European Commission

# Loan pricing and biodiversity exposure: Nature-related spillovers to the financial sector

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2023

*JRC Working Papers in Economics and Finance, 2023/11*

Joint Research Centre

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**EU Science Hub**
https://joint-research-centre.ec.europa.eu

JRC135774

Ispra: European Commission, 2023



How to cite this report: Becker A., Di Girolamo F. E., Rho C., *Loan pricing and biodiversity exposure: Nature-related spillovers to the financial sector*, JRC Working Papers in Economics and Finance, 2023/11, European Commission, Ispra, Italy, 2023, JRC135774.

## Executive summary

Economic growth often comes at the expense of the environment, resulting in the depletion of natural resources. Unfortunately, this has dire consequences, as it leads to irreversible changes in the structure and function of ecosystems, ultimately resulting in a loss of species diversity. Moreover, loss of biodiversity not only poses ecological risks, but also significant economic impacts, as it severely restricts the availability of vital natural resources, driving up costs across various industries.

As well as climate risk, biodiversity risk may thus affect the economy both in terms of physical risk and of transition risk. The dependency of business activities to operate properly through the physical provision of ecosystem services and biodiversity can be associated with the concept of physical risk, where a loss of biodiversity may lead to a likewise economic loss. On the other end, the negative impact of an economic activity imposed on biodiversity can manifest a transition risk, where e.g. the tightening of regulations may render certain business operations more costly or illegal.

From a financial point of view, the risk associated with biodiversity degradation or ecosystem degradation not only affects the creditworthiness of firms, but also raises concerns for lending institutions, which have extended credit to these firms, as there is an increased likelihood of default and potential loss of assets.

This means that the risk stemming from biosphere factors, commonly referred to as nature-related risk, may spill over from borrowers to lenders. As a result, it is increasingly important for financial institutions to consider proactively the potential impacts of biodiversity loss and environmental factors on their lending practices. By integrating nature-related risk assessments into their strategies, financial institutions can play a vital role in supporting the protection and conservation of biodiversity while safeguarding their own financial stability.

This paper contributes to the ongoing debate on the exposure of borrowers and lenders to risks related to natural capital and biodiversity. Specifically, it focuses on the impact of economic activity on biodiversity and its associated transition risk for the financial sector. It analyses the exposure to risk stemming from nature-related factors of firms operating globally and lenders based in the EU and the United Kingdom, finding that the level of exposure of EU lenders to biodiversity risk via their borrowing firms varies across lender countries and is influenced by factors such as borrower location and loan size.

Moving forward, we analyse syndicated loans issued between 2017 and 2022. Our results demonstrate that the level of biodiversity risk faced by the borrowing firms influences the pricing of these loans. This suggests that lenders charge a premium to account for the risk associated with biodiversity exposure, similar to the concept of a 'carbon premium' on emissions. In particular, we get three conclusions.

Firstly, there is a significant and positive correlation between the score of biodiversity exposure and the price of syndicated loans. This evidence highlights the need for further research in this area to enhance the data on natural capital and develop more refined indicators of biodiversity exposure. These indicators can inform practitioners on their investment decisions and incorporate nature-related spillovers as a factor for credit risk evaluation.

Moreover, the location of lenders and borrowers plays a crucial role in assessing potential biodiversity risks. When we control for the location of borrowers and lenders, we observe that the coefficient of the biodiversity score grows in magnitude and significance, and this effect is even stronger when we distinguish inside EU transactions from extra-EU deals. This suggest that the European financial sector is responsive to the efforts of regulators and policymakers in quantifying nature-related risks.

Finally, lenders appear to place greater emphasis on nature-related risk when issuing green or sustainable loans. This finding is important for EU policymakers, since the EU debt market is currently the largest for green bonds, and the EU Commission is introducing new regulations to structure green finance instruments in line with the European Green Deal. If nature-related risk is a significant component in pricing unconventional loan types as green ones, accurate quantitative metrics of this risk will be valuable for policy design.

Overall, our analysis highlights the relevance of biodiversity risk as a potential component for national and cross-border macro financial stability. This emphasizes the importance of coordination between financial regulators and monetary policy authorities, particularly in managing the financial spillovers to EU member states from countries outside the EU. As the understanding of nature-related risks continues to evolve, further research and analysis are necessary to build a more robust knowledge base. Exploring the links between biodiversity loss and financial risk can contribute to the development of effective risk assessment tools, mitigation strategies, and policy frameworks that promote long-term stability.

# Loan pricing and biodiversity exposure: Nature-related spillovers to the financial sector

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December 2023

**Abstract**

Biodiversity loss can have direct economic impacts, as it limits the availability of natural resources and increases costs across various industries. When firms face significant risks due to biodiversity loss, their creditworthiness may be jeopardized. This raises concerns for lending institutions that have provided credit to these companies, potentially leading to stricter lending conditions for borrowers. This paper analyzes how these risks spread from the real economy to the syndicated loans market in the European Union and United Kingdom. Firstly, we construct a country-level indicator of biodiversity exposure for EU lenders. Our findings show that the exposure of EU banks to biodiversity varies across countries, depending on the level of exposure of borrowing firms and the loan volumes. Secondly, using data on syndicated loans from 2017 to 2022, we observe a positive and significant correlation between loan pricing and the level of biodiversity exposure of the borrower. These findings suggest that creditors are increasingly incorporating nature-related information into their financing decisions, allowing them to diversify and pool risks. On the other hand, debtors cannot fully detach themselves from their dependence on natural capital and can only adjust their business models in the long run.

**Keywords:** Nature-related risk, Natural capital, Biodiversity, Financial sector, Banks, Debt financing, Syndicated loans, Loan pricing, Premium, International spillovers, Risk transmission, Borrower diversification, EU
**JEL Classification**: C55, G21, Q51, Q57

**Acknowledgments:** The authors thank Marco Petracco Giudici, Davide Fiaschi, Caterina Giannetti, Tommaso Luzzati, Stefano Ungaro as well as the participants to the Department Seminar at Pisa University, and the 2023 Sustainable and Impact Investment International Conference for helpful comments.


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## 1 Introduction

Economic growth often comes at the expense of the environment, resulting in the depletion of natural resources. Unfortunately, this has dire consequences, as it leads to irreversible changes in the structure and function of ecosystems, ultimately resulting in a loss of species diversity.

It is crucial for the economic and financial sector to consider biodiversity loss as a cost. In fact, the loss of biodiversity not only poses ecological risks but also significant economic impacts, as it severely restricts the availability of vital natural resources, driving up costs across various industries. On the one hand, economic activity depends on ecosystem services to exist and function intactly. On the other hand, economic activities can harm biodiversity.[1] This two-way relationship is referred to as double materiality in the literature.[2] In broad terms, the dependency of business activities to operate properly through the physical provision of ecosystem services and biodiversity can be associated with the concept of physical risk, where a loss of biodiversity may lead to a likewise economic loss. On the other end, the negative impact of an economic activity imposed on biodiversity can manifest a transition risk, where e.g. the tightening of regulations may render certain business operations more costly or illegal.

For instance, disruptions in ecosystem services, such as pollination, water provision, and soil retention, directly impact the availability of essential raw materials. This can increase the expenses associated with acquiring resources, potentially impacting industries like agriculture, fishery as well as any water- and land-dependent businesses which heavily rely on these services.[3] A study conducted by the World Bank (Johnson et al., 2021) quantifies that economic consequences of biodiversity loss are substantial and a collapse in ecosystem services could cause to a decline in global GDP of $2.7 trillion in 2030. To prevent biodiversity disruption, regulators are setting stricter rules for firms in key industries like the energy sector to diminish their potential impact on the environment in their production sites [4]. However, new regulations can translate into higher transition risk regarding biodiversity requirements to industrial sectors (Giglio et al.,

[1] Consider an ecosystem service like ground water, and an economic activity such as agriculture. Agriculture depends on ground water for its production process (for instance, growing crops). At the same time, agricultural activities impact the availability and quality of ground water through excessive exploitation of local water bodies, or the immission of chemicals used as fertilizers in local aquifers.

[2] The European Financial Reporting Advisory Group in an informal working paper defines double materiality as the union of impact materiality and financial materiality. A sustainability topic or information has double materiality if it is material from either an environmental perspective, a financial perspective, or both. See EFRAG (2022).

[3] For example, a decline in pollinators can significantly impact agricultural productivity, while water scarcity can directly affect operations reliant on water for cooling or purification processes.

[4] For example, fossil extraction through mining is an invasive process.

2023). As well as climate risk, biodiversity risk may thus expose the economy both to physical risk and transition risk.

The risk associated with biodiversity degradation or ecosystem degradation not only affects the creditworthiness of firms, but also raises concerns for lending institutions, which have extended credit to these firms, as there is an increased likelihood of default and potential loss of assets. This means that the risk stemming from biosphere factors, commonly referred to as nature-related risk, may spill over from borrowers to lenders. As a result, it is increasingly important for financial institutions to proactively consider the potential impacts of biodiversity loss and environmental factors on their lending practices. This may involve reallocating their portfolio to more sustainable and biodiversity-friendly projects and sectors, as well as taking measures such as adjusting interest rates or tightening lending criteria to reflect the risks associated with biodiversity degradation. By integrating nature-related risk assessments into their strategies, financial institutions can play a vital role in supporting the protection and conservation of biodiversity while safeguarding their own financial stability.

Despite academic research in the area of financial risks associated with biodiversity loss is still limited, several frameworks provide a foundation for investigating and understanding the potential financial implications of biodiversity loss. Notable examples include the biodiversity foot-printing methodology introduced by Berger et al. (2018), the framework proposed by Barker and Onifade (2020) for assessing biodiversity-related financial risk, and the handbook published by the University of Cambridge Institute for Sustainability Leadership (Rudgley and Seega, 2021) to help financial practitioners understand and recognize nature-related financial risks. Karolyi and Tobin-de la Puente (2023) summarize the regulatory framework related to biodiversity risks in financial markets, highlighting financing needs and recent biodiversity-linked financial transactions. Junge and Sassen (2020) conduct a systematic review emphasizing the importance of increasing awareness of biodiversity among financial institutions and outlining practical steps that they can take to address biodiversity-related risks.

