Global Banks, Climate Risk, and Credit Allocation

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Abstract

Title: **“**Global Banks, Climate Risk, and Credit Allocation”

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This study assesses banks’ international credit allocation decisions responding to severe climate events in their home country or abroad. Using a panel dataset of syndicated loans originated to European firms between 1985 to 2024, I found a significant decrease in loan amount by cross-border lenders when flood risk increases in the borrower’s country, but an increase in loan amount by cross-border lenders when flood risk increases in the lender’s country, in line with the credit reallocation argument. The effect is robust to accounting for borrower characteristics, regional macro-economic conditions, factors that are specific to time-invariant borrower and lender characteristics, and a variety of robustness concerns. The negative effect of flood risk in borrower’s country on cross-border loans is alleviated by cultural and geographic proximity between the borrower and the lender’s countries. Nevertheless, when the lender’s country is remote from the borrower’s country, both in terms of language and geographical distance, increased flood risk in lender’s country leads to a shift respective to cross-border loans. Finally, this study contributes to the recent literature on climate risk mitigation, by compounding insurance and banking sector.

Keywords: Cross-border Lending, Physical Risk, Borrower’s and Lender’s Country, Climate Risk.

Sumário

Título: “Bancos Internacionais, Risco Climático e Alocação de Crédito”

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Este estudo avalia as decisões de atribuição de crédito bancário internacional em resposta a graves fenómenos climáticos decorridos no país sede das instituições financeiras ou no estrangeiro. Através da utilização de um conjunto de dados de empréstimos sindicalizados concedidos a empresas europeias entre 1985 e 2024, constatei uma diminuição significativa do montante do empréstimo por parte dos beneficiários internacionais quando o risco de inundação aumenta no país do mesmo, mas um aumento do montante do empréstimo por parte dos beneficiários internacionais quando o risco de inundação aumenta no país do credor, em conformidade com o argumento da realocação do crédito. Os resultados são robustos perante as caraterísticas do beneficiário, as condições macroeconómicas de cada país e os fatores relacionais fixos entre beneficiário e credor ao longo do período em estudo. O efeito negativo do risco de inundação no país dos beneficiários sobre os empréstimos internacionais é atenuado pela proximidade cultural e geográfica entre os países do beneficiário e do credor. Adicionalmente, o aumento do risco de inundação no país do credor conduz a uma alteração na relação do mesmo com os empréstimos internacionais quando o país do beneficiário é distante do país do credor, tanto em termos de língua, como de distância geográfica. Por último, este estudo contribui para a recente literatura sobre a atenuação dos riscos climáticos ao associar os seguros e o setor bancário.

Palavras-chave: Empréstimos internacionais, Risco Físico, País do Beneficiário e do Credor, Risco Climático.

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1. Introduction

Climate hazards such as heat waves, droughts, and flooding are becoming more severe, persistent, and regular, providing substantial health and economic challenges (Di Sante et al., 2021; Alfieri et al., 2015). According to the recent studies, Europe has increased its susceptibility to extreme climate events such as floods and have experienced profound economic consequences, due to inadequate infrastructure, disrupted supply chains, restricted adaptation strategies, and dependence on metropolitan areas situated along significant rivers (Feyen et al., 2012; Altay N. et al., 2010). Consequently, businesses face a negative outlook, caused by inferior financial performance and more stringent loan terms (Agoraki K. K. et al., 2024; Huang H. H. et al., 2022).

In response to the fact that 15% of 46 European Union banks are exposed to high climate risks and their consequences, banks and financial institutions are increasingly factoring these hazards into their lending decisions, adopting measures as higher interest rates charged, stricter collateral requirements and greater number of covenant constraints imposed, leading to a significant lending reduction to areas more impacted by climate change (Meisenzahl R., 2023; Bua, G. et al., 2022; Javadi S. et al., 2020).

This emerging evidence contrasts with the complexity of coordinating climate policy across the world, further complicating the relationship between the role of banks and these climate phenomena, from an international perspective. Recent studies highlighted that banks that implement climate strategies often decouple it from their main value creating processes such as lending and investment (Furrer B.,2012). As an evidence of this process, banks are responding to stringent domestic climate rules by utilizing cross-border lending as a strategy to bypass regulatory constraints (Ongena et al., 2022).

This study seeks to address the following questions. Firstly, what is bank's role in providing loans in the aftermath of severe natural disasters? Specifically, does physical risk, whether materialized in the lender's home country or abroad, impact the provision of cross-border loans? Secondly, do cultural and geographic proximity affects the way in which banks extend cross-border loans when physical risk accentuates? Lastly, are there any heterogeneities across industries?

In order to address these questions, I employ panel regression models with fixed effects to estimate the relationship between cross-border lending, measured as the log change in the value-weighted amount of cross-border lending from country i to destination country j, and physical risks, defined as total damages normalized by GDP, in percentage terms. The sample comprises 19,748 syndicated loan deals granted to European firms retrieved from LPC DealScan database for the period between 1985 and 2024. The geographical scope of the study encompasses 41 borrower countries and 35 lender countries, as detailed in Table A2. Based on the country of borrowers and lenders, I further match the syndicated loan sample with flood events and macroeconomic characteristics, which are retrieved from EM-DAT database and IMF Outlook Database, respectively.

I explored the impact of physical risk on cross-border lending from two different perspectives: 1) the increased physical risk in the borrower's country and 2) the increased physical risk in the lender's country. The results demonstrated a significant decrease in loan amount by cross-border lenders when flood risk increases in the borrower's country, but an increase in loan amount by cross-border lenders when flood risk increases in the lender's country, both significant at 1% level. Specifically, the first perspective indicates that a standard deviation increase in physical risk in borrower's country results in a decrease of cross-border loans by 4.64%, which economically might be explained by the deteriorating creditworthiness of firms in impacted countries and the exacerbate information frictions around these events (Grossman and Hart, 1986). Additionally, the second perspective reveals that a standard deviation increase in physical risk in lender's country increases cross-border loans by 1.65%, resultant from banks reallocation of credit to foreign markets as a strategy to mitigate the risks from their own country.

Regarding the second question on the role of cultural and geographical proximity and on what extend it accentuates the relation between cross-border loans and physical risk, I follow Rose (2004) to introduce a dummy variable accounting for common language and previous colonial relation between countries as well as for geographical distance. The results indicated that cultural and geographical proximity between countries reduced the stringency of the aforementioned relationship 3 the impact of physical risks within the borrower's country on cross-border lending decreases in magnitude when countries were closer both culturally and geographically.

Furthermore, the results showed that the effect highlighted for the two baseline models is even larger in lead banks. This view is consistent with the fact that leader banks are frequently the biggest and most reputed institutions in the impacted nation, often prioritizing efforts to support the recovery of their domestic economy, by leveraging their central role in financial networks to mitigate local economic disruptions and gaps prior the governments help (Godlewski C. J., 2007).

