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Exposure of Slovenian economy and banking system to environmental degradation

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Macroeconomic and financial stability is becoming increasingly affected by intensifying environmental degradation, spanning both the climate change and nature depletion. In this study, we show that roughly 70% of Slovenian non-financial firms crucially depend on at least one or more ecosystem services, which are increasingly under threat by climate change and economic activity by itself. Moreover, given the intrinsic interconnectedness between the economy and the banking system, climate and nature-related risk is gaining relevance for financial stability, which is confirmed in this study by the constructed composite indicator of environmental risk.

JEL E01, G21, Q54

1. Introduction

In recent years, we have witnessed an increased frequency of extreme weather events alongside the intensified nature degradation, which has adversely affected economies and financial systems around the world. In this study, we examine the vulnerability of Slovenian economy and the banking system to environmental degradation. To do so, we explore to what extent economic activity depends on services that nature provides and are subject to depletion as a consequence of climate change, non-sustainable management of nature and land use, and economic activity itself. Moreover, given the connection between the real economy and the banking system, the corporate vulnerability to environmental degradation inevitably poses risks to financial stability, which is in this study examined through the lens of composite environmental physical risk indicator. We show that more than 70% of non-financial corporations (NFCs) in Slovenia critically depend on at least one ecosystem service. While the result is comparable to other euro area countries, Slovenian economy exhibits disproportionally large indirect dependency on ecosystem services through counterparts in the supply chain. The result reflects a high degree of global value chain integration by sectors with the largest dependency on ecosystem services, for example

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manufacturing and agriculture. On the side of physical risk mitigation, the most relevant ecosystem services supporting Slovenian economy are related to soil erosion stabilisation, flood and climate control, while in terms of resource availability water sources are particularly important. Considering the interconnectedness between dependency on nature and effect of economic activity on its degradation, we find that the impact of the Slovenian economy on environment, measured in terms of greenhouse gas (GHG) emissions and land use per output, is relatively limited and comparably lower than the median country in the euro area.

The dependency of the Slovenian economy on nature carries implications for financial stability in case environmental degradation affects performances of firms. To assess the exposure of the banking system to the environmental physical risks, construct a **composite risk indicator** that takes into account six different environmental hazards and the structure of the banking system portfolio. The results show that the physical risk increases with the severity of the chosen climate scenario as well as over time. While we already observe a slight increase in the physical risk in the current period, there is a substantial increase in the composite risk indicator in the next 20 years, mainly due to extreme heat and temperature related factors.

The structure of the study is as follows. In section 2, we discuss the relationship between an economy and the ecosystems. In section 3, we then extend the discussion with tying the banking system to climate related physical risks. In section 4, we conclude.

2. Interconnectedness between economy and the ecosystem

Recognising the dependency of the economy on ecosystem services plays a crucial role in evaluating exposure to physical risks associated with nature degradation. In particular, from the economic theory perspective, the natural capital can be perceived as one of the production inputs, alongside labour and other capital, and is thereby directly affecting production capacity of non-financial corporations and potential output of the overall economy. Moreover, to the extent that the dependency of production on ecosystem services also implies impact of firms on the nature's depletion, it also indicates economy's exposure to transition risks. Namely, given that terrestrial and marine ecosystems represent nature's capacity to absorb excessive carbon emissions (Rockström, et al., 2021), their preservation is pivotal to pursuing climate-related objectives. Consequently, firms and economies with higher dependencies on ecosystem are not only more exposed to physical risks but they are also more susceptible to regulatory and institutional polices associated with pursuing climate goals.

To quantify dependency of Slovenian economy on ecosystem services, we rely on the methodological framework laid out in Boldrini et al, 2023. In line with the seminal paper, denoted herewith ECB2023, we distinguish between direct dependency and indirect dependency, where the latter relates to exposure of non-financial corporations via their counterparts in the supply chains. The derivation of direct dependency is extracted from the ENCORE dataset[1], which assigns dependency scores to specific economic sectors in relation to 21 different ecosystem services. The direct dependency is complemented with the indirect exposure through global supply chains. The indirect dependency score is derived using EXIOBASE[2], which encapsulates environmentally-extended international supply-and-use (SUT) and input-output (IO) tables. The total dependency score (DS) for particular economy is then given by:

$$DS_{tot} = DS_{direct} + (1 - DS_{direct}) * DS_{indirect} \qquad (1)$$

Where DS_{direct} and $DS_{indirect}$ are quantitative measures taking values between 0, no dependency, and 1, very high dependency. The product in the aggregation attempts to minimise double counting, whereby in the case of very large direct dependency the impact through supply chains is minimised. We follow the convention in ECB2023, where high dependency is considered at the threshold value of 0.7, indicating severe impairment to production process in case of reduced ability to access the relevant ecosystem service.