The current literature on nature-related risks primarily focuses on the dependency dimension, assuming that an institution exposed to firms highly dependent on ecosystem services is more likely to be directly affected. Calice et al. (2021) explore the extent to which Brazilian banks are exposed to the loss of biodiversity through their lending to non-financial corporations, finding that such exposures are substantial, with 46% of corporate loan portfolios concentrated in sectors highly dependent on ecosystem services.

Van Toor et al. (2020) assess the exposure of Dutch financial institutions to the risk of biodiversity loss, developing a framework that evaluates the dependence of financial institutions' portfolios on various ecosystem services. Their methodology relies on the ENCORE database, which lists the dependencies of 86 business processes on 21 ecosystem services and 8 types of natural capital. The study reveals that Dutch financial institutions have provided 510 billion EUR to companies highly dependent on one or more ecosystem services. Additionally, they find that worldwide investments or loans by financial companies involved in environmental controversies with negative consequences for ecosystem services or biodiversity amount to 96 billion EUR.

Building on a similar methodology, Svartzman et al. (2021) provide a preliminary approximation of biodiversity-related exposure of the financial sector in France. Their study focuses on both dependencies and impacts, highlighting that 42% of the value of securities held by the French financial institutions comes from issuers that are highly or very highly dependent on one or more ecosystem service. They also estimate that this corresponds to the loss of almost 135,000 $km^2$ of intact or pristine nature. Salin (2023) assesses biodiversity-related transition risk in France by quantifying the use of built-up land by economic activities. The paper finds that, under the new regulatory 'no net land-take' (NNLT) target, the sectors most exposed to transition risk in France and unable to adapt to the NNLT policy are Mining and Quarrying and Food and Accommodation services. The forthcoming work Hirschbuehl (2024) uses ENCORE to quantify the extent to which European listed firms are exposed to ecosystem service dependencies and adversely impact biodiversity. Further, the author utilises these exposures and evaluates excess returns in a Fama and French (2015) asset pricing model. The results indicate that since the Paris Agreement, investors might have focused not only on CO2 emissions but also on other types of pollution. The study further suggests future refinements in nature-related risk assessments by adding data on ecosystem service provision and natural hazards and data from other European institutions on companies' pollution levels. In a likewise manner, Boldrini et al. (2023b) assess the dependencies of euro area economy on ecosystem services, focusing instead on corporate loans. The study shows that 75% of all corporate loan exposures inside the euro area have a strong dependency on at least one ecosystem service.

While there is an increasing urgency to quantify nature-related financial loss, the development of tools, standard scenarios or targeted stress tests are still in the early stages. Most of the modelling frameworks in the current literature primarily focus on climate change, with only few extending considerations to degradation of natural capital, such as the loss of biodiversity.

For instance, Hoepner and Rillaerts (2023) investigate the impact of biodiversity on the Credit Default Swaps term structure in the infrastructure sector, showing that investors perceive those risks as long-term issues. Firms that effectively manage these risks benefit from up to 93 basis points better long-term refinancing conditions compared to the worst-performing firms. Boldrini et al. (2023a) analyses the contribution of euro area economic activities to biodiversity loss by estimating biodiversity footprints. This paper uses corporate loans to companies located in the euro area, issued by euro area banks. Considering two primary drivers of biodiversity loss (land-use change and climate change), the results show that the economy has had a significant impact on biodiversity, equivalent to the loss of 582 million hectares of 'pristine' natural areas worldwide.

This paper contributes to the ongoing debate on the exposure of borrowers and lenders to risks related to natural capital and biodiversity. Specifically, it focuses on the impact of economic activity on biodiversity and its associated transition risk for the financial sector. To the best of our knowledge, this is the first study to analyze how this risk impact EU lenders operating globally on the syndicated loans market through international credit linkages. We do not limit our analysis to EU firms, but we particularly focus on firms operating worldwide, and lenders based in the EU and the United Kingdom. We start by developing a measure of biodiversity exposure for European lenders, finding that the level of exposure varies across countries and by borrower location as well as loan size. Moving forward, we analyze syndicated loans issued between 2017 and 2022. Our results demonstrate that the pricing of these loans is influenced by the level of biodiversity risk faced by the borrowing firms. This implies that lenders charge a premium to account for the risk associated with biodiversity exposure, similar to the concept of a 'carbon premium' on emissions (Ehlers et al., 2022).

Overall, our analysis highlights the relevance of biodiversity risk as a potential component for national and cross-border macro financial stability. This emphasizes the importance of coordination between financial regulators and monetary policy authorities, particularly in managing the financial spillovers to EU member states from countries outside the EU. As the understanding of nature-related risks continues to evolve, further research and analysis are necessary to build a more robust knowledge base. Exploring the links between biodiversity loss and financial risk can contribute to the development of effective risk assessment tools, mitigation strategies, and policy frameworks that promote long-term stability.

The paper is organized as follows. Section 2 provides an overview of relevant policy initiatives. Section 3 explains how the inputs to the model are derived. Section 4 presents the exposure of both lenders and borrowers. Section 5 analyzes the link between biodiversity risk and loan pricing at borrower level. Finally, Section 6 concludes.

## 2 Policy background

The recognition of biodiversity loss as a significant risk for the financial system has lead financial regulators to emphasize the need to address this risk to ensure financial stability. Policy initiatives are underway to encourage financial institutions to integrate nature-related risk into their risk management procedures and provide suitable monitoring and assessment tools.

In 2022, the European Parliament and the Council reached political agreement on the Corporate Sustainability Reporting Directive (CSRD, European Parliament and Council, 2022). The CSRD represents an important element of the European Green Deal. The CSRD incorporates the concept of 'double materiality'. Companies will have to report not only on how sustainability issues might create financial risks for the company, but also on the company's own impacts on people and the environment, including biodiversity.

In July 2021, the European Commission launched its renewed Strategy for Financing the Transition to a Sustainable Economy (European Commission, 2021). The strategy includes actions that highlight the importance of the financial sector in identifying and managing sustainability risk. In this context, a key issue relates to the ability of banks to absorb financial losses that may arise from exposures to companies and sectors negatively impacted by environmental degradation and biodiversity loss. The strategy foresees potential amendments to banks' capital requirements as a mean to enhance economic and financial resilience to sustainability risks. Additionally, the EU Sustainable Finance Taxonomy Regulation (European Commission, 2020) provides clear criteria to classify economic activities as environmentally sustainable and establishes rules for activities that have a substantial impact on biodiversity. In 2020, the European Commission published the EU Biodiversity Strategy for 2030 (Directorate-General for Environment, 2020), an ambitious program of measures to put Europe's biodiversity on a path to recovery by 2030 for the benefit of people, climate and the planet.

The Sustainable Finance Platform, an advisory body established under Article 20 of the Taxonomy Regulation, has also published a report (The Sustainable Finance Platform, 2020) emphasizing the importance of biodiversity for financial institutions and its effects on the security of financial sector and the economy. The report also provides case studies delivering evidence on how few financial institutions are already managing biodiversity-related risk.

The ECB has recognized the implications of the ongoing biodiversity emergency. In 2020, it issued a supervisory guide (ECB Banking Supervision, 2020) to manage environmental risks, especially biodiversity-related loss. Financial institutions were requested to perform self-assessments of their current practices and inform the ECB of their implementation plans to advance the management of climate-related and environmental risks. Based on these results, ECB (2022) highlights that two-thirds of the European financial institutions started targeting broader climate related risks, including their biodiversity exposure. The ECB (2022) identifies a set of good practices to meet the supervisory expectations outlined in the guide.

Internationally, the Taskforce on Nature-related Financial Disclosures (TNFD) released a publication (TFND, 2023) that marks a noteworthy development in the discussion about natural capital and financial stakeholders.[5] Formally launched in 2021, the TNFD provides guidance to organizations, in particular financial institutions, on how to report and act on evolving nature-related dependencies, impacts, risks and opportunities. Inspired by the task-force on climate-related financial disclosures, the initiative aims at integrating the biosphere into financial decision-making and redirect global financial flows towards nature-positive outcomes. The OECD has also emphasized the need for urgent and ambitious actions on biodiversity in its report on biodiversity and action (OECD, 2019). This report assesses current biodiversity-related financial flows and discusses key data and indicator gaps that need to be addressed to effective monitoring of biodiversity pressures and actions.

Additionally, the Network for Greening the Financial System (NGFS), an international coalition of central banks and supervisors established in 2017, acknowledges the crucial role of financial institutions in assessing and addressing biodiversity risks (Network for Greening the Financial System, 2019). While the NGFS primarily focuses on climate-related risks, in its 'Statement on Nature-Related Financial Risk'[6], it recognizes that nature-related risks, including biodiversity loss, could have significant macroeconomic implications, and that failure to account for, mitigate, and adapt to these implications is a source of risks relevant for financial stability. Hence, the NGFS highlights the need for a research-based assessment of the implications of biodiversity loss and subsequently announced the creation of a task-force to mainstream the consideration of nature-related risks in the coming year. The NGFS and the International Network for Sustainable Financial Policy Insights, Research and Exchange (INSPIRE) have established a joint NGFS-INSPIRE Study Group on Biodiversity and Financial Stability (NGFS and INSPIRE, 2022).

[5] Media coverage by the Financial Times, and recurrent citation at the World Biodiversity Summit, 21.09.2023.
[6] NGFS media archive.

The group pursues to understand how biodiversity loss threatens financial stability and provides a list of recommendations for central banks and financial supervisors to address nature-related risks in financial systems. This includes the development of suitable metrics, biodiversity-related scenario analyses and stress tests.