Moreover, I show that for industries crucial to disaster response, as Construction and Food sectors, there is a positive relationship between international lending amount and increasing flood risk. In contrast, industries heavily reliant on physical assets and substantial financing, as Manufacturing and Chemicals, face significant limitations in accessing cross-border credit post-disasters. These difficulties may arise from their impaired ability to meet agreed tranche amount payments and the collateral damage on their assets, leading to operational disruptions and potential cessation of activities (Altay N. et al, 2010; Rodríguez H. et al., 2007).

Lastly, I address the concern of insurance coverage. As the threat of flood-related disasters grows, governments, banks and insurers are stepping up their efforts to research and implement flood adaption strategies, since insured firms are more resilient, both operationally and financially, in the aftermath of disasters (Cordella and Levy-Yeyati, 2005), lowering risk of bank's payoffs and collateral assets. To this end, for the additional checks, I re-estimate the regressions measuring uninsured damages by GDP in percentage terms. The findings are consistent with the recent literature, by showing the increasing importance of insurance as a cost-effective way of mitigating climate financial impact and the increasing awareness of it across the financial sector (Prabhakar S. V. et al., 2015).

This study adds to the literature on international capital allocation and physical risk from climate events (Stefano Giglio et al., 2021; Bua, G. et al., 2022). Research on this broad topic has almost exclusively focused on single events or single countries affected, specifically from the recovery perspective of the country and their firms, or on divergences on loan pricing post-disaster (Correa et al., 2020; Brei, M. et al.,2019; Faiella, I. et al, 2018; Choudhary M. A. et al., 2017). This study differs from this line of literature by exploring the specific effect of floods on international credit allocation amount, accounting for the lender's perspective and following an expansive temporal and geographical perspective, to understand the main effect of climate events. Moreover, it also reveals the relevance of cultural difference in the syndicated loan market (Giannetti M. et al., 2011), particularly in cross-border lending. Finally, by contrasting with previous literature on banks tendency to lend to affected areas following domestic natural disasters and assisting affected populations (Rehbein, O. et al., 2022; Cortés, K. R. et al, 2017; Berg G. et al., 2012) this research gives a different perspective showing that this fact may not hold at the international level.

The dissertation is divided as follows. Section 2 reviews the related literature, focusing on the escalating awareness of climate risks in the banking system and financial industry, and on the insurance sectors. Section 3 presents the empirical strategy, describes the data collection and cleaning process, the construction of key variables and initial analysis. Section 4 reports and discusses the main results, while Section 5 describes the robustness checks. Section 6 concludes.

2. Literature Review

Climate-related disasters are becoming more common and placing more countries and regions at risk of disaster. Among these extreme hazards, floods represent the most prevalent natural disaster, characterized by their broad geographical distribution (UNISDR, 2017).

Rising temperatures and altered precipitation patterns are elevating risks and increasing frequency associated with riverine and pluvial flooding, (Arnell N. et al., 2013; 2016; Dankers R. et al., 2010; 2013). Europe ranks as one of the regions with the highest predicted increase in flood risk magnitude, due to projections demonstrating that river flood hazards are expected to abide by the trends already observed (Di Sante et al., 2021). Moreover, is expected that the frequency of floods extreme events to reach more than its double by 2050 (Alfieri et al., 2015).

According to estimations from 2024 Report of the European Environment Agency (EEA), twenty percent of the European population lives in areas exposed to riverine floods, percentage that has been growing since 2010. This increased risk can be attributed to population density and urbanization trends on countries prone to flooding risk (Kaspersen P. et al., 2017; Schaller N. et al., 2016; Salvadore et al., 2015; Chen et al., 2015; B. Jongman et al., 2014; Shuster et al., 2005). With poor adaptation, damages from riverine floods are projected to be three to six times higher than the present, depending on the Global Warming increase, predominantly in Western and Central Europe (Dottori et al., 2020; Feyen, L. et al., 2011; Roudier P. et al., 2016). These areas are characterized by extremes as reflect a population with a higher proportion of elderly people or higher unemployment rates (IPCC, 2023).

The impacts of climate change may be transmitted to the banking sector, through the materialisation of transition and physical risks, that can affect every sort of prudential risks, including credit, market, liquidity and operational risk, (BCBS, 2021a). These risks integrate part of the banks' systemic risk as indicated by a positive correlation between them and climate change, (Liu Y. et al., 2020; Hui-Min L. I. et al., 2021), thereby endangering the financial and macroeconomic stability, supressing annual growing rates persistently, (Hsiang S. M. et al., 2014) and the availability of credit (Zhou F. et al., 2023; Batten S. et al., 2016).

Accordingly, the materialization of these events can have a pronounced effect on banks' portfolio, since up to about 17% of global financial assets are directly exposed to climate risks and 40-54% are indirectly exposed via financial counterparties, (Battiston et al., 2017). Also, on bank's liquidity, since sensitivity and exposure to climate risk likely have negative impacts on liquidity creation, while adaptive capacity tend to contribute liquidity creation, (Lee, C. C., 2022; Xu X. et al., 2024).

The adaptation of banks and financial institutions to climate change has been extensively studied, focusing on either transition risks or physical risks.

Notably, focusing on transition risks, banks are gradually including climate-related risks into their lending conditions (Atanasova Christina V. et al., 2019), by charging larger spreads to businesses that are more vulnerable to extreme events (Javadi S. et al., 2020; 2021). Furthermore, following commitments to carbon neutrality and the Paris Agreement statements, banks are on average more likely to reduce their loan supply and exposure to high-emission firms, as well as increasing the climate risk premia for both, transition and physical climate risk, (Bua, G. et al., 2022). This shift occurs even though voluntary climate commitments alone have not significantly driven the syndicated loan reallocation (Hale G. et al, 2024; Reghezza et al., 2022; Kacperczyk Marcin T. et al., 2021). Remarkably, regional differences have surfaced. Whereas financing to high-carbon companies continues to be more prevalent in the U.S., banks in Europe are more inclined to lend to businesses that might profit from environmental legislation, (Mueller I. et al., 2022).

The emerging evidence that banks are exploiting gaps in the coordination of global climate policy further complicates the relationship between the role of banks and climate change. Ongena (2022) claims that banks are responding to stringent domestic climate rules by utilizing cross-border lending as a strategy to bypass regulatory constraints. In particular, banks reduce domestic credit to high-carbon risk borrowers while increasing lending to international borrowers in nations with laxer climate regulations. Therefore, cross-border lending is acknowledged as a vital conduit for the transmission of policy uncertainty shocks between countries (Cerutti E. et al., 2014; Hale et al., 2020), also creating a different dynamic within each, since domestic banks started to be inclined to augment their cross-border syndicated lending in response to heightened competition, (Cerutti E. et al, 2014; Biswas, S. et al., 2021).

