CETEX

Centre for Economic Transition Expertise

*Research and Policy at* **LSE**

# Understanding the double materiality of nature-related financial risks: evidence from the Mexican economy

## CETEx Working Paper No. 3

Carlos A. López-Morales, Karina Caballero Güendulain, Saul Basurto Hernandez, Luis O. L. Escobar-Farfán and Serafin Martínez Jaramillo

October 2026

**CETEx – the Centre for Economic Transition Expertise** – was established in 2024 at the London School of Economics and Political Science as a specialised research and policy centre to support the ambitious reforms required to deliver sustainable, inclusive and resilient economies and financial systems across Europe. The Centre is hosted by the LSE Global School of Sustainability and has founding funding from the Sequoia Climate Foundation, ClimateWorks Foundation, Children's Investment Fund Foundation, Sunrise Project and European Climate Foundation.
www.cetex.org

**The CETEx Working Paper series** publishes advanced empirical, theoretical and methodological research across a wide range of academic disciplines to advance understanding of transitions towards sustainable, inclusive and resilient economies and financial systems in CETEx's focus areas: Fiscal and Economic Policy, Monetary and Financial Markets, Emerging Markets and Developing Economies, and Nature. All papers undergo single blind peer review prior to publication. Dr Matthias Täger, CETEx, and Dr Richard Perkins, LSE Department of Geography and Environment, are the current series editors.


## Acknowledgements

The authors are extremely grateful to many CETEx colleagues. In particular, they would like to thank Elena Almeida, Matthias Täger and Chris Raggett for their incredible support during the editorial process and to the anonymous referees who helped them improve the paper substantially.

The views in this paper are those of the authors and do not necessarily represent the position of CETEx's senior management or funders. Any errors and omissions remain those of the authors.

Authors' declaration of AI use: The authors used Copilot (Basic) and Claude (Fable) for language editing and structural refinement during the last part of the revision process, and only for a very small number of cases. The tool was used exclusively to improve the clarity and readability of a limited number of paragraphs, including the introduction and policy recommendations, during the last round of revisions. No code, analytical steps, substantive arguments, conclusions or empirical claims were generated by these tools. All outputs were reviewed and, where necessary, corrected by the authors, who remain fully responsible for the content of the publication.

This paper was first published in October 2026 by CETEx at the London School of Economics and Political Science.



© The authors, 2026

Licensed under CC BY-NC 4.0



Suggested citation: López-Morales CA, Caballero Güendulain K, Basurto Hernandez S, Escobar-Farfán LOL and Martínez Jaramillo S (2026) *Understanding the double materiality of nature-related financial risks: evidence from the Mexican economy.* CETEx Working Paper 3. London: Centre for Economic Transition Expertise, London School of Economics and Political Science.

# Understanding the double materiality of nature-related financial risks: Evidence from the Mexican economy

Carlos A. López-Morales*[1], Karina Caballero Güendulain[2], Saul Basurto Hernandez[2], Luis O. L. Escobar-Farfán[3], Serafin Martínez Jaramillo[4]

[1]Centro de Estudios Demográficos, Urbanos y Ambientales. El Colegio de México
[2]Facultad de Economía, Universidad Nacional Autónoma de México
[3]Independent researcher
[4]The World Bank and London School of Economics and Political Science

**Abstract**

Understanding the links between ecology and finance is a difficult task, as they are mediated by finance's interaction with productive sectors and by the latter interacting with nature. An emerging concept useful here is the 'double materiality,' used to describe how economic activity interacts with nature, both depending on it and affecting it. Nature-related financial risks are commonly classified into physical, transition, and systemic risks, while the concept of double materiality captures the two-way relationship between economic activity and nature through dependencies on ecosystem services and impacts on ecosystems. This paper analyzes the double materiality of nature for the Mexican economy by combining a 263-sector input-output model with the ENCORE database, which features 'generic' scores of direct sectoral dependence on 25 ecosystem services and impact in 13 environmental categories. We construct 'total' dependence and impact scores capturing their diffusion throughout the economy's network of supply chains, and relate them to macroeconomic data and the national credit portfolio. We find that 48-66% of output, 47-53% of jobs, and 68-83% of credit are highly dependent on at least one ecosystem service, where the pair of values indicates direct and total effects, respectively. Similarly, 49-66% of output, 33-49% of jobs, and 54-68% of credit are highly harmful in at least one category of environmental impact. We go beyond ENCORE's generic assessments by studying water-related physical risks and land-related transition risks with an implementation of environmentally-extended input output and by assuming fulfillment of Mexico's commitments under Target 2 of the Kunming-Montreal Global Biodiversity Framework, respectively. We finally assess the limitations of our methods and procedures, and suggest policy measures promoting a better understanding of nature-related financial risks.

**Keywords—** Double materiality, Nature-related risk, Ecosystem Services, Input-Output Economics, Financial System
**JEL classification—** Q51, Q57

* Corresponding author: calopez@colmex.mx

# 1 Introduction

Activities in the financial sector are not exempt from the impacts of global environmental change, both at the national and global scales. Understanding the links between ecology and finance is, however, a difficult task, as they are mediated by the financial interactions with productive sectors, as well as how the latter interact with nature. Central banks and other institutions worldwide are increasing their efforts to understand nature-related financial risks and build an environmentally-resilient financial sector. On the one hand, the Network for Greening the Financial System (NGFS), a coalition of financial institutions and central banks from 91 countries established in 2017, recognizes the existence of financial risks due to exposure to productive activities that cause environmental degradation or are negatively affected by it (NGFS 2022). On the other, environmental institutions highlight the importance of understanding the links between ecology, economic production, and finance. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), for example, points out that the deterioration of ecosystems impairs their ability to provide services that are crucial for the functioning of the global economy (IPBES 2019). Furthermore, the Global Biodiversity Framework, proposed in 2022 by the Kunming-Montreal Convention on Biological Diversity (CBD), calls for a transformation of the global financial architecture such that financial flows align with the Convention's objectives of biodiversity conservation (CBD 2022).

An emerging concept in this context is the 'double materiality', which organizes nature-related financial risks into a two-way relationship (Guo et al. 2026; WEF 2010; Calice et al. 2021; Van Toor et al. 2020; Hadji-Lazaro et al. 2024; O'Donnell at al. 2025 and Ceglar et al. 2025). On the one hand, activities supported by the financial sector depend on services provided by nature such as water provision, climate regulation, pollination, etc. On the other hand, these same activities might deteriorate the same ecosystems that provide the resources they need, reducing their quantity and quality, hence creating a feedback effect that can amplify any impact from nature-related risks in different forms and channels.

Nature-related financial risks can be understood through two complementary dimensions. The first is double materiality (O'Donnell at al. 2025 and Ceglar et al. 2025), which describes the two-way relationship between economic activity and nature: economic sectors depend on ecosystem services while simultaneously affecting ecological systems through their environmental impacts. The second dimension concerns the mechanisms through which financial losses may materialize. These mechanisms are commonly described as physical risks, transition risks, and systemic risks. Physical risks arise from ecosystem degradation and the consequent reduction in ecosystem services. Transition risks arise from policy, technological, market, legal, or behavioral responses aimed at halting or reversing environmental degradation. Systemic risks emerge when physical and transition risks interact and propagate through economic and financial networks, causing cascading effects of contagion threatening the stability of the whole economy, including the financial sector (NGFS 2024). Under this framework, dependencies and impacts

should not be interpreted as separate risk types but rather as underlying sources of exposure that can generate multiple forms of nature-related financial risk.

Recent examinations of this double materiality exist for both developed (Van Toor et al. 2020; Hadji-Lazaro et al. 2024; Ceglar et al. 2025) and developing countries (Hadji-Lazaro et al. 2023; World Bank and Bank Negara Malaysia 2022), but also for global banks (O'Donnell et al. 2025). Their findings suggest that significant shares of financial portfolios exhibit high dependence on at least one ecosystem service and are highly exposed to productive activities with harmful biodiversity impacts. In Europe (Kedward et al. 2021), France (Svartzman et al. 2021), Brazil (Calice et al. 2021) and Malaysia (World Bank and Bank Negara Malaysia 2022), 40%, 42%, 46%, and 54% of loan portfolios, respectively, are linked to economic activities highly dependent on ecosystem services. Similarly, 15-38%, 70%, and 87% of loan portfolios in Brazil, Europe, and Malaysia, respectively, exhibit transition risks due to their financing of environmentally harmful activities. This literature suggests that the links between finance and ecology materialize through investments in productive activities that directly and indirectly depend on healthy nature, the degradation of which increases financial instability through higher production costs, higher default probabilities, and weaker valuation of assets.

In this paper, we contribute to the emerging literature on nature-related financial risks with a twofold objective. First, we adapt and expand the methodologies from (Hadji-Lazaro et al. 2024) and (Svartzman et al. 2021)) to examine the Mexican economy. Mexico is an exceptional case study because it is one of the few ecologically megadiverse countries in the world, its middle-income economy is highly tertiarized and integrated with the global economy, both productively and financially, and because adequate sources of economic, financial and environmental information are available. Other related studies for countries with similar characteristics in terms of being megadiverse include: Calice at al. 2021, World Bank and Bank Negara Malaysia 2022 and D'Orazio et al. 2026. We quantitatively operationalize the 'double materiality' by linking the ENCORE database (Exploring Natural Capital Opportunities, Risks and Exposure, NCFA (2024)), which attributes sector-specific categorical scores for *direct* ecosystem dependence and environmental impact, with an economy-wide input-output table (INEGI 2018b) to compute *total* scores of dependence and impact, therefore taking into account the economy's network of productive interdependence. We then assess the exposure of the financial system to the double materiality by studying the sectoral distribution of the credit portfolio as reported by the Mexican banking system.

Second, to show the macroeconomic relevance of the double materiality, we complement the above procedure by including sector-specific data on gross output and employment. We also go beyond ENCORE's generic assessments of dependence and impact, and use environmental, spatial and micro-level data from economic censuses to assess physical and transition risks for the particular cases of water and land use in natural protected areas, respectively. In this context, Mexico presents an especially relevant case for studying biodiversity loss-related financial risks because several characteristics suggest a priori that both dimensions of double materiality may be substantial but also, because

biodiversity has been declining at alarming rates as it is shown in (Martinez-Jaramillo et al. 2023). First, as one of the world's megadiverse countries, Mexico's economy relies on a wide range of ecosystem services, including water regulation, pollination, soil quality maintenance, and climate regulation. While biodiversity does not automatically imply greater economic dependence on ecosystem services, it does indicate that a significant share of productive activities is embedded in ecosystems whose functioning supports economic output. Second, Mexico maintains important agricultural, mining, tourism, and natural resource-based sectors, all of which are potentially sensitive to ecosystem degradation and therefore may generate significant physical risks. Third, Mexico's large manufacturing and export sectors are deeply integrated into domestic and global supply chains, suggesting that ecosystem dependencies may propagate beyond primary activities and affect sectors that appear only indirectly connected to nature. Finally, ongoing biodiversity conservation and restoration commitments may expose environmentally intensive sectors to transition risks. Taken together, these features lead us to expect that both ecosystem dependence and environmental impacts are not confined to a few nature-intensive sectors but are likely to be transmitted throughout the economy and the financial system via production networks.

Nevertheless, we are not claiming that Mexico's high natural endowment automatically implies high dependence on ecosystem services. Our claim is that high biodiversity increases the likelihood that economically valuable ecosystem services play an important role in production and livelihoods, but the degree of economic dependence remains an empirical question that depends on the structure of the economy.

Our main findings indicate that 48-66% of output, 47-53% of jobs, and 68-83% of credit portfolio in Mexico are highly dependent on at least one ecosystem service, where the pairs of values indicate direct and total dependence scores. Similarly, 49-66%, 33-49%, and 54-68% of output, jobs and credits are associated with economic activities that are highly harmful in at least one category of environmental impact. We find that financial exposure to water-related physical risks is not direct but rather transferred throughout the Mexican production network, as 83% of the national credit portfolio is allocated to sectors that are net importers of embedded water through their supply chains. For conservation-related transition risks, we assume that Mexico fulfills its commitment to Target 2 of the Kunming-Montreal Global Biodiversity Framework, placing at least 30% of the area of degraded terrestrial ecosystems under effective restoration. Such a policy would affect $1,141-8,829 and $21-703 million USD of output and credit value, respectively, along with 4,480-65,472 associated jobs, where the pair of values also indicate direct and total effects. These figures, however, are preliminary as they refer only to medium and large firms and exclude agricultural activities altogether.

The remainder of this paper is as follows. Section 2 overviews the existing literature on economy-wide analysis of the double materiality. Section 3 describes our empirical strategy and the data utilized. Section 4 presents the results and discusses them relative to the relevant literature, the replicability for other contexts, and policy making in Mexico. Section 5 finally concludes.

# 2 Literature Review

The literature featuring economy-wide assessments on the double materiality of finance has emerged mainly in the last five years. It closely follows the methodological approach introduced by (Van Toor et al. 2020), which we described in three main steps. First, researchers establish a correspondence between the industrial classification of the case of study, usually determined domestically at different degrees of sectoral resolution, and that of the ENCORE database (NCFA 2024), currently with a 271-sector resolution under the International Standard Industrial Classification of All Economic Activities (ISIC; UN (2008)). This correspondence yields sector-specific categorical scores ranging from 'very low' to 'very high' and describing each sector's dependence on 25 ecosystem services and its impacts on 13 categories of environmental damage. Since these scores are allocated independently for each sector (i.e., not taking into account its place in the economic system), they describe *direct* dependence or impact. Second, researchers identify rather heuristically the economic activities and financial magnitudes with different degrees of exposure to dependence and impact. We observe here a common threshold identifying activities with 'very high' and 'high' scores of dependence and impact. Third, some authors use input-output economics to estimate *indirect* dependence and impact, namely those dispersed through the economy's network of supply chains (Svartzman et al. 2021; Hadji-Lazaro et al. 2024). Others complement these procedures with case studies on particular aspects of the double materiality for particular sectors (for instance, Hadji-Lazaro et al. (2023) focus on transition risks for coke oven products in South Africa).