Lastly, the Dasgupta Review on the Economics of Biodiversity (Dasgupta, 2021) brings forward the importance for financial regulators and central banks to explore both the micro-prudential and macro-prudential consequences of nature-related financial risks. Stress tests are recommended to analyze the potential systemic risk arising from biodiversity loss and ecosystem degradation for the financial sector as a whole and individual financial institutions.

In conclusion, the policy framework is evolving and there is a growing recognition among financial regulators, policymakers, and international institutions regarding the significant risks posed by biodiversity loss to the financial system. Supervisors and policy makers should be equipped with suitable metrics and quantitative methods to enhance the understanding and management of biodiversity-related risks and their impact on the financial system.

## 3 Data inputs

In this section, a comprehensive overview of the data inputs used for our analysis is given. We begin by explaining the sources from which the data was obtained, followed by providing descriptive details regarding our datasets.

### 3.1 Data sources

The syndicated loans market often serves as a tool to understand bank lending policies and their effects, particularly when other credit information or aggregated data is lacking (Aramonte et al., 2015).[7] Although they represent only a portion of a bank's total lending, they offer to non-financial firms an alternative form of debt financing compared to bilateral lending or corporate bonds (Bardell et al., 2018). A syndicated loan is in fact a financing offered by a syndicate made up of a group of lenders that work together to provide funds for a borrower.[8] Syndicated loans not only alleviate the balance sheet restrictions of a single bank, but also reduce the concentration of risk by spreading the exposure among several lenders (Cerutti et al., 2015). Smaller lenders can also benefit from loan syndication by leveraging the informational advantages of larger banks

[7] Syndicated lending manifests an essential source of unrestricted large-scale lending for which a syndicate of multiple creditors, i.e. mainly commercial banks, issue a loan agreement to a borrower.

[8] Credit agreements involve multiple lenders which operationally arrange separate tranche payments. The collective sum of the individual disbursements by all lenders adds up to the full tranche amount.

and by diversifying their loan portfolios across different borrowers and countries.

Given that these contracts have a longer maturity period[9], the long-term risk of biodiversity exposure becomes a crucial factor that cannot be ignored. Hence, our focus is on syndicated loans extended by lenders located in the EU27 countries, as well as the United Kingdom, to global borrower between 2017 and 2022.

Credit data and information on lenders are sourced from Refinitiv's product Loan Connector, a market-leading source of comprehensive, real-time, and historical data on the global loan markets. The database contains comprehensive information of each syndicated loan and its corresponding tranches. This includes details such as the activation year, the number of lenders participating with their respective shares, the transaction amount along with the corresponding currency and spread margin, as well as the name of the borrowers.

We strive to integrate environmental considerations into our modelling framework, by incorporating information regarding the nature-related exposure of the borrowing firms. The information is sourced from MSCI,a private data provider focused on biodiversity and natural capital metrics, which assists investors in identifying and quantifying potential portfolio risks related to biodiversity.

We use the MSCI indicator Geographic Segment Exposure to Fragile Ecosystems to proxy the level of impact that economic activities of borrowers have on biodiversity.This indicator shows for each of the company's geographic segments the extent to which its operations are in areas with biodiversity sensitivity (high, medium, low).[10] It is important to note that this indicator can vary for a firm depending on its location. As a matter of fact, when firms operate in fragile ecosystems or areas under significant natural resource stress, such as extensive deforestation, they may face increased risk, as efforts to mitigate environmental impacts may lead to financial losses and operational adjustments. The transition risk can result from changes in policies, technologies, and consumer (or investor) preferences. For instance, if stricter regulations limit the use of harmful chemicals in a specific area, companies may experience an increase in compliance cost as they may need to invest in new technologies to mitigate their impact on the environment as well as develop sustainable practices. Therefore, firms with multiple production sites mostly have them in different locations and even continents, scoring more than one value for this indicator.[11]

[9] Short-term deals below 1 year are excluded.

[10] Retrieved in January 2023.

[11] Given the geographical nature of the original MSCI metric, in this paper we focus on the analysis of the

MSCI has been releasing this information since 2020 and offers a one-time account of firm's biosphere records without a follow-up creating a time-series. Hence, we assume that the biodiversity score remains invariant over time due to the inherent stability of ecosystems and the gradual pace at which nature alters.[12] By linking firms engaged in syndicated loan transactions with the corresponding biodiversity indicator from MSCI and excluding those firms with missing biodiversity indication, we produce a comprehensive sample of borrowers from various locations worldwide which allows us to analyze the relationship between nature-related exposure and their financing institutions.[13]

We further enhance this sample by including financial information of the borrowers involved, such as operating revenue and total assets. To obtain this data, we rely on the Orbis database, a proprietary product on firm financial statements provided by Bureau van Dijk. It offers comprehensive and reliable information on various financial metrics for companies worldwide.

### 3.2 Samples construction and data description

Our analysis has two primary objectives. Firstly, we aim to evaluate the impact of nature-related exposure on financing institutions from a lender perspective. We measure the extent to which the nature-related exposure of borrowers affects these institutions. Secondly, we seek to examine the correlation between the cost of credit and the nature-related risk that firms themselves are exposed to, from a borrower perspective. To achieve these objectives, we create two sub-samples from the larger sample of firms identified above,[14] where the information on the MSCI indicator and syndicated loans is complemented with a set of financial variables for each borrower necessary to address the research questions (see Figure 1). In this section, we report the summary statistics of our sub-samples, alongside describing the main variables of interest at the loan level.

We use Sample 1 (the lender-centric sub-sample) to analyze the exposure of lenders to nature-

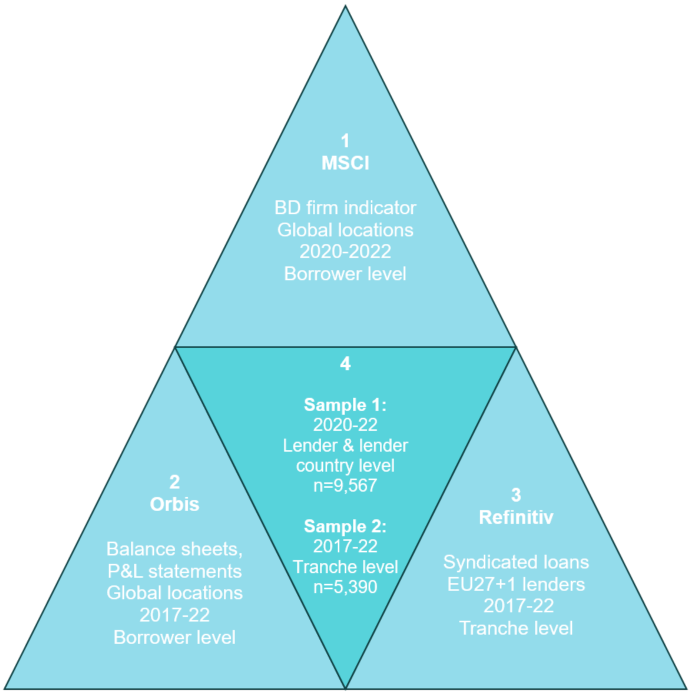
geographical dimension of biodiversity-related risk, not on sectoral or business-segment analysis.

[12]Holding the biodiversity score constant over a time interval feeds from the factual delay and slowness in the responsiveness of an ecosystem to certain factors of change. Adding to the inertia of the biodiversity status, it is not in synchrony with environmental change and detectable warning signals in approach of irreversible thresholds are absent. Altogether, the biosphere neither demonstrates tipping responses nor is as fast moving as records of climate change (Hillebrand et al., 2023).

[13]We merge the MSCI indicator and associated data with the loan information from Loan Connector based on the identifiers of the firms in MSCI (the LEI, or Legal Entity Identifier, the ISIN, or International Securities Identification Number, and the ticker). We identify roughly 1,400 companies using this approach. In few instances where all these identifiers are missing, we manually cross-checked the missing identifiers by reverting to firm names on https://www.lei-lookup.com.

[14]Our sample of reference consists of the firms with a populated MSCI indicator on biodiversity which are merged with syndicated loan transactions.

**Figure 1:** Dataset origin & properties – Synthesis of lender-centric and borrower-centric sample




related shocks. This sub-sample consists of firms equipped with a biodiversity indicator by MSCI, also being engaged in syndicated loan transactions, and for which information on revenue is available, this facor being necessary to aggregate the MSCI information of different locations for each borrower. Specifically, it is composed of 1,404 global borrowers, located in 61 countries, mainly in the EU and US, and 318 lenders which are domiciled in Europe (see Table 1). We group the financing institutions into five European regions: Nordic EU, Central EU, South EU, East EU, and United Kingdom (see country breakdown in Table A1.) Since Sample 1 is used to analyze the current level of exposure to biodiversity risk, we focus on recent loans issued between 2020 and 2022. Within this time frame, we identify a total of 9,567 loan transactions at the tranche level. The majority of these transactions originate from European Union countries, as EU lenders account for 75% of the full sample. Around half of the transactions are directed to EU borrowers, while 40% of the total transactions finance borrowers located outside a European country (US or other global locations).

To examine the relationship between biodiversity exposure and the cost of credit for the borrowers more in depth, we require additional firm-level controls, including balance sheet data as well as profit and loss statement data. Consequently, the number of borrowing firms decreases further, as we exclude those firms with missing information. This results in Sample 2 (the borrower-centric subsample) used to analyze the impact of nature-related risk on the cost

**Table 1:** Sample 1 (lender-centric) – 2020-2022

| | Count | Share (in %) |
|---|---|---|
| Unique borrowers | 1,404 | |
| Unique lenders | 318 | |
| Tranche transactions (2020-2022) | 9,567 | 100.00 |
| Country coverage | | |
| Borrower (global) | 61 | |
| Lender (EU27 + 1)† | 22 | |
| Allocation of loans among borrowers | | |
| EU | 4,855 | 50.75 |
| UK | 858 | 8.97 |
| US | 2,507 | 26.20 |
| Other global location | 1,347 | 14.08 |
| Allocation of loans among lenders | | |
| Nordic EU | 431 | 4.51 |
| Central EU | 5,131 | 53.63 |
| South EU | 1,547 | 16.17 |
| East EU | 104 | 1.09 |
| UK | 2,345 | 24.61 |

† Omission of some EU member states due to lack of coverage during the sample period (Bulgaria, Croatia, Cyprus, Latvia, Lithuania, Slovenia)

of credit (see Table 2). This sample comprises 630 borrowers located in 40 countries and 230 lenders in 19 countries. Sample 2 is specifically used to analyze price dynamics before and after the creation of our nature-related metric. Hence, we consider all transactions between the identified borrowers and lenders that were activated from 2017 onwards. Within this time period, Sample 2 consists of 5,390 loans, of which more than half were activated after 2020. From the lenders side, the distribution of the loans across countries remains very similar to that observed in Sample 1, while the share of loans among EU borrowers increases by 10%.