Despite the garnered consideration on bank's adaptation to transition risks and to regulatory disparities, there is still a dearth of research on the consequences of physical hazards, particularly in Europe. In fact, Stroebel and Wurgler (2021) documented that finance academics, professionals, regulators, and policy makers consistently think that regulatory risks are the key climate risk for investors and firms over the next 5 years, while physical risks are the top risk over the next 30 years. Since the impacts of the physical risk have the potential to significantly affect the dynamics of credit demand in impacted regions, they are becoming progressively more important.

Existing studies indicate a consensus that extreme climate events and their physical consequences influence economic stability and credit demand dynamics within the same country, inherently promoting the last one in areas exposed to that occurrence, (Cortés K. et al., 2017; Berg G. et al., 2012). Moreover, in a broad context, recent literature underscored that whether uncertainty is directly about the climate or indirectly about it through economic activity and feedback effects, realized climate damages have negative effects on the sectors of the economy exposed to that risk, put differently, an asset with positive exposure to climate risk will decline in value when an adverse climate shock occurs, (Giglio S. et al., 2021).

Focusing on specific climate disasters, the literature on lending supply demonstrates inconsistencies and limited scope. In the case of hurricanes, Brei, Mohan and Strobl (2019), showed that banks facing a negative funding shock strict their lending supply channels. Similarly, Lambert, Noth, and Otto (2012) observed that, following Hurricane Katrina, highly capitalized banks adjusted their risk-based capital ratios primarily by reducing loans. Parallel to this, Berg and Schrader (2009) found that following the Ecuador's volcanic eruptions, the likelihood of loan approvals decreased, reflecting the impact of natural disasters on credit supply.

Moreover, crossing flooding events, few papers specifically focus on this climate event and on its consequences on lending. Notably, Ganong and Noel (2023) showed that cash flow shocks from floods, for example due to the need to invest in rebuilding, might reduce homeowners' ability to make mortgage payments. Choudhary and Jain (2017), observed that, in Pakistan, banks disproportionately reduce credit availability to new borrowers as this reduction was not compensated by relatively more lending from less-affected banks. In a related context, Faiella and Natoli (2018) examined the effects of flooding in Italy and showed that the number of loans given to businesses was inversely correlated with their exposure to climate risk, regardless of credit demand or the presence of catastrophe insurance.

A different picture is offered when the research concentrates on the involvement of regional banks during these events. According to several research, regional lenders, that are heavily exposed to natural disasters in their main area of operation act strongly in the response of the disaster through increased lending to those climate prone areas, playing a crucial role in post-disaster recovery process (Celil H. et al., 2022).

In response to the surge in lending, banks reduce credit to businesses in unaffected regions in the affected country that are relatively less important for their corporate lending business by 3%, creating a reduction on employment of 2.4% and in tangible assets of 5.1%, primarily on banks with low capitalization, (Koetter M. et al., 2020; Ongena S. et al., 2020). Meanwhile, businesses based in flooded counties, in turn, increase corporate borrowing by 16% if they are connected to banks in unaffected counties (Ivanov I. et al., 2020). Thus, local banks play an effective role in reducing the overall tightening of the credit supply, with geographic closeness and longer relationships lessening lending limits, (Berg G. et al., 2012).

This reallocation of capital may occur both throughout a multi-market system and specifically within national borders. To illustrate, German banks significantly reduced their lending to small businesses in Germany's unaffected areas after the 2013 flood in Central Europe, as noted by Rehbein and Ongena (2020). On the other hand, Cortés and Strahan (2017) presented that often multi-market banks reallocate capital when local credit demand increases after natural disasters. Hence, to help lessen the impact of the demand shock on credit supply, banks decline loans in areas where they do not own branches and prioritize and protect their core markets.

In general, after observing natural calamities associated with climate change, banks price physical climate change risks, (Correa et al., 2020).

The swift increase in worldwide economic losses due to flooding has rekindled debates not only across financial institutions, but also among stakeholders across the insurance industry and governments regarding the role of insurance in mitigating these risks (Lamond J. et al., 2014). The close connection between these two sectors can reverse banks' potential ripple effect on their balance sheets, nowadays caused either due to unaffordability or unavailable insurance especially as banks become more vulnerable to climate events, (ECB, 2023a; BIS, 2021a).

To address the challenges currently faced around the world and specifically in Europe, the region is considering reforms to its insurance systems, driven by diverse risk profiles and public policy preferences, (Surminski S. et al., 2017; Paleari S., 2019). Risk mitigation through insurance have a significant impact on risk premia and lender's payoffs, since assets that are positively exposed to climate risk thus tend to require positive risk premia and, conversely, assets that are negatively exposed to climate risk, such as marginal mitigation and hedging investments that pay off primarily when climate damages are realized, will have negative risk premia, since these assets provide an insurance against bad states of the world, (Stefano Giglio et al., 2021).

Therefore, full adaptation or complete insurance coverage against extreme weather risk remain unattainable. Remarkably, only about a quarter of climate-related catastrophe losses are currently insured in the European Union (ECB, 2023a).

3. Empirical strategy

3.1. Empirical Specification

The intention of the study is to examine how physical risk occurring in lenders or borrower's home country influences the allocation of cross-border loans. Thos this end, the study focuses on two distinct relationships: the relationship between cross-border loans and flood risks in lender's country, and the relationship between cross-border lending and flood hazards in borrower's countries.

Reaching these objectives necessitates overcoming two critical challenges. The first challenge pertains to the increasing frequency of flood events in each country over time, which may influence loan demand from both domestic and international banks, to cover damages caused by extreme weather events. The second challenge concerns the potential presence of omitted variables that could simultaneously impact a country's vulnerability to flooding and cross-border lending activity. On the one hand, the growing frequency and severity of flood events induces higher operation costs and higher credit demand, which may not be fully absorbed by local banks. As a result, this gap in credit provision leads to greater credit provision by international banks who see this as an opportunity to maximize earnings by charging larger spreads. On the other hand, countries experiencing severe flood risks may be perceived as economically unstable in the long term, which can lead to reduced credit provision by international banks, further exacerbated by the heightened information frictions faced by them when compared to local banks, thus amplifying the perception of economic instability and discouraging credit allocation. Furthermore, flood events may potentially destroy collateralized assets, which would lower creditworthiness. To address these challenges, I incorporate borrower fixed effects and lender fixed effects to absorb firm- and bank-specific effects that do not vary over time.

