other financial service providers towards supporting the cause of nature protection.

5.1.2. Pillar 2: Development of MNB's social and international relations

- **Deeper co-operation with domestic partners**: Cooperation with domestic stakeholders of the government, the market, and the society that are relevant for climate change will also be relevant for nature related risks. Given the complexity and non-linearity of nature, collaborating with relevant agencies and institutions that possess greater expertise and access to nature-related data would enhance the analysis of nature-related financial risks. This may include notably collaboration with the Hungarian Ministry of Agriculture, the Hungarian Central Statistical Office, and academia, as well as others.

- **Raising awareness, sharing knowledge, and building capacity on green finance including through trainings**: Improved awareness is essential to effectively address nature-related risks. Similar to the green finance trainings, MNB could launch dedicated trainings to collect and share knowledge on nature-related risks (for example in the area of data availability, measurement approaches and modelling). Trainings on nature-related financial risks and best practices on risk management may help improve the understanding and processes in-place at domestic financial institutions.
- **Active involvement in international efforts regarding climate-related financial risks and green finance**: Global coordination and co-operation will be important to understand nature-related financial risks and help develop approaches to measure, assess, and monitor these risks, especially given the emerging, fast-growing research. International bodies such as the OECD and the NGFS may take a leading role to facilitate knowledge exchange and develop a globalised understanding of these risks. For example, the MNB may take a leading role in the Nature Taskforce of the NGFS in the integration of nature-related financial risks into the current climate workstreams. Moreover, since the adoption of the Kunming-Montreal Global Biodiversity Framework in 2022, there has been significant international efforts on biodiversity. The MNB can support these endeavours with the upcoming COP16 in Cali to highlight the progress made and coordinate with global partners on the development of financial product innovation and the assessment of financial risks arising from nature-related losses.

5.1.3. Pillar 3: Further greening of MNB's own operations

- **Efforts to further decrease the ecological footprint of the MNB**: A clear plan to identify and mitigate any nature related impacts would help the credibility of MNB in leading the implementation of its operations. However, differently from climate, increased complexity and need for granular information regarding nature-related risks may make it more difficult to measure the impact of the footprint on nature. Concretely, the MNB may choose to utilise biodiversity offsets to support ecosystem services and reduce the impact of operations on nature.
- **Efforts to further increase environmental disclosures of MNB**: In line with existing initiatives on reporting frameworks, such as TNFD and the Corporate Sustainability Reporting Directive (CSRD), MNB could attempt to disclose information on its nature impact. For example, the TNFD disclosure framework consists of conceptual foundations for nature-related disclosures, a set of general requirements, a set of recommended disclosures structured around the four recommendation pillars of governance, strategy, risk and impact management, and metrics and targets. To conduct TNFD reporting effectively, MNB could follow several steps. First, establish governance structures that ensure clear oversight of nature-related risks and opportunities. This strategy should outline short, medium, and long-term goals for managing nature-related risks and opportunities. Furthermore, implementing processes to identify, assess, and manage these risks is vital. Selecting appropriate metrics to measure nature-related risks and impacts is another critical step. In addition to mean species abundance (MSA), other potential metrics include natural capital depletion, ecosystem service dependency, and land-use change. Regularly publishing disclosures that align with TNFD recommendations will provide transparent and consistent information on nature-related risks and opportunities, enhancing the bank's accountability and public trust. However, given the emerging nature of these risks, in the short term, flexibility in reporting of these risks may be beneficial. Akin to the TCFD reporting undertaken by the MNB, this disclosure may include analysis of the nature-related impacts of the assets held on the MNB's balance sheet, in the form of an impacts and dependencies assessment. Similar to the TCFD reporting, multiple metrics may be employed, including (for example) such metrics as mean species abundance (MSA) to examine the potential impact to biodiversity. From this analysis, the MNB may disclose how its processes around governance, strategy, and impact management related to its own portfolios in MNB's reserve management reflect nature-related risks and opportunities, also with respect to its mandate. Moreover, this disclosure can offer leadership and

a forward-looking perspective on the MNB’s view on the development of nature-related financial risks and financial product development.

5.2. Short-term considerations

The MNB could leverage the resources provided by the OECD, NGFS and TNFD, as well as by domestic institutions, to identify relevant available data and metrics. To achieve this, improved domestic and global co-operation and collaboration is essential. The MNB's active participation and collaboration with bodies like the OECD, NGFS and the FSB (FSB, 2024[40]) can enhance the development and adoption of global regulatory reporting frameworks. Existing and future work, such as the NGFS conceptual framework, the forthcoming NGFS work on the supervisory dimension of nature-related risks, starting in June 2024 and the OECD supervisory framework, can be leveraged to establish common definitions on nature-related financial risks in Hungary (OECD, 2023[38]) (NGFS, 2023[41]). Concretely, the NGFS is embarking on integrating nature-related considerations into its workstream on supervision, with the objective to consolidate and exchange supervisory practices, as well as assess the adequacy of existing principles and disclosures to conduct effective supervision. The MNB can participate in this work and help further these efforts by reflecting upon their own experience and analysis of nature-related risks. Coordination and knowledge-sharing with relevant domestic and international institutions may also help identify relevant metrics and indicators based on the experience and assessment undertaken by these institutions.

Existing works on nature-related financial risks could benefit from further enhancement through the application of advanced methodologies. This may include an examination of firm concentration within identified high-risk sectors, the use of domestic multi-region input-output models (MRIOs), and, where available, using firm-level data to assess intra-sectoral differences in risk. Moreover, the MNB may undertake a stocktake of current KPIs used by market participants to measure nature-related risks to assess their ‘environmental usefulness’ and establish best practices around metrics to support analytical work on nature-related financial risks.

Additionally, the MNB already employs prudential approaches to manage financial risks across the financial system, which can be extended to address nature-related risks. Further analysis of the Hungarian financial system’s exposure to such risks may enhance the MNB’s toolkit for risk assessment and mitigation. Specifically, to better understand the channels through which these risks may propagate across the financial system, including interconnectedness, financial contagion, concentration, and complexity. The analysis could include identifying which financial institutions are most exposed to the more prevalent nature-related financial risks and the extent to which these financial institutions are interconnected with the broader financial system. **Given the high dependency and impact of the financial system on water-related ecosystem services, this could be a suitable starting point for this analysis.**

5.3. Medium-term considerations

In the medium term, MNB may develop supervisory expectations for credit institutions to identify, assess and manage nature-related risks into their governance structures, processes, and risk management controls. The MNB could expect credit institutions to regularly undertake impacts and dependencies assessments to understand their exposure to nature-related risks and show what steps are being taken to ensure capacity to manage these risks under all areas of the supervisory expectation. Recognizing the emerging nature of these risks, the MNB should provide flexibility initially, allowing financial institutions to adapt their approaches based on evolving understanding and identification of key metrics. The metrics and indicators identified under the short-term considerations may serve as a foundation to help guide financial institutions on their choice of metrics. This flexibility will enable institutions to enhance their understanding of nature-related risks within their portfolios while facilitating the identification of the most relevant metrics for reporting. This may include a mix of qualitative and quantitative metrics which serve as proxies for nature-related transition and physical risks. An initial starting point may be MNB's current Recommendation on "climate-related and environmental risks and the integration of environmental sustainability considerations into the activities of credit institution" (MNB, 2022[36]).

In anticipation of global nature scenarios, such as those developed by the NGFS, the MNB may start to assess how to refine its approach to nature scenario analysis and stress testing. This may include developing approaches to tailor scenarios for domestic contexts and accommodate the locality of nature-related financial risks. In supporting these efforts, the MNB may opt to requesting qualitative and quantitative information from credit institutions, such as the geo-location data of economic assets at risk, and the relationship between those assets and their investors or economic actors downstream in the value-chain, to help support the development of this approach. Moreover, the MNB may draw upon the market information which will become available under the Corporate Sustainability Reporting Directive (CSRD) disclosure to help identify key areas of focus. The MNB may draw upon lessons from their 2023 climate scenario analysis and macro financial monitoring reports (MNB, 2023a[34]) (MNB, 2023b[42]). The MNB should aim for an integrated assessment of both climate and nature-related financial risks, as well as more traditional forms of risk, and consider their interconnectedness and cumulative impacts on the financial system. Moreover, the results of MNB's current economic and monetary forecasting analysis could be integrated to provide a forward-looking view of how nature-related financial risks may be relevant for the central bank's objectives. Whilst such practices are nascent at this time, given the relevance of nature-related risks for inflationary pressures, analysis on agricultural commodity prices may serve as a suitable starting point to integrate these risks into forecasting analysis.

5.4. Long-term considerations

In the long term, understanding the domestic implications of nature loss will be crucial for Hungary. Given the country's unique biodiversity and economic dependence on certain natural resources, the MNB should prioritize these risks to ensure that it can continue to meet its objectives in the long-term. The MNB can incorporate considerations of nature loss alongside other financial risks in its stress testing practices through the development of scenarios to conduct economic and financial risk analysis based for example on the NGFS technical recommendations (NGFS, 2023[26]). In this assessment, three drought scenarios were developed; however, future scenarios may further refine these scenarios and include additional components of nature-related risks, including water pollution and soil degradation from fertiliser and pesticide use, or a loss of pollinators due to land-use change. In time, analysis of cross-border risks could be integrated into regular assessment of nature-related financial risks. This might be a priority for Hungary, given the interconnectedness of their economy with other European economies, particularly regarding trade in the agriculture and manufacturing sectors. These cross-border assessment may be undertaken through joint scenario exercises; however, such assessments will be contingent on most authorities first understanding the risks in their domestic jurisdictions. In practice, integrating cross-border risks into nature-related financial risk assessments involves first understanding domestic risks, then collaborating with counterparts through joint scenario exercises. Hungary would analyse how interconnected sectors like agriculture and manufacturing are affected by nature-related risks, both domestically and from neighbouring countries. Regular monitoring and reporting would follow, ensuring preparedness and coordinated mitigation strategies.

Beyond assessment, if the MNB deems it appropriate and suitable for their objectives, they may consider adjustments to monetary and prudential frameworks to reflect nature-related considerations. Such actions could reflect the MNB's 'Green Capital Requirement Programme', which offered capital discount for eligible gross exposures under Pillar II (MNB, 2020[43]) (MNB, 2023c[44]). Whilst the current framework already includes agricultural activities with positive impacts on biodiversity and broader nature, this could be extended to also include other key sectors regarding nature-related financial risks, such as manufacturing.

In addition to existing measures, such as to promote sustainable agricultural practices, with crop rotation and organic farming, the programme could ensure all thresholds are aligned with the targets outlined updated National Biodiversity Strategy and new EU regulation. For example, the targets outlined on reduced fertiliser use by 20% and nutrient leaching by 50% in agriculture. It should be noted that such action is relevant for the objectives of the MNB given its “green mandate” for the promotion of environmental sustainability (MNB, 2021b[45]). However, this may not be applicable to other jurisdictions, given differences in national circumstances and objectives.