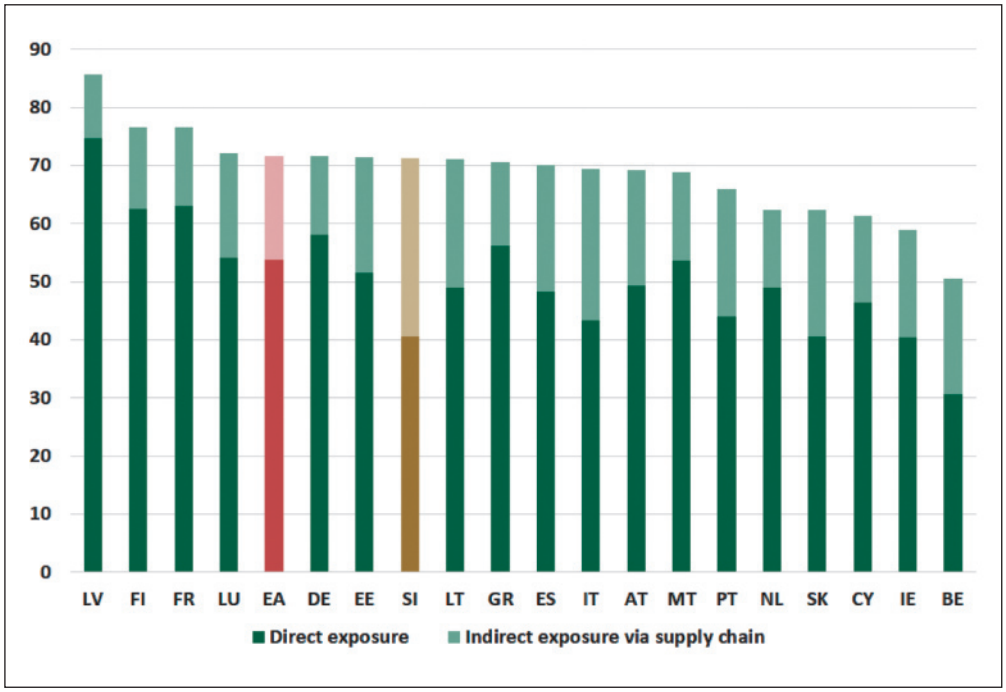
In case of Slovenia, the critical dependence on at least one ecosystem service, i.e. dependency score exhibiting the 0.7 threshold, is exhibited by roughly 70% of non-financial corporations as shown in Figure 1. While the total dependency score in Slovenia is comparable to the euro area average it disproportionally reflects the indirect exposure via supply chains, which stands the highest among the euro area countries (30% of firms). On the other hand, the share of firms exhibiting critically high direct dependency is fairly limited, 40%, with Belgium being the only country with lower direct exposure.

The above average indirect exposure to nature depletion could reflect a relatively strong concentration of dependency within manufacturing and agricultural sectors. In general, these sectors exhibit highest dependency on ecosystem services (Figure 2), while at the same time they are highly integrated into international supply chains. This is particularly the case in Slovenia, where import content of

[1] https://www.encorenature.org/en

[2] https://www.exiobase.eu/

Figure 1: Share of NFCs with high exposure to at least one ecosystem service (in %)