Therefore, the regression model is as follows:

$$Cross\text{-}border\ Lending_{\mathrm{if(c1)b(c2)t}} = \beta PhysicalRisk_{c1t-1} + \gamma X_{c1t-1} + \alpha + \mu + \varepsilon_{c1t-1} \quad (1)$$

Where *i* represents the loan, *f* denotes the firm, *b* refers to the bank, and *t* indicates the time-period. The term *f(c1)* identifies firm *f* located in country *c1*, while *b(c2)* represents bank *b* operating in country *c2*. $Cross\ 2\ border\ Lending_{\mathrm{if(c1)b(c2)t}}$ is the log transformed cross-border loan amount that lender *b (*from country *c2)* extends to borrower *f* (in country *c1)* in year *t,* computed as the deal amount multiplied by the share of lender b in the deal, since calculating cross-border lending based on solely lender shares addresses misrepresentation concerns to measure cross-border loans. For instance, if loan sizes decrease due to higher volume of damages, a bank's total lending to a borrower could diminish even if its loan share increases (Ongena et al., 2022).

The variable of interest is Physical Risk, calculate by the total damages caused by flood events as a proportion of GDP (Damage-to-GDP), in percentage terms, registered in the borrower's country *c1* in year t. I expect the estimated coefficient of β to be negative, assuming that banks reassess the riskiness of the international borrower in face of the materialization of physical risk and react by reducing lending.

Lastly, α and μ denote lender and borrower fixed effects, respectively. X_{c1t-1} includes macroeconomic conditions (unemployment rate (%), population growth (%), real GDP change (%) and government gross debt (%)) of borrower's country, all measured in year t-1.

This analysis is based on the assumption that flood events in a given year t-1 will have an impact on loan demand within the following year t, as international lenders may require time to assess firms' damages and provide financing to address the economic consequences of such events.

To answer the question of how banks respond to the increased flood risk in their home country in allocating credit elsewhere, I estimate the following Equation:

$$Cross\text{-}border\ Lending_{\mathrm{if(c2)b(c2)t}} = \mu + \beta PhysicalRisk_{c2t-1} + \gamma X_{c2t-1} + \varepsilon_{c1t-1} \quad (2)$$

where the dependent variable and the macroeconomic attributes of the nations utilized as control variables are identical to those in Equation 1. The independent variable, Physical Risk, is determined by the total losses normalized by GDP resulting from flood incidents recorded in the lender nation ($c2$) in year t-1. X_{c1t-1} represents macroeconomic conditions of borrower's country, all measured in year t-1. Given the focus on lender's home country, only borrower fixed effects are incorporated in this specification, represented by μ.

3.2. Data

According to the research's nature, the data can be classified into two main categories. The first category encompasses deals-related activity, which are used as dependent variables in this analysis, while the second category includes country-level data related to flood occurrences and macroeconomic indicators. Table A1 provides the variables' description.

Syndicated Loans Database

The Syndicated Loans data were obtained from LPC DealScan database, formerly known as LoanConnector. This comprehensive database includes variables such as deal amount, maturity, tranche type and amount, with lender and borrower identifiers and their respective countries. Aligned with the established literature, syndicated loans were used as the primary measure of cross-border lending, (De Haas and Van Horen, 2013; Gao and Jang, 2021). The dataset spans from 1985 to 2024, with the specific filtering criteria and selection processes outlined in this section.

My analyses focus on corporate borrowers and on the identification of cross-border loans. Firstly, corporate borrowers were categorized under the variable Broad Industry Group as "Corporates", while observations categorized under "Diversified Financial Services Company" in the Borrower Type variable were excluded. Secondly, cross-border loans were identified when the lender's operating country and the lender parent's operating country differed from the borrower's country (De Haas and Van Horen, 2013).

To enable further analysis, a variable representing the lead lender role was created. This dummy variable is assigned a value of 1 if the lender is classified as a "lead," "arranger," "senior," "admin," "bookrunner," "global coordinator," or "solo lender."

In addition, coding errors in the data were revised. This includes duplicates (induced by conflicting information on tranche amount and loan amount, and differences between deal amount denominated by USD and that denominated by other currencies) as well as inconsistencies in deal dates (deal active date and maturity date), covenants, and amount at the loan-tranche level.

The geographical dispersion of the sample is detailed in Figure A4.

Flood Events Characteristics

The flood data were collected from EM-DAT, The International Disaster Database, which complies information from diverse sources, including UN agencies, non-governmental organizations, reinsurance companies, research institutes, and press agencies. The data focuses on Hydrology events classification, specifically on Flash Flood, Flood (General), Ice Jam Flood and Riverine Flood. Notwithstanding specific constraints, such as data deficiencies and the detailed nature of physical risk measures, this database has gained prominence among researchers in catastrophe studies (Lamond J. et al., 2014; Paleari S., 2019; H. S. Celil et al., 2022), offering critical indicators, including Total Damages, Uninsured Damages, Insured Damages (adjusted for CPI), Magnitude, and Total Number of Affected Individuals.

I measure the independent variable of the presented models as total damages divided by gross domestic product (GDP), in percentage terms, for each flood event per year, during the period from 1985 to 2024 and covering 41 borrower countries and 35 lender operating countries, as detailed in Table A2.

Figure A1 and A2 illustrate the cumulative incidence of flood occurrences and their economic repercussions in relation to GDP across European nations. As anticipated, Western and Central Europe exhibit a greater prevalence of these occurrences in comparison to Eastern Europe. Nonetheless, substantial disparities are seen in the capacity to alleviate the economic repercussions of floods, with Eastern European nations encountering comparatively bigger difficulties. Figure A3 further underscores the substantial discrepancy between the two groups, Western and Central Europe and Eastern Europe, in terms of insured damages relative to GDP.

A comparison of Figure A2 and A3 reveals that the first group exhibits not only a greater ratio of insured damages to total damages, but also a significantly greater volume of insured damages compared to Eastern Europe. This disparity highlights an insufficient insurance coverage and increased susceptibility to the economic repercussions of floods.

Country Characteristics

The country-specific variables are from the annual economic statistics retrieved from the IMF World Economic Outlook (WEO) Database, October 2024 edition, including real GDP change (%), population growth (%), government gross debt (%), and unemployment rate (%). Additional variables that capture between-country proximity were collected from Rose (2004): the logarithmic distance between the borrowing and lender nations, as well as a binary variable that indicates if the two countries speak the same language.

3.3. Summary Statistics

To obtain a more granular analysis of syndicated cross-border deals a dataset was constructed by merging loan-specific data with flood events and macroeconomic indicators at the country-year level. In Table 1 is the reported summary statistics.

The final sample consists of 19,748 cross-border loan deals, 3,173 unique lenders and 13,236 unique borrowers. On average, the loan amount of these deals is 1,208.3 million of US dollars, with a standard deviation of 2,779.602. Each syndicated loan involves between 1 and 127 lenders and an average life of 4.8 years. The tranche amount for each deal averages 535.687 million of US dollars, with a standard deviation of 1252.550 million US dollars. On average, the number of tranches by each deal accounts for 3, varying between 1 and 20. Furthermore, lender's share, a variable used to constructed cross-border lending, averages on 16.906%. It was only used reported loan shares without imputing for the missing observations. Additionally, observations with incorrect values were removed, including total loan shares larger than 100 or loan shares equal to 0.