The findings in these studies highlight the relevance of the double materiality for the financial sectors of the economies studied. According to (Van Toor et al. 2020), Dutch financial institutions have provided EUR 510 billion (as of 2018) to companies highly dependent on at least one ecosystem service, EUR 193 billion to firms involved in negative environmental impacts, while at least EUR 28 billion face transition risks due to the expansion of protected areas for conservation. For South Africa, (Hadji-Lazaro et al. 2023) estimate that 50% of output depends on two or more ecosystem services, while 70% of final demand, 59% of profits, 46% of wages, 40% of employment, 52% of taxes, and 83% of net exports are linked to industries highly dependent on ecosystem services. (Calice et al. 2021) find that 46% of the portfolio allocated by Brazilian banks to non-financial entities concentrates in sectors dependent on at least one ecosystem service, while 15%-38% would be at risk under conservation measures. For commercial Malaysian banks, (World Bank and Bank Negara Malaysia 2022) find 54% of the loan portfolio highly dependent on ecosystem services, while 87% of it is allocated to environmentally-harmful industries. (Martinez-Jaramillo et al. 2023) argue that an important share of the Mexican credit portfolio exhibits high degrees of exposure to the double materiality, even if only considering the direct effects of dependence and impact. (Kedward et al. 2021) reveal that 40% of the European Central Bank's portfolio depends highly on ecosystem services, while 70% is allocated to activities causing biodiversity loss. Similarly, (Mundaca and Heintze 2024) estimate that 27% of equity investments made by the ten largest European banks,

some USD $335 billion in which UBS Group AG and Deutsche Bank AG stand out, are highly dependent on ecosystem services.

Our findings are broadly consistent with the emerging literature on nature-related financial risks, which emphasizes that financial exposures to biodiversity loss arise not only through direct dependencies on ecosystem services but also through indirect dependencies embedded in supply chains. This is consistent with the evidence stated in Almeida et al. (2026) that the indirect effects of localized shocks can increase substantially when transmitted through the supply chain, reaching firms not directly connected to sectors affected by the original impact of a nature-related shock. However, Almeida et al. (2026) also mention that most of the evidence found so far weather, climate and natural-disaster shocks; assessments of the propagation of nature degradation itself to the whole economy remain limited. The Mexican case extends this literature by demonstrating that these transmission channels are particularly relevant in a megadiverse emerging economy characterized by strong regional variation in ecosystem conditions and economic activity.

Similar patterns have been documented in analyses of European countries, where sectors with a low direct dependence on ecosystem services become exposed through their links to nature-intensive industries. In the Netherlands, Van Toor et al. (2020, 16) note that first-order scores underestimate the dependence of secondary industries such as food processing on pollination. For France Svartzman et al. (2021, 34–35) and Hadji-Lazaro et al. (2024) find that every issuer in the investment portfolio becomes at least slightly dependent on all ecosystem services once upstream dependencies are included. For the euro area, Boldrini et al. (2023, 21) found that the share of corporate loans highly dependent on at least one ecosystem service increases from 61% to 75% when the supply-chain dependencies are included. Finally, for the United Kingdom Ranger et al. (2024, 7) estimate that about half of nature-related risks originate from overseas through supply chains, with sectors such as services and manufacturing being the most exposed in financial terms.

Consistent with the concept of double materiality, nature-related risks are both financially material to economic actors and shaped by the impacts of economic activities on natural systems. These risks can propagate through supply chains and production networks, implying that sectors with limited direct dependence on ecosystem services may nevertheless be exposed through indirect linkages. Consequently, assessing nature-related risks requires consideration of both direct and indirect transmission channels across the economy (Ceglar et al. 2025 and O'Donnell et al. 2025).

Since the pioneering study by (Van Toor et al. 2020), the literature has contributed with reflections on some of the procedure’s shortcomings and with some methodological advancements to address them. (Mundaca and Heintze 2024), for instance, identify three main limitations and challenges. First, the ways in which economic activities actually depend on and impact nature are contingent to conditions that are specific to the locations of firms and their supply chains, the details of which are not observable in the generic scores of the ENCORE database. Second, several procedures for aggregating

ENCORE data to correspond to classifications operating at different sectoral resolutions can generate different dependency and impact scores, while assuming firm-homogeneity within the same industry. Third, assessments for direct dependencies on ecosystem services underestimate materialities due to the exclusion of indirect effects dispersed throughout an economy's network of supply chains. Some efforts do exist to address some of these limitations. To overcome generic scores, authors have introduced spatially-explicit assessments of financial risks (see Hadji-Lazaro et al. (2023) for South Africa and Martinez-Jaramillo et al. (2023) for Mexico). To go beyond direct assessments by considering the contribution of supply chains, authors utilize input-output economics (see Van Toor et al. (2020); and Hadji-Lazaro et al. (2024)). Others have attempted to address limitations simultaneously, like the study by (Hadji-Lazaro et al. 2023), who use input-output economics to estimate the diffusion of indirect effects, include socioeconomic and spatial data for improved local context, and elaborate on defining 'key sectors' using combined criteria of economic and environmental importance.

The contribution of this paper to the literature is as follows. First, we adapt the methodology advanced by (Hadji-Lazaro et al. 2024) and (Svartzman et al. 2021) to operationalize the double materiality linking the ENCORE database to an input-output model of the Mexican economy. Our adaptation highlights the role of supply chains in the diffusion of each sector's ecosystem dependence and environmental impact, and to that objective we develop sector-specific aggregate scores of total dependence and impact (see next section).

Second, after recognizing the limitations of generic scores of dependence and impact in the ENCORE database, we use data specific to the Mexican case to analyze water-related physical risks and land-related transition risks. For this exploration, we combine an application of the environmentally-extended input-output model of the economy for water analysis and spatial data at the firm level from economic censuses. Finally, our approach to the Mexican case also evaluates the strengths and limitations of the methodology, and identifies some avenues for further research.

# 3 Methods and data

## 3.1 Modeling the double materiality with input-output economics

The building blocks of the input-output model of the economy are sector-specific equations balancing total output and total demand. The latter is composed by the sum of intermediate demand as implied by production, therefore endogenous to the model, and final demand, which is treated exogenously. If the economy consists of $N$ sectors, the generic equation describing these relationships for the $i$-th sector is as follows:

$$x_i = \sum_{j=1}^{N} a_{ij}\, x_j + y_i$$

*( 1 )*

where $x_i$ measures the total output of sector $i$; $a_{ij}$ represents the inputs produced by sector $i$ required to produce a unit of output in sector $j$; $x_j$ is the total output of sector $j$, and $y_i$ is the final demand for the output of sector $i$. To represent (1) for all the $N$ industries in an economy, we re-write in matrix form:

$$\mathrm{x} = \mathbf{A}\mathrm{x} + \mathrm{y}$$

*( 2 )*

or,

$$(\mathbf{I} - \mathbf{A})\mathrm{x} = \mathrm{y}$$

*( 3 )*

where **A**, known as the *matrix of technical coefficients*, is of dimension $N$ x $N$ and contains all the coefficients $a_{ij}$ capturing the direct industrial interdependence given current technology, whereas **I** is the $N$ x $N$ identity matrix. Note that equations (2) and (3) represent an economic model that determines the gross output of all $N$ sectors simultaneously, $\boldsymbol{x}$, as required to satisfy the sum of endogenous intermediate demand, **A**x, and exogenous final demand $\boldsymbol{y}$. Mathematically, it is a system of equations that can be solved as follows:

$$\mathrm{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathrm{y} = (\mathbf{I} + \mathbf{A} + \mathbf{A^2} + \mathbf{A^3} + \cdots)\mathrm{y} = \mathbf{L}\mathrm{y}$$

*( 4 )*

where **L**, known as the *Leontief inverse*, is also of dimension $N$ x $N$. Its generic entry, $l_{ij}$, describes the total output from sector $i$ needed to satisfy one unit of final demand of sector $j$, including the intermediate demand for the required inputs from all sectors in the economy. We write the power series expansion of **L** to indicate that it takes into account the infinite inter-sectoral loops of interaction as implied by the matrix of technical coefficients. In that sense, **L** contains a complete description of the economy's supply chains for each of the $N$ sectors (Miller and Blair 2022).

To model the double materiality of dependence and impact, we construct two additional matrices, **D** and **P**, to organize the scores of direct dependence on ecosystem services and direct environmental impact, respectively, which come from the ENCORE database (see the following sections). Let $M$ be the number of ecosystem services and $Q$ the number of categories of environmental impacts in the database. Therefore, matrices **D** and **P** have dimensions $M$ x $N$ and $Q$ x $N$, respectively. The generic entry of matrix **D**, $d_{mj}$, measures the direct dependence of the $j$-th sector to the $m$-th ecosystem service. Similarly, the generic entry of **P**, $p_{qj}$, measures the direct score of the $j$-th sector in the $q$-th category of

environmental impact. For illustration purposes, we find it useful to compute the aggregate direct scores for both ecosystem dependence and environmental impact for the $j$-th industry:

$$d_j = \sum_{m=1}^{M} d_{mj} \tag{5}$$

$$p_j = \sum_{q=1}^{Q} p_{qj} \tag{6}$$

Note that, since there are 25 ecosystem services in the ENCORE database, $d_j \in [0,25]$. If the $j$-th sector had 'very high' dependence on all 25 services, it follows that $d_j = 25$. Alternatively, if it was independent to all 25 services, then $d_j = 0$. Similarly, since there are 13 categories of environmental impact in the ENCORE database, $p_j \in [0,13]$, where similar considerations apply. The computation of total scores (i.e., including direct and indirect effects) of sectoral dependence on ecosystem services is straightforward:

$$\mathbf{\Omega} = \mathbf{DL} \tag{7}$$

Matrix $\mathbf{\Omega}$ has dimension $M$ x $N$, and its generic entry $\omega_{mi}$ displays the total dependence score on the $m$-th ecosystem service exhibited by the economy's supply chain to the $i$-th industry. That is,

$$\omega_{mi} = \sum_{j=1}^{N} d_{mj}\, l_{ji} \tag{8}$$

Using the entries of $\mathbf{\Omega}$ thus computed, we calculate the aggregate score of total dependence for the $j$-th industry by adding over ecosystem services. That is,

$$\omega_j = \sum_{m=1}^{M} \omega_{mj} \tag{9}$$

Similarly, to obtain the total scores of sector-specific environmental impact, we compute:

$$\mathbf{\Phi} = \mathbf{PL}$$

*( 10 )*

Matrix $\mathbf{\Phi}$ has dimension $Q$ x $N$, and its generic entry $\phi_{qi}$ displays the total impact in the $q$-th environmental category inflicted by the economy's supply chain to the $i$-th industry. That is,

$$\phi_{qi} = \sum_{j=1}^{N} p_{qj}\, l_{ji}$$

*( 11 )*

Finally, we calculate the aggregate score of total impact for each industry $j$ by summing over impact categories. That is,

$$\phi_j = \sum_{q=1}^{Q} \phi_{qj}$$

*( 12 )*

Note that this procedure is a slight departure from methodological choices in Svartzman et al. (2021) and Hadji-Lazaro et al. (2024). They report direct and indirect effects separately, therefore not showing total effects explicitly. Also, they normalize the entries of matrix $\boldsymbol{L}$ to compute relative sectoral contributions in each sector's supply chains. Instead of using such a normalization, we choose to use the absolute magnitudes of entries $l_{ij}$, as they allow for a better comparison between total and direct effects. We also show total effects explicitly to make visible the actual scores as implied by the technological structure of the economy. The contributions of supply chains (the indirect effects) are still visible in the differences between direct and total effects, which we illustrate with the distance between sector-specific aggregate scores for direct and total dependence, $d_j$ and $\omega_j$, as defined by (5) and (9), and direct and total impacts, $p_j$ and $\phi_j$, as defined by (6) and (12).

We perform two additional computations with these distances, one measuring the difference in absolute terms ($\omega_j - d_j$ for dependence, $\phi_j - p_j$ for impact), the other measuring it in relative terms ($\omega_j / d_j$ for dependence, $\phi_j / p_j$ for impact). In both cases, the larger the distance between the direct and the total aggregate scores for a given sector, the larger the contribution of the economy's supply chain to that sector's dependence and impact. Absolute differences are useful to identify the relevance of indirect effects attributable to supply chains independently of each sector's direct dependence and impact scores; relative differences are useful to identify indirect effects attributable to supply chains that are larger than each sector's direct dependence and impact scores, which happens when $\omega_j / d_j \geq 2$ for dependence scores and when $\phi_j / p_j \geq 2$ for impact scores.

## 3.2 Color coding for heatmaps

The ratings for direct dependence and impact in the ENCORE database are categorical: 'no data,' 'no link,' 'very low,' 'low,' 'medium,' 'high,' and 'very high.' 'No link' refers to when the economic activity for which the score is constructed is known to either not depend on the corresponding ecosystem service, or to not have an impact in the corresponding environmental category. 'No data' refers to the case in which there is no sufficient evidence for the level of dependence or impact of a particular economic activity (UNEP-WCMC 2024). In the latest version of the ENCORE database (NCFA 2024), these ratings are constructed using a combination of quantitative data and qualitative assessments, drawing from the best data available (UNEP-WCMC 2024). Following the methodology of (Svartzman et al. 2021), we assign discrete numerical scores to each of these categories, as shown in Figure 1. In order to operationalize the methodology of the previous section, we collapse the 'no link' and 'no data' categories into a single score to describe 'none' dependence nor impact, and we further allocate the particular color palette shown in the Figure for producing heatmaps. These choices allow us to construct the matrices **D** and **P**, therefore enabling the computation of matrices $\boldsymbol{\Omega}$ and $\boldsymbol{\Phi}$ as defined in equations (7) and (10), and containing the total scores of dependence and impact, respectively. Unlike the direct scores in **D** and **P**, which are discrete, the total scores of $\boldsymbol{\Omega}$ and $\boldsymbol{\Phi}$ are continuous, and we organize them in quintiles for visualization purposes (see Figure 1).

*Figure 1 Color and numerical codes for direct and total dependence and impact*

| Direct dependence and impact | | | | | |
|---|---|---|---|---|---|
| Very High | High | Medium | Low | Very Low | None |
| 1 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| **Total dependence and impact** | | | | | |
| Very High | High | Medium | Low | Very Low | None |
| Quintile 5 | Quintile 4 | Quintile 3 | Quintile 3 | Quintile 1 | 0 |

Source: own elaboration.