To analyze price changes over time, the main variable of interest is the margin of the loans. In Table 3, we present summary statistics of the syndicated loan margin. While the mean and the median values are very similar, the range of values extends from 17.5 basis points to 775 basis points, primarily due to few outliers at the upper end of the range. To address any potential skewness caused by these outliers, and to linearize the distribution, we estimate the baseline results using the natural logarithm of the margin of which the statistics are also reported in Table 3.

Figure 2 illustrates the average margin of syndicated loans over time, distinguishing between deals within the EU27 and deals involving the UK or any other country outside the EU27 (deal outside EU). The data shows that deals closed within the EU have a higher margin after the introduction of the biodiversity score in 2020. This first descriptive suggests that the biodiversity indicator provided by MSCI may contribute to the risk assessment made by investors and lenders when evaluating their debtors.

**Table 2:** Sample 2 (borrower-centric) – 2017-2022

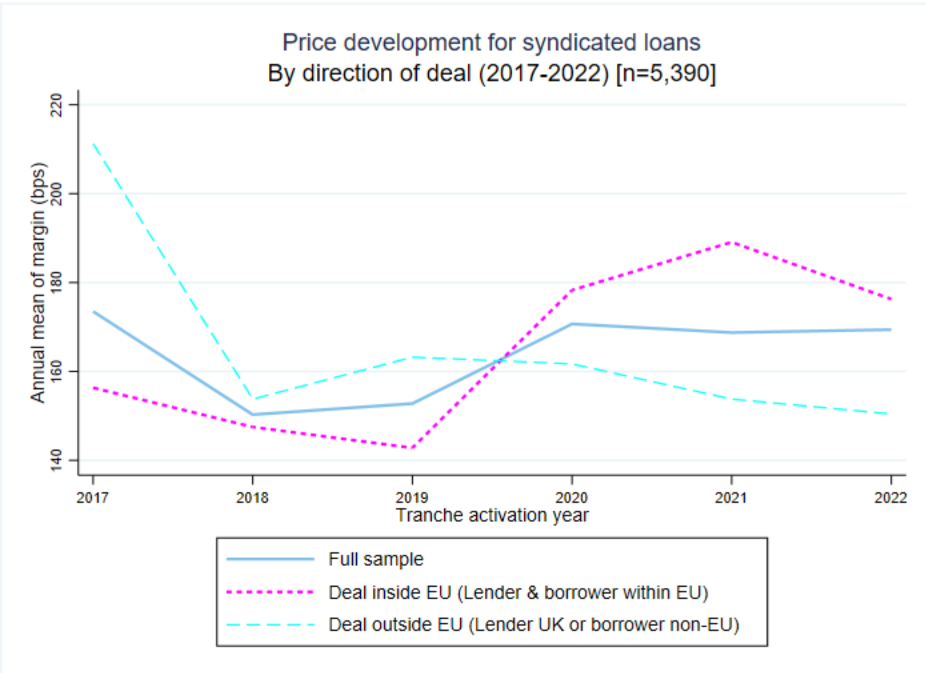
| | Count | Share (in %) |
|---|---|---|
| Unique borrowers | 630 | |
| Unique lenders | 230 | |
| Tranche transactions (2017-2022) | 5,390 | 100.00 |
| Loans activation | | |
| 2017 | 96 | 2.29 |
| 2018 | 616 | 14.69 |
| 2019 | 1,044 | 24.90 |
| 2020 | 787 | 18.77 |
| 2021 | 1,649 | 39.34 |
| 2022 | 1,183 | 21.95 |
| Country coverage | | |
| Borrower (global) | 40 | |
| Lender (EU27 + 1)[†] | 19 | |
| Allocation of loans among borrowers | | |
| EU | 3,408 | 63.32 |
| UK | 447 | 8.29 |
| US | 1,068 | 19.81 |
| Other global location | 467 | 8.66 |
| Allocation of loans among lenders | | |
| Nordic EU | 199 | 3.69 |
| Central EU | 2,866 | 53.17 |
| South EU | 1,091 | 20.24 |
| East EU | 15 | 0.28 |
| UK | 1,219 | 22.62 |

[†] Omission of some EU member states due to lack of coverage during the sample period.

**Table 3:** Distribution of the dependent variable – Sample 2 (2017-22)

| | Mean | Sd | P50 | P75 | P95 | Min | Max |
|---|---|---|---|---|---|---|---|
| Margin (bps) | 164.02 | 76.34 | 163.84 | 200.00 | 275.00 | 17.50 | 775.00 |
| Log of margin (bps) | 4.98 | 0.55 | 5.10 | 5.30 | 5.62 | 2.86 | 6.65 |
| **Observations (tranches)** | 5,390 *(full Sample 2)* | | | | | | |

**Figure 2:** Price development for syndicated loans – By deal direction in-/outside EU (2017-22)



Other features of the loans are available in Table 4. As a key loan characteristic, the average maturity of the loans in the sample scores more than 4 years,[15] with an average value of loans of around 13 thousands, and a term spread of 0.4.[16] The table also lists borrower characteristics. The firm size is proxied by the borrowers' total assets, and the operating revenue informs about its profitability.[17] Based on Ehlers et al. (2022), we also integrate the creditworthiness of each borrower by relying on three major rating agencies: Standard and Poor's (S&P), Moody's, and Fitch.[18] The outcome of this scale alignment is a harmonized borrower rating. The average harmonized rating is roughly 12, corresponding to an S&P rating of BBB-. The range of harmonized borrower ratings in our sample spreads from a minimum of 0 (Default), to a maximum of 19 (AA in the S&P rating scale). The composition of the industrial landscape can be drawn from the sectoral coverage of borrowing firms in Table A2.

Lastly, Table 4 shows that on average 14 lenders participate to a loan syndication. The last metric of interest is the loan ratio of the lender to the lender country, which signals the size of each creditor with respect to the syndicated loan market of the lender country. It reaches 23%.[19]

**Table 4:** Descriptive statistics of main control variables – Sample 2 (2017-22)

| **Continuous variables** | Mean | P50 | Sd | Min | Max |
|---|---|---|---|---|---|
| *Loan characteristics* | | | | | |
| Log of loan amount (thd €) | 13.47 | 13.62 | 1.33 | 8.41 | 16.30 |
| Log of deal amount (thd €) | 14.01 | 14.14 | 1.10 | 9.62 | 16.71 |
| Loan duration (years) | 4.78 | 5.00 | 1.32 | 1.00 | 12.00 |
| Termspread | 0.36 | 0.31 | 0.67 | -2.50 | 2.67 |
| *Borrower characteristics* | | | | | |
| Harmonized borrower rating | 12.10 | 12.00 | 2.87 | 0.00 | 19.00 |
| Log of total assets (thd €) | 16.76 | 16.68 | 1.39 | 9.69 | 20.65 |
| Log of operating revenue (thd €) | 15.88 | 15.92 | 1.55 | 6.63 | 19.38 |
| *Lender characteristics* | | | | | |
| Lender # | 14.52 | 13.00 | 8.66 | 1.00 | 42.00 |
| Loan ratio lender to lender country | 22.77 | 17.55 | 17.94 | 0.00 | 91.54 |
| **Observations (tranches)** | | 5,390 *(full Sample 2)* | | | |

[15]The tenor is the number of years from the activation date up to the maturity of the loan. While the maximum tenor in theory is unrestricted, since eternal repayments exist, the sample cut-off has been set at 30 years due to the matching with the complementary variable 'Yield', as well as the computation of the term spread.

[16]The term spread is defined as the difference between the interest rate of a government bond with an equivalent maturity to the syndicated loan and the reference rate of the syndicated loan in the currency of denomination. We obtain government bonds data from either national central banks or Bloomberg.

[17]The choice of the fiscal year for financial accounts from Orbis is determined by the release year of the biodiversity indicator on MSCI.

[18]If S&P is not available, we first revert to the Moody's rating, otherwise to Fitch's assessment. To make the divergent rating scales by these agencies comparable, we use an ordinal variable ranging from 0 to 21, where 0 represents a default grade and 21 represents the highest investment grade.

[19]It puts the lender (numerator) and lender country (denominator) into perspective by dividing the lender share of accumulated syndicated loans by the total amount of syndicated loans per country for Sample 2 (2017-22).

## 4 Computation of the biodiversity exposure score

This section explains how we assess the level of risk that EU lenders face when lending to borrowers around the world, and who are exposed to nature-related risks. To do this, we conduct a study using Sample 1 to first analyze the exposure of identified borrower and then examine the spillover effect to EU lenders.