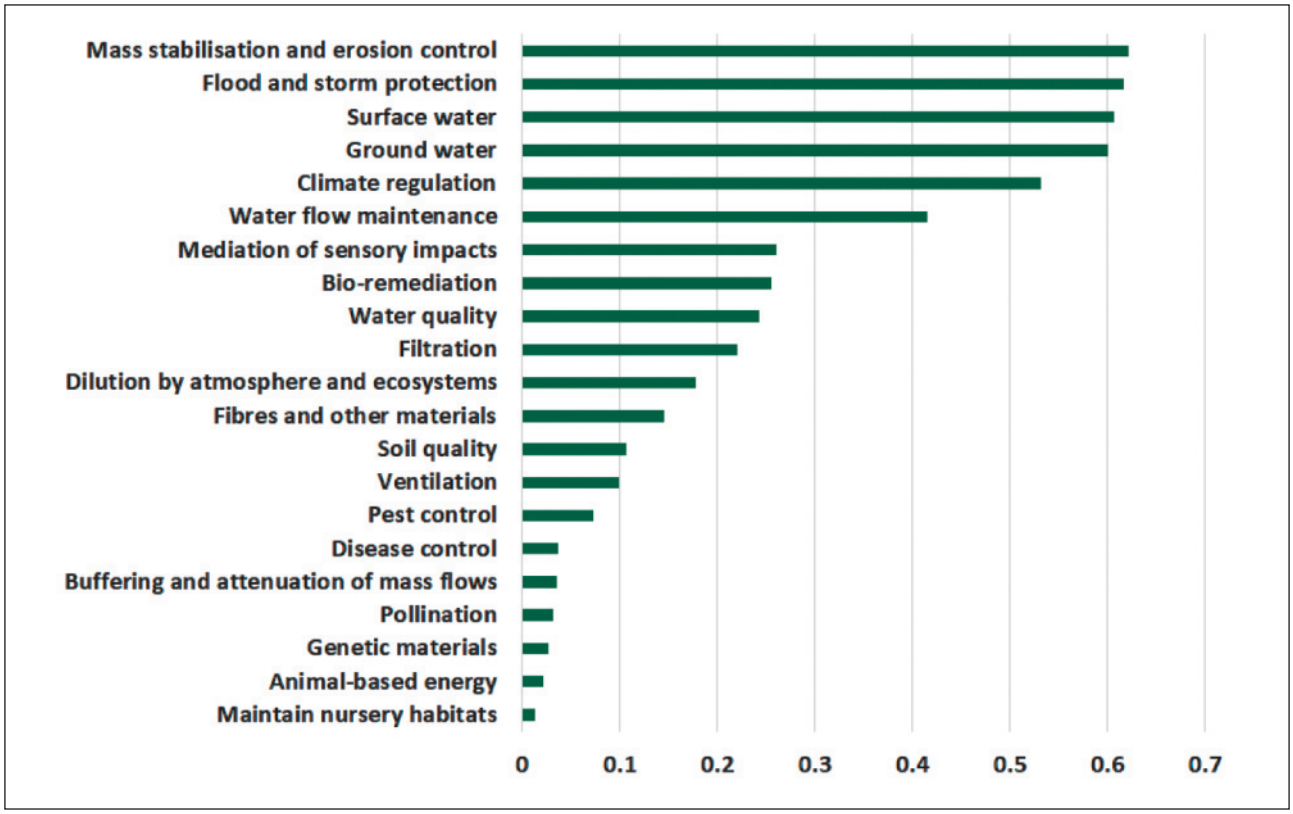


Source: Encore, Exiobase, Boldrini et al 2023
Note: Share of non-financial corporations with dependency score for at least one ecosystem service exceeding threshold value of 0.7.

Figure 2: Dependency on ecosystem services per economic sectors
x-axis: ecosystem services, y-axis: economic activity (NACE sections), value: direct dependency (from 0 to 1))

Source: Encore, Boldrini et al (2023)
Note: Dependency scores by NACE sectors extracted from the Encore database.

Figure 3: Relative importance of ecosystem services for Slovenian economy



Source: Encore, Exiobase, Boldrini et al (2023)
Note: Figure 3 shows average dependency scores of non-financial corporations in Slovenia per individual ecosystem services.

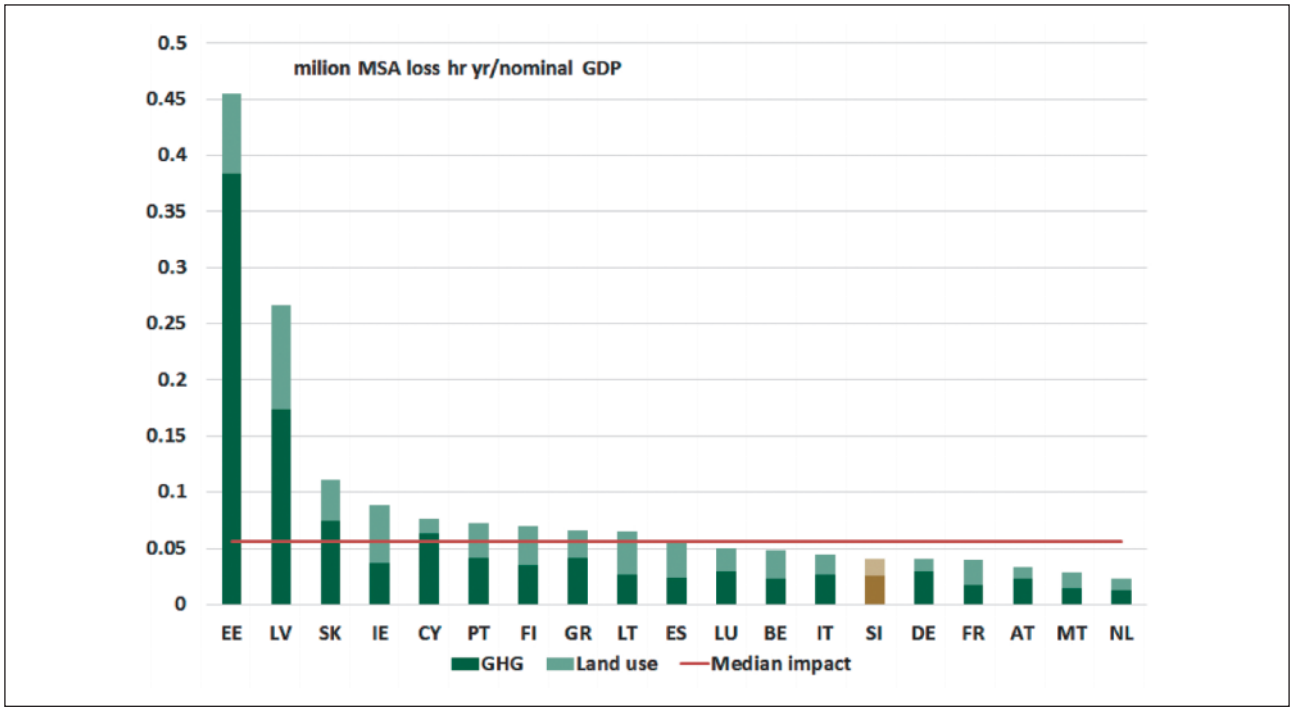
production in the respective sectors stands at roughly 70% and 50%.[3] Moreover, the manufacturing sector represents a comparably larger part of the Slovenian economy as the corresponding share of value added in GDP stands roughly 5 percentage points above the one in the euro area.[4]
Most relevant ecosystem services supporting Slovenian economy relate to **provisioning services** (surface and ground water sources) and **regulating services** (mass and soil erosion stabilisation, flood control, and climate control and mitigation), as shown on Figure 3. The regulating services are closely related to control and mitigation against physical climate hazards, while provisioning services to direct resource availability. In this context, forests and other vegetation ensuring climate control and prevention against avalanches and floods play a particularly important role.
An example of the impact of devastating floods was in Slovenia manifested last year with the direct damages estimated at replacement costs amounting to roughly EUR3bn or 5% of GDP.[5] In the context of flood risks, the analysis conducted by Pavlič (2023) shows that 5.6% of value added and 6.1% of total employment in Slovenia is directly exposed to the impact of floods with magnitude consistent with 100-year recurring rate. The estimates masks substantial regional and sectoral heterogeneity, whereby particularly smaller regions, highly dependent on manufacturing activity, exhibit highest exposure with value added and employment at risks exceeding 12% respectively.
While dependency on ecosystem services emulates exposure to physical risks, the view needs to be complemented with the impact that economic activity has on the nature. This is important both in the context of understanding to what extent the activity of firms is endogenously affecting nature-related production resources as well as in the context of susceptibility of firms to transition risks, stemming from regulation aimed at preservation of nature. The impact on nature and biodiversity is in the analysis of Ceglar et al. (2023) considered through green-house-gas emissions (causing climate change) and unsustainable land-use. Additional pressures on biodiversity, such as overexploitation of natural resources, pollution, nitrogen deposition and hunting, are not considered in this study, which leads to underestimation of the real impact on biodiversity. In terms of impact per nominal output, measured as million mean species abundance (MSA)-loss-ha-year/nominal GDP,