## 3.3 Scenarios of exposure to physical and transition risk

As we stated before, nature degradation can be translated into financial risk because of its double materiality, stemming from the dependencies and impacts that financed economic activities have on nature, originating either from physical or transition risks. It is worth mentioning that the concepts of dependencies and impacts are not uniquely related to physical and transition risks respectively, rather, they are related to each other. For example, the access to a clean source of water by a water-intensive industry (dependency) can be reduced by both an unhealthy, degraded ecosystem (physical risk), or due to the implementation of a strict policy of water use (transition risk), resulting from bad practices in the management of residual, contaminated water (impacts). However, in this study we present two examples of how physical and transition risk materialize and how their impacts can be transmitted to the entire economy.

In order to go beyond the generic assessments of matrices **D** and **P** from the ENCORE database, we model two scenarios using specific data for the Mexican case to assess a physical risk (the use of water) and a transition risk (the expansion of conservation areas). Water risk is implemented with a standard computation of the environmentally-extended input-output model (Miller and Blair 2022), which includes a vector of sector-specific water coefficients measuring volumes required to generate one unit of output, as reported by Mexico's water commission (CONAGUA). That is,

$$\mathrm{w} = \begin{bmatrix} w_1 \\ \vdots \\ w_N \end{bmatrix} = \begin{bmatrix} \frac{W_1}{x_1} \\ \vdots \\ \frac{W_N}{x_N} \end{bmatrix}$$

*( 13 )*

$W_i$ is the total volume of water directly consumed by sector $i$. Therefore, the total volume of water withdrawals in the Mexican economy can be computed as follows:

$$W_Q = \mathbf{w}^T \mathrm{x} = \mathbf{w}^T \mathbf{L} \mathrm{y}$$

*( 14 )*

where a $T$ denotes transposition. Finally, to obtain the matrix of inter-sectoral flows of embedded water we compute:

$$\mathbf{W} = \widehat{\mathbf{W}} \mathbf{L} \widehat{\mathbf{Y}}$$

*( 15 )*

where $\widehat{\mathbf{W}}$ and $\widehat{\mathbf{Y}}$ are diagonal matrices organizing vectors w and y, respectively, in their principal diagonal, and zeroes everywhere else. Matrix **W** is of dimension $N$ x $N$, and its generic entry $W_{ij}$ measures the volume of water embedded in the products that the $i$-th sector delivers to the $j$-th sector given the observed pattern of final demand, and in that sense it captures the extent to which each industry is exposed to risks determined by their direct and indirect dependence on water use and availability.

For the transition risk scenario, we study some economic implications of target 2 of the Kunming-Montreal Global Biodiversity Framework, in which Mexico would subject to effective restoration a land extension at least equivalent to 30% of terrestrial degraded ecosystem areas. To identify the location and extent of such areas, we use the so-called 'Restoration Priority Areas' (RPAs) defined in the National Restoration Program of Mexico's Biodiversity Commission (CONABIO 2024). We then utilize INEGI's directory of economic units to geographically locate production units under the NAICS classification system in the Mexican territory (INEGI 2024). Apart from its punctual location, INEGI's directory also shows the size of the firm as measured by employment. Based on firms' coordinates, we perform a spatial match identifying those located within RPAs and therefore exposed to

environmental policy regulation. We then compute the average output and the number of jobs in each industry exposed to such regulation using microdata from the 2019 Economic Census (INEGI 2019). Finally, to illustrate financial exposure we assume proportionality between industrial output and credit to obtain a measure of the total credit value at risk, since there are no data available on credit at the firm level.

## 3.4 Data

Our approach to identify nature-related financial risks utilizes several sources of information. We first establish a correspondence between the industrial classification of the latest version of the ENCORE database (2024), which reports dependence for 25 ecosystem services and 13 categories of environmental impact (see Table 1) for 271 industries using the ISIC classification system (NCFA 2024), and that of Mexico's input-output database (INEGI 2018b), which contains 263 sectors under the North-American Classification System (NAICS, (INEGI 2018a).[1] The resulting correspondence allows the construction of matrices **D** and **P**, containing the direct scores of dependence to each ecosystem service by each of the 263 sectors in the Mexican economy, and the direct scores for each of the 263 sectors in each of the 13 categories of environmental impact, respectively.

*Table 1 List of ecosystem services and environmental impacts in the ENCORE database*

**List of ecosystem services and environmental impacts in the ENCORE database**

| | Ecosystem service | | Environmental impact |
|---|---|---|---|
| 1 | Water flow regulation | 1 | Disturbances |
| 2 | Rainfall pattern regulation | 2 | Toxic pollutants of soil and water |
| 3 | Storm mitigation | 3 | Volume of water use |
| 4 | Flood control | 4 | Solid waste |
| 5 | Water supply | 5 | Extension of land use |
| 6 | Soil and sediment retention | 6 | GHG emissions |
| 7 | Local (micro and meso) climate regulation | 7 | Non-GHG emissions |
| 8 | Water purification | 8 | Nutrient pollutants |
| 9 | Global climate regulation | 9 | Invasive species |
| 10 | Solid waste remediation | 10 | Area water use |
| 11 | Visual amenity services | 11 | Area seabed use |
| 12 | Spiritual, artistic and symbolic services | 12 | Biotic resource extraction |
| 13 | Air filtration | 13 | Abiotic resource extraction |
| 14 | Noise attenuation | | |
| 15 | Biological control | | |
| 16 | Education, scientific and research services | | |
| 17 | Dilution by atmosphere and ecosystems | | |

[1] The equivalence table will be included as Supplementary File, and can be found here.

18 Mediation of sensory impacts (other than noise)
19 Recreation related services
20 Biomass provisioning
21 Genetic material
22 Animal-based energy
23 Soil quality regulation
24 Nursery population and habitat maintenance
25 Pollination

Source: NCFA (2024).

In addition, this correspondence allows for linking with other socioeconomic data for the Mexican economy, also described under the NAICS industrial classification, such as employment and location as reported in INEGI's economic census (INEGI 2019), and the firms' directory (INEGI 2024). These sources report the location of 4.8 million firms while describing their size in terms of employees. For financial data, we used the total credit portfolio issued by both commercial (Banco de México 2024a) and developing banks (Banco de México 2024b), as published in the System of Economic Information of Mexico's central bank. [2] Such data report the total amount of credit provided by the banking system to each sector under the NAICS classification system, which ensures compatibility with the other datasets used. Finally, the physical risk scenario is based on data by Mexico's water commission displaying total withdrawals per main economic use (CONAGUA 2019). Unfortunately, the water data are not organized under the NAICS classification system. Therefore, a much coarser correspondence links it with the rest of the economic information to construct the vector of water coefficients, $\boldsymbol{w}$, as described in equation (13) of the previous section.

# 4 Results

## 4.1 Economy-wide assessment of ecosystem dependence and environmental impact

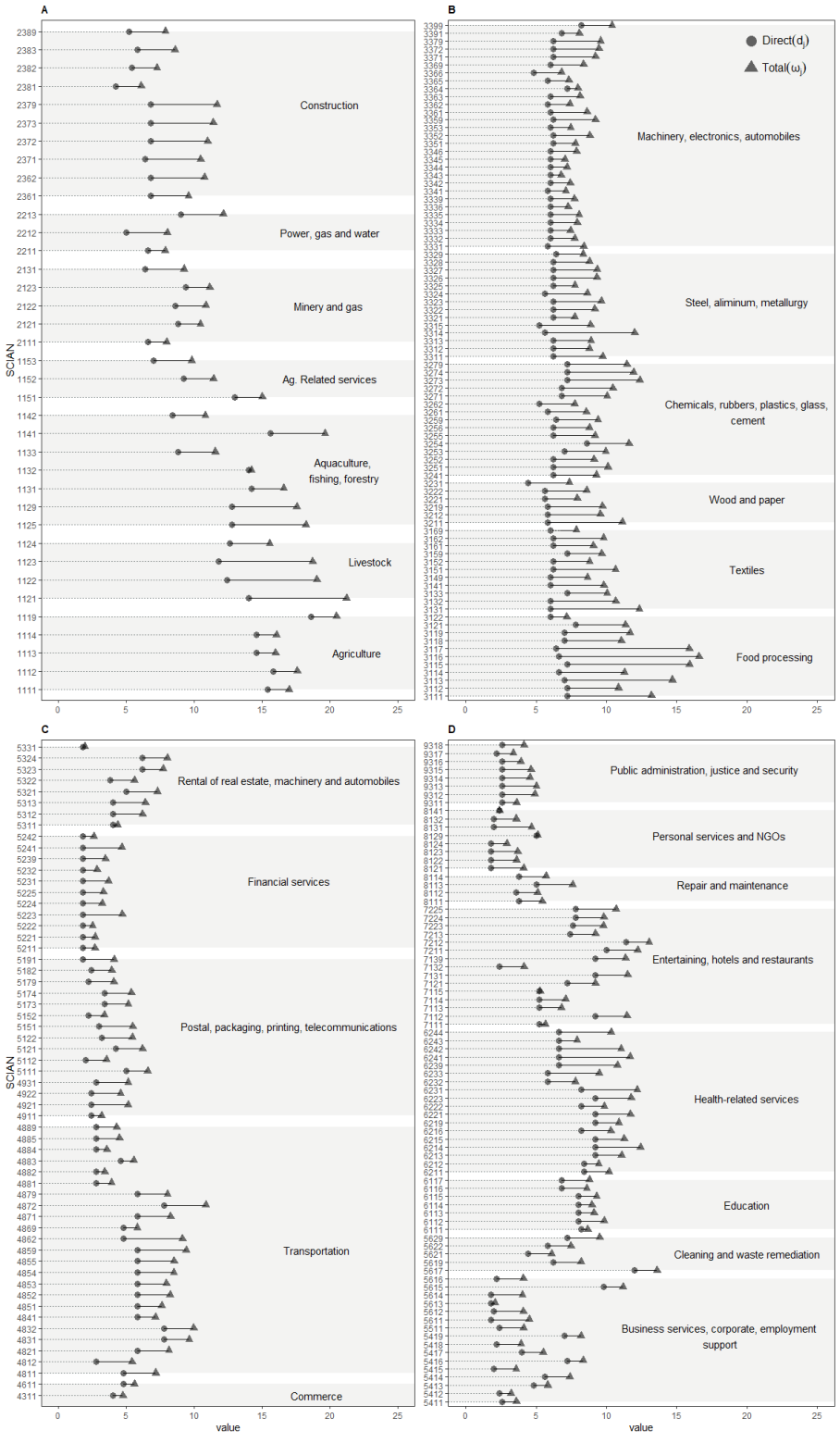
Figures 2 and 3 display the direct and total aggregate scores of both ecosystem dependence (defined in expressions 5 and 9 of the methodology) and environmental impact (defined in expressions 6 and 12) of the 263 sectors comprising the Mexican economy. Aggregate scores for direct dependence and impact are useful to distinguish the intensity with which sectors depend on ecosystem services and inflict environmental damage. Aggregate scores of total dependence and impact add the indirect effect as determined by the economy's supply chain to each sector. Note that the distance between

[2] The data will be included in a Supplementary File, and are available here for commercial banks and here for development banks

direct and total scores therefore represents indirect effects exclusively, namely the contribution of the economy's supply chain for each sector. Recall that while direct scores ($d_j$ and $p_j$) come directly from the ENCORE database, total scores ($\omega_j$ and $\phi_j$) are computed with the input-output model featured in this paper.

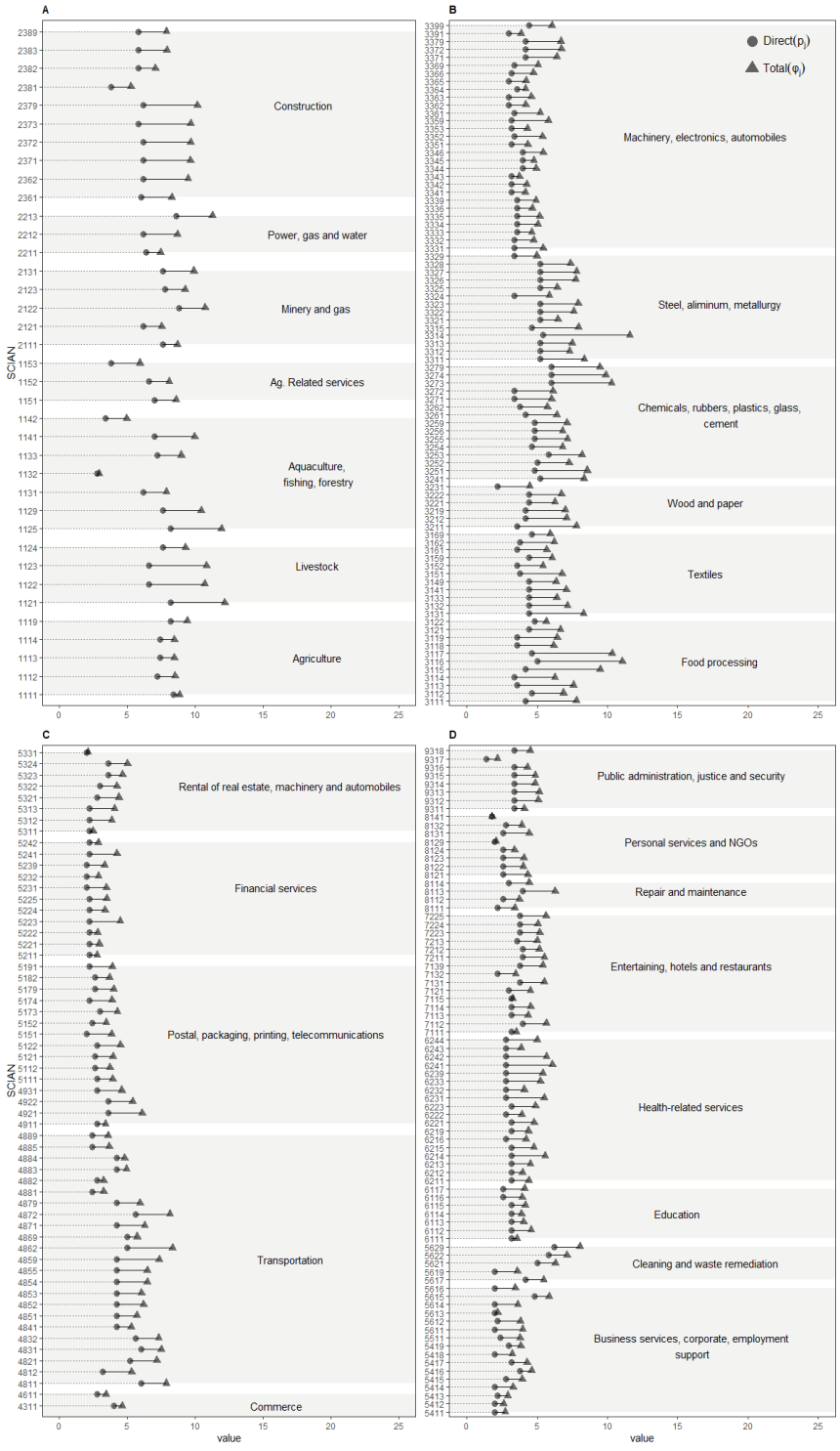
Direct dependence on ecosystem services is stronger for primary activities, notably agriculture (NAICS 1111-1153) and mining (2111-2131), and for utilities (power generation and water, 2211-2213) and construction 2361-2389, see Panel A of Figure 2). Manufacturing (Panel B) and services (Panels C and D) exhibit lower direct dependence scores, although particular activities stand out: food processing (3111-3122); glass, cement, and steel (3271-3279); and furniture (3371-3399) for the case of manufacturing; and transport (4811-4879), education (6111-6117), health (6211-6232), hotels, restaurants, entertainment (7121-7225), and real estate (5311-5324), for the case of services. As shown in Table 2, sectors whose supply chains have the highest *relative* dependence include finance (5223, 5241, 5231) and personal services (8121-8123), as well as some manufacturing, notably food processing (3113, 3115, 3116) and non-ferrous metal industries (3314). Sectors with the highest *absolute* indirect dependence include almost all activities in food processing (3111, and 3113-3117), livestock and aquaculture (1121-1123, 1125, 1129) and light-manufacturing (3132, 3211, 3273, 3274).