### 4.1 Biodiversity exposure score at the borrower level

For borrowers, nature-related exposure refers to the degree to which their business activities and operations are vulnerable to environmental risks. According to the MSCI database, a borrower may have different levels of biodiversity sensitivity depending on where its branches are domiciled. The indicator is in fact location-specific. To calculate one 'biodiversity exposure score' for each borrower – the borrower score – we aggregate the MSCI values by computing a weighted average based on the size of the operating revenue of the borrower across regions. First, we determine the annual operating revenue ($OR_{i,n}$) generated by each borrower $i$ in a specific area $n$:

$$OR_{i,n} = TR_{i,n} * RS_{i,n}, \quad (1)$$

where $TR_{i,n}$ is the total operating revenue of the firm as reported by Orbis, and $RS_{i,n}$ is the share of revenue produced by the borrower in that location $n$, as reported in the MSCI database. After, we calculate the final biodiversity exposure score of each borrowing firm $i$ ($BD\ \ score_i$). This is done by weighting the biodiversity exposure score of borrower $i$ in a specific location $n$ ($GeoBD\ \ score_{i,n}$) by the operating revenue ($OR_{i,n}$) of borrower $i$ in the same location $n$:

$$BD\ \ score_i = \frac{\sum_{n=1}^{N} GeoBD\ \ score_{i,n} * OR_{i,n}}{\sum_{n=1}^{N} OR_{i,n}}. \quad (2)$$

The overall score assigned to each firm is a continuous variable that falls within a range of 1 to 3, and is used to assess and categorize the level of biodiversity exposure with higher values indicating a greater potential involvement in biodiversity-related matters. Specifically, a score of 1 indicates a low exposure to biodiversity, while a score of 3 reflects a high exposure to biodiversity.

Table 5 provides an overview of the borrower position across four macro regions: the EU, the UK, the US, and other global locations. The data reveals that around half of the European syndicated loans have been granted to EU borrowers, followed by borrowers in the US and other regions.

On average, all regions exhibit a biodiversity score of 2.2, indicating a moderate level of risk. However, US borrowers stand out, demonstrating both a higher exposure to biodiversity risks and greater variability compared to their counterparts in the EU and UK (with a standard deviation of 0.17, surpassing the EU and UK's 0.14 deviation). These differences can be attributed to the distinct geographical characteristics of each region. European countries boast moderate variations in temperature, climate, and ecological setups. In contrast, the US and other global locations offer extreme climate zones and more fragile ecosystems, like deserts and tropical forests, and this translates into higher nature-related risk exposure of their local borrowing firms.

**Table 5:** Descriptive statistics of biodiversity score of lenders by borrower regions – Sample 1 (2020-22)

| **BD score** | Mean | P50 | Sd | Min | Max | Tranches |
|---|---|---|---|---|---|---|
| **EU** | 2.15 | 2.12 | .14 | 1 | 2.65 | 4,855 |
| **UK** | 2.22 | 2.18 | .14 | 1.92 | 2.65 | 858 |
| **US** | 2.37 | 2.34 | .17 | 1.92 | 3 | 2,507 |
| **Other global location** | 2.23 | 2.2 | .2 | 1 | 3 | 1,347 |
| **All borrower regions** | 2.22 | 2.18 | .18 | 1 | 3 | 9,567 |
| **Observations** | 9,567 *(full Sample 1)* | | | | | |

## 4.2 Biodiversity exposure score at the lender and country level

As the nature-related risks of borrowing companies may be transmitted to their financing institutions, lenders themselves are also exposed to nature-related risks. For instance, if a lender has a significant loan portfolio exposed to industries highly dependent on natural resources, their financial stability and profitability may be at risk. Our method thus calculates the scores ($BD\ score^l_j$) for each lender $j$ by weighting the biodiversity score $BD\ score_i$ of the firms borrowing from that lender by their loan amount by tranche $tranche_{i,j}$[20]:

$$BD\ score^l_j = \frac{\sum_{i=1}^{I} BD\ score_i * tranche_{i,j}}{\sum_{i=1}^{I} tranche_{i,j}} \quad (3)$$

The methodology assigns more riskiness to lenders that have provided larger credits to borrowers with higher biodiversity exposure scores. The rationale behind this is that lenders who have extended substantial loans to borrowers with high biodiversity exposure may be more vulnerable to nature-related risks due to their financial support.

To determine the countries with a greater concentration or quantity of risky financial institutions, we gather and combine data from the lenders operating within each country. By summing up the final biodiversity exposure scores of lenders within a specific country, we evaluate the

[20] We recall that Sample 1 considers tranches between 2020 and 2022.

overall level of biodiversity risk associated with lending activities in that particular country. We compute the biodiversity score for each country $c$ weighting the biodiversity score $BD\ \ score^l_j$ by the loans of all lender institution located in country $c$.

**Figure 3:** Map of biodiversity exposure of syndicated loans – Sample 1 (2020-2022)

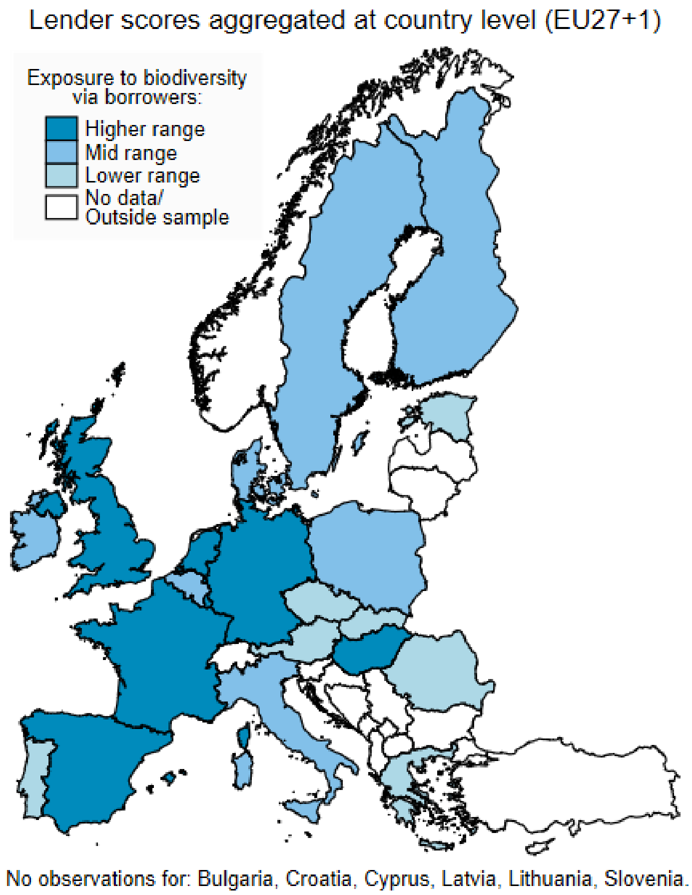



Figure 3 showcases the aggregated biodiversity exposure of lenders in each EU27 country and the UK. Based on a sample of global firms financed by syndicated loans, the map offers an intuitive understanding of the concentration and distribution of nature-related risk within the financial sector. The results shows that the lenders in Germany, France, Luxembourg, Netherlands, Spain and UK have the highest exposure to biodiversity through their participation in the syndicated loans market. When comparing with the size of the loans, we observe that countries with a more developed syndicated loan market are also those with higher biodiversity risk exposure. Specifically, the UK, France, Germany and Spain account for almost 75% of our sample, and when including the Netherlands and Italy, this figure reaches 90%. As our analysis focuses on a specific fraction of international financial flows, it is challenging to determine the extent to which our results can be generalized to the entire spectrum of international financial flows.

Consequently, while our findings indicate a high biodiversity exposure in a country through the syndicated market, it does not automatically imply a potential systemic risk for the financial system as a whole.

## 5 Exploring the link between biodiversity risk and loan pricing

### 5.1 The model

By evaluating the exposure of borrowers and understanding the potential risks posed by environmental factors, lenders could make informed decisions about financing activities and effectively manage their own exposure to nature-related risks. Banks typically assess and price any significant risk that could impact a borrower's ability to repay a loan, including climate or nature-related risks. A study by Ehlers et al. (2022) reveals that borrowing firms with higher carbon footprints have faced a risk premium in the syndicated loan markets since the Paris Agreement. This indicates that carbon risks are being taken into account and priced by lenders. In a similar vein, we aim to investigate whether banks have started incorporating the pricing of nature-related financial risks, given the increasing awareness and likelihood of their materialization. To do this, we examine the dynamic behaviour of loan prices to determine if there has been a significant reaction to the introduction of the MSCI indicator.

We argue that the borrowers with high exposure to nature-related risks should receive higher loan prices, and this relationship should have become more evident after the publication of the MSCI indicator. Our main hypothesis is that the biodiversity indicator contributes to the variation in loan prices among borrowers. To assess this, we use Sample 2 and specifically examine the interest margin of its syndicated loans (from 2017 onwards), which serves as a proxy for the credit risks priced by banks. Our model is configured as follows:

$$margin_{ijbl,t} = \alpha + \beta(BD\ \ score_{b,t} \times Score\ \ issuance_{b,t}) + \gamma X_{ij,t} + \delta_i + \psi_j + \mu_b + \varphi_l + \tau_t + \varepsilon_{ijbl,t}, \quad (4)$$

where we use $i$ to refer to the individual tranche, $j$ to represent the individual loan, $b$ to identify the borrowing firm, $l$ to indicate the lender, and $t$ to refer to the time. In the model specification, the dependent variable is denoted as *margin*, which refers to the interest margin of a specific tranche and the independent variable is the *BD score*, which refers to the biodiversity score computed at the borrower level. Additionally, we include the variable *Score issuance* in the model composition, which takes into account whether the tranche of a loan was activated before, during the same year, or after the issuance of the *BD score* for the firm the loan was syndicated to:

$$Score\ \ issuance_{b,t} = \begin{cases} 0 & \text{if t>year of tranche activation of loan j} \\ 1 & \text{if t=year of tranche activation of loan j} \\ 2 & \text{if t<year of tranche activation of loan j} \end{cases} \tag{5}$$

While our sampling includes tranches activated as early as 2017, MSCI started to publish the indicator from 2020 onwards. Table 6 informs about the relative timing of issuance of the *BD score* and tranche activation. The majority of tranches have been activated before the *Score issuance* (47%), implying a post-existent *BD score*, while 31% of tranches have been extended in the same year. Pre-existence of the *BD score* applies to 21.58% (21.28% 1 year prior and 0.3% 2 years prior respectively).