Annex A. Technical implementation and methodological overview

This annex provides detailed guidance of the methodology used to assess the Hungarian financial system's exposure to physical and transition risks originating from its interactions with natural ecosystems. Drawing from the Supervisory framework, the paper (i) undertakes a risk identification and prioritisation assessment to identify nature-related risks with the greatest relevance for financial materiality based on loan level data held by Hungarian financial institutions. It builds on an impact and dependency assessment that considers impacts as a proxy for transition risks and dependencies as a proxy for physical risks using ENCORE; (ii) Assesses the direct and indirect economic impact of three exploratory sub-scenarios on possible nature-related shocks using input-output analysis; (iii) Explores the different financial risk channels by which economic risks stemming from nature-related losses assessed previously may be transmitted in the Hungarian financial system; (iv) provides supervisory recommendations based on the results.

Data and data gaps

The implementation of the supervisory framework requires an understanding of where gaps exist with regards to data and assessment tools and what can be done to tackle these gaps.

The first gap can be identified in the access to data on transmission channels: Several approaches to assess financial risks and dependencies on biodiversity (including the approaches developed in the Handbook for Nature-related Financial Risks and the corporate and financial disclosure approaches developed by TNFD) require identification of the financial and economic transmission channels by which geographically located changes in biodiversity influence financial outcomes. This requires geo-location data of economic assets at risk, and the relationship between those assets and their investors or economic actors downstream in the value-chain. Several initiatives exist which are increasing the availability of these areas of data. However, further action is needed to increase transparency and data availability in these areas.

The second gap regards multidimensional indices: Recent literature suggests a broader consensus on the complexity of biodiversity and its measurements. A single metric or index is generally insufficient to provide a comprehensive view of the state of biodiversity, making it necessary to use them together. A number of studies suggest that different metrics may be used together to provide a broader understanding of biodiversity processes. For example, while the Potentially Disappeared Fraction (PDF) reflects the percentage of species richness that could be lost due to environmental pressures, the Biodiversity Impact Metric (BIM) could help understand the key element in a supply chain causing biodiversity losses. When used together, these metrics could deliver more granular information. Additional research is necessary to determine the viability of multidimensional indices as instruments to measure biodiversity risk.

The third gap in the assessment can be identified in the need for standardisation and comparability of data and outcomes: Each biodiversity measurement has its own assumptions and characteristics. Considering the need to use different metrics simultaneously to obtain comprehensive information on different aspects on the state of biodiversity, there could be issues with reconciliation of data due to the differences in methodologies. Quality checks and verification for nature-related data have been recently called for by many financial institutions to ensure comparability of data and analyses. Thus, further developments are required to explore approaches of standardisation to ensure coherent and comparable data.

Lastly, gaps exist regarding the translation of biodiversity data into useful financial metrics: Analysed metrics and indicators focus on the delivery of information related to environmental considerations. This means that they provide enough information for driving environmental decision making. Nevertheless, this information remains insufficient for finance-related purposes. For this reason, further actions are needed to effectively translate current biodiversity metrics into relevant information that can provide insights on biodiversity risk. This also accounts for biodiversity's role in mediating climate risks. Further research needs to identify decision-useful biodiversity data that can be translated into financial risks.

Risk identification and prioritisation

The methodology adopts a structured approach to identifying and prioritising financial risks associated with nature. It begins with a detailed analysis of economic activities from the ground up, based on asset-level data. This bottom-up perspective is essential for the initial phase of the assessment, focusing on the impact and dependency links that connect the financial system to activities either affecting or reliant on natural ecosystems. This crucial stage enables the quantification of the materiality of economic activities. It essentially measures the extent to which these activities pose risks to nature, and vice versa. The approach to assessing impacts and dependencies, however, is centred exclusively on financial assets linked to economic activities. This focus is key to discerning how physical and transition risks intersect within the financial ecosystem.

To systematically assess the impacts and dependencies, the framework outlines five principal methodological steps: First, the scope of financial assets relevant to the analysis is evaluated. Second, these financial assets are connected to specific economic activities. Third, the materiality of each non-financial corporation's impact on, or dependency on, ecosystem services is determined. Fourth, the degree of materiality of these impacts or dependencies for each ecosystem service is calculated, considering their significance to the financial system's overall portfolio. Finally, the extent to which impacts and dependencies on ecosystem services overlap across various economic sectors is examined. This structured approach provides a comprehensive foundation for understanding the intricate relationship between economic activities and the natural environment, guiding the assessment of nature-related financial risks.

Data on Hungarian securities

The dataset under examination, sourced from the MNB, includes a comprehensive inventory of securities held by Hungarian financial institutions. This inventory specifies the instrument type, outstanding capital amount, and customer classification, among other details. The focus of the analysis is on securities issued by non-financial corporates and individuals identified as primary agricultural producers, collectively referred to as "firms".

This data is systematically collected due to the legal mandate requiring all Hungarian financial institutions to report their holdings to the MNB by a specified deadline. This regulatory framework ensures the dataset's comprehensiveness and accuracy, providing a solid foundation for the analysis.

However, due to confidentiality constraints, the dataset omits identifiers for individual borrowers and lenders. This necessitates conducting the analysis at the instrument level rather than at the firm level. This approach treats the Hungarian financial system as a monolithic entity, navigating the constraint to provide a comprehensive overview of the financial sector's interactions with natural capital as a whole.[17]

The central component of the analysis is the industry classification variable, detailed at the 4-digit NACE level for firms, as included in the dataset from the MNB. Of the 615 industry classifications defined by NACE at this level of detail, the dataset encompasses instruments linked to 597 categories, thereby covering a broad spectrum of economic activities.

This classification facilitates the precise alignment of securities with their respective economic sectors and, subsequently, with their impact and dependency ratings, as defined by the ENCORE framework's materiality assessments. For each of the 615 sectors, the analysis evaluates the reliance on specific ecosystem services, such as crop pollination, water supply, and flood protection, as well as the effects on biodiversity, encompassing habitat conversion and pollution. The analysis involves aligning sectoral activities with relevant ecosystem services, following ENCORE's standardised classifications, as detailed below.

ENCORE framework

The methodology deployed for the assessment of both physical and transition risks is based on the application of the open-access ENCORE framework. This framework, a collaborative development by the Global Canopy, UNEP FI, and UNEP-WCMC, systematically evaluates the extent of economic activities' dependence on specified ecosystem services and their consequent impacts on natural capital assets. It thus provides materiality ratings for various production processes, not requiring therefore firm identifiers to assess impacts and dependencies. For the allocation of these materiality ratings, denominated as dependency and impact scores, the ENCORE tool scrutinizes each sector's potential dependence on ecosystem services and its prospective implications for natural capital, drawing upon comprehensive sector research and expert consultations. Dependency scores are ascertained by gauging the significance of the functional loss and financial impact ensuing from disruptions in ecosystem services, with a gradation spanning from limited to severe. Conversely, impact scores appraise the frequency, immediacy, and severity of anticipated effects on natural capital.

The ENCORE framework plays a pivotal role in assessing the complex relationships between Hungary's economic sectors and the ecosystem services essential to them. This analysis of interactions between sectors financed by the Hungarian financial system and ecosystem services pinpoints vulnerabilities: sectors highly dependent on ecosystem services encounter increased physical risks, whereas those impacting these services negatively face transition risks. Such an approach facilitates a systematic identification and quantification of risks and opportunities, underscoring the fundamental dependencies and impacts of economic sectors on natural capital.

Direct materiality ratings

ENCORE uses a modified version of the GICS industry classification system to attribute production processes to economic activities. In this context, a "production process" refers to the sequence of operational steps or activities that culminates in the creation of a product or service, to which materiality ratings have been attributed for each ecosystem service.

The ENCORE tool attributes one of 5 levels of materiality ratings for each production process – ecosystem service pair, ranging from very low to very high, or an N/A marker. The production processes have been matched with the instruments in the MNB data, whose obligors are classified using the NACE industry classification system, through a GICS – NACE correspondence table provided by UNEP-WCMC.

In transitioning from one industry classification system to another, such as from GICS to NACE, it's important to acknowledge the inherent loss of information that occurs due to the imperfect alignment between the two systems. The mapping is not a precise one-to-one correspondence, as multiple NACE codes may correspond to a single GICS code and vice versa, leading to potential oversimplifications or ambiguities in the classification of industries. Despite these challenges, a correspondence table matching all 615 NACE codes with ENCORE production processes was successfully developed.

After linking production processes to NACE codes and assigning associated impact and dependency scores for each ecosystem service/impact driver, these qualitative ratings were converted to quintiles, ranging from 0 to 1.[18] When multiple production processes corresponded to a single NACE code, the materiality rating for that industry identified at the 4-digit level, was determined as the simple average of the ratings for each associated process, rounded up to the nearest higher quintile (multiple of 0.2).[19] The resulting tables present the direct impacts and dependencies of each 4-digit NACE industry on 12 impact drivers for impacts and 21 ecosystem services for dependencies, termed as "standard" direct materiality ratings,[20] encompassing the full spectrum of potential materiality ratings per ENCORE.

Indirect materiality ratings

In assessing materiality ratings for each industry, this analysis incorporates both direct and indirect (upstream) impacts and dependencies. Following precedents in the literature ((Boldrini, Ceglar and Lelli, 2022[46]), (Svartzman et al., 2021[47])), the approach for determining upstream materiality ratings posits that a sector's total indirect impact / dependency is the weighted average of the direct materiality ratings of all sectors within its supply chain.

The identification of sector-specific value chains required the use of the EXIOBASE3 input-output table for 2022. This analysis attributed ENCORE production processes -and consequently, the associated materiality ratings- to EXIOBASE3 sectors through the EXIOBASE to NACE correspondence table, coupled with an in-house matching between NACE and ENCORE production processes.

Given that the original ENCORE materiality ratings are not regionalised, meaning that the production process is considered to have the same impacts and dependencies regardless of where the economic activity takes place, the decision was made to compute globalised metrics for indirect impacts and dependencies to ensure consistency.[21]

The process involved reconfiguring the EXIOBASE3 input-output table into a consolidated global industry framework by aggregating sectoral data across different countries into a singular global economy representation, intentionally overlooking country-specific distinctions. Subsequently, the Leontief inverse matrix was calculated to assess the purchase relationships among sectors and their contributions throughout the value chain. This matrix encapsulates the global economy's interconnectedness, illustrating the total industry demand per unit demand of another, encompassing the entire value chain. Through this matrix, indirect impacts and dependencies for each industry were determined, calculated as the weighted average of the direct materiality ratings from all other industries, based on their significance in the upstream value chain.