*Figure 2 Direct ($d_j$) and total ($\omega_j$) aggregate scores of ecosystem dependence in the Mexican economy*




Source: own elaboration.

*Figure 3 Direct ($p_j$) and total ($\phi_j$) aggregate scores of environmental impact in the Mexican economy*




Source: own elaboration.

*Table 2 Sectors with largest relative and absolute supply chain dependence on ecosystem services*

| | NAICS code | Sector | Relative $\omega_j/d_j$ | NAICS code | Sector | Absolute $\omega_j - d_j$ |
|---|---|---|---|---|---|---|
| 1 | 5223 | Credit unions and savings institutions | 2.61 | 3116 | Slaughter and processing of meat | 9.99 |
| 2 | 5241 | Insurance companies | 2.59 | 3117 | Preparation and packaging of seafood | 9.50 |
| 3 | 3116 | Slaughter and processing of meat | 2.51 | 3115 | Dairy product manufacturing | 8.71 |
| 4 | 5611 | Business management services | 2.50 | 3113 | Sugar and Confectioner Manufacturing | 7.71 |
| 5 | 3117 | Preparation and packaging of seafood | 2.48 | 1121 | Cattle farming | 7.23 |
| 6 | 8131 | Commercial and professional organizations | 2.34 | 1123 | Poultry farming | 6.93 |
| 7 | 5191 | Other information services | 2.28 | 1122 | Pig farming | 6.64 |
| 8 | 8121 | Beauty salons and clinics | 2.28 | 3314 | Non-ferrous metal industries, exc. aluminum | 6.40 |
| 9 | 5614 | Secretarial support and similar services | 2.24 | 3131 | Fiber, Yarn, and Thread Mills | 6.34 |
| 10 | 3115 | Dairy product manufacturing | 2.21 | 3111 | Animal feed manufacturing | 6.01 |
| 11 | 3314 | Non-ferrous metal industries, exc. aluminum | 2.14 | 1125 | Aquaculture | 5.44 |
| 12 | 4921 | Couriers and express delivery services | 2.14 | 3211 | Sawing and preservation of wood | 5.33 |
| 13 | 3113 | Sugar and Confectionery Manufacturing | 2.10 | 3273 | Cement and concrete products | 5.18 |
| 14 | 3131 | Fiber, Yarn, and Thread Mills | 2.06 | 6241 | Social work services | 5.08 |
| 15 | 8123 | Funeral services and cemetery mgt. | 2.06 | 2379 | Other civil engineering constructions | 4.88 |
| 16 | 5612 | Facilities Support Services | 2.04 | 1129 | Exploitation of other animals | 4.75 |
| 17 | 5231 | Securities Intermediation and Brokerage | 2.04 | 3274 | Lime and Gypsum Product Manufacturing | 4.74 |
| 18 | 8122 | Laundries and dry cleaners | 2.01 | 3114 | Fruit and Vegetable Preserving | 4.69 |
| 19 | 4812 | Nonscheduled Air Transportation | 1.94 | 3119 | Other food industries | 4.68 |
| 20 | 9313 | Promotion of economic development | 1.93 | 3132 | Fabric Mills | 4.66 |

Source: Own elaboration.

Structural patterns of direct environmental impact are somewhat similar to direct ecosystem dependence, with primary activities and utilities showing the economy's

highest scores, although notably joined by oil and non-oil mining (2111-2131 Panel A of Figure 3). Particular manufacturing activities stand out (Panel B), like glass, cement, aluminum, and metallurgy (3272-3329), food processing industry (3111-3122), textiles and wood (3131-3231), and chemicals, plastics and pharmaceuticals (3241-3259). Services exhibit lower direct impact (panels C and D of Figure 3), although transport (4811-4889) and cleaning and waste-remediation (5617-5622) stand out. As seen in Table 3, food processing (3111-3117) stands out for environmental impact attributable to its supply chain, both in relative and absolute terms. Relative impact from supply chains is also substantial for finance (5223 and 5241), health activities (6231, 6233, 6239, 6241, 6242) and telecommunications (5151). Sectors with the highest absolute impact due to supply chains include farming (1121-1123), aquaculture (1125), construction (2371-2373), food processing (3111-3117), wood (3211), cement (3273), chemicals (3251), non-ferrous metals (3274, 3279) and textiles (3314).

*Table 3 Sectors with largest relative and absolute environmental impact due to supply chain*

| | **NAICS code** | **Sector** | **Relative** $\varphi_j/p_j$ | **NAICS code** | **Sector** | **Absolute** $\varphi_j - p_j$ |
|---|---|---|---|---|---|---|
| 1 | 3115 | Dairy product manufacturing | 2.26 | 3314 | Non-ferrous metal industries, exc. aluminum | 6.19 |
| 2 | 3117 | Preparation and packaging of seafood | 2.25 | 3116 | Slaughter and processing of meat | 6.06 |
| 3 | 3116 | Slaughter and processing of meat | 2.21 | 3117 | Preparation and packaging of seafood | 5.74 |
| 4 | 6241 | Social work services | 2.17 | 3115 | Dairy product manufacturing | 5.29 |
| 5 | 3211 | Sawing and preservation of wood | 2.16 | 3273 | Cement and concrete products | 4.30 |
| 6 | 3314 | Non-ferrous metal industries, exc. aluminum | 2.15 | 1123 | Poultry farm | 4.23 |
| 7 | 3113 | Sugar and Confectioner Manufacturing | 2.11 | 3211 | Sawing and preservation of wood | 4.19 |
| 8 | 5223 | Credit unions and savings institutions | 2.04 | 1122 | Pig farming | 4.10 |
| 9 | 3231 | Printing and related industries | 2.03 | 3113 | Sugar and Confectioner Manufacturing | 3.99 |
| 10 | 6242 | Community food and housing | 2.03 | 1121 | Cattle farming | 3.98 |
| 11 | 5611 | Business management services | 1.99 | 2379 | Other civil engineering constructions | 3.96 |
| 12 | 6231 | Nursing care facilities | 1.97 | 3131 | Fiber, Yarn, and Thread Mills | 3.91 |
| 13 | 6239 | Other residential care facilities | 1.93 | 3274 | Lime and Gypsum Product Manufacturing | 3.89 |
| 14 | 5241 | Insurance companies | 1.92 | 2373 | Construction of communication routes | 3.88 |
| 15 | 5151 | Radio and television broadcasting | 1.92 | 3251 | Manufacturing of basic chemicals | 3.78 |

| | | | | | |
|---|---|---|---|---|---|
| 16 3131 | Fiber, Yarn, and Thread Mills | 1.89 | 1125 | Aquaculture | 3.74 |
| 17 6233 | Care Retirement Communities | 1.87 | 3111 | Animal feed manufacturing | 3.59 |
| 18 3111 | Animal feed manufacturing | 1.85 | 3279 | Products based on non-metallic minerals | 3.47 |
| 19 5313 | Real estate services | 1.85 | 2372 | Urbanization works | 3.47 |
| 20 3114 | Fruit and Vegetable Preserving | 1.84 | 2371 | Works for water, oil, gas, power and telecomm. | 3.45 |

Source: Own elaboration.

## 4.2 Financial exposure to ecosystem dependence and environmental impact in the Mexican economy

Utilizing the color code of Figure 1, Figures Figure 4 and Figure 5 disaggregate the direct and total scores of ecosystem dependence and environmental impact discussed above, and show the intensities for both direct and total dependence and impact on each of the 25 ecosystem services and 13 environmental categories in the ENCORE database. Direct dependence in Figure 4 shows the generalized importance of water-related services, particularly for agriculture, mining, manufacturing and utilities, as well as for particular services (health, education, and hotels and restaurants). Several economic activities appear as directly independent (color blue) on various ecosystem services. The heatmap for direct impact in Figure 5 shows the highest scores concentrating in agriculture (water and land use, toxic pollution, nutrient pollution, invasive species, and GHG and non-GHG emissions), mining, and heavy manufacturing (disturbances, toxic pollution, water use, seabed use), whereas light manufacturing and services show rather moderate and lower scores of direct impact. Similarly, several economic sectors have a null direct impact (color blue) in several environmental categories.

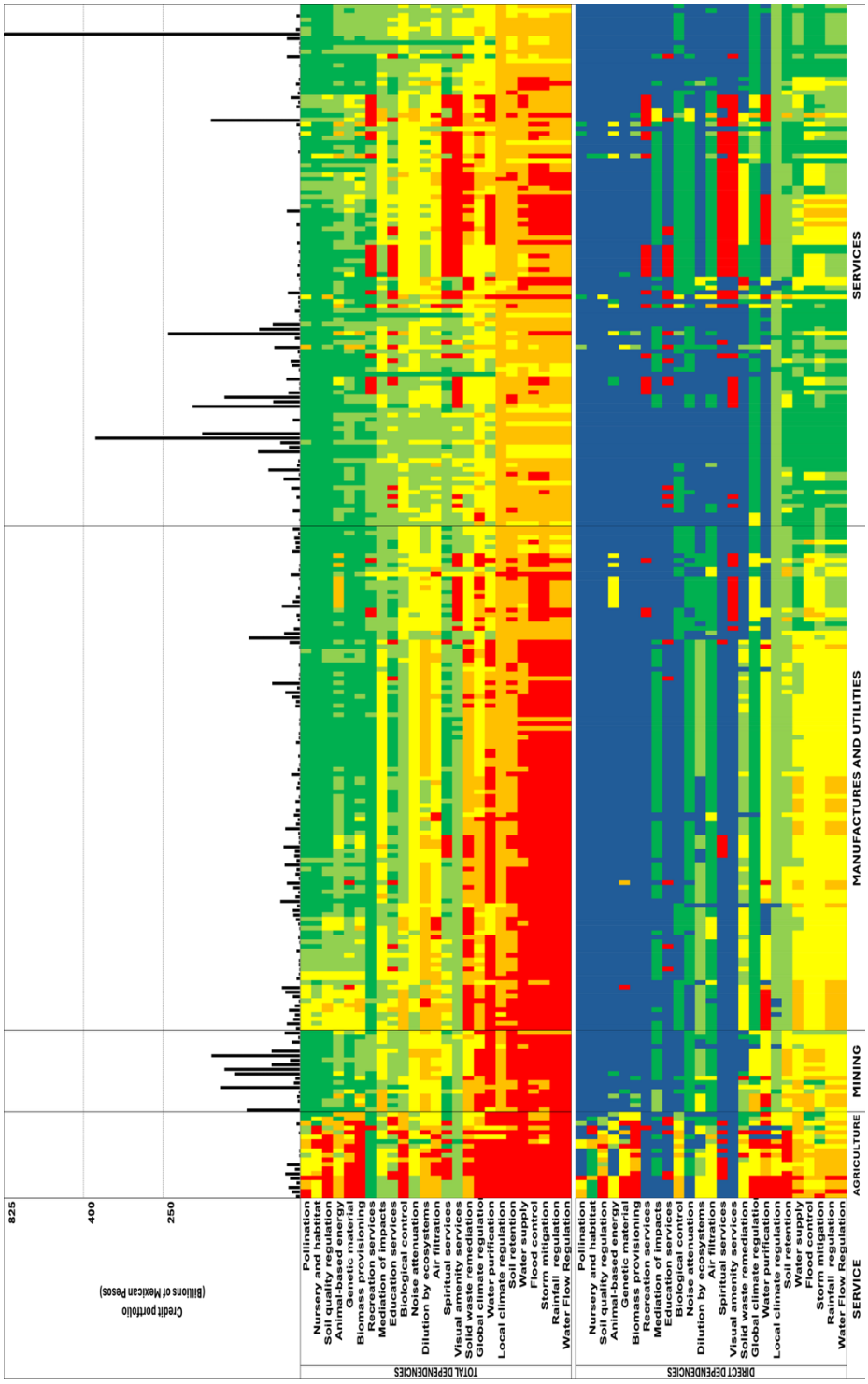
The heatmaps for both total dependence and impacts add the contribution of the economy's supply chains. Notably, not a single sector remains independent of ecosystem services or has a null impact when considering its participation in the economy's supply chains (that is, no blue colors remain in the heatmaps for total dependence and impact). Practically all activities in agriculture, mining, manufacturing, education, and health services exhibit 'very high' (red) total dependence on all water-related services, as well as 'very high' total impact on the generation of pollutants (nutrients, GHGs and non-GHGs, solid waste and toxic substances) and on land and water use. This behavior is a result of direct dependence and impact being 'transferred' throughout the economy's network of supply chains. Food processing, for instance, is reported as directly independent of pollination, nursery and habitat, soil quality, animal-based energy, and the provision of genetic material and biomass. However, after considering the relevance of agriculture in its supply chain, it has 'medium' to 'very high' dependence on these ecosystem services. Similar situations are observed for other manufacturing sectors, especially for water-related and remediation services (noise attenuation, dilution by ecosystems, and air filtration).