[3] The import content of particular sectors is computed using input-output tables, following the approach of (Radovan, 2022).

[4] See Manufacturing, value added (% of GDP) | Data (worldbank.org).

[5] Sprejet program odprave posledic škode v sektorju ribištva in akvakulture zaradi poplav | GOV.SI

Figure 4: Environmental footprint of euro area economies per output produced

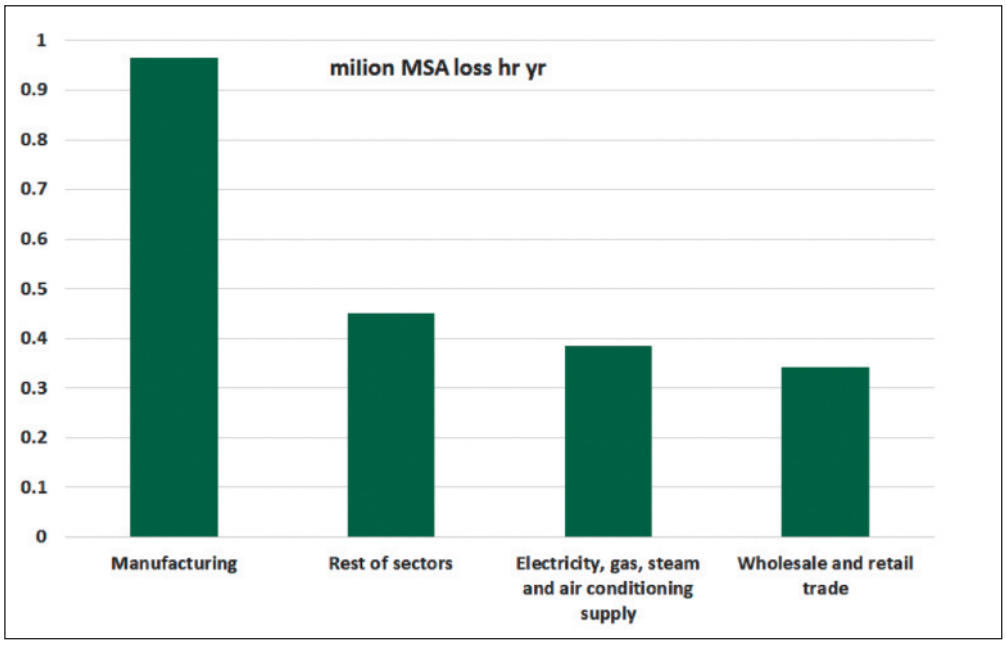


Source: AnaCredit, Exiobase, Ceglar et al (2023)
Note: The mean species abundance (MSA) losses are computed taking into account the GHG emissions and the area of land used in the production weighted by country nominal GDP for the reference year 2021.

Slovenia falls within the euro area countries with below median impact on nature, Figure 4. Focusing on particular activities, Figure 5 shows that sectors that degrade nature the most are often those that heavily depend on ecosystem services. For example, manufacturing sector is the sector that on the one hand exhibits high dependency on ecosystem services and at the same time produces the greatest adverse impact on the nature.