The indirect materiality ratings derived from the 163 EXIOBASE3 sectors were translated to the 4-digit NACE level, considering the simple average in instances where multiple EXIOBASE3 industries matched a single NACE code.

Total materiality ratings

The total materiality ratings aggregate direct and indirect dependencies to calculate a comprehensive score for each sector. The chosen methodology for calculating the total materiality rating reflects a nuanced understanding of how environmental impacts are distributed across a sector's direct operations and its extended value chain. (Boldrini, Ceglar and Lelli, 2022[46])

(A)

$$MR_t = MR_d + (1 - MR_d) \times MR_i$$

Here, MR_d and MR_i quantify materiality levels on a scale from 0 (none) to 1 (very high), with indirect ratings adjusting for direct measures in calculating the total.

This method recognises the compound nature of environmental impact. Yet, there is a weighting factor adjusting the indirect materiality rating based on the direct relationship. This implies that if a sector has a high direct materiality rating, the potential for additional impact through indirect means is somewhat reduced, reflecting a form of diminishing returns on the total environmental impact. This ensures that supply chain influences are integrated without overshadowing or diminishing direct relationships. The calculation of a total materiality rating seems to be prone to various aggregation methods given the high correlation between direct and indirect measures.

Since indirect effects have an amplifying effect on the direct relationships, when total materiality ratings are constructed the threshold for a relationship to be considered "high or very high" is increased to 0.7.

Cautious materiality ratings

For the calculation of the cautious impact and dependency scores, only materiality ratings above medium for each ENCORE production process were considered, with scores normalised and attributed to the respective NACE codes.

This effectively amounts to attributing a materiality rating of 0.5 to all pairs of production processes and ecosystem services designated as high, 1 to those classified as very high, and 0 to all other pairs. Unlike the calculation of standard direct scores, no rounding was applied after consolidating the production process scores at the NACE level, maintaining the original precision of the ratings.

Just like for the standard materiality ratings, a set of indirect materiality ratings was developed for the cautious approach. Unlike the standard method, which applied standard direct ratings as multipliers for sectors in the upstream value chains, this careful approach utilised the cautious direct ratings. This approach to calculating cautious materiality ratings is similar in spirit to the methodology employed by previous studies such as (van Toor et al., 2020[48]), (World Bank, 2022[49]), and (Calice, Diaz Kalan and Miguel, 2021[50]).

It may appear counterintuitive that the cautious materiality ratings assigned to the portfolio are lower in absolute terms compared to standard materiality ratings. Since this cautious approach assigns a value of 0 to all sectors which have a materiality rating of medium or below, approximately 56% of the industries (343 out of 615) within the 615 4-digit NACE categories exhibit no dependencies on any ecosystem service. Additionally, about 11% of these industries (65 out of 615) have no impact on any driver. The scores for the portfolio are computed as a weighted average, taking into account each industry's share within the portfolio. Therefore, it is not surprising that the resulting absolute values are lower than those of standard ratings. It is important to understand that these scores should not be viewed as absolute metrics but rather used comparatively to assess the materiality of impact drivers and ecosystem services relative to each other, based on the same scale.

Portfolio scores

For each impact driver and ecosystem service, the portfolio's dependency score is calculated as the weighted average of each sector's cautious impact or dependency scores, with weights corresponding to their shares in the portfolio. The cautious set of materiality ratings was chosen for the preliminary selection of economic sectors, ecosystem services, and impact drivers. This approach, which focuses solely on high and very high materiality ratings, enables the identification of the most critical ecosystem services and impact drivers based on the portfolio's dependency scores.

Sectoral disaggregation

To pinpoint the sectors that contribute most significantly to the portfolio's ratings, the intermediary step in the methodology is examined, which involves weighting the materiality ratings of each sector by their portfolio share before calculating the average for each ecosystem service. Figure 8 breaks down the total cautious materiality ratings attributed to the overall portfolio, among the 1-digit NACE sectors contributing to them. In other words, the sum of a row corresponding to an ecosystem service / impact driver equals the total materiality rating of the portfolio for that ecosystem service. In this table, the value in each cell corresponds to the total cautious materiality rating of 4-digit NACE sectors, multiplied by their share in the portfolio, and aggregated at the 1-digit NACE level. Assuming that all ecosystem services are equally and crucially important for a production process, the aggregate materiality rating of a given sector by summing the values across ecosystem services is calculated.

This methodology takes into account both materiality ratings and portfolio shares associated with each sector. However, by separately weighting each ecosystem service with the portfolio share, the method prioritizes materiality ratings over financial exposure. An alternative approach, as suggested by (van Toor et al., 2020[48]), could involve distributing the portfolio amount across ecosystem services using specific weightings before aggregation. This alternative would emphasize the financial portfolio amount over the raw materiality ratings, under the assumption that a production process can continue its economic activity to a certain extent even if a dependent ecosystem service fails. The chosen methodology here already uses cautious materiality ratings, indicating that an economic activity would face significant disruption from a detriment to an ecosystem service it depends on. Consequently, it links economic activity, and thus the financial assets related to that activity, to each ecosystem service individually.

Directness and indirectness

The directness measure was constructed by subtracting the simple average of indirect standard materiality ratings from the simple average of direct ratings in order to determine two distinct measures of directness for impacts and dependencies separately.

Upstreamness and downstreamness

This methodology integrates crucial concepts for analysing economic sectors within production networks, such as “downstreamness from primary inputs” (total backward linkages) and “upstreamness from final demand” (total forward linkages). Total forward linkages reflect a sector's overall impact on downstream sectors, encompassing both direct and indirect linkages. Conversely, total backward linkages signify a sector's impact on upstream sectors, capturing its dependence on interindustry inputs. This perspective transcends traditional linear views of supply chains, acknowledging the complexity and interconnectedness of contemporary production networks.

From a methodological point of view, total backward linkages of a sector corresponds to the column total of the Leontief inverse, whereas total forward linkages corresponds to the row total of the Ghosh inverse. The approach adopted in this study aims to place the sectors in their relative positions within the Hungarian production network, instead of the global supply chain. Therefore, in calculating the upstreamness and downstreamness measures only the coefficients of the rows and columns corresponding to the remaining Hungarian sectors were taken into account. An alternative strategy could be to evaluate the relative importance of sectors not only domestically, but as parts of the global economy.

Economic risk assessment

Domestic Scenarios: Calibrating the direct shock vectors

The direct shock vectors applied in the domestic scenarios are built combining materiality ratings with water consumption data per sector. The direct shock has two components. To obtain the first one, the first step consists in aggregating the information on blue and green water consumption per sector available in the EXIOBASE 3 satellite account. For each sector, the total water consumption is divided by the sector's total output, resulting in a measurement of water consumption per unit of output. The first component of the shock vectors is then calculated through scaling the values of water consumption per unit of output between the range of 1 to 60. This first component of the direct shock vector is a baseline value that remains constant for all scenarios and materiality ratings. Note that the Hungarian sector of "N-fertiliser" is excluded from the normalization step as it represents a large outlier in terms of water consumption per unit of output while being a negligible sector in the large macroeconomic picture of the Hungarian economy.

The second component of the direct shock is a function of the cautious approach for the materiality ratings. For each Hungarian sector, the materiality ratings of "climate regulation" (MR_{cr}), "waterflow maintenance" (MR_{wm}), "surface water" (MR_{sw}) and "ground water" (MR_{gw}) are averaged according to the following equation:

(B)

$$MR_{avg} = \frac{MR_{cr} + MR_{wm} + 2 * (MR_{sw} + MR_{gw})}{6}$$

As it can be seen in Equation (B), the averaged materiality rating (MR_{avg}) attributes double weight to surface water and ground water. It should be highlighted that since the cautious approach is employed, the second component of the direct shock is zero for sectors that do not have high or very high materiality ratings for the selected dependencies.

The results of the averaged materiality rating (MR_{avg}) for each sector are then employed to build the second component of the direct shock. The underlying idea of this component is that for the sectors that have a MR_{avg} which falls in the range of high and very high materiality it should be expected that production will shut down for a period because of their high and very high dependence on the ecosystem services that are less/not provisioned during the drought period. The size of this component changes for each sector according to their averaged materiality rating value and to each scenario. A high materiality rating has a multiplicative effect of 0.5x, while a very high materiality rating has a multiplicative effect of 1x. Concerning the scenarios, in the low impacts scenario the sector is assumed to shut down its operations for 1 month of the year, in the medium impacts for 2 months, and in the severe impacts scenario for 4 months.

Table 7 below summarizes the 6 possible calibration formulas for the second component of the direct shock.

Table 7. The six possible calibrations for the second component of the direct shock

	High materiality rating $(\mathbf{0.8} < \boldsymbol{MR_{avg}} \leq \mathbf{1})$	Very high materiality rating $(\boldsymbol{MR_{avg}} = \mathbf{1})$
Low impacts scenario	$\left(\frac{1}{12}\right) * 0.5 * 100$	$\left(\frac{1}{12}\right) * 1 * 100$
Medium impacts scenario	$\left(\frac{2}{12}\right) * 0.5 * 100$	$\left(\frac{2}{12}\right) * 1 * 100$
Severe impacts scenario	$\left(\frac{4}{12}\right) * 0.5 * 100$	$\left(\frac{4}{12}\right) * 1 * 100$

The next step consists of adding the first component, which is independent from the materiality ratings and does not change in the scenarios, to the second component, which varies in each scenario and according to the sector's materiality ratings. For each sector, the final value of this addition consists in a percentage reduction in total output ($\Delta x\%$):

(C)

$$\Delta \mathrm{x}\% = (first\ component) + (second\ component)$$

Finally, the percentage reduction in total output is multiplied by the total output of the Hungarian sectors in order to obtain the final direct shock vector (k) employed in the Multi-Regional Input-Output analysis.

Domestic Scenario: Estimating indirect upstream impacts, indirect downstream impacts and the shares of total output impacted for each Hungarian sector

Once the column shock vectors (k) of total direct output loss are calibrated, they are used to estimate indirect upstream and downstream impacts for each scenario. To estimate the upstream indirect impacts in the Hungarian economy, it is employed a Leontief Multi-Regional Input-Output Model based on Leontief's original works ((Leontief, 1991[51]); (Leontief, 1963[52])) and recently implemented for scenario analysis by NGFS (2023). As shown by (Dietzenbacher, 2015[53]), the standard input-output approach employed in this study operates similarly to the inoperability input-output models (IIM) (Okuyama, 2014[54]). The model relies on two main assumptions: (1) all sectors operate at constant returns of scale and (2) factors of production are complementary and not substitutable among each other. The main implication of the second assumption is that sectors would not easily find substitutable inputs in the short-run.