Moreover, on flood events data, the final sample includes 668 events, ranging between 1 and 6 events per year on each European country, with an annually average value of 12,296 of Total People Affected. Total Damages and Insured Damages relative to GDP have an average value in percentage of 0.029 and 0.016 and a standard deviation in percentage of 0.112 and 0.049, respectively. The independent variable on borrowers averages 0.027 and on lender's country averages 0.030 in percentage.

Table 1: Summary Statistics

This table provides the summary statistics of the collected sample - cross-border loan deals in the syndicated loan market, the number of flood events at a Country frequency rate and Country Characteristics at an annual rate. The sample covers the period between 1985 -2024.

	Obs.	Mean	Std. Dev.	Minimum	Maximum
Countries Characteristics					
Unemployment Rate (%)	329366	8.333	4.504	0.501	31.944
Population Growth (%)	329349	0.000	0.001	-0.170	0.107
Population	329389	49.769	28.611	0.248	148.459
GDP Change (% Real)	329374	1.833	2.871	-15.100	24.616
Gov. Gross Debt (%)	328358	69.211	28.670	3.765	213.152
Common Language	323834	0.566	0.496	0.000	1.000
Log (Distance)	323824	3.140	3.134	0.000	7.781
Flood Events					
Number of events	164682	1.779	1.221	1.000	6.000
Total People Affected	164682	12396.926	56253.752	0.000	1700000.000
Insured Damage to GDP (%)	164682	0.016	0.049	0.000	1.453
Total Damage to GDP(%)	329419	0.029	0.112	0.000	2.959
Physical Risk in Borrower's Country	169091	0.027	0.115	0.000	2.959
Physical Risk in Lender's Country	160328	0.030	0.110	0.000	2.959
Real Insured Damage	164682	553213.534	1759197.749	0.000	10907517.000
Syndicated Loans					
Deal Amount USD	328933	1203.295	2779.602	0.000	75000.000
Average Life (year)	19951	4.824	3.516	0.000	160.080
Tranche Amount USD	328491	535.687	1252.550	0.000	39900.000
Number of Lenders	329419	13.472	13.752	1.000	127.000
Lender Share	63810	16.906	20.917	0.001	100.000

An unconditional univariate analysis, as in Figure A5, shows that the flood occurrences in European Countries and the cross-border lending go hands in hands. It’s worthwhile to mention that in 2005, when flood incidents reached a zenith of 41 occurrences, there was a notable rise in the volume of cross-border syndicated loans. After that it is possible to understand that both the frequency of flood incidents and the loan quantities exhibited continuous fluctuations, albeit the general growth in both metrics. Despite the noticeable relation, this concurrent variation may reflect a pure correlation. The following regression analysis formally tests whether and how increasing climate hazards influence lending patterns.

4. Results

Prior to exploring the regression models, Figure A6 shows that the ratio of cross-border syndicated loans and total damages in the borrower country do not clearly or linearly correlate. Examining the plot figure is evident that Germany, United Kingdom, Spain, France, and Italy are at the same time the countries more impacted by flood events in terms of total damages and the ones that do not show disproportionately high levels of cross-border lending in relation to their total lending, even though being the nations with the highest cross-border lending values.

The next sections, with the usage of syndicated loans to measure cross-border lending and the Total-Damage-GDP to study physical risks caused by flood events, are going to give clearer evidence of how lenders react to the occurrence of these events and their collateral damages.

4.1. Main Results

The regression analysis starts with the baseline model described in Equation 1, where cross-border lending is regressed on physical risks caused by flood events in the borrower country. Table 2 reports the results on Equation 1. Specifically, Column (1) delineates the preliminary phase of the study, integrating borrower and lender fixed factors, in order to consider unique time-invariant attributes to the borrower, thereby tackling unseen heterogeneity. Based on these results, Column (2) integrates national macroeconomic control variables for each year of the sample, as outlined in the Methodology section. Column (3) presents the findings for the most extensive specification, incorporating both borrower and lender fixed effects.

Table 2: Cross-border Lending in Borrower's Country

This table presents the estimates derived from Equation 1, where the independent variable is Physical Risk in the Borrower's Country, measured as total damages normalized by GDP. The dependent variable is Cross-border Lending, constructed as log(1+loan amount × share of cross-border lenders). The sample covers the period 1985-2024. Column (1) reports the first stage plus borrower and lender fixed effects. Column (2) includes country macro-economic controls and borrower fixed effects. Column (3) includes country macro-economic controls and lender and borrower fixed effects. Country macro-economic control variables are Unemployment Rate (%), GDP Change (% Real), Population Growth and Government Gross Debt (%). Borrower and lender fixed effects are indicated at the bottom of each column with "Yes" or "No". Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Cross-border Lending		
	(1)	(2)	(3)
Physical Risk in Borrower's Country	-0.474***	-0.491***	-0.516***
	(0.079)	(0.087)	(0.079)
GDP Change (% Real)		0.003	0.003
		(0.004)	(0.003)
Unemployment Rate (%)		-0.025***	-0.019***
		(0.003)	(0.003)
Population Growth (%)		-2.624	-0.635
		(8.729)	(7.890)
Gov. Gross Debt (%)		0.005***	0.003***
		(0.001)	(0.001)
Borrower FE	Yes	Yes	Yes
Lender FE	Yes	No	Yes
N	62207	62399	61902
adj. R-sq	0.566	0.444	0.567

As borrower fixed effects, macroeconomic variables driving year fixed effects, and lender fixed effects are progressively incorporated, the coefficient for Physical Risk becomes increasingly negative and statistically significant at 1 % level across all specifications, respectively 0.474, 0.491 and 0.516 in absolute terms, indicating robustness of these results. In the baseline model, this implies that a standard deviation increase in physical risk in borrower's country results in a decrease of cross-border loans by 4.64%, (0.115*(exp (-0.516) -1) * 100). This pattern indicates that the greater the damages caused by flood events in borrower countries, the lower is the volume amount lent to those same countries, reflecting the creditors' risk perception, with countries particularly susceptible to natural catastrophes being less desirable for funding.

This response aligns with the fact that banks were one of the primary adopters of climate risk assessment into their lending business models (Huang H. H. et al., 2022), since this expertise enables them to recognize their clients' credit risk exposure to these events and study how physical losses make put options in lending contracts more attractive for borrowers, threatening their payoffs (Jensen and Meckling, 1976). Moreover, hypothesizing for exacerbate cross-border information frictions, the heightened informational uncertainty, particularly in cross-border disaster contexts, renders loan contracting inherently incomplete, increasing post-contractual opportunism that adversely affects lenders' welfare (Grossman and Hart, 1986).