The activity of firms inherently depends on financing, an important part of which is in the Slovenian economy provided by the banking system. In this context, interconnectedness between economy and ecosystem renders implications for financial stability. While in the context of real economic activity, nature and ecosystems services are of particular importance given their role in production function, the environmental physical risks may provide a more wholesome

Figure 5: Sectors with greatest impact on nature



Source: AnaCredit, Exiobase, Ceglar et al (2023)
Note: The MSA losses are computed taking into account the GHG emissions and the area of land used in the production weighted by the country nominal GDP for the reference year 2019.

view in case of the financial system. The exposure of the Slovenian banking sector to environmental physical risks is explored in the next section.

3. Exposure of banking system to environmental physical risks

Climate and nature change will increase the likelihood of extreme weather events, which consequently prompts the increase of physical risks to take place. This can directly and indirectly result in physical damages that can have a significant impact on the financial system throughout. Policy makers started developing physical risk indicators that take into account climate change risks.[6] These physical risks indicators help us to analyse more effectively how these risks may affect firms' performance, what would be the effect on the financial systems and thus monetary policy and price stability.

For the purpose of this analysis we construct **climate risk score indicators** for physical risk based on environmental data sourced from the Environmental Agency of the Republic of Slovenia. The indicators have been defined at the municipality level and include data for six hazards, of which two are chronic and four acute risk hazards, following the NGFS (Network for greening the financial system) definition of environmental physical risk.[7] Chronic risk is defined as risk emanating from gradual change in precipitation or temperatures, while the acute risks stem from extreme heat, floods, windstorms and droughts.[8] The risk indicators for the specific hazard have been constructed based on the standardised deviation of the specific variable relative to the reference period 1981-2010, across three time periods and three RCP (Representative concentration pathways) scenarios designed by the IPCC (International Panel for Climate Change), for all hazards, except floods.[9] The three RCP scenarios included in this analysis are the RCP 2.6, RCP 4.5 and RCP 8.5 scenarios which foresee different socioeconomic pathways with GHG (Greenhouse gas) emission paths which correspond to a temperature increase of 1 ºC, approximately 2 ºC and 4 ºC by 2100 respectively.[10] Thus, the RCP 8.5 scenario is the most severe scenario in terms of temperature increases. The flood risk indicator has been constructed on the basis of deviation of the share of the municipality area exposed to any type of flood relative to the national average of the share across municipalities. The indicators are currently defined at the municipality level. The indicator construction is subject to change pending on alternative definitions of the hazards, different statistical methods in the aggregation or standardisation of the data and/or higher granularity, e.g. at the cadastre parcel level for NFCs.

To evaluate the exposure of the Slovenian banking system we construct a composite risk indicator aggregated across all six hazards, also taking into account the structure of the banking system NFC portfolio. The composite risk indicator (CRI) for municipality i is thus defined as the sum of the individual hazard risk scores (RS) for the municipality across all hazards h, while the banking composite risk indicator is defined as the weighted sum of the municipality risk scores, weighted by the share of NFC exposures in that municipality in the total NFC exposures of the banking system.[11]

$$CRI_i = \sum_{h=1}^{6} RS_h$$

$$BCRI = \sum_{i=1}^{212} CRI_i * w_i$$

where the weight for municipality is defined as follows:

$$w_i = \frac{Exposures\_NFC_i}{Exposures\_NFC\_system}$$

The composite risk indicators for each hazard are calculated for a historical reference period (1981-2010) and three 30-year time periods extending until 2100, across the three RCP scenarios with different levels of temperature increases. The following chart shows the banking system composite risk indicator for the NFC portfolio, assuming no changes in the bank portfolio structure over time.

The results show that the physical risk increases with the severity of a scenario and through time, with an increase in physical risk observable already in the current period (Figure 6). While the composite risk indicator is the highest

[6] To better understand the effects of climate change, surveys could be of use for policy making as well. For example, in August 2023, Slovenia was hit by floods. According to the Bank of Slovenia's Survey on access to finance for businesses (Banka Slovenije, 2024), 20% of firms report that they were affected by the floods. A share of 11% of firms were directly affected. Those firms, which reported that they were affected by the floods, 20% of them reported substantial damages to their businesses. To cover the damages and losses, 62% of surveyed firms reported that they will finance from own resources, 13% of firms count on the help of the government, 6% of firms will take bank loans, while other firms will utilise other resources. 63% of the affected firms will not apply for a moratorium, either because they do not have a banking loan or they will manage to cover the losses and damages without moratoria.