The model is based on Equation (D):

(D)

$$\Delta x = L.\Delta f$$

Equation (D) indicates that there is a relationship between final demand (Δf) and the total output of the economy (Δx) that is governed by the (L) total requirements matrix (Leontief-Inverse). In simple words, in this model a change in demand leads to a variation in total output given by the proportion of the coefficients in the total requirements matrix (L). Following Equation (E), the total requirements matrix (L) can be obtained from the matrix (A) of technical coefficients, which is provided by EXIOBASE 3.

(E)

$$L = (I - A)^{-1}$$

By employing Equation (D) it is possible to estimate the upstream indirect impacts generated by the final direct shock vector (k) in the Hungarian economy. For this, the Δf component is replaced by the column vector k. The result of this operation is a vector (u) of indirect upstream total output loss for each sector of the economy. In order to account only for the indirect effects, the (L) total requirements matrix is substituted by the total indirect requirements matrix (LI). The operations to find the LI matrix and the u vector are shown below, respectively:

(F)

$$LI = L - I$$

(G)

$$u = LI.k$$

The indirect downstream impacts are calculated through the employment of the (G) output inverse matrix (Ghosh-Inverse) (Ghosh, 1958[55]). The output inverse (G) matrix is derived from the matrix (B) of allocative coefficients, which in turn is obtained through pre-multiplying the inverse of the diagonalised output vector (x) by the Z matrix:

(H)

$$B = \hat{x}^{-1}Z$$

The (G) output inverse matrix is found through the relationship between total output, allocative coefficients, and the value-added vector (v):

(I)

$$x' = v(I - B)^{-1}$$

(J)

$$G = (I - B)^{-1}$$

The G output inverse matrix indicates how the output of each sector is distributed among other sectors and is at the basis of the Ghosh supply model (1958) (Ghosh, 1958[55]). The main assumption underlying this model is that there is a fixed allocation of output over sectors. This study is aware of the limitations and criticisms addressed towards the Ghosh supply model ((Dietzenbacher, 1997[56]); (Oosterhaven, 1988[57])), however, in light of a lack of well-established alternatives for the analysis of downstream indirect effects, the Ghosh model is employed, nonetheless.

As displayed in Equation (I), the Ghosh model gives the output of the economy as a function of the value-added vector (v). Therefore, assuming constant returns of scale, a value-added vector (n) that is equivalent to the final direct shock vector (k) is found through multiplying elementwise the calibrating vector (c) with the value-added vector (v). Vector n is then plugged into a combination of equations (I) and (J) in order to find the vector (t) of indirect downstream total output loss. As in the upstream case, the output inverse matrix (G) is substituted by the indirect output inverse matrix (GI) to account only for the indirect effects. The operations to find GI and the vector (t) of total downstream indirect impacts are displayed below in Equations (K) and (L):

(K)

$$GI = G - I$$

(L)

$$t = GI'.n$$

Finally, the total impacts are calculated by adding the direct shock vector k with the vector u of indirect upstream total output loss and the vector t of indirect downstream total output loss. The shares of total output impacted for each Hungarian sector are calculated by dividing elementwise sum of vectors k, u and t by the vector x of total output of the economy.

Domestic Scenario: Estimating GDP Impacts and Net Foreign Currency Generation

GDP impacts are estimated by converting total output results to value-added. For this, the value-added vector (v) is multiplied by the inverse and diagonalised total output vector (x) resulting in a row vector (a) with information on the value-added per unit of output for each sector of the economy. Using this vector a, the direct shock vector k, the vector u of indirect upstream total output loss and the vector t of indirect downstream total output loss are all converted from output loss to value-added loss, and their resulting values are added. The result of this addition for each scenario is a measurement of the impact in terms of GDP loss.

Foreign currency generation analysis follows a similar logic. First, the data available in matrix Z of intermediate consumption and in vectors f (final demand) and x (total output) is employed to calculate the ratios of exports per unit of output and of imports per unit of output for each Hungarian sector. By employing these ratios, the total impact in terms of output loss previously calculated is then converted into exports and imports reductions for each sector. The resulting values are subtracted in order to find the net value of foreign currency generation. The result for some sectors will be negative as these are sectors that import more than export, hence, as the shock generates output reduction, these sectors are expected to decrease their negative pressure upon the balance-of-payments.

The Cost-Push Input-Output Price Model for Inflationary Pressures

The analysis of relative price changes and inflationary pressures is carried out with a Leontief price model ((Miller, 2021[58]); (Weber, 2024[59])). The model is based on equation (M) in which L' is the transposed Leontief matrix, v_c is the value-added per unit of output for each sector calculated with data previous from the shock, and p_0 is a vector of 1s that correspond to the base index prices.

(M)

$$p_0 = L'.v_c$$

The logic behind the model is that changes in costs of production (primary input costs) result in changes in sectoral unit costs of production. As the model assumes that demand still pulls the productive system, output quantities are fixed, but output prices change following increasing costs of production. In the model, cost hikes are passed along the productive system until they become final consumption prices. Nominal wages and profits are held constant. Consequently, when costs per unit of output increase in the v_c vector, the resulting p_0 vector displays the aggregated increase in final prices, indicating the upward inflationary pressure affecting each sector.

The value-added vector (n), which was previously employed in the Ghosh model for downstream indirect impacts, is multiplied by the inverse and diagonalised total output vector (x) resulting in a vector (m) with information on the value-added per unit of output for each sector after the shock. Vector m is then inserted in equation (M) in the place of v_c as shown in Equation (N). The result of this operation is the vector p_1 that indicates final price upward pressures from cost-push inflation. The operation is repeated for each scenario.

(N)

$$p_1 = L'.m$$

Calculating the foreign exposure assessment

The foreign exposure assessment is calculated through interacting the Z matrix of interindustry consumption in EXIOBASE 3 with a “mask” vector of 0s and 1s that is constructed based on the cautious approach of the materiality ratings. The value in the mask vector is “one” when the *foreign sector* is associated to high or very high materiality ratings in terms of impacts and dependencies and “zero” otherwise. A different mask was built for each dependency and impact variable. In this way, the foreign sectors that import from and export to Hungary which are not associated to high or very high materiality ratings have their value zeroed. After multiplying the mask with the Z matrix, the values of exports and imports are added up. The result of this calculation is then divided by another value in order to generate the shares presented. For the Hungarian exports, the denominator is a sum of all the exports to foreign sectors plus the exports consumed by foreign final demand. For the imports, the denominator is composed by the sum of all imports made by Hungarian domestic sectors plus the imports made by domestic final demand. It should be noted that this is the theoretical “step-by-step” procedure. In practice, the steps might be executed in a different order and there might also be additional steps when manipulating the data depending on the software and coding techniques employed.

Exploring Foreign Exposure

The exploratory exposure materialization scenario begins with similar steps to the foreign exposure assessment. For each type of impact analysed (soil pollutants, water pollutants, water use and solid waste) a mask was applied to the Z matrix of interindustry consumption, and the total Hungarian exports purchased by foreign sectors associated to high and very high impact ratings is calculated. The resulting matrix of this operation is then horizontally aggregated, generating a vector of 163 rows with export values for each Hungarian sector. The next step is to transform this vector into a vector of total direct output exposure (r) by filling with zeros the rows corresponding to all the sectors that are not Hungarian. The result is the column vector (r) of 7987 rows in which only the rows corresponding to Hungarian sectors may display values different from zero.

The vector p is then employed in a similar model used to calculate upstream impacts for the domestic scenario. Vector p is plugged in Equation (D) in the place of the final demand (Δf) vector in order to find the vector (q) of total output exposure:

(O)

$$q = L.r$$

The upstream exposure is calculated through a similar procedure, but using the LI matrix instead of L:

(P)

$$q_i = LI.r$$

In the tables presented in the main text, “first wave exposure” displays data from vector r, “upstream exposure” from vector q_i and “total output exposure” from vector q.

Finally, the “share of sector’s total output exposed” is calculated by dividing every element in vector q by the one occupying the same position in vector x of total output of the economy.

Table 8. Hungarian economic exposure to foreign transition risk affecting water use sectors

Hungarian sector	First wave exposure (M. EUR)	Upstream exposure (M.EUR)	Total output exposure (M.EUR)	Share of sector’s total output exposed
Manufacturing	25,862.23	4,848.15	30,710.38	24.82%
Wholesale And Retail Trade	1,927.44	1,995.06	3,922.50	15.64%
Transportation And Storage	1,857.22	1,098.23	2,955.45	12.53%
Agriculture, Forestry And Fishing	1,994.97	443.36	2,438.33	22.09%
Administrative And Support Service	609.48	1,049.44	1,658.92	12.43%

Note: The table displays the Top 5 most exposed Hungarian sectors to foreign transition risks affecting foreign sectors with high and very high impact in terms of water use. The first wave exposure column indicates the total value of Hungarian exports that are sold to highly impacting foreign sectors. The column of upstream exposure indicates the value of the upstream Hungarian production that is needed for producing the exported products and, hence, is also exposed to risk. The total output exposure column is the sum of the first wave exposure and the upstream exposure. The last column on the right displays the share of each sector’s total output that is exposed to the transition risk. Taking “Manufacturing” as an example, the value of 24.82% represents the share of the sector’s output that is exported to foreign sectors associated with high and very high impact in terms of water use.
Source: EXIOBASE 3, ENCORE.

Table 9. Hungarian economic exposure to foreign transition risk affecting water polluting sectors

Hungarian sector	First wave exposure (M. EUR)	Upstream exposure (M.EUR)	Total output exposure (M.EUR)	Share of sector’s total output exposed
Manufacturing	32,363.71	6,166.22	38,529.93	31.14%
Wholesale And Retail Trade	2,082.37	2,333.98	4,416.35	17.61%
Transportation And Storage	2,083.49	1,258.09	3,341.58	14.17%
Agriculture, Forestry And Fishing	1,819.60	376.58	2,196.19	19.89%
Administrative And Support Service	835.39	1,240.50	2,075.90	15.55%

Note: The table displays the Top 5 most exposed Hungarian sectors to foreign transition risks affecting foreign sectors with high and very high impact in terms of water pollutants. The first wave exposure column indicates the total value of Hungarian exports that are sold to highly impacting foreign sectors. The column of upstream exposure indicates the value of the upstream Hungarian production that is needed for producing the exported products and, hence, is also exposed to risk. The total output exposure column is the sum of the first wave exposure and the upstream exposure. The last column on the right displays the share of each sector's total output that is exposed to the transition risk. Taking "Manufacturing" as an example, the value of 31.14% represents the share of the sector's output that is exported to foreign sectors associated with high and very high impact in terms of water pollutants.
Source: EXIOBASE 3, ENCORE.