Among the macroeconomic variables regressed, GDP Change is one of the indicators that exhibits a positive impact. This can be attributed to the fact that, despite the substantial harm that flood disaster can inflict, the economies of the impacted nations often recover quickly from such shocks, demonstrating low vulnerability and ensuring that foreign investors are not deterred. In contrast, Unemployment Rate (%) and Population Growth (%), two important macroeconomic indicators to account for post-disasters vulnerability, exhibit negative dynamics on cross-border lending, with the first one being significant at 1% level. Government Gross Debt (%) also stand out as one of the most influential factors, with the same level of significancy, emphasizing the critical role of internal economic conditions of the borrower's country in credit allocation.

The first part of the regression analysis concludes with the second baseline model described in Equation 2, where cross-border lending is regressed on physical risks caused by floods in the lender's country. Table 3 reports the results of these regressions.

The initial stage of this analysis is presented in Column (1). In Column (2) the same model as in Column (1) is expanded to incorporate national macroeconomic control factors for each year and borrowing country. In Column (3), since incorporating lender fixed effects into this specification is deemed too restrictive, loan fixed effects created another possible solution to the addressed problem.

According to Ongena (2022), these fixed effects offer a better exemplary approach for managing loan demand in a syndicated loan environment, being more granular than the standard borrower and time comparison, since a borrower may obtain more than one loan in a year. This can be explained, since in a syndicated loan, the lead arranger, typically the sole bank responsible for determining the loan terms, establishes the key conditions of the deal. Whereas the participant banks simply join the agreement after these terms are set. Consequently, the participant banks have limited interaction with the borrower, ensuring that their loan supply decisions remain independent of the borrower-specific loan demand. The outcomes of these three models are shown in Table 3.

Table 3: Cross-border Lending in Lender's Country

This table presents the estimates derived from Equation 2, where cross-border lending is regressed on the independent variable, Physical Risk, on the Lender's Country, measured as total damages normalized by GDP. The dependent variable is the Cross-border Lending, constructed as log(1+loan amount × share of cross-border lenders). The sample covers the period 1985-2024. Column (1) reports the first stage, including borrower fixed effects. Column (2) includes borrower's country macro-economic controls. Column (3) includes country macro-economic controls and loan fixed effects. Country macro-economic control variables are Unemployment Rate (%), GDP Change (% Real), Population Growth and Government Gross Debt (%). Borrower and lender fixed effects are indicated at the bottom of each column with "Yes" or "No". Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	Cross-border Lending		
	(1)	(2)	(3)
Physical Risk in Lender's Country	0.159**	0.140**	0.309***
	(0.062)	(0.062)	(0.065)
GDP Change (% Real)		0.002	0.002
		(0.004)	(0.225)
Unemployment Rate (%)		-0.024***	-0.033
		(0.003)	(0.807)
Population Growth (%)		-8.514	-10.141
		(9.439)	(9.817)
Gov. Gross Debt (%)		0.005***	0.041
		(0.001)	(0.257)
Borrower FE	Yes	Yes	No
Lender FE	No	No	No
Loan FE	No	No	Yes
N	62810	62499	60362
adj. R-sq	0.442	0.443	0.460

All the interactions reveal a significant positive relation between total damages within the home country and cross-border lending, of 0.159, 0.140 and 0.309, respectively, indicating an aligned interaction between greater financial efforts from lender's country and investment in foreign unaffected countries. Effect that is amplified between Column (2) and Column (3) with the addition of loan fixed effects, since they ensure the analysis isolates differences between participant banks within the same syndicated loan, rather than variations across loans, (Ongena et al., 2022). In the Equation 2 described in Column 2 this implies that a standard deviation increase in physical risk in lender's country results in an increase of cross-border loans by 1.65%, (0.110*(exp (0.140) -1) * 100).

Economically, this observed correlation might indicate the shift of banks' lending strategy for international loans, to mitigate potential financial risks in their domestic loan business, which often increase following climate events in their operating country. This reallocation of resources may also lead to an increased credit supply or heightened competition in the markets of unaffected countries (Correa R. et al., 2022), by following the hypothesis that this events exacerbate information frictions, making banks more probable to redirect funds to areas where monitoring costs are lower, (Ilabaca F. E. et al., 2024).

The macroeconomic variables also provide insights into these results. GDP Change (% Real) has a favourable, but not statistically significant, correlation with changes in the borrower nation, suggesting that the amount of cross-border financing increases with other nations' economic stability and prosperity, which is consistent with assessments by international agencies that highlight the vulnerability of lower-income nations relative to higher-income countries to climate change, (Report of the Secretary-General, United Nations, 2022).

On the other hand, both Population Growth (%) and Unemployment Rate (%) exhibit the opposite effect. This highlights the economic fragility of borrowing nations and points to a contrary dynamic where lesser cross-border lending is linked to greater unemployment rates. However, when loan-specific characteristics are taken into account, the importance of these variables decreases.

4.2. Heterogeneities

In this section, to further complement the study, a series of tests across different heterogeneities between lender and borrower characteristics was conducted.

The first analysis conducted on both equations evolved the lender's relevant role in the syndicated market and on each deal, since that lead banks often contribute with market-specific lending expertise and borrower insights to syndicated loans and may introduce specific heterogeneities (Cerutti E. et al., 2014).

Table 4 presents the results. Columns (1) to (4) analyse the impact of the lender's role and the country to which the lender belongs, by using the variable on lender's role created. Column (1) and (3) focuses on cases where the lender assumes a Lead Role, while Column (2) and (4) examines scenarios where the lender does not hold this position.

Table 4: Cross-border Lending and Lender's Characteristics

This table presents the estimates derived from Equation 1 and Equation 2, filtered based on different a specific lender characteristic: Primary Role. Column (1) and (2) represent Equation 1, where the independent variable is Physical Risk in the Borrower's Country, measured as total damages normalized by GDP. Column (3) and (4) represent Equation 2, where the independent variable is Physical Risk in Lender's Country, measured as total damages normalized by GDP. The dependent variable, in both equations, is the Cross-border Lending, constructed as log(1+loan amount × share of cross-border lenders). The sample covers the period from 1985 to 2024. Equation 1 and 2 are filtered by the Primary Role of Lenders: Column (1) and (3) include cases where the dummy variable for Lead Lender equals 1, and Column (2) and (4) includes cases where it equals 0. For further details on each variable refer to Table A1. All columns (1) through (6) include country, borrower and lender fixed effects. Fixed effects are indicated at the bottom of each column with "Yes" or "No." Standard erro rs are reported in parentheses. Statistical significance levels are denoted as follows: *** p<0.01, ** p<0.05, * p<0.1.