[7] https://www.ngfs.net/en/ngfs-climate-scenarios-phase-iv-november-2023

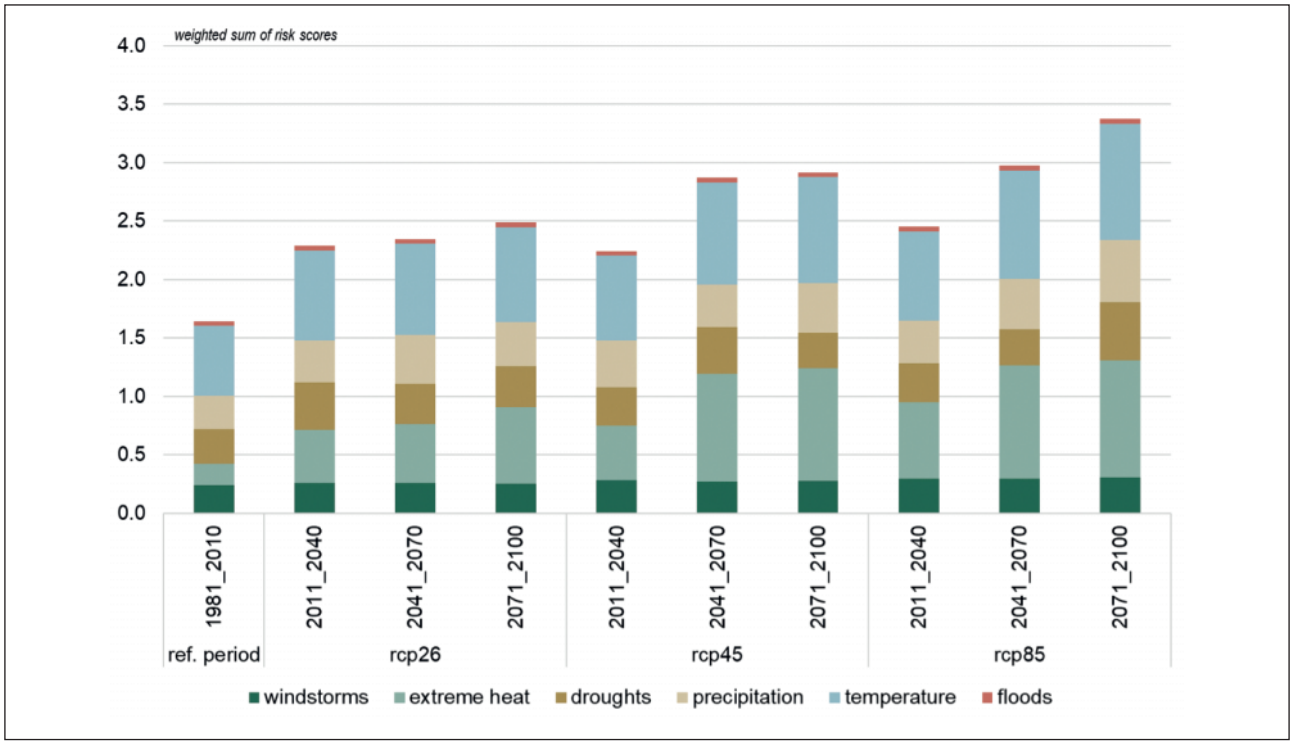
[8] Extreme heat is defined in terms of number of days with tropical nights, defined as days when the night temperature does not decrease below 20 ºC. Droughts are defined in terms of the number of days when the soil water deficit index exceeds 60, windstorms are defined in terms of maximum wind-speed gusts, floods are defined in terms of the frequency of floods ranging from very rare (catastrophic) to frequent floods. The flood maps have been revised following the catastrophic floods of August 2023 in Slovenia.

[9] The min-max method on a scale 0-1 was used to standardise the risk scores.

[10] https://meteo.arso.gov.si/uploads/probase/www/climate/text/sl/publications/povzetek-podnebnih-sprememb-temp-pad.pdf