Similarly, as seen in Figure 5, agriculture stands out with ‘high’ and ‘very high’ total impacts in almost all environmental categories. Livestock activities, mining, construction and utilities also stand out in total impacts due to dominant ‘high’ and ‘very high’ scores. Environmental impact from manufacturing and services also increases substantially when considering the indirect effects of their supply chains. The highest impact ratings for these activities correspond mainly to disturbances, emissions of toxic pollutants and GHGs, particularly by light industry (wood and paper), petroleum derivatives, and chemicals. In general, the environmental impact of supply chains for services is of lower importance relative to primary activities and manufacturing, although waste collection stands out (for disturbances and emissions of GHGs and other toxic pollutants), as well as health services (for the generation of solid waste).

Figures Figure 4 and Figure 5 also display the sectoral distribution of the credit portfolio in the Mexican economy as reported by its banking institutions, and Table 4 identifies the 20 sectors with the largest shares in the national credit portfolio, representing two thirds of the total, and displays their respective total scores of dependence and impact. Notably, public administration (9312) claims the largest share in the credit portfolio (16%) while exhibiting relatively low total aggregate scores of dependence and impact, which are dominated by ‘high’ dependence on water-related services and by ‘high’ and ‘very high’ impacts due to emissions (both GHGs and non-GHGs), land and water use, generation of solid waste, toxic pollutants and disturbances.

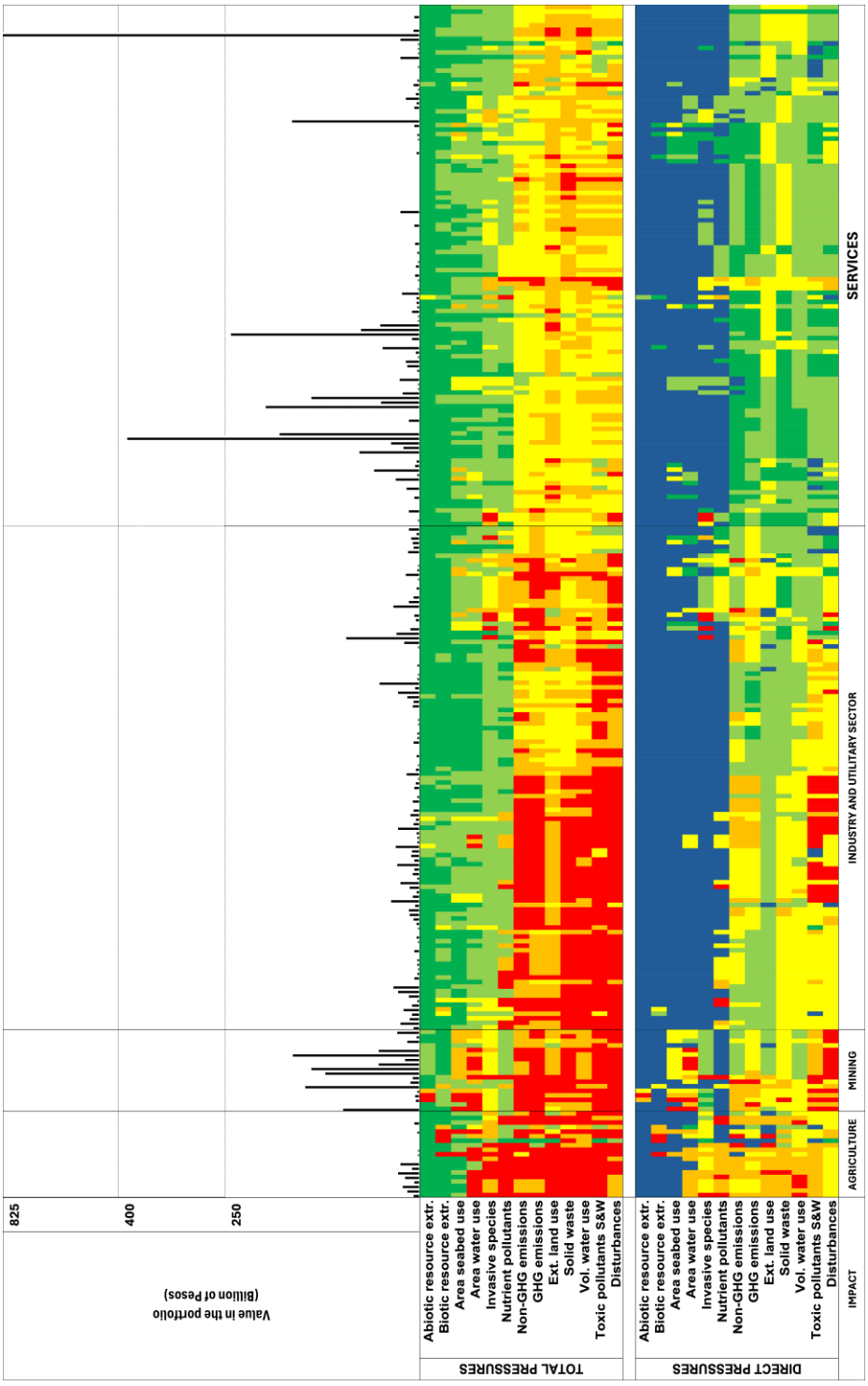
Non-financial services, including professional and scientific (5419), real estate (5311 and 5313), corporate (5511), telecommunications (5179) and business management (5611) claim 15.3% of the national credit portfolio, while also exhibiting low total scores for both dependence and impact. Ecosystem dependence for these sectors is dominated by similar patterns of ‘high’ and ‘very high’ total dependence on water-related services; while environmental impact is dominated by ‘medium’ to ‘high’ scores for emissions (GHGs and non-GHGs), land and water use, generation of solid waste and toxic pollutants, and disturbances. Financial services (5221, 5224 and 5225) claim 12.5% of the national portfolio while exhibiting even lower aggregate scores of total dependence and impact, which are explained mainly by ‘high’ total dependence on water-related services and by ‘medium’ to ‘high’ scores in the impact categories just mentioned. Construction activities combined (2361, 2362, 2373, 2379) claim 9.5% of the national credit portfolio and exhibit much higher aggregate total scores of dependence and impact, dominated by ‘very high’ scores in water-related services, ‘high’ scores for local climate regulation, and ‘medium’ to ‘high’ scores in remediation services (air filtration, dilution by ecosystems, noise attenuation).

*Figure 4 Direct and total dependence to ecosystem services and distribution of credit portfolio*




Source: own elaboration.

*Figure 5 Direct and total scores of environmental impact and distribution of credit portfolio*




Source: own elaboration.

Environmental impact from construction sectors is dominated by 'high' and 'very high' impact scores on almost all categories, except for the extraction of biotic and abiotic resources and the generation of nutrient pollution. Power generation (2211), oil and gas extraction (2111), wholesale trade (4311) and manufacturing of vehicle parts (3363) appear as relevant sectors in the credit portfolio (2.9%, 2%, 2%, and 1 % of the total, respectively) while exhibiting moderate aggregate scores of total dependence and impact, also dominated by 'high' and 'very high' dependence on water-related services, remediation services (mediation of impacts, dilution by ecosystems, solid waste remediation), and on the local and global climate. Environmental impact from power generation and oil and gas extraction is dominated by emissions (GHGs and non-GHGs), land and water use, use of seabed (for oil extraction), generation of solid waste and toxic pollutants, and disturbances. The environmental impact of the manufacturing of vehicle parts is explained by 'high' scores in disturbances and emissions of toxic pollutants, and 'medium' to 'high' scores in emissions (GHGs and non-GHGs), solid waste, and water and land use.

*Table 4 The 20 sectors with largest shares in the national credit portfolio and their total aggregate scores of ecosystem dependence and environmental impact*

| NAICS code | Sector | % Credit share | Total dependence score $\omega_j$ | Total impact score $\varphi_j$ |
|---|---|---|---|---|
| 9312 | Public administration in general | 16.4 | 4.9 | 5.1 |
| 5224 | Credit mediation, non-commercial banking | 7.5 | 3.2 | 3.4 |
| 5419 | Professional and scientific services | 4.9 | 8.2 | 3.8 |
| 5311 | Non-mediated rental of real estate | 4.0 | 4.4 | 2.5 |
| 5225 | Services related to credit mediation | 3.6 | 3.3 | 3.5 |
| 7211 | Hotels, motels and similar | 3.3 | 12.2 | 5.5 |
| 2373 | Highway construction | 3.3 | 11.4 | 9.7 |
| 2211 | Power generation, transmission and distribution | 2.9 | 7.9 | 7.5 |
| 5313 | Services related to real estate | 2.8 | 6.4 | 4.1 |
| 2362 | Non-residential building | 2.8 | 10.7 | 9.5 |
| 2361 | Residential building | 2.4 | 9.6 | 8.3 |
| 2111 | Oil and gas extraction | 2.0 | 8.0 | 8.7 |
| 4311 | Wholesale trade of groceries and food | 1.9 | 4.8 | 4.6 |
| 5221 | Multiple banking | 1.5 | 2.7 | 3.0 |
| 5511 | Corporate | 1.5 | 4.1 | 3.8 |
| 5179 | Other telecommunications services | 1.2 | 4.1 | 4.0 |
| 2379 | Other civil constructions | 1.1 | 11.7 | 10.2 |
| 2371 | Infrastructure (water, oil, gas, power, telecomm.) | 1.0 | 10.5 | 9.6 |
| 3363 | Manufacturing of parts for motor vehicles | 1.0 | 8.1 | 4.6 |
| 5611 | Business management services | 1.0 | 4.5 | 4.0 |

Source: Own elaboration.

Table 5 provides an economy-wide summary and establishes the links between other socioeconomic variables (gross output and employment) and sectoral credit portfolio. A significant number of sectors (145 out of 263) exhibit 'high' or 'very high' direct scores on at least one ecosystem service, representing 48% of gross output, 47% of total employment, and 68% of the credit portfolio. These numbers increase when considering the cascade effects through the economy's supply chains, since now 189 sectors have 'high' or 'very high' indirect dependence on at least one ecosystem service, representing 66% of gross output, 53% of employment and 83% of credit. A similar behavior is seen with regard to environmental impact. In total, 103 sectors (out of 263) have 'high' or 'very high' direct score for at least one impact category, representing 49% of gross output, 33% of employment and 54% of credit. When considering the indirect effects throughout industrial supply chains, 170 sectors exhibit 'high' or 'very high' scores in at least one impact category, representing 66% of gross output, 49% of jobs and 68% of credit.

*Table 5 A summary of economy-wide financial exposure to ecosystem dependence and environmental impact*

| | Sectors with high or very high score | Output value (Million USD) | Jobs (millions) | Credits (millions USD) |
|---|---|---|---|---|
| **Direct dependence** | 145 | 1,041,423 | 28 | 86,124 |
| **%** | 55.13% | 47.78% | 46.91% | 68.25% |
| **Total dependence** | 189 | 1,432,482 | 32 | 104,797 |
| **%** | 71.86% | 65.72% | 53.19% | 83.05% |
| **Direct impact** | 103 | 1,065,516 | 20 | 68,095 |
| **%** | 39.16% | 48.88% | 32.87% | 53.96% |
| **Total impact** | 170 | 1,436,179 | 29 | 85,249 |
| **%** | 64.64% | 65.89% | 49.10% | 67.56% |

Source: own elaboration.

## 4.3 Scenario 1: physical risk

The previous assessment of ecosystem dependence highlights the economy-wide importance of water-related services, although it is based on generic direct scores from the ENCORE database. As a means of illustrating the substitution of these generic scores with data on actual water use in the Mexican economy, we complement with an application of the environmentally-extended input-output model (see equations 13-15 in the methodology). Table 6 shows water withdrawals in physical units per economic use as reported by Mexico's water agency (CONAGUA 2019). Note the dominion of agricultural activities: the combination of crop agriculture, agro-industry, aquaculture, livestock, and other agriculture claims 76% of total yearly withdrawals. Water allocated to urban centers

comes second in importance with 15% of total use (urban industry 1%, urban services 2.7%, and households 11%). Therefore, the economic use of water is 78,997 $HM^3$ per year, from which we exclude households' volumes, which are treated exogenously in the input-output model.

We establish a sectoral correspondence between the NAICS classification used in the input-output table and the one used by the water agency to construct a vector of water coefficients (equation 13 in the methodology). These coefficients represent each sector's direct dependence on the water supply as measured by the volume of water used per unit of output. Figure 6 shows that the highest water coefficients correspond to crop production (0.096 $HM^3/Million\ pesos$, Panel A), followed by thermoelectric power (0.007 $HM^3/Million\ pesos$, Panel B). Self-supplied activities (mining, construction and some manufacturing) exhibit the lowest unitary requirements (0.00017 $HM^3/Million\ pesos$), just below manufacturing and service activities served by the urban water sector (0.0002 $HM^3/Million\ pesos$, panels C and D of Figure 6). We compute matrix W (equation 15 in the methodology) to describe the physical flows of water embedded in inter-sectoral transactions of the input-output table, which is shown in Figure 7.

Figure 7 reports the inter-industrial flows of embedded water in the Mexican economy in 2018. Each cell represents the volume of water embodied in goods and services supplied from sector i to sector j through the production process. The figure therefore captures not only direct water use but also the indirect transfer of water dependencies across supply chains.

Several patterns emerge. First, water-intensive primary sectors act as important upstream suppliers of embedded water to a broad range of downstream activities. Second, many manufacturing and service sectors exhibit substantial dependence on water resources despite relatively limited direct water use, reflecting their reliance on inputs produced by water-intensive sectors. Third, the concentration of large flows among specific sectors suggests potential channels through which water scarcity or ecosystem degradation could propagate throughout the economy.