	Cross-border Lending			
	Lead	Non-Lead	Lead	Non-Lead
	(1)	(2)	(3)	(4)
Physical Risk in Borrower's Country	-0.491***	-0.117		
	(0.066)	(0.161)		
Physical Risk in Lender's Country			-0.243***	0.066
			(0.058)	(0.101)
Country FE	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes
Lender FE	Yes	Yes	No	No
N	22735	5651	22978	5855
adj. R-sq	0.651	0.685	0.598	0.631

Following the results on Equation 1, that established a negative relationship between cross-border lending and damages caused by flood events in borrower countries, the findings from Table 4 - Column (1) and (2) - reveal that this relationship persists and becomes more pronounced and statistically significant at the 1% level when the sample is restricted to Lead Banks. Specifically, the results indicate that for leader banks, an increase in physical risk in

Borrower's country by a standard deviation result in a decrease of cross-border lending by 4.46%, reinforcing the idea that when lead lenders possess less specialized knowledge about the borrower or the specific disaster context, they tend to further reduce cross-border lending.

This behaviour also aligns with the empirical result that leader banks, being less reliant on information provided by syndicate members, rely heavily on their own costly expertise in this context, (Zhao Y. et al., 2024).

Additionally, Columns (3), contrasting with the previous results of Equation 2, present a strong negative correlation, at a 1% level, between the rise in total damages and cross-border lending when banks play a leading role in the transaction. Economically, this may be explained by the fact that major bank, which are frequently the biggest and most reputed institutions in the impacted nation (Godlewski C. J., 2007), give priority to aiding in the recovery of their own economy instead of foreign reallocating their loan business.

The second part of heterogeneities' analysis continues with a comprehensive study considering the attributes of each country, in geographic and cultural proximity. Recent literature indicates that cultural and geographical disparities between lead banks and borrowers substantially affect the terms of syndicated loans, and these disparities persist even after recurrent interactions between the contractual parties (Giannetti M. et al., 2011).

Therefore, Equation 1 and 2, were examined based on two criteria, following Rose (2004). The first one accounting for the presence of a shared language or a historical colonial relationship between the borrower and lender nations, and second one on the geographical distance separating the two nations, resulting in the formation of two groups: one for geographically proximate countries and another for the remaining pairs. Table 5 presents the results. Column (1) and Column (2) present Common Language criteria, whereas Column (1) depicts relations in which the borrower and lender have cultural relation proximity, Column (2) represents the opposite situation. Results reveal that although Physical Risk coefficient is negative in both cases, (-0.025 and -0.415, respectively), and that the effect is sixteen times more negative and statistically significant in the absence of a cultural and historical link between the countries. Therefore, for culturally distant countries, a standard deviation increase in physical risk in borrower's country results in a decrease of cross-border loans by 3.91%.

Concerning Column (3) and Column (4), the geographical distance requirement between countries is the main topic. Geographically closer nations, mainly those with shared borders, are represented in Column (3), whilst those farther away are represented in Column (4). The results suggest that geographically proximate countries exhibit a lower negative coefficient compared with distant countries, in absolute terms. Alike cultural distance, the coefficient becomes more negative as geographic distance expands, which may indicate that the amount of cross-border loans to the nation harmed by floods decreases with increasing geographic distance between them.

Table 5: Cross-border Lending in Borrower's Country Characteristics

This table presents the estimates derived from Equation 1, filtered based on different borrower country characteristics: Comm on Language and Group Distance. The independent variable is Physical Risk in the Borrower's Country, measured as total damages normalized by GDP. The dependent variable is the Cross-border Lending, constructed as log(1+loan amount × share of cross-border lenders). The sample covers the period from 1985 to 2024. Columns (1) and (2) report Equation 1 filtered by Common Language and Columns (3) and (4) report Equation 1 filtered by Group Distance. Specifically, Column (1) includes cases where the dummy variable for Common Language equals 1 as Column (2) includes cases where the dummy variable equals 0, Column (3) reports resu lts for borrower-lender pairs with shorter distances, while Column (4) reports results for pairs with greater distances. For further details on each variab le refer to Table A1. All columns (1) through (4) include country, borrower and lender fixed effects. Fixed effects are indicated at the bottom of each column with "Yes" or "No." Standard errors are reported in parentheses. Statistical significance levels are denoted as follows: *** p<0.01, ** p<0.05, * p<0.1.

	Cross-border Lending			
	Common Language		Group Distance	
	C.L.	No C.L.	Short	Large
	(1)	(2)	(3)	(4)
Physical Risk in Borrower's Country	-0.025	-0.415***	-0.346***	-0.488***
	(0.186)	(0.066)	(0.089)	(0.092)
Country FE	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes
Lender FE	Yes	Yes	Yes	Yes
N	2789	25131	11968	15681
adj. R-sq	0.691	0.652	0.678	0.659

The results on these four columns speak to the importance of informational and monitoring costs in international lending transactions, consistent with the higher importance of culture in the form of an informal institutional, (North D. C. et al., 1990; Brenton P. et al., 1999). Furthermore, it is congruent with the basic idea that geographic and cultural distance act as a proxy for transaction cost, information asymmetry and unfamiliarity effect, (Aggarwal R. et al.,2009), since foreign banks are short for soft information on local firms compared with their domestic counterparts, meaning that their subjective perceptions play a particularly important role in the decision making. Economically, cultural differences might make negotiations more cumbersome, with culturally distant borrowers increasing the lenders' disutility from writing the contract, increasing time, resources and cost of information gathering needed in writing contracts.

The heterogeneities analysis continues with the model described in Equation 2. Table 6, which has the same structure as Table 5, now delves deeper into the cultural differences between the loan-giving nations, impacted by flood events and the loan-seeking countries.

Table 6: Cross-border Lending in Lender's Country Characteristics

This table presents the estimates derived from Equation 1, filtered based on two borrower country characteristics: Common Lan guage and Group Distance. The independent variable is Physical Risk in the Lender's Country, measured as total damages normalized by GDP. The dependent variable is the Cross-border Lending, constructed as log(1+loan amount × share of cross-border lenders). The sample covers the period from 1985 to 2024. Columns (1) and (2) report Equation 1 filtered by Common Language and Columns (3) and (4) report Equation 1 filtered by Group Distance. Specifically, Column (1) includes cases where the dummy variable for Common Language equals 1 as Column (2) includes cases where the dummy variable equals 0, Column (3) reports results for borrower-lender pairs with shorter distances, while Column (4) reports results for pairs with greater distances. For further details on each variable refer to T able A1. All columns (1) through (4) include country, borrower and lender fixed effects. Fixed effects are indicated at the bottom of each column with "Yes" or "N o." Standard errors are reported in parentheses. Statistical significance levels are denoted as follows: *** p<0.01, ** p<0.05, * p<0.1.