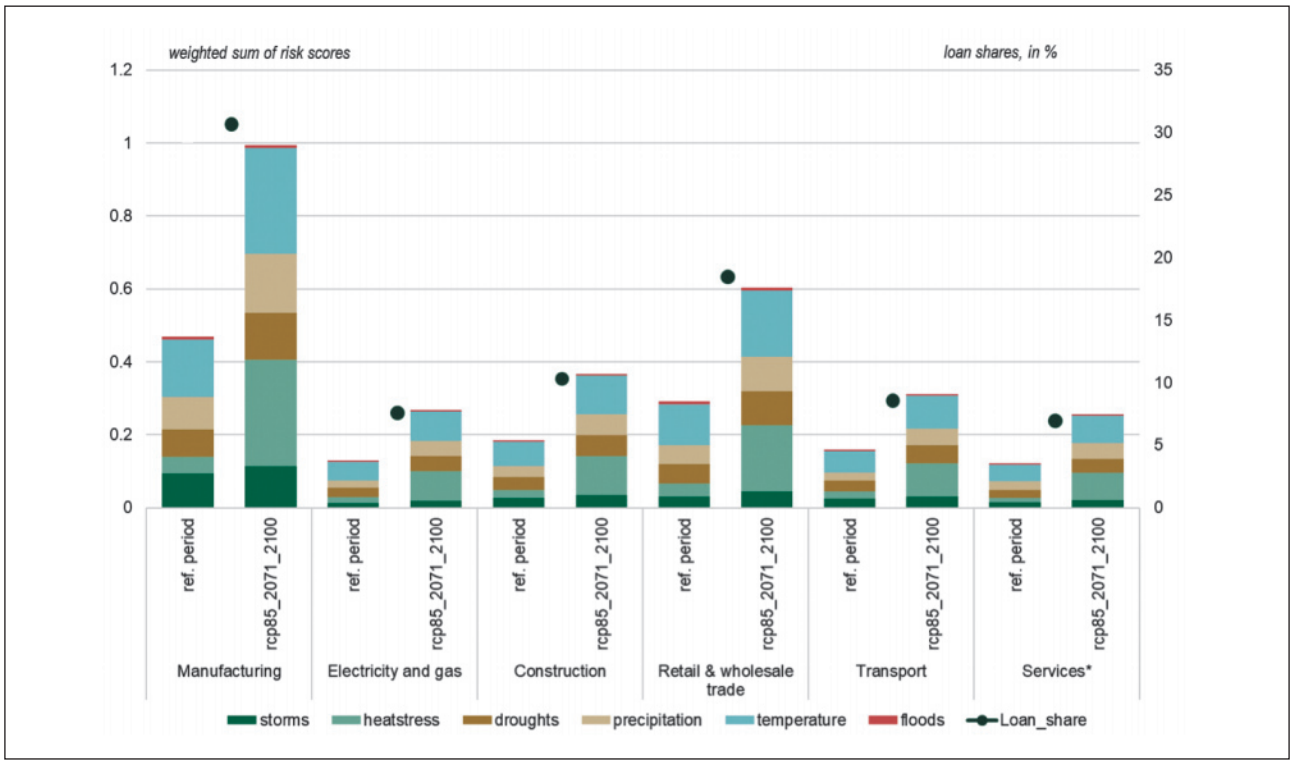
[11] The cut-off date for calculating the weights is 31.12.2023.

Figure 6: Banking composite risk indicator for the NFC portfolio across scenarios and time



Note: Rcp26, rcp44 and rcp88 denote climate scenarios corresponding to a temperature increase of 1 ºC, approximately 2 ºC and 4 ºC by 2100 respectively. The left-hand side axis represents the weighted sum of risk scores. The units are per se dimensionless but have good representative indicative and relativity power showing the differences across time, scenarios, and type of risk exposure.

Figure 7: Composite risk indicator across two periods and loan share of selected economic activities



Note: The chart shows a comparison of the composite risk indicator in the reference period and the RCP 8.5 scenario for the 2071-2100 period. The loan shares (rhs) of selected economic activities are calculated using data as of 31.12.2023. Services denotes that the chart shows the value of the climate risk indicator and loan shares for professional, scientific and technical activities only. The left-hand side axis represents the weighted sum of risk scores. The units are per se dimensionless but have good representative indicative and relativity power showing the differences across time, scenarios and type of risk exposure.*

for the RCP 8.5 scenario at the end of the 21st century, there is a substantial increase in the composite indicator already in the 2011-2040 period. The composite risk indicator increases by 105% in the RCP 8.5 scenario in the 2071-2100 period relative to the reference period, with the greatest relative change observable for the risk score from extreme heat and precipitation. The change observed in the current period (2011-2040) is also non-negligible, with the composite risk indicator increasing by 39.5% in the RCP 2.6, 36.6% in the RCP 4.5 and 49.4% in the RCP 8.5 scenario. Moreover, the greatest contribution to the composite risk indicator in the reference period comes from chronic risk in general, specifically temperatures, droughts, and precipitation, while the greatest contribution in the 2011-2040 period across scenarios (in particular scenarios RCP 4.5 and RCP 8.5) comes from acute risk (of which extreme heat and droughts are the most pronounced). This marks a change in the drivers of climate risk, which reveals the increasing importance of acute risks already in the current period and in general going forward until 2100.

The colour shading reflects relative size of estimated composite risk indicator across hazards and activities. The exposure analysis also reveals that physical risk is likely to be concentrated in few sectors (Figure 7), specifically manufacturing, construction, electricity and gas, retail and wholesale trade, transport, and some services activities (professional, scientific and technical activities). In fact, these sectors account for over 80% of the composite risk indicator, the majority concentrated in manufacturing activities, particularly in energy-intensive activities. This may lead to risk amplification via higher transition risks and interactions between physical and transition risks.

While the risks are concentrated in these sectors, as shown in the heatmap (Table 1), the risk indicator increases across all sectors with the severity of the climate scenario and the length of the scenario horizon (risks are highest towards the end of the century). The greatest relative change on average across scenarios and periods though can be observed in the mining, electricity and gas and ICT (Information and communications) sectors.