Table 10. Hungarian economic exposure to foreign transition risk affecting solid waste sectors

Hungarian sector	First wave exposure (M. EUR)	Upstream exposure (M.EUR)	Total output exposure (M.EUR)	Share of sector's total output exposed
Manufacturing	24,665.92	4,558.79	29,224.71	23.62%
Wholesale And Retail Trade	1,544.26	1,833.36	3,377.62	13.47%
Transportation And Storage	1,510.65	984.77	2,495.42	10.58%
Administrative And Support Service	680.32	992.26	1,672.58	12.53%
Professional, Scientific And Technical	659.23	620.29	1,279.52	14.27%

Note: The table displays the Top 5 most exposed Hungarian sectors to foreign transition risks affecting foreign sectors with high and very high impact in terms of solid waste. The first wave exposure column indicates the total value of Hungarian exports that are sold to highly impacting foreign sectors. The column of upstream exposure indicates the value of the upstream Hungarian production that is needed for producing the exported products and, hence, is also exposed to risk. The total output exposure column is the sum of the first wave exposure and the upstream exposure. The last column on the right displays the share of each sector's total output that is exposed to the transition risk. Taking "Manufacturing" as an example, the value of 23.62% represents the share of the sector's output that is exported to foreign sectors associated with high and very high impact in terms of solid waste.
Source: EXIOBASE 3, ENCORE.

Financial risk assessment

Credit risk assessment

The assessment of the credit risk for the Hungarian financial system takes into account the economic assessment results as proxies for overall credit risk. The analysis includes descriptive statistics of MNB data on the outstanding debt instruments at the end of 2022 such as amounts, maturity and currency. Additionally, historical data on loan performance within sectors in Hungary is considered.

The next step calculates the probability of default. This is proxied by the sector-specific economic shock identified beforehand in the three scenarios. While there are clear limitations to this approach, this allows to translate the economic impact of a nature shock to the holdings of financial institutions in that sector of the economy. The proxy was used to estimate the percentage of loans that could become non-performing.

Only uncovered loans were considered for the analysis. Whenever a loan was backed by a collateral, the assumption was that the bank would be able to quickly recover the collateral value and that this would not be affected. However, this is likely to represent a very conservative estimate, given that in the event of an economic downturn, the physical collateral may lose significant value, and the banks would recover a smaller amount. Another caveat includes the fact that in 2022 40% of the agricultural sector was insured. However, while the insurers suffered losses higher than the premia, it would be difficult to estimate the increase in premia for the following years notwithstanding government support.

Market risk assessment

The assessment of the market risk for the Hungarian financial system takes into account the economic assessment results as proxies for overall market risk. The analysis assesses what would be the effect on public debt to GDP ratio using the results from the economic assessment.

Additionally, the analysis looks at existing corporate bond issuances to understand what sectors are most exposed to a nature-related shock.

Financial system interaction

Given the lack of lender and borrower identifiers in the data used in the assessment, the MNB undertook the assessment of financial concentration. The assessment assigns an impact and a dependency score to each financial instrument based on the I&D analysis results. Then, it screens for financial instruments linked to sectors highly or very highly exposed to nature-related risks (twice, once for impacts and once for dependencies). After grouping the resulting elements by financial institution identifier, the assessment ranks the top financial institutions in terms of percentage of exposure to nature-related risks.

Annex B. Supportive information

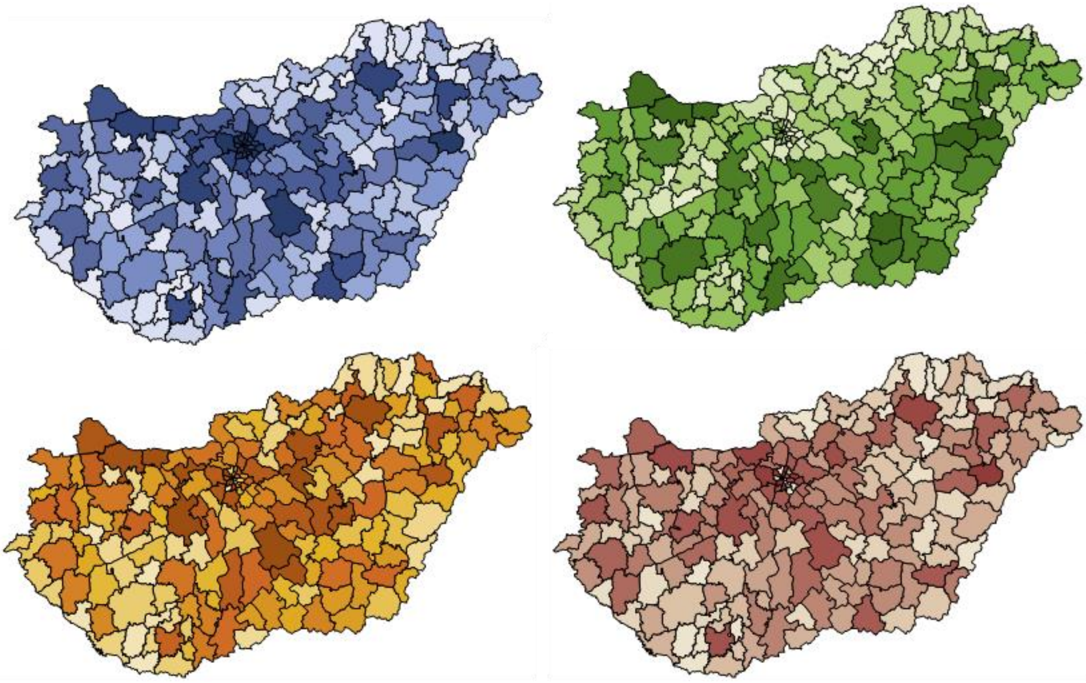
Risk identification and prioritisation

Geographic scope

The detailed distribution of portfolio exposure across Hungary's districts is presented in Figure 35. However, due to data limitations, the specific allocation of instruments within Budapest's districts for the majority of the sample was unclear. Consequently, instruments in Budapest have been apportioned among its districts according to the proportional shares (weights) of available values.

Figure 35. Distribution of exposures across the districts of Hungary

Clockwise starting with upper left corner, “Total exposure”, “Agriculture, Forestry and Fishing”, “Real Estate”, and “Manufacturing”.



Source: MNB.

Summary statistics

The latest data from FIGARO 2023 offers a comprehensive economic analysis that highlights the pivotal roles and contributions of various sectors to the national economy of Hungary.

At the forefront of the economic landscape is the “Manufacturing” sector, which stands out with a gross output of EUR 114.29 billion. This sector is significantly integrated with the global supply chain, evidenced by its heavy reliance on foreign inputs, which account for approximately 67% of its total inputs. Such a substantial external dependency, reflected by a domestic input ratio of merely 0.32, exposes the sector to global market fluctuations. In contrast, “Agriculture, Forestry, and Fishing” plays a vital role in the economy with a total output of EUR 11.95 billion. Dominated by domestic inputs, which comprise about 73% of its total inputs (EUR 4.60 billion), this sector demonstrates a strong foundation in local production capabilities. The domestic input ratio of 0.73 highlights its relative independence from foreign inputs, contrasting sharply with the “Manufacturing” sector. The sector's significant contributions to intermediate outputs (EUR 8.30 billion) and final demand (EUR 3.64 billion) further underline its essential role in providing goods for both economic activities and consumption. In complement to the connectedness indicators developed above, the intermediate consumption ratio of 0.69 further indicates the sector's integral part in the broader economic ecosystem, as a substantial portion of its output is utilised within the economy as inputs for other production processes.

The nuanced financial landscape across sectors is revealed through a comparative analysis of loan portfolio amounts and total production outputs. “Agriculture, Forestry, and Fishing” illustrates moderate financial support relative to its size, with a loan portfolio of EUR 2.90 billion against its total output. On the other hand, the “Manufacturing” sector's low loan-to-production ratio, with a loan portfolio of EUR 8.64 billion, might indicate various strategic financial decisions, ranging from cautious lending to focused investments in specific sub-sectors. “Real Estate Activities”, with a loan portfolio of EUR 7.07 billion against a total output of EUR 18.27 billion, showcases a different aspect of financial dynamics. The high level of financing relative to its output reflects the sector's capital-intensive nature and reliance on external financing for development projects. Collectively, these observations demonstrate the complex relationship between sectoral economic contributions and financial resource allocation. While “Manufacturing” and “Agriculture, Forestry, and Fishing” exhibit lower loan-to-output ratios, indicating either efficient capital use or unmet financial needs, sectors like “Real Estate” rely heavily on external financing, highlighting their investment-driven nature.

Table 11. Summary statistics of one-digit NACE sectors in Hungary

NACE code	NACE description	Intermediate inputs	Domestic input ratio	Gross output	Intermediate consumption ratio	Compensation of employees	Gross operating surplus	Portfolio amount
A	Agriculture, Forestry And Fishing	6.26	0.73	11.95	0.69	1.29	5.59	2.90
B	Mining And Quarrying	0.35	0.63	0.74	0.83	0.10	0.28	0.71
C	Manufacturing	86.44	0.32	114.29	0.59	13.27	13.28	8.64
D	Electricity, Gas, Steam	3.12	0.66	5.56	0.70	0.80	1.47	2.45
E	Water Supply	1.40	0.70	2.44	0.65	0.68	0.27	0.11
F	Construction	13.72	0.67	21.88	0.23	2.73	4.81	1.99
G	Wholesale And Retail Trade	13.76	0.66	27.81	0.47	7.00	6.44	5.78
H	Transportation And Storage	7.81	0.59	15.57	0.69	3.98	3.05	5.55
I	Accommodation And Food Service	3.38	0.74	5.40	0.14	1.46	0.33	1.08
J	Information And Communication	4.73	0.64	12.02	0.59	3.22	3.97	1.24
K	Financial And Insurance	3.25	0.84	8.48	0.63	2.08	2.42	9.54
L	Real Estate	4.46	0.82	18.27	0.31	0.60	12.70	7.07
M	Professional, Scientific And Technical	5.41	0.68	13.96	0.74	3.72	4.50	4.35
N	Administrative And Support Service	3.02	0.69	7.91	0.89	2.86	1.77	1.67
O	Public Administration And Defence	4.07	0.80	14.76	0.09	6.31	3.72	0.54
P	Education	1.43	0.84	7.21	0.08	3.96	1.58	0.05
Q	Human Health And Social Work	3.94	0.48	10.98	0.03	5.14	1.22	0.17
R	Arts, Entertainment And Recreation	1.76	0.73	3.80	0.07	1.22	0.59	0.26
S	Other Service Activities	1.29	0.70	3.00	0.26	0.74	0.89	0.20

Note: EUR billions. Domestic input ratio is defined as the intermediate inputs purchased from Hungarian sectors as a share of total intermediate inputs. Intermediate consumption ratio is defined as the outputs used as inputs by other industries as a share of gross output.
Source: Figaro 2023 edition for the year 2021.