From a financial-risk perspective, the figure illustrates that nature-related dependencies are transmitted through production networks. Consequently, sectors that appear only moderately exposed when considering direct water use may nevertheless face significant indirect exposure through their supply-chain relationships.

*Table 6 Water concessions per economic activity, Mexico 2018*

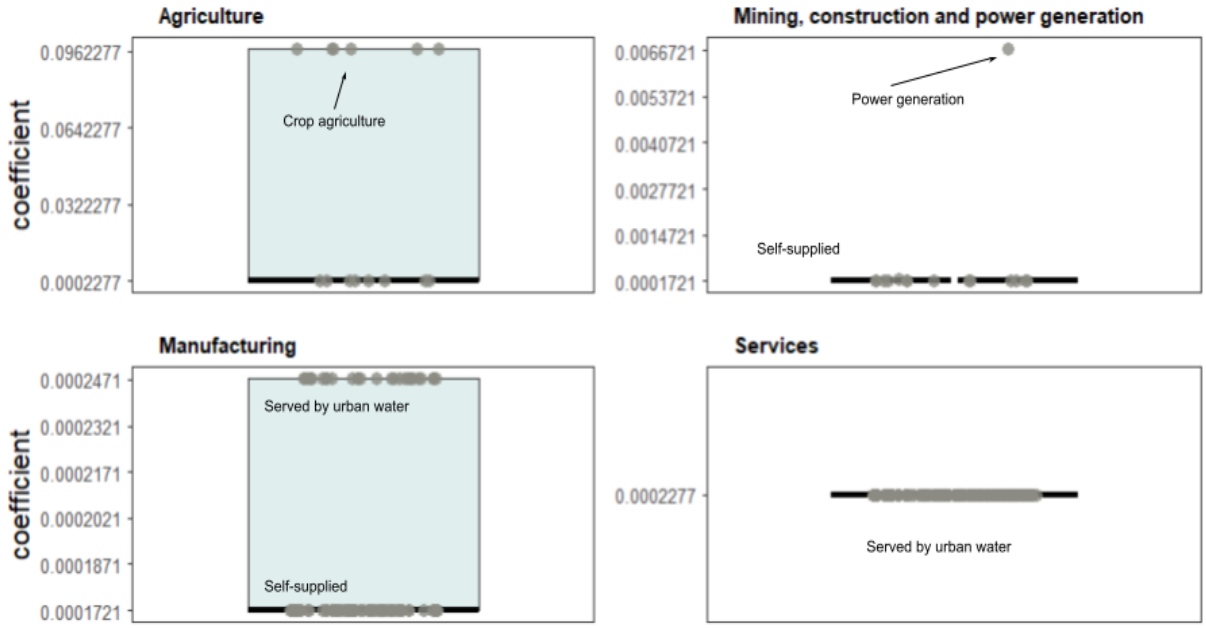
| | **Use $HM^3$** | % |
|---|---|---|
| Agriculture | 59,950.0 | 67.5 |
| Agro-industry | 4.2 | 0.0 |
| Aquaculture | 1,160.0 | 1.3 |
| Self-supplied Services | 1,637.0 | 1.8 |
| Self-supplied industry | 2,694.0 | 3.0 |
| Thermoelectric generation | 4,147.0 | 4.7 |

| | | |
|---|---|---|
| Livestock | 226.0 | 0.3 |
| Urban industry | 884.3 | 1.0 |
| Urban services | 2,367.20 | 2.7 |
| Households | 9,842.5 | 11.0 |
| Other agricultural | 5,927.0 | 6.7 |
| Commerce | 0.1 | 0.0 |
| Other | 1.0 | 0.0 |
| Total | 88,840.2 | 100.0 |

Source: own elaboration with data from CONAGUA (2019).

Matrix **W** disaggregates the economic use of water (78,997 $HM^3$ in 2018) and shows the sectors that are more exposed to water-related disruptions. While water is essential for all economic transactions (there are no empty cells), the largest volumes of indirect transactions are concentrated in specific activities. Reading Figure 7 horizontally reveals the relevance of embedded water downstream each sector's supply chain. Notably, agriculture stands out for the volume of water delivered indirectly to the rest of the economy, especially to food processing, automobile production, commerce, telecommunications, finance, health activities, hotels and restaurants, and government. Thermoelectric power generation also stands out for its deliveries of embedded water, given the generalized use of electricity as an essential production input for the economic system, particularly to manufacturing activities and services. Alternatively, reading the Figure vertically shows the relevance of water upstream in each sector's supply chain. Construction and the auto industry are shown to depend indirectly on water used in agriculture, manufacturing and services, while commerce depends also on agricultural water and from a variety of services. Note in Figure 7 the relevance of the principal diagonal of matrix **W**, showing the importance of intra-sectoral transactions for each sector's supply chain.

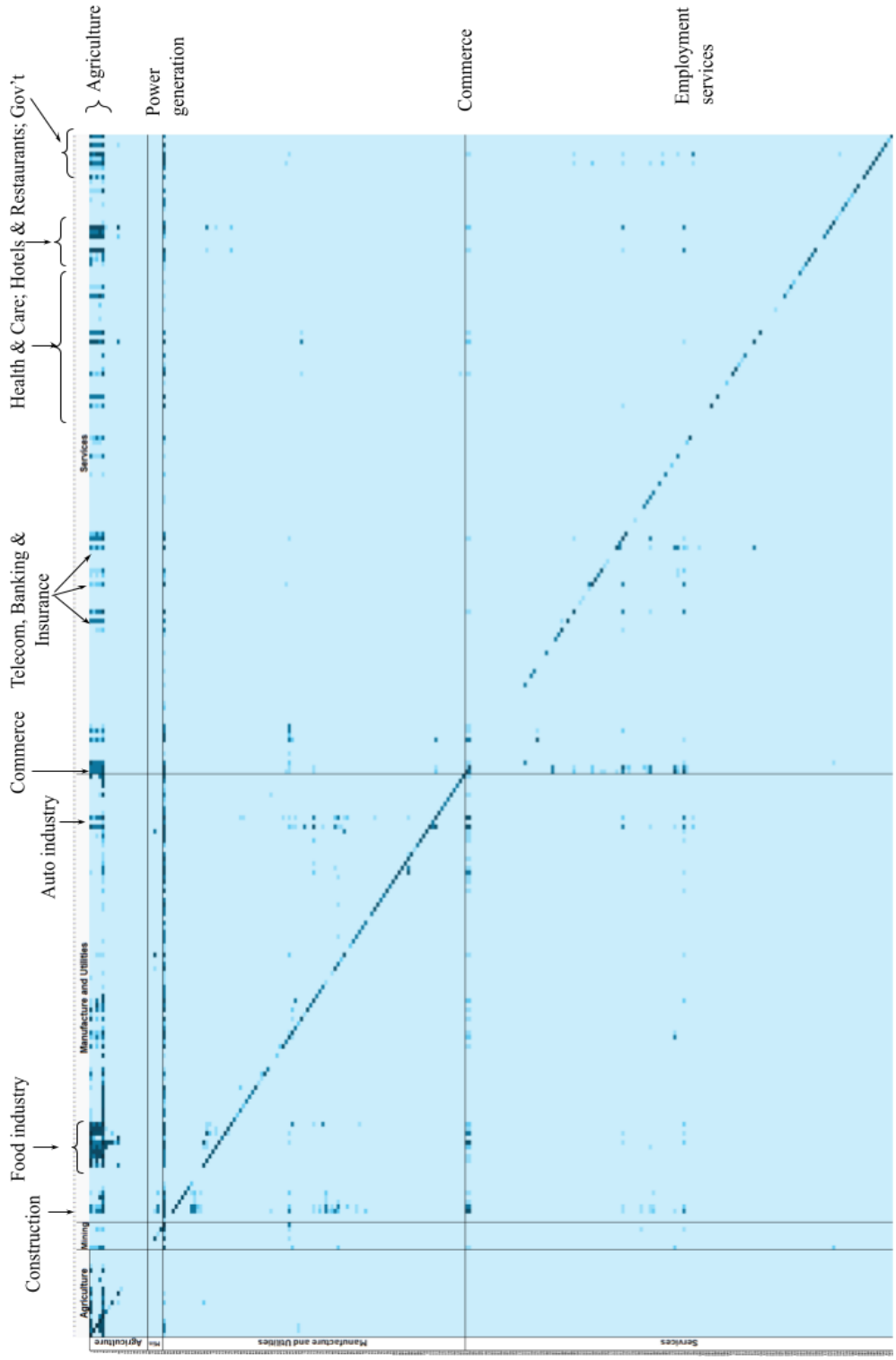
*Figure 6 Distribution of water coefficients per major group of economic activity. HM^3/Million pesos*




Source: own elaboration with data from CONAGUA (2019) and INEGI (2018b).

Figure 8 shows the balance of embedded water in terms of the volumes delivered upstream to each sector ('Purchases'), and the volumes delivered downstream by each sector ('Deliveries'). The balance shows whether a sector is a net exporter of embedded water (volumes in deliveries larger than in purchases) or a net importer (otherwise). As can be seen, water embedded in deliveries concentrates in a small group of industries: agriculture (1111-1119), thermoelectric power generation (2211), commerce (wholesale, 4311, and retail, 4611) and the auto industry (3361, 3363). Water embedded in purchases concentrates also in agriculture (reflecting intra-sectoral transactions), the food industry (3111-3122), hotels and restaurant (7211, 7225), and in the auto industry and commerce (wholesale and retail). Net exports of embedded water concentrate in agricultural activities and power generation, while net imports concentrate in the food industry, hotels and restaurants, and less so the auto industry and commerce. Although Figure 8 shows the largest flows of embedded water, we observe that the majority of sectors trade embedded water even in smaller volumes (see financial services in the box), such that the majority of sectors (182) behave as net importers of embedded water, while only 79 are net exporters.

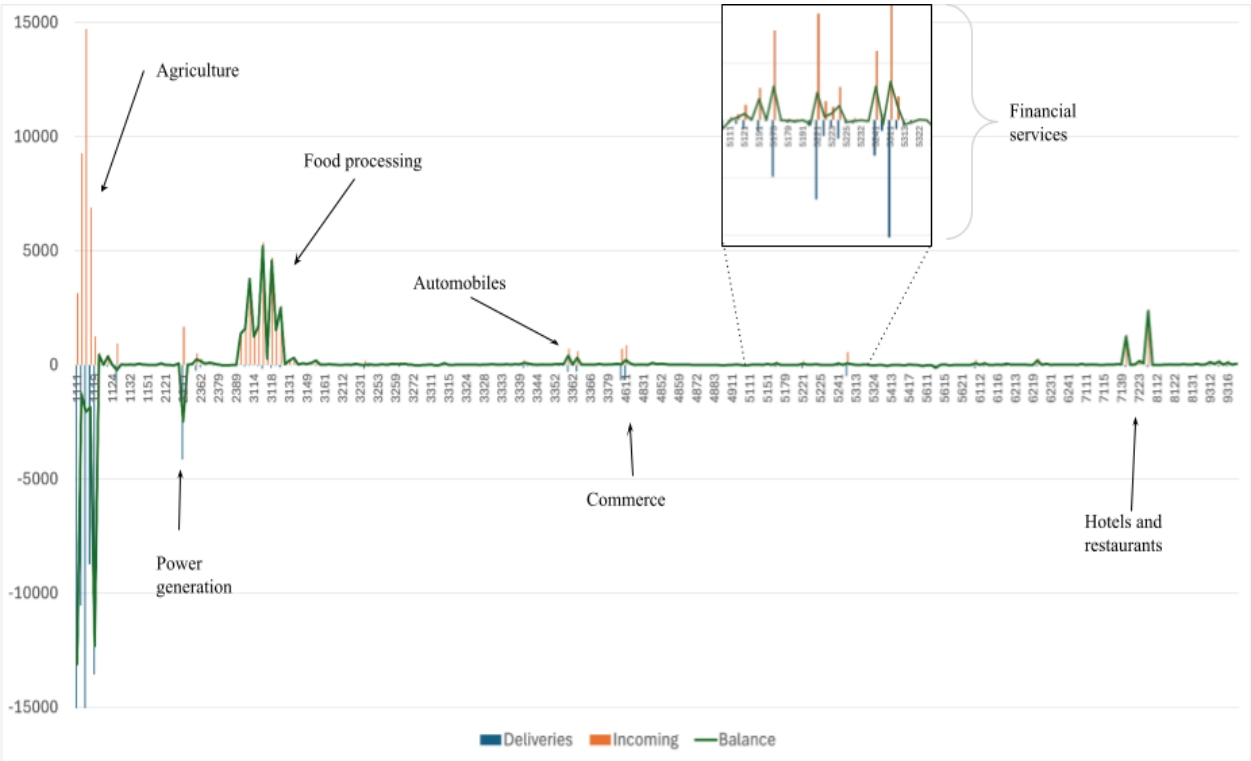
*Figure 7 Inter-industrial flows of embedded water in the Mexican economy. 2018. HM³*




Source: own elaboration.

Table 7 summarizes the flows of embedded water and links them to the exposure of the national credit portfolio per major group of economic activity. Agriculture uses the most water and concentrates the largest exports of embedded water, but does not have a direct impact on the national credit portfolio (only 2.6% of the national total). In contrast, 83% of the credit portfolio is concentrated in manufacturing (12.6%) and service activities (69%), which are net importers of water (26,256 $HM^3$ and 5,473 $HM^3$, respectively). Water risk does not come mainly from direct use, but is transferred from upstream in supply chains. Note that small volumes of direct and indirect use, such as in services or manufacturing, are not to be interpreted as a weak dependence or as low importance, given the essentiality of water as a factor or production with no substitutes. Rather, these numbers imply that these activities, even if relying on relatively small volumes of water, can be affected by small disturbances both in their water supply and for other sectors in their supply chains.

*Figure 8 Sectoral balance of embedded water in the Mexican economy. 2018. $HM^3$*




Source: own elaboration.