The main message from this exposure analysis is that the banking system is exposed to physical risks, which are set to increase significantly, also when taking the bank portfolio structure into account. Moreover, risks are concentrated in few sectors, which may lead to risk amplification and interaction with existing transition risks, particularly so in the energy-intensive activities. Some part of climate risk increase is unavoidable, as there is an increase in the composite risk indicator already in the current period, though

Table 1: Heatmap of risk indicators in the reference period across hazards and activities

Econ. activity	Windstorms	Extreme heat	Droughts	Precipitation	Temperatures	Floods
Agriculture, forestry & fishing						
Mining & quarrying						
Manufacturing						
Electricity & gas						
Water supply & sewerage						
Construction						
Wholesale & retail trade						
Transportation & storage						
Accommodation & food service						
Information & communication						
Finance & insurance						
Real estate activities						
Professional, scientific & technical activities						
Administration & support						
Public administration & defence, social security						
Education						
Human health & social work						
Arts, entertainment & recreation						
Other service activities						

Source: Own calculations based on environmental data from National Environmental

limiting the amount of carbon emissions going forward will likely contribute to a significant decrease in overall risk, as measured by the composite risk indicator.

The results confirm the necessity of acting (swiftly) to reduce emissions globally. It should be mentioned that the analysis only focuses on the NFC sector and can be extended to include the household sector portfolio. The exposure of the NFC portfolio could also be modelled at a more granular level. In addition, the exercise is based on a static balance sheet assumption, i.e. considering no changes in the bank portfolio structure. The exposure analysis is a preliminary assessment of the exposure of the banking system to physical risks based on six hazards indicators which have been defined statistically. The risk assessment may change significantly depending on dynamic changes in the bank portfolio or considering alternative definitions of the composite risk indicator.[12]

4. Conclusion

This study examines vulnerability of Slovenian economy and banking system to environmental degradation**.** We find that more than 70% of Slovenian non-financial firms crucially depend on at least on or more ecosystem services. Given the structure of Slovenian economy and its high integration into global value chains, a large part of the assessed dependency reflects an indirect exposure through counterparts in the supply chains. Considering the high interconnectedness between real economy and the banking system, high direct and indirect dependency of firms on nature intensifies risks for financial stability, stemming from local and global environmental degradation. The intensified exposure to physical risk is confirmed by the composite risk indicator presented in this study, which is expected to be exacerbated even further according to the available scenarios.

Thus, addressing the highlighted vulnerabilities will require extensive investment in both, adaptive and transformative technologies in the future. The investment in the adaptive technologies is particularly relevant in the context of the current economic model and the structure of dependency of Slovenian economy on nature that was presented in this study. Nevertheless, to ensure a sustainable growth of productivity of the Slovenian economy on the basis of reduced energy dependency and resilience to global supply shocks, investment in transformative technologies will play a crucial role.

This study provides an initial step towards mapping the most material hazards coming from environmental degradation for the economy and in turn the banking sector. Integrated assessment of climate change and nature degradation will be necessary in the future to more accurately capture the implications for Slovenian economy, with special focus on supply chain dependency. Assessment of compound shocks from climate change and nature degradation, including biodiversity loss, will require collaborative efforts in a multidisciplinary environment between economists and financial experts, environmental and climate scientists, and insurance experts. According to the NGFS conceptual framework on nature degradation and implication for financial risk assessment (NGFS, 2023), three stage approach is recommended in this process: (i) mapping of the most material risks for economy, (ii) development of forward-looking scenarios and estimation of economic consequences, and (iii) integration into financial toolboxes (such as stress test).

[12] E.g.: median vs. maximum projections of the climate variables, alternative definitions of the particular hazards, different aggregation methods.

References

Banka Slovenije. (2024, Februar). *Raziskava o dostopnosti finančnih virov za podjetja*. Rezultati anket, Banka Slovenije. Pridobljeno iz: https://bankaslovenije.blob.core.windows.net/publication-files/raziskava_o_dostopnosti_financnih_virov_februar-2024.pdf

Boldrini, S., Ceglar, A., Lelli, C., Parisi, L., & Heemskerk, I. (2023, November). Living in a world of disappearing nature: physical risk and the implications for financial stability. *European Central Bank: Occasional Paper Series, No 333*.

Ceglar, A., Boldrini, S., Lelli, C., Parisi, L., & Heemskerk, I. (December 2023). *The impact of the euro area economy and banks on biodiversity*. Pridobljeno iz ECB Occasional papers: https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op335~79fbc42228.en.pdf?e0811f3c6688da05df37d40aa78a84b9

Pavlič, D. (2023, December). *Assessment of the Slovenian Economy's Exposure Using Flood Maps*. Retrieved from Banka Slovenije Short Economic and Financial Analyses: https://bankaslovenije.blob.core.windows.net/publication-files/kefa_pavlic_final.pdf

Radovan, J. (2022, April). *An import-adjusted approach to quantify the contributions to real GDP growth in Slovenia*. Retrieved from Banka Slovneije Discussion Papers: https://bankaslovenije.blob.core.windows.net/publication-files/pa_4_2022.pdf

Rockström, J., Beringer, T., Hole, D., Griscom, B., Mascia, M. B., Folke, C., & Creutzig, F. (2021, Septeber 15). We need biosphere stewardship that protects carbon sinks and builds resilience. *Proceedings of the National Academy of Sciences of the United States of America, Vol. 118*.