**Table 6:** Timing of score issuance relative to tranche activation – Sample 2 (2017-22)

| Score issuance | **Tranches** | **Share (in%)** |
|---|---|---|
| **Post-existent** | 2,556 | 47.42 |
| Same year | 1,671 | 31.00 |
| 1 year prior | 1,147 | 21.28 |
| 2 years prior | 16 | 0.30 |
| **Pre-existent** | **2,834** | **52.58** |
| **Observations** | 5,390 *(full Sample 2)* | 100.00 |

We account also for the control variables denoted as **X**, such as loan-, borrower-, and lender-characteristics listed in Table 4. Importantly, Equation 4 includes a set of fixed affects to capture specific unobserved shocks. In particular, $\delta$ indicates fixed effects for tranches, $\psi$ for loans, $\mu$ for borrowers, $\varphi$ for lenders and $\tau$ denotes the year fixed effects. Furthermore, we introduce categorical variables to the model in order to capture additional factors that may influence the results. These variables represent whether the loan is categorized as a conventional or unconventional types of loan by the borrower, whether both parties are EU-located, and those in which one or both are extra-EU domiciled, the macro region of the borrower (US, UK, EU, Other), and the European lender macro region (EU: Nordic, Central, South, East; UK). Finally, $\varepsilon$ is the zero-mean error term.

### 5.2 Estimation results

Table 7 presents the estimates obtained through an iterative process of constructing the model specification. This process involved adding variables one by one across columns (1) to (7), which represents the complete configuration of regressors. The purpose of this procedure is to assess the impact of group-specific controls, fixed effects (FE), and other variables of interest on the model's fit to the data. The table provides information on the proportion of variance in the dependent variable that can be explained by the independent variables, which is represented by the $R^2$ value. A higher $R^2$ indicates a better fit of the data to the model. Additionally, the table also indicates the overall significance of the model, which is assessed through an $F-test$. With respect to standard errors, their unit of clustering occurs at the level of unique lenders (230 groups), following a larger unit of aggregation, which is favorable compared to smaller ones like unique borrowers (630, see Table 2) or unique tranches (1,188). The coefficients are presented for a log-level model, with the dependent variable being the logged margin.[21]

**Table 7:** Estimations of ln(margin) – Iterative model construction, Sample 2 (2017-2022)

| | (1) | (2) | (3)$^\star$ | (4)$^\star$ | (5$^\star$) | (6)$^\star$ | (7)$^\star$ |
|---|---|---|---|---|---|---|---|
| BD score × Score issuance | | | | | | | |
| Post-existent | 0.00987 | -0.00189 | 0.0515** | 0.0523** | 0.0514** | 0.0504* | 0.0495* |
| | (0.34) | (-0.08) | (2.05) | (2.04) | (2.04) | (1.96) | (1.96) |
| Same year existent | 0.115*** | 0.0969*** | 0.143*** | 0.144*** | 0.147*** | 0.144*** | 0.147*** |
| | (4.05) | (3.46) | (4.80) | (4.73) | (4.81) | (4.57) | (4.64) |
| 1+ year pre-existent | 0.164*** | 0.112*** | 0.201*** | 0.201*** | 0.203*** | 0.197*** | 0.199*** |
| | (4.75) | (2.88) | (4.78) | (4.77) | (4.84) | (4.77) | (4.85) |
| Conventional loan | No | No | No | No | No | Yes | Yes |
| Inside EU | No | No | No | No | Yes | No | Yes |
| Borrower region | No | No | Yes | Yes | Yes | Yes | Yes |
| Lender region | No | No | No | Yes | Yes | Yes | Yes |
| *Characteristics* | | | | | | | |
| Loan-related | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Borrower-related | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Lender-related | No | Yes | Yes | Yes | Yes | Yes | Yes |
| $R^2 overall$ | 0.355 | 0.397 | 0.415 | 0.416 | 0.418 | 0.417 | 0.419 |
| $R^2 adjusted$ | 0.345 | 0.387 | 0.404 | 0.405 | 0.407 | 0.406 | 0.408 |
| $F-test$ | 10.842 | 29.383 | 45.098 | 35.149 | 35.749 | 39.900 | 37.831 |
| Observations$^\dagger$ | 5,383 | 5,383 | 5,383 | 5,383 | 5,383 | 5,383 | 5,383 |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$.
Clustered at lender level (Standard errors in parentheses).
$^\star$Absorbed FE:
Loan-related FE (Loan type, tranche & deal activation year)
Borrower-related FE (Firm private n/y, NACE2 industrial sector, BD score issuance year)
Lender-related FE (Bank n/y, lender & lender parent operating region)
$^\dagger$ 7 singletons were removed in the estimation from full Sample 2.

Columns (1) and (2) present the estimation results without fixed effects. In the first column, only the interaction term of *BD score* × *Score issuance* is considered, without any other variables. In the second column, the model includes additional controls for loan-, borrower-, and lender-related characteristics. In both columns, the interaction term has a positive and highly significant coefficient for two out of the three categories (levels 'Same year existent' and '1+ year existent'). Specifically, in the model with controls (Column (2)), when a tranche is activated in the same

[21]Coefficients are to be interpreted after multiplying with 100 in order to arrive at the percentage change.

year that the *BD score* was issued for a borrower, the loan margin increases by 9.69 basis points, holding all other variables constant. When the *BD score* existed before the activation of a loan tranche by one or more years ('1+ year pre-existent' level of interaction term), the effect is even more pronounced at 11.2 basis points. On the other hand, for tranches issued when the biodiversity risk metric did not exist for a firm ('Post-existent' level of interaction term), it appears that the risk is not taken into account by loan syndications. However, once the indicator becomes available and informs investor's lending decisions, the potential biodiversity risk is factored in (second and third level of interaction term). The longer the *BD score* is issued prior to a tranche activation, the greater its impact on the pricing. These initial results from a reduced model specification align with our expectations and suggest that biodiversity exposure and the associated risks may significantly contribute to lenders' risk evaluation of new loans.

Including fixed effects (Column (3)) and regional controls on the borrower and lender location (Columns (3) and (4)) strengthens the effect of the *BD score*. The coefficient for the *BD score* increases in magnitude while remaining highly significant. For the same year existence category, the coefficient increases by approximately half of the previous value (14.3 and 14.4 basis points, respectively), and doubles for the pre-existence category (20.1 basis points). Interestingly, the coefficient for the post-existent *BD score* (score issued after the tranche activation) is also positive and significant, but much smaller in absolute terms compared to the other levels of the interaction term. This indicates that investor awareness of biodiversity and other nature-related risks existed even before the MSCI risk assessment. It is thus possible that reliance on other sources or associated information on natural capital influenced lending and pricing decisions before specific biodiversity metrics were established.

To further investigate the impact of the relative location of borrowers and lenders on loan pricing, we introduce a dummy variable that indicates when the tranche is issued within the EU, meaning between a borrower and a lender both headquartered in one of the EU27 countries.[22] Column (5) shows that the inclusion of the *Inside EU* variable slightly strengthens the effect of the *BD score* for the same year and pre-existence categories. Overall, the results remain broadly consistent with those in Column (4).

The last control variable we introduce is *Conventional loan*, a categorical variable indicating whether the loan is classified as conventional, green, or sustainable.[23] We observe that in the

[22]For consistency, we apply the EU27 composition to the pre-Brexit years 2017-2019.

[23]In the database, this variable is referred to as 'Market segment of loan', and we consolidate various types such

previous specifications, the effect of the *BD score* has partially absorbed the effect of the *Conventional loan.* In Column (6), the coefficient size of the interaction term slightly decreases, while the *Conventional loan* variable remains highly significant with a positive contribution of the two unconventional categories.[24] Extracting this effect brings forward that it is essential to account for novel instrument types that reflect greater perceived riskiness by investors. Failing to include these types would inflate coefficients, particularly the coefficient of the *BD score* variable.[25]

Lastly, when testing the full variable selection (Column 7), that includes *Conventional loan*, *Inside EU* and the other control variables and fixed effects, the results on the *BD score* remain consistent.

Figure 4 provides a visual representation of the results obtained from the comprehensive model presented in Column 7 of Table 7. It illustrates the marginal effect of borrowers' *BD score*, ranging from low to high values, on the loan price. The plot shows a consistently positive and increasing marginal effect across the entire range of values, with a 95% confidence interval. The vertical lines indicate the median, 75th percentile, and 95th percentile of the *BD score* distribution for borrowers in Sample 2. These lines reveal that the majority of borrowers in the sample have a medium to high level of biodiversity exposure, ranging from 2.0 to 2.9.

### 5.3 Robustness

Our findings are statistically robust and remain unaffected when using different controls and specifications. To enhance the analysis, we make a minor transformation to the interaction term. Instead of categorizing *Score issuance* into three levels, we create a dummy variable that combines cases with the same year and pre-existence into one category. The results in Table A3 demonstrate that in this combined category, referred to as 'Pre-existent', the *BD score* remains highly significant across all iterative model specifications. Furthermore, the magnitude of the effect increases from 11.9 basis points in Column (1) to 15.5 basis points in Column (7).