*Table 7 Net exporters and importers of embedded water and exposure of national credit portfolio*

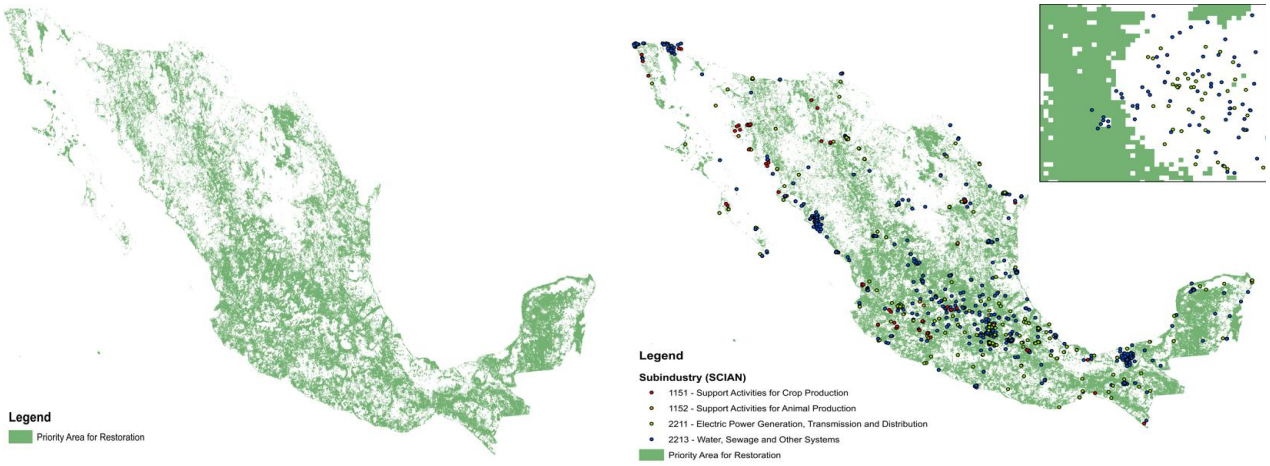
| Group of activities | In deliveries downstream $HM^3$ | In purchases upstream $HM^3$ | Net balance of embedded water $HM^3$ | % of credit portfolio |
|---|---|---|---|---|
| Agriculture | 67,269.6 | 37,315.1 | -29,954.5 | 2.6 |
| Mining, construction, power generation | 4,771.2 | 2,995.7 | -1,775.4 | 15.0 |
| Manufacturing | 2,989.0 | 29,245.0 | 26,256.0 | 12.6 |
| Services | 3,966.9 | 9,440.9 | 5,473.9 | 69.8 |
| Total | 78,996.7 | 78,996.7 | - | 100.0 |

Source: own elaboration.

## 4.4 Scenario 2: transition risk

Also as a means of illustrating what a transition risk may look like using real data for the Mexican economy, we study the implications of adopting Target 2 of the Kunming-Montreal Global Biodiversity Framework. Panel (a) in Figure 9 shows the spatial distribution of so-called 'restoration priority areas (RPAs),' as defined by Mexico's Biodiversity commission and comprising 75.5 million hectares (40% of the national territory, CONABIO (2024)). While this fraction is larger than the 30% target, the map shows the location of potential restoration should Mexico adopt such Target. Panel (b) of Figure 9 displays the intersection between RPAs and the location of large and medium-sized firms pertaining to sectors exhibiting 'high' or 'very high' impact on land use. In INEGI's database, large and medium-sized firms refer to the number of employees: more than 250 for large firms, and between 50 and 249 employees for medium-sized firms.

*Figure 9 Transition risk scenario*




(a) Restoration Priority Areas

(b) Large and medium-sized firms

Source: (INEGI 2019) and (CONABIO 2024).

The overlap between large and medium-sized firms and RPAs indicates that if the Mexican government was to adopt this restoration policy, it would directly affect four sectors: support activities for crop production and animal production (1151, 1152), power generation (2211), and water distribution (2213). Particular facilities in these sectors that may be affected are responsible for $1,141 USD million in gross output, 4,480 jobs, and $21 USD million in credit portfolio (see Table 8). If we consider the indirect linkages in the supply chains of these firms, we count 479 firms from 37 sectors as potentially affected, mainly in activities that are location-dependent: aquaculture (1125), services related to crop production (1151), metal ore mining (2122), mining-related services (2131), water distribution (2213), several manufacturing activities, particularly food processing (3113, 3115, 3116, 3117), wood and textiles (3211, 3131), tourism-related services (4855, 4871), and entertainment (7131, 7139, 7112). As Table 8 shows, these sectors generate $8,829 million USD in gross output, have 65,471 employees and represent a credit portfolio of $703 million USD.

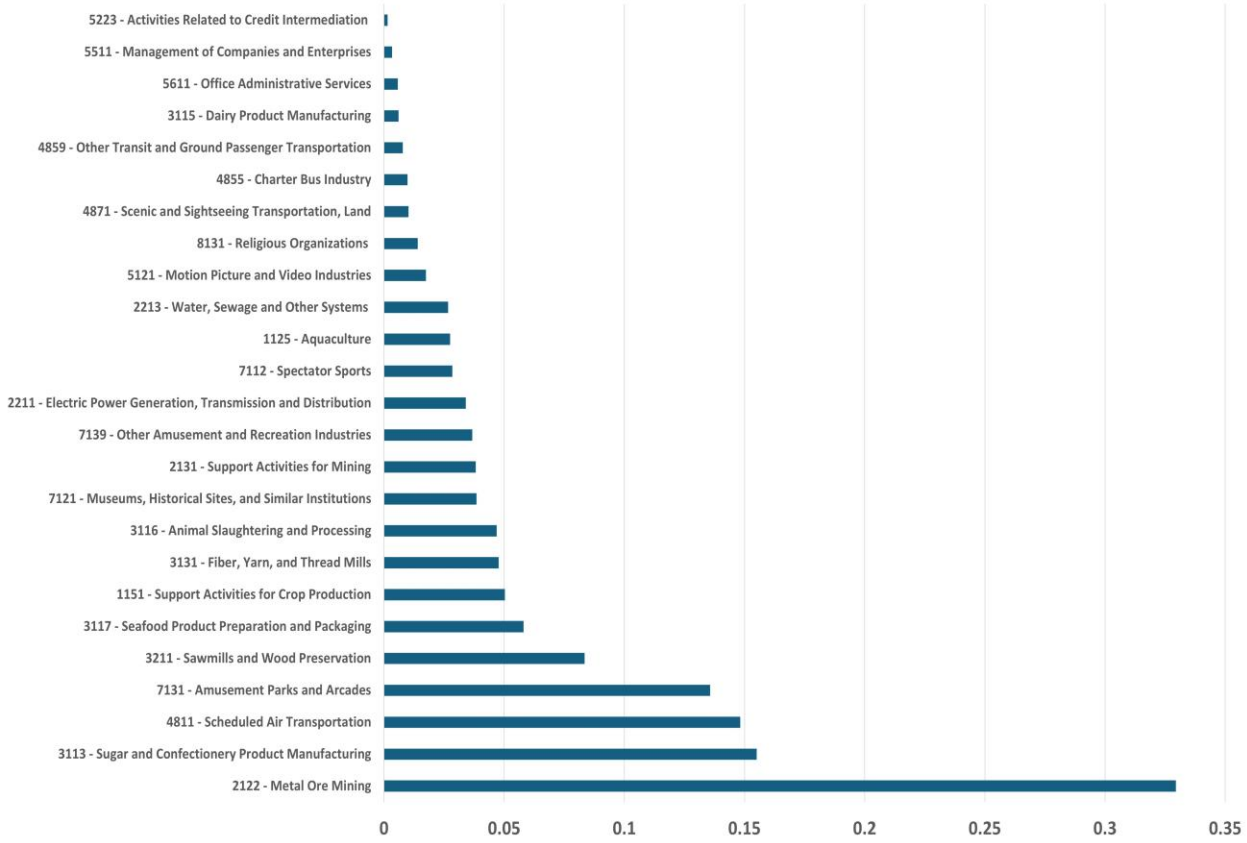
The contrast between direct and total effects shows the compounding of potential impact that a transition risk may have on the economy and its financial sector. In any case, these results are indicative as the impacts on employment and production including micro and small businesses, and the agricultural sector, should also be considered. Finally, Figure 10 shows the proportion of sectoral credit that is located within any RPA, as proxied by its sectoral output. Notably, a third of metal ore mining's (2122) credit portfolio would be compromised by the restoration policy. Other sectors with significant credit shares compromised by the policy include the food processing industry, tourist-related transport, and several entertainment-related activities.

*Table 8 Transition risk: Economic and financial exposure to ecological restoration*

| **Direct Pressure** | **Industry** | **Output (M USD)** | **Jobs** | **Debt (M USD)** |
|---|---|---|---|---|
| **Number** | 4 | 1,141.11 | 4,480 | 21.28 |
| **Percentage** | 1.5% | 0.0524% | 0.02% | 0.02% |
| **Total Pressure** | **Industry** | **Output (M USD)** | **Jobs** | **Debt (M USD)** |
| **Number** | 37 | 8,828.75 | 65,471 | 703.02 |
| **Percentage** | 14.1% | 0.4050% | 0.24% | 0.56% |

Source: own elaboration.

*Figure 10 Credit at risk (% of total credit by industry)*




Source: (Banco de México 2024a), (Banco de México 2024b) and (CONABIO 2024).

## 4.5 Discussion and implications

While previous studies have primarily relied on sector-level assessments of ecosystem-service dependencies, our approach combines firm-level geospatial information with input-output linkages and biodiversity indicators. This allows us to identify not only which sectors are exposed, but also where exposures are concentrated geographically and how they propagate through production networks.

### 4.5.1 Relevance and limitations

We use this section to highlight two methodological aspects of our approach that, in our view, promote analytical transparency and reproducibility. We also identify four main limitations relevant when interpreting the results or iterating for other contexts, which are indeed consistent to the assessment of (Mundaca and Heintze 2024). The first aspect promoting transparency and reproducibility is the numerical treatment of the ENCORE database allowing for the construction of scores for total dependence and impact with a standard implementation of input-output economics (i.e., including the indirect effects dispersed by the economy's network of supply chains). Second, once the double

materiality of dependence and impact is thus understood, we simply relate it with a description of the sectoral allocation of loans in the financial system. This relation is instrumental in providing a meso-level summary of nature-related financial risks: it is therefore possible to identify particular sectors of interest, situate them in terms of their position in the national credit portfolio, and identify their dependence on ecosystem services and their environmental impact, including the effects explained directly or indirectly through the economy's supply chains.

We highlight four aspects in terms of caveats and limitations. First, laying at the foundation of the analysis is a correspondence between the industrial classifications of the ENCORE database and those of the datasets for the country of interest (input-output tables, economic censuses, financial information and environmental data). Establishing correspondences between different industrial classifications is exposed to researchers' discretion and therefore needs to be performed judiciously, for it may frequently require the linkage between coarser and finer resolutions. Second, while the ENCORE database is an excellent platform upon which to build initial meso-level analysis of direct dependence and impact, it features generic scores, therefore not capturing conditions particular to the country of interest. This is problematic because economic activities may have alternative production technologies with different scores of dependence and impact, even independent of geography or due to particular regulations; or because the same production technology will have different implications in different ecological contexts, as in ecologically megadiverse countries like Mexico. Therefore, the particularization of sectoral scores to better reflect local conditions constitutes an important area of further research and improvement.

Third, going beyond generic assessments of direct dependence and impact can mean following two non-exclusive, complementary routes, both of which require the availability of adequate sources of information. One route relies on the availability of input-output tables capturing the economic specificity of the case of interest. The main advantage of performing an input-output computation is that, unlike ENCORE's generic scores of direct dependence and impact, the indirect scores are case-specific and explained by the structure of the economy under analysis. The second route relies on the availability of other socioeconomic and environmental data able to either represent local conditions or go beyond the meso-level scale of analysis. Our scenarios for Mexico describing water-related physical risks and location-specific transition risks due to environmental policy constitute attempts in this direction.

The results broadly confirm the expectations derived from Mexico's economic and ecological characteristics. While high levels of dependence are unsurprising in primary sectors such as agriculture and mining as it has been commonly found, an important finding is the extent to which these dependencies are transmitted through supply chains to manufacturing and service activities. This suggests that biodiversity-related financial risks in Mexico arise not only from direct reliance on ecosystem services but also from the specific economy's productive interconnectedness.

Finally, the assessment of nature-related financial risks relies on the adequate availability of data on the sectoral distribution of the national credit portfolio. In our assessment, we utilized publicly available financial information describing each sector's aggregate credit position. We were therefore unable to distinguish credit quality or its time horizons, leading us to use heuristic assumptions (namely, proportionality to gross output) to perform analysis at the firm level. While detailed financial information is often politically sensitive or subject to case-specific disclosure regulations, central banks and other institutions in the financial sector need to establish reference frameworks to adequately bridge financial data to economic and environmental data at multiple scales of analysis, ultimately contributing to fostering the environmental resilience of the financial system.

### 4.5.2 Policy Recommendations

This section presents general policy recommendations stemming from our analysis. We organize them in two main topics: proactive regulatory measures by central banks and other financial institutions, and production of adequate data and capacity building for analysis integrating finance and ecology. In terms of improving financial regulation, our analysis points at the need of including nature-related risks beyond those coming from climate change. The concept of the double materiality shows that ecosystem dependence and environmental impact go well beyond a stable climate and the emission of GHGs to include the whole portfolio of ecosystem services (provision, regulation, and cultural) as well as impacts relevant at the local, regional and global scales. A proactive environmental regulation of finance would seek to minimize its exposure to environmentally-harmful activities while fostering the conservation of ecosystems providing crucial services to the activities relevant to both the present and future allocations of credit portfolio. For the Mexican case, the recently developed 'Sustainability Taxonomy' for the financial system (SHCP 2023) is a step in the right direction. The relationship between this Taxonomy and economy-wide assessments of the double materiality such as ours is a natural next step given the shared use of the NAICS industrial classification, while representing an opportunity to also contribute to existing global initiatives, like the one behind the development of the ENCORE database.