The manufacturing sector's high output amount coupled with significant foreign reliance underscores the need for strategic policy interventions aimed at enhancing the sector's resilience and domestic production capabilities, thereby ensuring its contribution to national economic resilience and sustainable growth. "C – Manufacturing", in particular, warrants a focused policy dialogue to address its external dependencies given its sheer size, and to strategize on bolstering domestic production capacities, thereby enhancing its contribution to national economic resilience and sustainable growth.

Regarding Agriculture, the moderate financial support relative to the size of the sectors suggests either prudent financial management or potential gaps in financial needs for expansion.

Current state of domestic and regional ecosystems

The following provides an overview assessment of different ecosystems and their services, both within Hungary and in the neighbouring region. Given the multi-dimensionality of nature-related risks, as well as fragmented and incomplete data covering the current and future state of ecosystems, this review gathers data from a variety of sources to offer an assessment. However, the assessment does not analyse the quality or credibility of data available, but rather draws upon data from multiple sources to establish an overarching perspective on the estimated current and future state of relevant ecosystems.

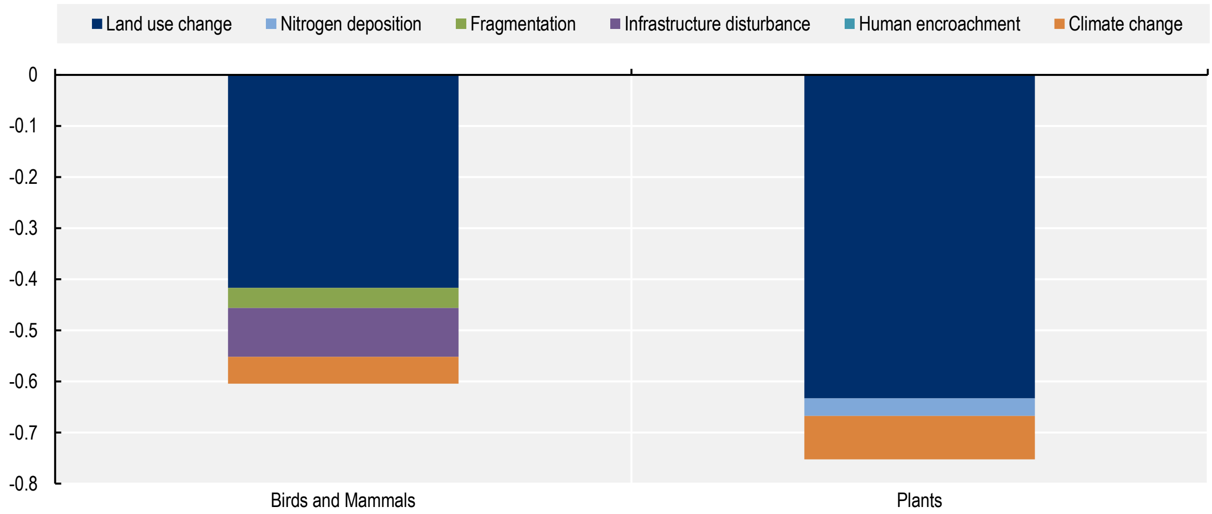
Biodiversity and terrestrial ecosystems

There has been a significant decline in the state of Hungary's biodiversity and natural capital, with their Natural Capital Index (NCI) estimated between 3.2-9.9%, evidencing a 90% loss in the availability of major supporting ecosystem (Czúcz et al., 2008[60]) (CBD, 2024[23]). This is reflected by Hungary's mean species abundance (MSA) score of 0.32, which is significantly below the scores of all neighbouring countries that average 0.46 (see Figure 36). Similarly, the extent of natural forest and land cover are substantially below the level observed in neighbouring countries, with a percentage of 17% and 22% respectively, compared to averages of 39.5% and 52% for neighbouring countries. Similar estimates of tree cover are recorded by Global Forest Watch, which indicates change in a relatively stable low baseline in forest cover, with an estimated net gain in forest cover between 2000 and 2020 of 4.1% (Global Forest Watch, 2024[61]). Moreover, only an estimated 37% of the forests in Hungary are considered semi-natural, with indigenous tree stocks constituting 57% of tree covered areas (CBD, 2024[23]). Physical risks stemming from biodiversity loss are also recorded by the WWF biodiversity risk filter, which scores physical risks from biodiversity to be 4.64 (out of 5.0), with particular risks for regulating and supporting as well as cultural services. At the sub-national level, the three regions with the highest physical risk scores include Győr-Moson-Sopron, Hajdú-Bihar, and Jász-Nagykun-Szolnok all with a score of 5.0 (WWF, 2023[62]).

The primary driver of MSA loss for both birds and mammals as well as plants is land use change, which is responsible for -0.417 and -0.633 (out of 1.0) of MSA loss respectively (see Figure 36). This is significantly driven by the extent of agroecosystems, which constitute 65.76% of Hungary's total terrestrial territory (European Commission, 2019a[11]). Specifically, 64.7% of Hungary's land coverage is dedicated to agricultural land, the third highest in the EEA38+UK, whist having the 7th lowest coverage of forests and semi-natural areas at 26% (European Environment Agency, 2019[63]). Analysis of Hungarian ecosystems indicates that despite their agroecosystems offering food provisioning value, agroecosystems offer little multifunctionality in terms of ecosystem services and offer low capacity for other services (Tanács et al., 2023[64]). The expanse of agroecosystems is at the cost of alternative ecosystems, such as grasslands, which declined on average by 1.31% per year between 1987 and 1999 (Biró et al., 2013[65]). However, similarly to forest cover, decline in grasslands have stabilised in recent years covering 10.8% of the country's territory (CBD, 2024[23]). Following land use change, climate change and infrastructure disturbance are the next most significant drivers of biodiversity loss, as measured by decline in MSA.

The evidence on the loss of birds and mammals offers a mixed picture on the state of biodiversity. Bird populations seem to be relatively stable, with positive trends for farmland birds, the Great Bustard, and the Imperial Eagle (Báldi and Batáry, 2011[66]) (CBD, 2024[23]). However, long-distance migratory birds show declining tendencies more frequently. For mammals, there has been a positive trend in the populations for two large carnivores, the wolf and lynx, which both have peripheral populations in Hungary (CBD, 2024[23]). Moreover, pollinator decline presents a significant risk for the Hungarian economy because 75% of Hungarian crops depend on pollinators (The Hungarian Government, 2023[10]). There is limited evidence on the state of pollinators; however, one assessment in 2005 on bumblebee species found 7 out of 25 species (28%) were critically endangered, with 10 species showing a negative trend (Sárospataki, Novák and Molnár, 2005[67]).

Figure 36. Drivers contributing towards MSA loss



Note: Contribution towards reduction in MSA by pressure driver.
Source : GLOBIO

Surface and groundwater

Hungary is particularly exposed to negative transboundary environmental risks related to water supply as 95% of its surface water is received from neighbouring countries, primarily via the Danube, Tisza, and Dráva (CBD, 2024[23]) (ClimateADAPT, 2023[68]) (ICPDR, 2020[69]). Within the European Union, Hungary receives the 3rd highest volume of external inflow of water from neighbouring countries at 91,500 million m3, and the 5th smallest internal flow of water at 5,580 million m3, based on a 20-year average (Eurostat, 2023[70]). Currently, 2.7 million m3 is produced from groundwater sources in Hungary, which provides between 95-97% of drinking water for the population (Ministry for Environment and Water, 2006[71]) (Barreto et al., 2017[14]). Whilst there are some risks from pollution ammonia and nitrate, these risks are relatively low and predominately affect shallow aquifers which constitute a small proportion of groundwater extraction (Ministry for Environment and Water, 2006[71]). Approximately 50% of the groundwater bodies in Hungary are divided by national borders (Barreto et al., 2017[14]). Hence, the reliability and continuity of water-related ecosystem services are not only dependent on the state of ecosystems within Hungary, but also the surrounding region.

Hungary is exposed to both the risks from extreme drought and floods (OECD, 2013[72]). For example, extreme droughts in 2012 results in a EUR 1.4 billion loss or 1.4% loss in GDP; conversely, 25% of Hungary's territory and 18% of the population are exposed to flood risks (OECD, 2018[13]). According to the WWF water risk filter, the water-related physical risks in Hungary are considered moderate, with scores of 1.91, 3.14. and 3.35 out of 5 for water scarcity, flooding, and ecosystem services status, respectively (WWF, 2021[73]). However, the risks from drought, flood, and heavy precipitation are assessed to be significantly increasing in the future (ClimateADAPT, 2023[68]) (WWF, 2021[73]). Future risks may arise from changes to seasonal water dynamics, which have been recorded to decrease by 27.89% in Hungary since 2000 (UNEP, 2019[74]). This evidence aligns with other analysis which indicates changes to and declining precipitation in Hungary (Szabó, Bartholy and Pongrácz, 2024[75]) (Ilona et al., 2022[76]). Whilst changes in the variability and levels of precipitation may increase exposure to risks from drought and floods, it presents a substantial risk to agricultural activities in Hungary, given the high level of rainfed compared to irrigated crops (with a ratio of 1.78) (FAO, 2020[25]). At a sub-national level, the Great Northern and Southern Plains are most exposed to river-related flooding, with 25.8% and 37.8% of the regional population exposed to a

100-year return period, respectively (OECD, 2015[77]). Moreover, the Great Plains are also particularly exposed to droughts (OECD, 2018b[78]) (Buzási, Pávölgyi and Esses, 2021[79]). The disappearance of freshwater habitats, at 85%, reflects the increased vulnerability to drought due to the lack of resilience from available green and blue water provided by nature (The Hungarian Government, 2023[10]).

Water pollution is a material risk within Hungary, according to the WWF water risk filter, with a country rank of 174 and a score of 5, is consistent throughout all regions of Hungary (WWF, 2021[73]). According to the Convention on Biological Diversity (CBD), 56% of freshwater surface bodies and approximately 70% of artificial lakes are classified as 'at risk' due to organic and nutrients loads. None of the 108 groundwater bodies are considered 'at risk' due to human intervention; however, 46 sites are listed as 'possibly at risk', due to nitrate pollution (CBD, 2024[23]).

Atmosphere and pollution

Long-term trends indicate Hungary's annual average temperature increased by 1.15 degrees between 1907 and 2017, exceeding the global average temperature rise of 0.9 degrees (Ministry of Technology and Innovation, 2018[80]). The greatest increase in hot days has been in Central and Southern Hungary (Ibid). Several studies highlight the relationship between temperature variability and precipitation rates in the region, particularly in the summer and autumn seasons (Mika and Lakatos, 2009[81]) (Szabó, Bartholy and Pongrácz, 2024[75]) (Ilona et al., 2022[76]). This relationship indicates the impact climate change has on the functioning of other ecosystems, for example freshwater. Beyond climate change, Hungary is exposed to certain air pollutants above EU standards. Hungary experienced level of BaP, NO2, O3, and PM10, above EU standards between 2017 and 2021 as an annual mean. This was particularly significant for BaP, which was recorded at levels 84.3% above EU standards in 2021 (European Environment Agency, 2023a[82]). Some of these chemicals may constitute towards degradation of ecosystems through acidification, eutrophication, and crop damage (European Environment Agency, 2023b[83]). Beyond this, there is little evidence to establish potential relationships between pollution and the functioning of ecosystems.