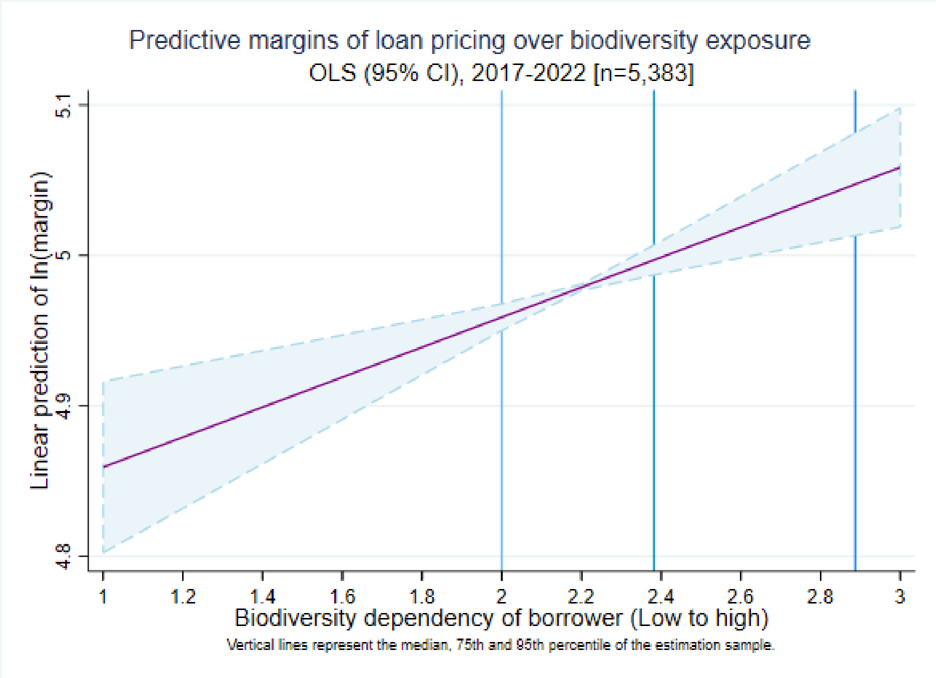
Furthermore, we perform additional regressions using the loan margin as the dependent variable in levels instead of logs, as depicted in Table A4. For the sake of clarity, we present the complete variable specification with explicit coefficients for all covariates.

as Asset-based, Covenant, Lite, Leveraged, etc., into the 'Conventional' category for our analysis. Sample 2 is composed of 66.18% conventional, 1.52% green, and 32.3% sustainable loans.

[24]The 'Green loan' type contributes 14.1 basis points, while the 'Sustainable loan' type contributes 3.02 basis points (Table A5 Column (2)). The reference category is 'Conventional loan'.

[25]To improve estimation accuracy, targeted measures of physical risk could be incorporated to balance the model composition.

**Figure 4:** Predicted prices and biodiversity exposure of global borrowers (Sample 2)




Finally, to further ensure the robustness of our analysis, we include fixed effects at the lender level. By pooling the OLS regression based on the lender identifier, we are able to account for constant features specific to recurrent lenders, even without a time series structure as in a panel dataset (see Table A5). In this pooled OLS configuration (Columns (3) and (4)), most standard errors (SE) appear to be smaller, indicating a decrease in the discrepancy between the sample estimate and the true value in the population. However, there are a few exceptions, such as slightly larger SE in loan characteristics, which can be considered negligible. Additionally, the lender characteristics (loan ratio) show both inflated coefficients and increased significance in both columns, suggesting the capture of lender-specific effects and how each lender performs in relation to the domestic market of syndicated loans.

## 6 Discussion and conclusion

This paper makes a valuable contribution to the ongoing discussion surrounding the risks associated with nature and biodiversity for borrowers and lenders. Our study examines the impact of these risks on the syndicated loans market in the European Union, focusing on globally operating firms with lenders based in the EU and the United Kingdom.

Our analysis begins by constructing a measure of biodiversity exposure for European lenders. The results demonstrate that the level of exposure varies across countries and is influenced by factors such as borrower location and loan size.

Moving forward, we obtain three conclusions inspecting syndicated loans issued between 2017 and 2022. Firstly, there is a significant and positive correlation between the score of biodiversity exposure and the price of syndicated loans. This evidence highlights the need for further research in this area to enhance the data on natural capital and develop more refined indicators of biodiversity exposure. These indicators can inform practitioners on their investment decisions and incorporate nature-related spillovers as a factor for credit risk evaluation.

Moreover, the location of lenders and borrowers plays a crucial role in assessing potential biodiversity risks. When we control for the location of borrowers and lenders, we observe that the coefficient of the biodiversity score grows in magnitude and significance, and this effect is even stronger when we distinguish inside EU transactions from extra-EU deals. This suggests that the European financial sector is responsive to the efforts of regulators and policymakers in quantifying nature-related risks.

Additionally, lenders appear to place greater emphasis on nature-related risk when issuing green or sustainable loans.This finding is important for EU policymakers, since the EU debt market is currently the largest for green bonds, and the EU Commission is introducing new regulations to structure green finance instruments in line with the European Green Deal. If nature-related risk is a significant component in pricing unconventional loan types as green ones, accurate quantitative metrics of this risk will be valuable for policy design.

As the understanding of nature-related risks continues to evolve, further research and analysis are necessary to build a more robust knowledge base. By exploring the connections between natural capital, biodiversity loss and financial risks, researchers can contribute to the development of effective risk assessment tools for investors, mitigation strategies for corporations, and policy frameworks that promote long-term stability.

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# Appendix

## A Data description

**Table A1:** Country breakdown of lender regions (EU27+1)

| # | Region | Country |
|---|---|---|
| | *EU* | |
| 1 | Nordic | Denmark |
| 2 | Nordic | Estonia |
| 3 | Nordic | Finland |
| 4 | Nordic | Latvia |
| 5 | Nordic | Lithuania |
| 6 | Nordic | Sweden |
| 7 | Central | Austria |
| 8 | Central | Belgium |
| 9 | Central | France |
| 10 | Central | Germany |
| 11 | Central | Ireland |
| 12 | Central | Luxembourg |
| 13 | Central | Netherlands |
| 14 | South | Cyprus |
| 15 | South | Greece |
| 16 | South | Italy |
| 17 | South | Malta |
| 18 | South | Portugal |
| 19 | South | Spain |
| 20 | East | Bulgaria |
| 21 | East | Croatia |
| 22 | East | Czech Republic |
| 23 | East | Hungary |
| 24 | East | Poland |
| 25 | East | Romania |
| 26 | East | Slovakia |
| 27 | East | Slovenia |
| | *Extra EU* | |
| 28 | | United Kingdom |

**Table A2:** Distribution of industrial sectors (borrowers) – Sample 2 (2017-2022)

| | **NACE2 classification (Section level)** | Tranches | Share (in %) |
|---|---|---|---|
| A | Agriculture, forestry and fishing* | 0 | 0.00 |
| B | Mining and quarrying | 229 | 4.25 |
| C | Manufacturing | 2,122 | 39.37 |
| D | Electricity, gas, steam and air conditioning supply | 524 | 9.72 |
| E | Water supply; sewerage, waste management and remediation activities | 11 | 0.20 |
| F | Construction | 173 | 3.21 |
| G | Wholesale and retail trade; repair of motor vehicles and motorcycles | 242 | 4.49 |
| H | Transportation and storage | 302 | 5.60 |
| I | Accommodation and food service activities | 110 | 2.04 |
| J | Information and communication | 500 | 9.28 |
| K | Financial and insurance activities | 411 | 7.63 |
| L | Real estate activities | 187 | 3.47 |
| M | Professional, scientific and technical activities | 248 | 4.60 |
| N | Administrative and support service activities | 120 | 2.23 |
| O | Public administration and defence; compulsory social security | 9 | 0.17 |
| P | Education | 2 | 0.04 |
| Q | Human health and social work activities | 12 | 0.22 |
| R | Arts, entertainment and recreation | 48 | 0.89 |
| S | Other service activities | 140 | 2.60 |
| T | Activities of households as employers; Undifferentiated goods- and services-producing activities of households for own use* | 0 | 0.00 |
| U | Activities of extraterritorial organizations and bodies* | 0 | 0.00 |
| | **Observations** **5,390** *(full Sample 2)* | | |

* From the official 21 NACE2 sectors at section level, 18 are represented in our sample (A, T and U not populated).

Table A2 lists the 18 populated out of 21 existent NACE2 industrial sectors at section level (alphabetical code) represented in Sample 2. The sample is composed of dominant capital-intense industries (such as manufacturing, electricity, mining and quarrying) and service-intense sectors (such as financial and insurance activities, transportation and storage, professional, scientific and technical activities). The ICT sector (information and communication technologies) falls between the two as it combines manufacturing and services industries, specifically the storage, retrieval, manipulation, transmission or receipt by electronic means of digital data.

## A.1 Loan data – Imputation protocol

To increase coverage across a range of lenders, we employ an empirical protocol to estimate missing values in the dependent variable, margin, based on observed characteristics specific to the sample. We focus on clusters of observations that exhibit similar behavior in margin changes, indicating comparable pricing conditions. These clusters are determined based on three criteria: whether lenders and borrowers are located within or outside the EU[26], the duration of the loan, and the time difference in years between the date the deal was issued and the often delayed activation of the tranche. Missing margin values are imputed using the mean or median of their respective reference cluster, taking into account the spread between the maximum and mean observed for each cluster.[27] These imputations are applied at the level of tranche-lender pairs, aligning with this rationale.[28] Particularly the subsequent activation dates of tranches belonging to a single deal exhibit greater pricing oscillations.

[26]The dummy variable 'Inside EU' distinguishes between cases where both parties are EU-located, or where one or both are extra-EU domiciled.

[27]If the difference exceeds a threshold value, the median is used for imputation; otherwise, the mean is employed.

[28]Due to the cross-border nature of syndicated loan in general, and the spatial relevance in our analysis in particular, we account for deal direction of credit transactions by considering whether borrowers and lenders are both located in- or outside the EU (EU dummy variable). In case of the UK, its status alters between the pre-Brexit (2017-2019) and post-Brexit (2020-2022) period. In order to rule out any underlying effect of price variations subject to EU membership, two imputation approaches are tested: One which holds the EU27 status constant over the sampling period (2017-2022), the other differentiating between the EU28 until 2019, and the UK treated as extra EU from 2020 onwards. Both margin imputations yield the similar descriptive and inferential results. Out of simplicity reasons (time-invariant regional composition), sample 2 is based on imputation relying on the UK status to be outside of the EU throughout the sampling period.