In terms of information development, we pinpoint the benefits from a stronger collaboration between Mexico's statistical office (INEGI), the various environmental institutions under the Ministry for the Environment (SEMARNAT, its acronym in Spanish), and its Central Bank. This collaboration could yield spatially-explicit information linking data on credit portfolios, economic production and the environment, ranging from the provision of water-related services, to the location of natural protected areas and to ecological integrity. Our analysis also highlights the benefits of not restricting the analysis to assessing direct dependence and impacts, but including the diffusion of risks throughout the economy's network of supply chains. Building capacity to analyze the double materiality with input-output economics is instrumental in understanding the relevance of supply chains, both upstream and downstream of any particular activity, and the characteristics of ecological-economic systemic vulnerabilities. In this context, building capacity for scenario analysis is of great importance for understanding the

financial relevance of different physical and transition risks, for which the econometric and complex networks methods reviewed by Almeida et al. (2026) offer robust methodological extensions, and for which the newly available global datasets they review on habitats and species occurrence, combined with the national sources discussed above, can greatly improve our results.

# 5 Conclusions

This paper analyses nature-related financial risks in the Mexican economy by understanding the ways in which the productive system mediates the 'double materiality' of nature for finance. We measure the the dependence of financed activities on ecosystem services and their impacts on nature, so we can use these measurements as proxies for exposures to nature-related physical and transition risks. Our analysis features two moments. First, we use the ENCORE database to assess the direct dependence on 25 ecosystem services and the direct impact in 13 environmental categories for a disaggregation of the Mexican economy consisting of 263 economic sectors. Second, we implement standard methodologies from input-output economics to construct measures of indirect dependence and impact dispersed throughout the production network of the Mexican economy.

Our assessment indicates that, while there are several economic sectors directly independent of certain ecosystem services or with zero direct impact in certain environmental categories, all exhibit some degree of dependence and impact when considering their supply chains. In particular, we find that 48%, 47%, and 68% of national output, jobs, and credit portfolio, respectively, have 'high' or 'very high' direct dependence on at least one ecosystem service, and that 49%, 33%, and 54% of output, jobs, and credits have 'high' or 'very high' direct impact on at least one environmental category. These percentages increase substantially when considering the indirect linkages through supply chains, as 66%, 53%, and 83% of output, jobs, and credits show 'high' or 'very high' total dependence on at least one ecosystem service, and 66%, 49%, and 68% of the same variables have 'high' or 'very high' total impact on at least one environmental category. These findings suggest that nature-related financial risks are likely to be economically relevant rather than confined to a narrow set of environmentally intensive activities.

Given both the relevance of economic dependence on water-related services and Mexico's status as a megadiverse country, we explore two additional scenarios with environmental and spatially-explicit economic data to better understand the physical dependence on water and the potential impacts of conservation measures. For the water-related physical risk, we find that 83% of the national credit portfolio is allocated to sectors whose water dependence is mainly located in their supply chains (i.e., they are net-importers of embedded water), and are therefore highly exposed to water disruptions, even if small in volume. For conservation-related transition risks, we find that while prohibiting economic activities in ecologically sensitive areas would directly affect a relatively small number of medium and large firms in only four economic sectors, the indirect impacts would spread

through supply chains to 479 medium and large firms from 37 sectors, representing US$8.8 billion in gross output, 65,500 jobs and US$700 millions in the national credit portfolio. These impacts from ecological conservation are, however, merely preliminary as our estimates exclude small firms and agricultural activities.

Beyond documenting sectoral dependencies and impacts as other previous works, our findings raise broader questions regarding the resilience of the Mexican economy and financial system to biodiversity loss and ecosystem degradation. The results suggest that nature-related risks are not confined to a limited set of primary sectors but are transmitted through production networks, creating indirect exposures across a much larger share of economic activity. From this perspective, biodiversity loss should not be viewed solely as an environmental concern but also as a potential source of economic and financial vulnerability. While our analysis does not quantify future financial losses, it highlights channels through which ecosystem degradation could affect firms, sectors, and ultimately financial institutions.

We accompany the analysis with an assessment of both strengths and limitations of our methodological approach, and suggest policy recommendations promoting a better understanding and management of nature-related financial risks by central banks and other institutions in the financial sector. Important avenues for further research include the exploration of ways to reduce financial exposure to activities with negative impacts on the environment, and the calibration of dependence and impact scores to better represent local contexts in terms of production technologies, ecological conditions, and environmental legislation.

A particularly important implication of our results is that nature-related financial risks have an economy-wide reach: the interconnectedness revealed by the input-output network implies that shocks originating in ecosystem degradation, or in policies to reverse it, can cascade through value chains to sectors far removed from the original source of environmental pressure, which is one of the systemic dimensions of nature-related risks identified by the NGFS (NGFS 2024, 14). Consequently, policies focused exclusively on the most nature-intensive sectors may underestimate the breadth of potential exposures. This underscores the importance of adopting economy-wide approaches to monitoring and managing biodiversity-related financial risks.

# 6 Credit authorship contribution statement

**Carlos A. López-Morales** Writing – original draft, Writing – review and editing, Investigation, Methodology, Visualization, Conceptualization, Data curation. **Karina Caballero-Güendulain** Writing – original draft, Writing – review and editing, Investigation, Methodology, Visualization, Conceptualization, Data curation. **Saúl Basurto Hernández** Writing – original draft, Writing – review and editing, Investigation, Methodology, Visualization, Conceptualization, Data curation. **Luis O. L. Escobar-Farfán** Investigation, Methodology, Visualization, Data curation, Writing – review and editing. **Serafín Martínez**

**Jaramillo** Writing – review and editing, Investigation, Conceptualization, Data curation, Supervision.

# 7 Funding sources

This study was promoted, funded and co-developed by UNDP BIOFIN Mexico and the research team. BIOFIN, a global initiative spanning 130 countries, supports the development and implementation of national Biodiversity Finance Plans through a standardized process aimed at diversifying, increasing, and improving resource efficiency. BIOFIN would also like to acknowledge its donors for their continued support and for making this study possible.

# 8 Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The opinions expressed here are those of the authors and do not represent the views of their corresponding affiliations.

# 9 Acknowledgments

The authors are grateful to Alonso Martinez, Nepomuk Dunz and Mathilde Salin for their valuable comments on earlier versions of the manuscript. The authors express their gratitude to BIOFIN Mexico for their support.

# 10 Data availability

All the data utilized in this paper is public and available upon request.

# References

Almeida, Elena, Jelica Rastoka, Chiara Colesanti Senni, and Lea Naemi Weigand. 2026. *Analyzing the Indirect Effects of Nature-Related Shocks on the Economy: Methodological Approaches and Insights*. URPP Equality of Opportunity Discussion Paper Series No. 86. University of Zurich. https://www.urpp-equality.uzh.ch/dam/jcr:00bb5cb4-f9e2-4ffb-8656-2b3171d805a0/86_URPP_Chapter3_LWeigand_updated.pdf.

Banco de México. 2024a. *Crédito de La Banca Comercial Por La Principal Actividad Del Acreditado. Cuadro CF762*. Conjunto de datos. Sistema de Información Económica. Banco de México. https://www.banxico.org.mx/SieInternet/.

Banco de México. 2024b. *Crédito de La Banca de Desarrollo Por La Principal Actividad Del Acreditado. Cuadro CF768*. Conjunto de datos. Sistema de Información Económica. Banco de México. https://www.banxico.org.mx/SieInternet/.

Boldrini, Simone, Andrej Ceglar, Chiara Lelli, Laura Parisi, and Irene Heemskerk. 2023. *Living in a World of Disappearing Nature: Physical Risk and the Implications for Financial Stability*. Occasional Paper Series No. 333. European Central Bank. https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op333~1b97e436be.en.pdf.

Calice, Pietro, Federico Diaz Kalan, and Faruk Miguel. 2021. *Nature-Related Financial Risks in Brazil*. World Bank.

CBD. 2022. "Kunming-Montreal Global Biodiversity Framework." *Report of the Conference of the Parties to the Convention on Biological Diversity*.

Ceglar, Andrej, Mark Jwaideh, Emma O'Donnell, Francesca Danieli, Carlo Pasqua, John Hutchinson, Francesco Cimini, Juan Sabuco, Jimena Alvarez, Nicola Ranger and Irene Heemskerk. 2025. "*Nature at Risk: Implications for the Euro Area Economy and Financial Stability*". Occasional Paper Series No. 380. European Central Bank. doi:10.2866/3014103.

CONABIO. 2024. *Reporte: Identificación de Áreas Elegibles Para La Restauración Ambiental En México En El Marco Del Desarrollo Del Programa Nacional de Restauración*. CONABIO.

CONAGUA. 2019. *Estadísticas Del Agua En México*. Comisión Nacional del Agua, Secretaría de Medio Ambiente y Recursos Naturales.

D'Orazio, Paola, Peter Karlström, Matias Ossandon Busch, and Miguel Sarmiento. 2026. "*Pricing Nature across Borders: Global Banks' Response to Nature-Linked Financial Policies*". CETEx Discussion Paper Series: Land and Ocean, Policy Briefing Paper No. 8. Centre for Economic Transition Expertise, London School of Economics and Political Science.

Guo, Chunying, Matthew Agarwala, Mark Freeman, Ben Groom, and Emily McKenzie. 2026. "Introduction to the Special Issue. Biodiversity and Finance: Risk, Disclosure and Double Materiality." *Ecological Economics* 240: 108798. https://doi.org/https://doi.org/10.1016/j.ecolecon.2025.108798.

Hadji-Lazaro, Paul, Julien Calas, Antoine Godin, Pamela Sekese, and Andrew Skowno. 2023. "Socio-Economic and Spatially-Explicit Assessment of Nature-Related Risks." *AFD Research Papers*, no. 302: 1–60.

Hadji-Lazaro, Paul, Mathilde Salin, Romain Svartzman, et al. 2024. "Biodiversity Loss and Financial Stability as a New Frontier for Central Banks: An Exploration for France." *Ecological Economics* 223: 108246.

INEGI. 2018a. *Sistema de Clasificación Industrial de América Del Norte*. INEGI. Available at: https://www.inegi.org.mx/scian/.

INEGI. 2018b. *Sistema de Cuentas Nacionales de México. Matriz Insumo-Producto*. INEGI. Available at: https://www.inegi.org.mx/programas/mip/2018/#datos_abiertos.

INEGI. 2019. *Censos Económicos 2019: Conjunto de Datos Abiertos*. INEGI. Available at: https://www.inegi.org.mx/programas/ce/2019/.

INEGI. 2024. *Directorio Estadístico Nacional de Unidades Económicas (DENUE)*. Conjunto de datos. Instituto Nacional de Estadística y Geografía. https://www.inegi.org.mx/app/mapa/denue/.

IPBES. 2019. *Global Assessment Report on Biodiversity and Ecosystem Services*. UN.

Kedward, Katie, Josh Ryan-Collins, and Adrienne Buller. 2021. "Quantitative Easing and Nature Loss: Exploring Nature-Related Financial Risks and Impacts in the European Central Bank's Corporate Bond Portfolio." *Available at SSRN 3922913*.

Martinez-Jaramillo, Serafin, Franz Mora, Luis Escobar-Farfan, and Ricardo Montanez-Enriquez. 2023. "Dependencies and Impacts of the Mexican Banking Sector on Ecosystem Services." *See Https://Www. Banxico. Org. Mx/Sistema-Financiero/d/% 7BC0066818-3826-DF36-5673-E8009795ACD4% 7D. Pdf (Accessed November 22 November 2024)*.

Miller, Ronald E., and Peter D. Blair. 2022. *Input-Output Analysis: Foundations and Extensions*. 3rd ed. Cambridge University Press.

Mundaca, Luis, and Jan-Niklas Heintze. 2024. "Banking on Ecosystem Services." *Ecological Economics* 224: 108284.

NCFA. 2024. *ENCORE: Exploring Natural Capital Opportunities, Risks and Exposure*. The Natural Capital Finance Alliance, UK.

NGFS. 2022. *Statement on Nature-Related Financial Risks*. Network for Greening the Financial System.

NGFS. 2024. *Nature-Related Financial Risks: A Conceptual Framework to Guide Action by Central Banks and Supervisors*. Technical document. Network for Greening the Financial System. https://www.ngfs.net/sites/default/files/medias/documents/ngfs-conceptual-framework-nature-risks.pdf.

O'Donnell, Emma and Ranger, Nicola and Sabuco, Juan and Seddon, Nathalie. 2025. "*Banks at Risk: Quantifying Endogenous Nature Risk Exposure of G-SIBs*" (September 26, 2025). Available at SSRN: https://ssrn.com/abstract=5533799 or http://dx.doi.org/10.2139/ssrn.5533799

Ranger, Nicola, Tom Oliver, Jimena Alvarez, et al. 2024. *Assessing the Materiality of Nature-Related Financial Risks for the UK*. Green Finance Institute.

https://www.greenfinanceinstitute.com/wp-content/uploads/2024/04/GFI-GREENING-FINANCE-FOR-NATURE-FINAL-FULL-REPORT-RDS4.pdf.

SHCP. 2023. *Taxonomía Sostenible de México*. Secretaría de Hacienda y Crédito Público. Gobierno de México.

Svartzman, Romain, Etienne Espagne, Gauthey Julien, et al. 2021. *A "Silent Spring" for the Financial System? Exploring Biodiversity-Related Financial Risks in France*. No. 826. Banque de France.

UN. 2008. *International Standard Industrial Classification of All Economic Activities. Rev. 4*. Department of Economic; Social Affairs. Statistics Division.

UNEP-WCMC. 2024. *Explanatory Note on the Updated ENCORE Knowledge Base Outlining Business Dependencies and Impacts on Nature*. Online document. UNEP-WCMC, Global Canopy,. https://https://encorenature.org/resources/explanatory-note-on-the-updated-encore-knowledge-base-outlining-business-dependencies-and-impacts-on-nature.

Van Toor, Joris, D Piljic, G Schellekens, M Van Oorschot, and M Kok. 2020. "Indebted to Nature: Exploring Biodiversity Risks for the Dutch Financial Sector." *De Nederlandsche Bank*.

WEF. 2010. *Biodiversity and Business Risk: A Global Risks Network Briefing*. World Economic Forum, PricewaterhouseCoopers.

World Bank, and Bank Negara Malaysia. 2022. *An Exploration of Nature-Related Financial Risks in Malaysia*. World Bank.