Soils and nutrients

The state of soil is estimated to be in good condition, but land used for agriculture is endangered by chemical and physical processes, including erosion and acidification, caused by inadequate land and fertiliser utilisation (European Environment Agency, 2015[84]). Short-term impacts and rates of soil degradation are expected to be moderate; however, longer term impacts, with climate change, are expected to be more substantial factor, especially for crop production (Birkás and Dekemati, 2023[85]). Water erosion affects 25% of the total land area of Hungary, more than one-third of agricultural land, and 16% by wind erosion (Kertész and Gergely, 2011[86]). Moreover, soils are identified as a key mitigator for both excess carbon and groundwater in Hungary (Ministry of National Development, 2017[87]). Hence, degradation of soils may have implications for the functioning of climate regulation and freshwater ecosystems in the region.

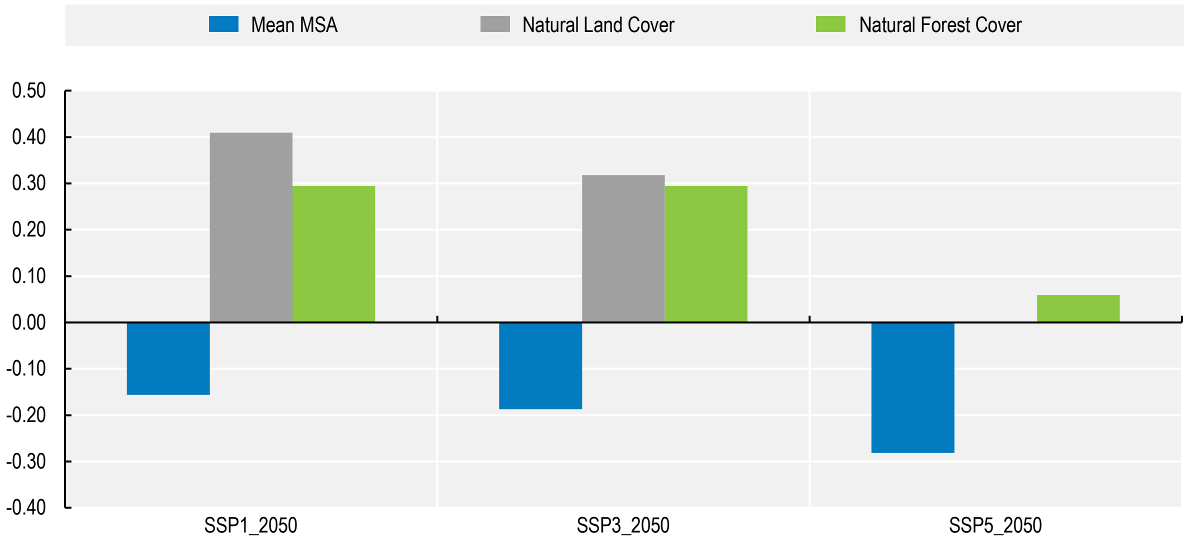
Future state of ecosystems

There is limited data availability on the projected future state of ecosystems and ecosystem services. The following offers an insight into the potential future trends of risks, whilst acknowledging the hindrances from holistic data coverage and uncertainties in modelling techniques.

The GloBio model provides a forward-looking assessment of changes to MSA, natural land and forest cover by 2050, under three scenarios, SSP1, SSP3, and SSP5. These scenarios reflect three IPCC shared socio-economic pathways; a future oriented towards sustainability (SSP1), a future determined by a politically divided world (SSP2), and a future with continued global dependency on fossil fuels (SSP5)

(GloBio, 2019[88]). The GloBio projects reveal a decline in MSA under all three scenarios, ranging from 16-28%, from the least to most severe scenario, compared to the 2020 baseline (see Figure 37). Conversely, the projections estimate an increase in natural land and forest cover in Hungary, except for natural land cover under SSP5, which remains unchanged compared to 2020 baseline. However, all projected changes are modest, with all changes under 0.1 in absolute terms, compared with the historical decline which is estimated to exceed at least -0.6 for all three measures. Hence, future projections indicate a modestly positive outcome for land and forest cover, but a potential increase in risk for biodiversity with further declines in MSA.

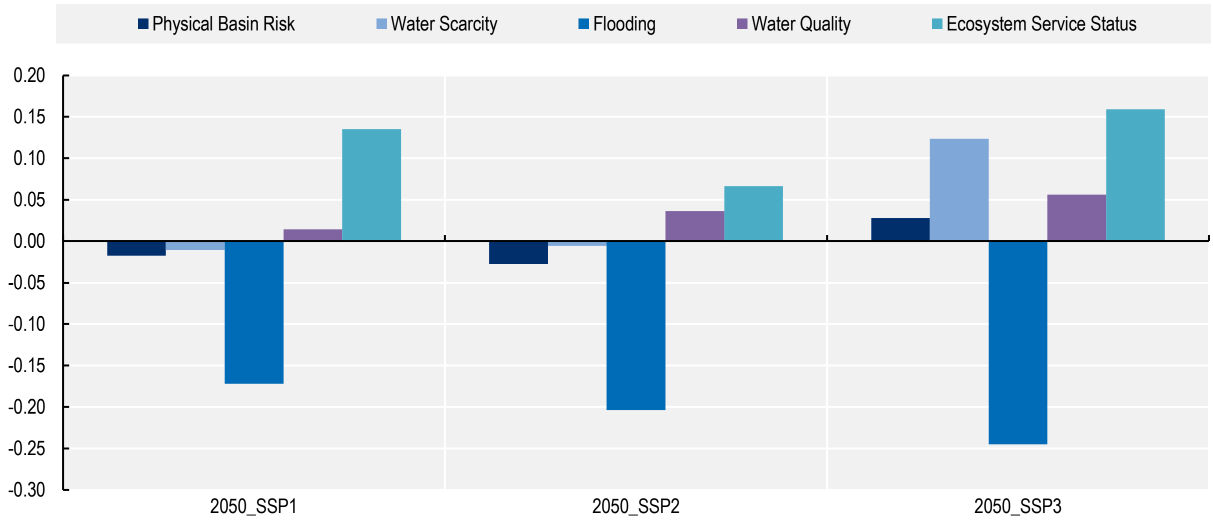
Figure 37. Projected future state of biodiversity in Hungary



Note: The chart shows the relative % change in mean species abundance (MSA), natural land cover, and natural forest cover by 2050 under three shared socio-economic pathways, SSP1, SSP3, and SSP5, baselined to 2020.
Source: GloBio

The WWF water risk filter offers scenario projections of proxies for water-related physical risks in Hungary by 2050 (WWF, 2023[62]). The shared socio-economic pathways used by WWF, are relatively less severe than the pathways used by GloBio, and are characterised by optimistic, current trends, and pessimistic projections. The projections indicate a significant reduction in flood risk by 2050, with a relative reduction in risk by 17-25% depending on the scenario. Conversely, the projections indicate relative increases in risks for ecosystem service status (7-16%) water quality (1-6%), and water scarcity, with a 12% increase under the most severe scenario (see Figure 38). Hence, the most significant increase in future water-related risks may come from the disruption of ecosystem services and the interconnection between water supply and broader components of nature. The potential future increase in water-related risks is also highlighted in Hungary's Seventh National Communication and Third Biennial Report for the UNFCCC, where it highlights potential changes precipitation patterns. Specifically, a reduction by 5-10% in average summer precipitation by 2021-2050 and by 20% by 2071-2100 (Ministry of National Development, 2017[87]).

Figure 38. Projected future state of water-related physical risks in Hungary



Note: The chart shows the relative % change in proxies for physical risks in Hungary by 2050 under three shared socio-economic pathways, SSP1, SSP2, and SSP3, baselined to 2020.
Source: WWF Water Risk Filter

Domestic scenario supportive evidence

This section provides a literature review of historical studies and forward-looking scenarios related to drought and decline of water system in Hungary and the surrounding region. The purpose is to offer supporting evidence to the narrative of the domestic scenario outlined in the economic assessment. Additionally, it examines case studies of drought in various regions to help calibrate the initial shock for the domestic scenario.

Literature review of historical studies and forward-looking scenarios

Several studies have analysed historical weather and precipitation patterns within Hungary and documented a marked decrease in overall precipitation levels, combined with an increase in mean temperature. There is consensus that historical precipitation levels have fallen, by over 20% in some estimations, with some disparity over the seasonal changes, but most studies estimate the most marked decrease to occur in spring and autumn months (Ilona et al., 2022[76]; Szabó, Bartholy and Pongrácz, 2024[75]; Mika and Lakatos, 2009[81]; Domonkos and Tar, 2003[89]; Mohammed et al., 2020[90]). Several studies highlight the correlation between higher temperatures and decreases in precipitation, as well as the high variability in precipitation in the region, with Hungary's mean temperature 0.77 degrees higher in 1971-2020 compared with 1871-1916 (Szabó, Bartholy and Pongrácz, 2024[75]; Ilona et al., 2022[76]).

This may have a marked effect on water availability in the country, affecting climate regulation, waterflow maintenance, surface and ground water. Hungary has already suffered from water-related risks in recently, with more than 103 severe agricultural droughts detected between 1950 and 2010 in Eastern Hungary, with severe hydrological drought recorded in 16% of total monthly rainfall events (Mohammed et al., 2020[90]). There are several factors which are driving increased water-related risks, including land cover change, climate change, and intensive land use (Spinoni et al., 2013[91]).