**Table A3:** Estimations of ln(margin) – Iterative model construction, Sample 2 (2017-2022)

| | (1) | (2) | (3)⋆ | (4)⋆ | (5⋆) | (6)⋆ | (7)⋆ |
|---|---|---|---|---|---|---|---|
| BD score × | | | | | | | |
| Score prior | | | | | | | |
| Post-existent | 0.0153 | -0.000199 | 0.0603** | 0.0609** | 0.0599** | 0.0584** | 0.0574** |
| | (0.53) | (-0.01) | (2.49) | (2.45) | (2.48) | (2.35) | (2.37) |
| Pre-existent | 0.119*** | 0.0983*** | 0.151*** | 0.152*** | 0.155*** | 0.152*** | 0.155*** |
| | (4.49) | (3.74) | (5.62) | (5.54) | (5.60) | (5.27) | (5.33) |
| Conventional loan | No | No | No | No | No | Yes | Yes |
| Inside EU | No | No | No | No | Yes | No | Yes |
| Borrower region | No | No | Yes | Yes | Yes | Yes | Yes |
| Lender region | No | No | No | Yes | Yes | Yes | Yes |
| *Characteristics* | | | | | | | |
| Loan-related | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Borrower-related | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Lender-related | No | Yes | Yes | Yes | Yes | Yes | Yes |
| $R^2 overall$ | 0.355 | 0.397 | 0.414 | 0.416 | 0.417 | 0.417 | 0.419 |
| $R^2 adjusted$ | 0.345 | 0.387 | 0.404 | 0.405 | 0.407 | 0.406 | 0.408 |
| $F\text{-}test$ | 10.855 | 31.773 | 43.122 | 32.121 | 34.759 | 37.522 | 37.524 |
| Observations† | 5,383 | 5,383 | 5,383 | 5,383 | 5,383 | 5,383 | 5,383 |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$.
Clustered at lender level (Standard errors in parentheses).
⋆ Absorbed FE:
Loan-related FE (Loan type, tranche & deal activation year)
Borrower-related FE (Firm private n/y, NACE2 industrial sector, BD score issuance year)
Lender-related FE (Bank n/y, lender & lender parent operating region)
† 7 singletons were removed in the estimation from full Sample 2.

**Table A4:** Estimations of margin – Full model specification, Sample 2 (2017-2022)

| | OLS | | | |
|---|---|---|---|---|
| | (1) | | (2) | |
| BD score × Score prior (n/y) | | | | |
| Post-existent | 14.54*** | (4.09) | | |
| Pre-existent | 25.93*** | (5.99) | | |
| BD score × Score issuance (years) | | | | |
| Post-existent | | | 14.45*** | (3.94) |
| Same year existent | | | 25.85*** | (5.89) |
| 1+ year pre-existent | | | 26.39*** | (4.18) |
| Conventional loan | | | | |
| Green | 18.54*** | (2.72) | 18.53*** | (2.71) |
| Sustainable | 2.132 | (1.13) | 2.123 | (1.14) |
| Inside EU (n/y) | 24.53*** | (5.51) | 24.53*** | (5.51) |
| Borrower region (global) | | | | |
| EU | 13.47** | (2.24) | 13.49** | (2.24) |
| UK | 19.53*** | (3.47) | 19.56*** | (3.42) |
| US | 10.91** | (2.21) | 10.98** | (2.15) |
| Lender region (EU27+1) | | | | |
| Nordic EU | 6.045 | (1.49) | 6.049 | (1.49) |
| Central EU | 4.347* | (1.95) | 4.345* | (1.95) |
| East EU | 7.988 | (1.26) | 7.987 | (1.26) |
| UK | 7.358** | (2.37) | 7.358** | (2.37) |
| *Loan characteristics* | | | | |
| Log of loan amount (thd €) | -0.469 | (-0.32) | -0.477 | (-0.32) |
| Log of deal amount (thd €) | -3.647* | (-1.86) | -3.646* | (-1.86) |
| Loan duration (years) | -7.738*** | (-6.75) | -7.739*** | (-6.74) |
| Termspread | 4.691*** | (2.88) | 4.704*** | (2.84) |
| *Borrower characteristics* | | | | |
| Log of total assets (thd €) | -3.863** | (-2.50) | -3.855** | (-2.51) |
| Log of operating revenue (thd €) | 2.265 | (1.62) | 2.261 | (1.62) |
| Harmonized borrower rating | -4.945*** | (-6.05) | -4.945*** | (-6.06) |
| *Lender characteristics* | | | | |
| Lender # | -0.637*** | (-3.51) | -0.635*** | (-3.39) |
| Loan ratio lender to lender country | 0.0109 | (0.20) | 0.0108 | (0.20) |
| $R^2 overall$ | 0.461 | | 0.461 | |
| $R^2 adjusted$ | 0.451 | | 0.451 | |
| $F-$ *test* | 38 | | 39 | |
| **Observations** † | 5,383 | | 5,383 | |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$.
Clustered at lender level (Standard errors in parentheses).
Absorbed FE:
Loan-related FE (Loan type, tranche & deal activation year)
Borrower-related FE (Firm private n/y, NACE2 industrial sector, BD score issuance year)
Lender-related FE (Bank n/y, lender & lender parent operating region)
† 7 singletons were removed in the estimation from full sample 2.

**Table A5:** Estimations of ln(margin) – Full model specifications, Sample 2 (2017-2022)

| | OLS | | Pooled OLS | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| BD score × Score prior (n/y) | | | | |
| Post-existent | 0.0574** | | 0.0421 | |
| | (2.37) | | (1.57) | |
| Pre-existent | 0.155*** | | 0.146*** | |
| | (5.33) | | (4.93) | |
| BD score × Score issuance (years) | | | | |
| Post-existent | | 0.0495* | | 0.0352 |
| | | (1.96) | | (1.28) |
| Same year existent | | 0.147*** | | 0.140*** |
| | | (4.64) | | (4.36) |
| 1+ year pre-existent | | 0.199*** | | 0.184*** |
| | | (4.85) | | (4.42) |
| Conventional loan | | | | |
| Green | 0.141*** | 0.141*** | 0.148*** | 0.147*** |
| | (4.72) | (4.44) | (4.89) | (4.64) |
| Sustainable | 0.0310** | 0.0302** | 0.0242 | 0.0234 |
| | (2.05) | (1.97) | (1.52) | (1.46) |
| Inside EU (n/y) | 0.122*** | 0.122*** | 0.129*** | 0.129*** |
| | (4.62) | (4.62) | (4.48) | (4.47) |
| Borrower region (global) | | | | |
| EU | 0.220*** | 0.222*** | 0.205*** | 0.207*** |
| | (5.78) | (5.82) | (4.85) | (4.89) |
| UK | 0.261*** | 0.265*** | 0.252*** | 0.255*** |
| | (5.68) | (5.74) | (5.29) | (5.32) |
| US | 0.252*** | 0.259*** | 0.239*** | 0.244*** |
| | (6.92) | (6.86) | (6.49) | (6.42) |
| Lender region (EU27+1) | | | | |
| Nordic EU | 0.0575* | 0.0578** | -16.64*** | -16.69*** |
| | (1.95) | (1.99) | (-9.48) | (-9.48) |
| Central EU | 0.0340* | 0.0338* | 0.195*** | 0.192*** |
| | (1.90) | (1.90) | (4.02) | (3.98) |
| East EU | 0.0559* | 0.0557* | -6.136*** | -6.157*** |
| | (1.76) | (1.76) | (-9.35) | (-9.36) |
| UK | 0.0507** | 0.0507** | -0.0549 | -0.0553 |
| | (2.25) | (2.26) | (-1.48) | (-1.47) |
| *Loan characteristics* | | | | |
| Log of loan amount (thd €) | -0.000998 | -0.00178 | 0.00376 | 0.00307 |
| | (-0.10) | (-0.17) | (0.35) | (0.28) |
| Log of deal amount (thd €) | -0.0356** | -0.0355** | -0.0386** | -0.0385** |
| | (-2.30) | (-2.30) | (-2.33) | (-2.33) |
| Loan duration (years) | -0.0327*** | -0.0327*** | -0.0355*** | -0.0356*** |
| | (-5.59) | (-5.58) | (-6.06) | (-6.05) |
| Termspread | 0.0248* | 0.0261* | 0.0274* | 0.0285** |
| | (1.81) | (1.91) | (1.92) | (2.02) |
| *Borrower characteristics* | | | | |
| Log of total assets (thd €) | -0.0328*** | -0.0320*** | -0.0302*** | -0.0296*** |
| | (-3.34) | (-3.22) | (-2.98) | (-2.89) |
| Log of operating revenue (thd €) | 0.0158* | 0.0154* | 0.0144* | 0.0140* |
| | (1.96) | (1.90) | (1.73) | (1.68) |
| Harmonized borrower rating | -0.0282*** | -0.0282*** | -0.0281*** | -0.0281*** |
| | (-5.85) | (-5.86) | (-5.56) | (-5.57) |
| *Lender characteristics* | | | | |
| Lender # | -0.00740*** | -0.00722*** | -0.00806*** | -0.00790*** |
| | (-5.52) | (-5.34) | (-6.00) | (-5.81) |
| Loan ratio lender to lender country | 0.000474 | 0.000464 | 0.232*** | 0.232*** |
| | (1.21) | (1.18) | (9.55) | (9.55) |
| $R^2 overall$ | 0.419 | 0.419 | 0.447 | 0.447 |
| $R^2 adjusted$ | 0.408 | 0.408 | 0.411 | 0.411 |
| $F-\ test$ | 38 | 38 | – | – |
| **Observations**† | 5,383 | 5,383 | 5,383 | 5,383 |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$.
Clustered at lender level (Standard errors in parentheses).
Absorbed FE:
Loan-related FE (Loan type, tranche & deal activation year)
Borrower-related FE (Firm private n/y, NACE2 industrial sector, BD score issuance year)
Lender-related FE (Bank n/y, lender & lender parent operating region)
† 7 singletons were removed in the estimation from full sample 2.