Numerous studies document the historical relationship between climate change and increased likelihood of drought in Hungary, and more broadly in the Carpathian Region and the Danube Basin (Spinoni et al., 2013[91]) (Pistocchi et al., 2015[92]) (Jaagus et al., 2021[93]) (Jakubinský et al., 2019[94]) (Pinke and Lövei, 2017[95]). The studies display overarching analysis of historical declines in precipitation measures, specifically Standardised Precipitation Index (SPI) and Standardised Precipitation Evapotranspiration Index (SPEI) (Mohammed et al., 2022[96]; Alsafadi et al., 2020[97]; Jaagus et al., 2021[93]). The decline in the secondary measure, SPEI, is particularly relevant because the inclusion of evapotranspiration, the connection between natural land cover and the hydrological cycle. Forests and natural vegetation play a pivotal role in contributing towards the hydrological cycle through inception and transpiration (Gribovszki et al., 2019[98]). The substantial declines in SPEI underscore the links between the historically low levels of natural land and forest cover in Hungary with the decline in precipitation levels. These studies reveal the vulnerability of Hungary and particularly the agricultural sector to drought risks. The following table offers an overview of the identified relevant studies, their indicators, and results:

Table 12. Historical studies of drought in Hungary and the surrounding region on agriculture

Identified Studies	Region	Drought Indicators	Drought Results	Sectoral Impact
(Mateescu et al., 2013[99])	Romania	SPI, Aridity Index, soil moisture, heat waves, ETP, satellite data	N/A	Decline in agricultural yield between 15.7% - 80.2% depending on the crop.
(Mohammed et al., 2022[96])	Hungary	SPI and SPEI	Western Hungary has been more prone to drier conditions.	High correlations between wheat and maize yields and drought periods.
(Pinke and Lövei, 2017[95])	Hungary	Historical temperature and precipitation between 1921-2010; PaDI	N/A	Climate accounted for 33-67% of yield variability between 1981-2010, with average annual yield loss between 6.1%-15.3%
(Harsányi et al., 2021[100])	Hungary	SPI and SPEI	Agricultural drought is more severe in Western Hungary	Loss in sunflower yield between 42.03% - 32.89% for severe drought years.
(Fiala et al., 2014[101])	Hungarian-Serbian cross-border area	PaDI and Moisture availability	PaDI values varied between 4-7.1 degrees/100mm	Drops in agricultural yields of over 40% compared to average.

Source: Academic studies

A few studies undertake forward-looking scenario analysis to assess the future potential changes in drought hazard in the region. These studies predominantly consider climate change in their analyses but can still be a useful indicator of potential future risks. A 2016 study of the Carpathian Basin projects 6-13 years between 2021 and 2050 to have severe droughts, with PaDI values greater than 10, compared with historical droughts with scores between 6-8 (Mezösi et al., 2016[102]). Similarly, a study on the Danube River Basin projects summer months to be 15% drier in future, compared to a 1981-2010 baseline, with a precipitation decrease of above 30% by 2070-2099 in the summer months for southern Danube countries (including Hungary) (Bisselink et al., 2018[103]). The study projects heavily increased water scarcity by the end of the century, especially in the summer months, for southern Danube countries. Whilst the study focuses on climate change, it acknowledges the roles of land use change and water demand on increased water scarcity (Ibid). Finally, as part of Hungary's submission to the UNFCCC, their biennial report presents projections for future climatic and precipitation changes in the region. The projections indicate a mean temperature change of 1.4-2.6 degrees in summer months by mid-century, with a higher degree of warming in the eastern and southern parts of the country (Ministry of National Development, 2017[87]). This is particularly relevant because most agricultural activity occurs in these regions of the country, in the Hungarian Great Plains. Whilst annual precipitation is projected to remain unchanged, all estimations portray a reduction of average summer precipitation by 5-10% by 2021-2050, and by 20% in the period 2071-2100 (Ibid).

Sector-specific transmission channels

Several studies highlight the impact of drought on agricultural crop yields in Hungary, particularly sunflower, maize, and wheat crops (Mohammed et al., 2022[96]; Harsányi et al., 2021[100]; Pinke and Lövei, 2017[95]). Across the Danube Basin region, 24% of water extractions are used for agricultural purposes and significant trends in the maximum number of consecutive dry days is expected to limit agricultural yields (Bisselink et al., 2018[103]). Agricultural production in Hungary is concentrated in the Southern and Eastern regions of the country, in the Great Plains, which is also identified as the region subject to expected higher temperature increases and particular risk of drought. Hungarian agriculture is already significantly impacted by drought, in 2022 severe drought and heat-related impacts reportedly caused agricultural damage estimated to be over 1bn EUR (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2022[104]). Hence, drought-related risks may have substantial impacts on agricultural yields in Hungary.

A substantial proportion of Hungary's energy supply comes from sources which are dependent on water. Nuclear power and biofuels and waste constitute 39% and 27% of Hungary's domestic energy production, respectively, as well as 16.7% and 11.2% of its total energy supply, respectively (IEA, 2022[105]). Several studies acknowledge the impacts on energy production from climate variability in Europe, the study highlights the correlation between water variability for cooling and nuclear energy production in summer months (Després and Adamovic, 2020[106]; Ministry of National Development, 2017[87]). According to the World Meteorological Organisation, nearly 60% of reported weather-related nuclear production losses since 2017 in Europe were associated with plants located near rivers or lakes (World Meteorological Organisation, 2022[107]). The impact of drought-related risks on nuclear production in Hungary has previously been reported, with the Paks Nuclear Power Plant scaling back operations in 2022 due to high temperatures in the Danube River (Dlhopolec et al., 2023[108]). The energy industry is particularly dependent on surface water, responsible for 77% of water use (Barreto et al., 2017[14]). Moreover, declines in crop yields from drought may have a significant impact on the availability of biofuels in Hungary. Across the EU, the agricultural sector is the biggest producers of biomass at 69% (OECD, 2023[109]). Therefore, Hungary's energy production is directly and indirectly exposed to drought-related risks through water availability for cooling and from declined crop yields for biomass production.

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Notes

[1] In the context of this analysis, impact drivers are defined as "a measurable quantity of a natural resource that is used as an input to production or a measurable non-product output of business activity" (Natural Capital Coalition, 2016[112]), while ecosystem services are defined as "final outputs or products from ecological systems that enable or facilitate business production processes" (ENCORE, 2024[22]) (Haines-Young and Potschin, 2012[111]).

[2] This result emanates more from the methodological decisions made in calculating the indirect and total impacts ratings, rather than the inherent characteristics of the Hungarian lending portfolio. The calculations of indirect and total standard impact ratings, explained in detail in Technical implementation and methodological overview, result in 614 of the 615 four-digit NACE industries being allocated a total materiality rating strictly higher than 0.7. The relative prominence of impacts over dependencies, however, is robust to various different indirect and total materiality calculation methods.

[3] Previous studies exhibit significant variability regarding this conclusion, even when employing similar methodologies. For instance, a study by the DNB finds that the Netherlands faces greater exposure to physical risks, amounting to EUR 510 billion, compared to transition risks, which stand at EUR 96 billion (van Toor et al., 2020[48]). Conversely, the World Bank's study on Malaysia indicates a higher exposure to transition risks, affecting 87% of the portfolio, as opposed to physical risks, which impact 54% of the portfolio (World Bank, 2022[49]).

[4] For more information about the data on financial securities, please refer to Technical implementation and methodological overview.

[5] For more information about the ENCORE framework, please refer to Technical implementation and methodological overview

[6] 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. For more information on other ecosystem services, please see https://encorenature.org/en.

[7] For a detailed explanation of the methodology employed in the calculation of the cautious materiality ratings please refer to Technical implementation and methodological overview.

[8] Using EXIOBASE3 for sector-specific value chain data, indirect impacts and dependencies for each sector are calculated, enhancing the understanding of each sector's broader environmental footprint. Then, total materiality ratings are calculated, aggregating direct and indirect scores based on a methodology that ensures that supply chain influences are integrated without overshadowing or diminishing the direct relationships. For further information on the construction of combined total materiality ratings, please refer to Technical implementation and methodological overview.

[9] However, it's important to remember that since these records are derived from administrative sources, firms are often registered or headquartered in specific counties or districts, typically closer to major cities, but this registration location does not necessarily indicate where their economic activities actually occur.

[10] MSA is an indicator of naturalness or biodiversity intactness, it measures the mean abundance of original species relative to their abundance in an undisturbed ecosystem. A MSA score of 0 would indicate a

completely destructed ecosystem, whereas a score of 100 would refer to a pristine ecosystem (IPBES, 2018[113]).

[11] Green water refers to the fraction of precipitation which is contained within the soil and plants.

[12] Evapotranspiration is the biophysical process of transferring water to the atmosphere through evaporation from the soil and transpiration from plants.

[13] The periods of sector shutdown are taken from historical analysis on the duration of meteorological droughts, which shows droughts in Central Europe have last up to 4 months on several occasions (European Environment Agency, 2022[110])

[14] The assessment employs data from 2022 available in EXIOBASE 3 and the cautious approach for materiality assessment detailed in the previous section to identify foreign sectors that trade with Hungary and the physical and transition risks associated to them.

[15] The ‘first wave’ indirect effects refer to the economic impact of sectors which are directly upstream or downstream for sectors which are affected by the initial shock or hazard.

[16] These KPIs may include but are not limited to tonnes of water use per unit of production, km2 of land use per unit of production, or volume of fertilizer used per hectare of crops. These are example KPIs and do not reflect specific recommendation on metrics or KPIs to be used.

[17] In other words, limited financial data restricts the analysis of the diverse types of exposures to nature-related financial risks, and prevents exploring bank and firm heterogeneity in this context.

[18] N/A=0, Very Low=0.2, Low=0.4, Medium=0.6, High=0.8, and Very High=1.

[19] Integrating multiple impact and dependency scores from individual production processes into a single, overarching sector-wide rating leads to an inherent reduction in precision. As noted in (Svartzman et al., 2021[47]) the aggregation method applied can vary and is subject to discretion. Potential strategies might involve using the unadjusted simple average, opting for the highest rating to anticipate the most severe scenario, or selecting the lowest rating to reflect a more cautious stance. The strategy adopted in this study involves rounding the simple average to the nearest higher multiple of 0.2. This approach balances accuracy with a degree of aggressiveness in the aggregation process, while still preserving the original ENCORE classifications, which range from Very Low to Very High.

[20] The publicly available version of ENCORE documents eleven impact drivers, but a more recent version shared privately includes data on a twelfth impact driver: “biological alterations / interferences”.

[21] The methodology for establishing global measures of indirect impacts and dependencies diverges from those calculating region and sector-specific indirect materiality ratings, still utilizing ENCORE. These methodologies incorporate country-specific value chains when determining upstream materiality ratings, leading to scenarios where identical sectors in different countries inherently receive varying indirect materiality ratings due to the distinct composition of their upstream value chains, notwithstanding uniform direct dependencies and impacts.

Assessing nature-related risks in the Hungarian financial system: Charting the impact of nature's financial echo

This paper presents a technical assessment of nature-related risks within the Hungarian economy and financial system. The study draws upon the OECD Supervisory Framework to (i) prioritise various nature-related risks by conducting an impact and dependency assessment, identifying key economic sectors, and pinpointing the critical natural capital assets that are most crucial to the financial system; (ii) assess the direct and indirect economic impact of three exploratory scenarios on possible acute nature-related shocks using input-output analysis; (iii) explore the different financial risk channels through which economic risks stemming from nature-related losses may be transmitted within the Hungarian financial system; and (iv) provide supervisory recommendations based on the results.

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