	Cross-border Lending			
	Common Language		Group Distance	
	C.L.	No C.L.	Short	Large
	(1)	(2)	(3)	(4)
Physical Risk in Lender's Country	-0.139	-0.203***	0.159*	-0.437***
	(0.188)	(0.070)	(0.096)	(0.093)
Country FE	Yes	Yes	Yes	Yes
Borrower FE	Yes	Yes	Yes	Yes
Lender FE	No	No	No	No
N	2850	25409	12134	15925
adj. R-sq	0.649	0.591	0.600	0.609

Equation 2 is the basic model that serves as its foundation. Across Columns (1) to (4), two cultural and geographical criteria are integrated in the analysis. Following Table 6, it becomes evident that the omission of these variables introduces significant bias, illustrated by the shifted sign of the relation between physical risk and volume of cross-border when these variables are included.

Columns (1) and (2), focusing on the Common Language criteria, suggest a negative correlation between cross-border lending and physical risk, even statistically significant at a 1% level in cases where cultural ties exist. These results, as before, potentially reflect the importance of cultural relations, since they suggest that lender's strategy foreign reallocation is supplanted by cultural relations, having this one and their informational costs greater impact on their lending decision process.

Moreover, when the criteria relate to the geographical distance between nations, the results point to the same dynamic. The findings suggest a statistically negative association between cross-border lending and the increasing physical risk in the lender nation, in absolute term when countries are distant between each other. This behaviour underscores the previous impact of information asymmetry and the tentative to potentially foster greater lending diversity, relying on the cultural and geographical proximity.

5. Additional Checks

The final section examines the resilience of the prior findings by presenting a different metric for physical risk and considering a different duration for the accessibility of foreign loans after a climate event. Additionally, it presents a further analysis on the industries affected by these calamities.

The initial robustness check is presented in Table A3, where physical risk is measured via uninsured damages adjusted for GDP, assessed one-year post-flood occurrence. As previously noted, insurance coverage may introduce considerable bias owing to its typically favourable correlation with promoting private risk-reduction behaviour and risk mitigation of collateral damages for banks. This is an effect particularly strong in low- to middle-income countries, such as Europe countries, which face financial constraints when impacted by shocks or in anticipation of them. Insurance reduces the likelihood of defaults, thereby relaxing the country's borrowing constraints and improving access to capital markets (Cordella T. et al., 2015).

Aligned with the baselines from Equations 1 and 2, respectively, this second physical risk assessment confirms the two primary findings. First, when significant floods occur in borrower nations and collateral assets sustain uninsured damages, lenders curtail cross-border lending. Second, when uninsured damages happen in their own nations, banks expand their lending abroad. Notably, the first finding's effect size is significant and over 1.5 times greater, 0.770 in absolute terms, as the second's effect size is significant and positive 3 0.202 in absolute terms, highlighting the vital role insurance plays in reducing market disruptions. Although insurance being far from a "silver bullet" in addressing climate change, it already offers significant capacity and ability to understand, manage, and spread risks associated with weather-related events, principally in industrialized countries, (E. Mills, 2007).

The second robustness check examines the baseline model's assumption that flood disasters would have an impact on cross-border loans a year after they occurred. In reality, the availability of accurate information for banks regarding physical damages to collateralized assets is often significantly delayed, due to the time required to evaluate and quantify losses, conduct risk assessments, complete internal approvals during negotiations, and allow firms to assess their financial conditions and needs. To take this into consideration, the baseline models that corresponded to Equations 1 and 2 were re-estimated. This time, Physical Risk was assessed as cumulative damages normalized by GDP over four lagged periods rather than as total damages adjusted by GDP lagged by one year.

Table A4 present the results of these revised regressions for the borrower's country and the lender's home country, respectively. The findings from these tables once again corroborate the results obtained previously. In particular, verify that physical risk and cross-border loans have a negative correlation when floods occur in the borrower's nation and a positive correlation when they occur in the lender's nation. The fact that both regressors are still statistically significant supports the validity of the preliminary findings.

The final analysis explores Equation 1 and 2, to account for heterogeneities across the relation between physical damages in borrower's and lender's country over cross-border lending. Both equations were analysed separately for the 34 industries presented in the dataset, identified through the "Major Industry Group" variable of the borrower. Table A5 and A6 depict the regressions' results.

From Table A5 is highlighted that most industries show a negative relationship with cross-border lending and businesses located in flood-affected countries, with significant impacts observed in sectors as "Aerospace and Defence", "Automotive", "Healthcare" , "Technology" and "Chemicals, Plastics and Rubber". These findings contribute to the economical suggestion that industries heavily dependent on physical infrastructure and supply chains are more affected by flood catastrophes. Their vulnerability diminishes the creditworthiness of the firms within these sectors and a subsequent reallocation of credit to others, due to their limitations on tranche amount payments and assets damage.

Nonetheless, some industries deviate from this trend, “Construction," "Real Estate Investment Trusts (REITs)," "Restaurants," "Retail and Supermarkets," "Services," and "Wholesale", display positive regressors. Despite “Wholesale” being the only industry where the positive effect is statistically significant, these sectors appear to play critical roles in post-catastrophe recovery. This idea is consistent with recent literature on post-climate disasters activities which states that firms in finance, insurance, and real estate sectors are more likely to engage in disaster preparedness activities and reopen more rapidly compared to businesses as education, health care, social assistance, and public administration (Altay N. et al, 2010).

On the other hand, Table A6 highlights the perspective when the climate disasters happen in the lender home country, showing different dynamics. From this results, banks post-disaster are more likely to lend internationally to firms within industries heavily dependent on physical assets and specific supply chains as “General Manufacturing” and “Shipping”, showing a different credit reallocation perspective.

6. Conclusion

Climate-related disasters are becoming more common and possibly placing more countries and regions at risk of disaster. As one of the regions most likely to witness an increase in flood hazards, Europe must be prepared to manage these events and have the ability to react accordingly. Therefore the aim of this study is to examine how banks react to increased physical risk and the spread consequences of climate change in allocating their credit portfolios internationally. With the usage of syndicated loans data from 1985 to 2024, along with compiled data state-level flood events in Europe and fixed effects panel regression models, I found a significant decrease in loan amount by cross-border lenders when flood risk increases in the borrower's country. On the opposite side, I found an increase in loan amount by cross-border lenders when flood risk increases in the lender's country. The effect is robust to accounting for borrower characteristics, regional macro-economic conditions, factors that are specific to time-invariant borrower and lender characteristics, and the insurance coverage concern. Furthermore, the effects showed to be stronger in lenders that take lead roles. Finally, with deeper exploring on the influence of cultural drivers of cross-border lending, the study showed that cultural and geographic closeness alleviates the negative impact of flood risk in the borrower's country and weakens the positive impact of flood risk in the lender's country.

Overall, this study contributes to the recent literature on climate change and its consequences for the banking sector (Kacperczyk M. T. et al., 2022; Benincasa E. et al., 2022; Reghezza A. et al., 2022; Ivanov I. et al., 2018), since research on this topic has almost exclusively focused on single events or single countries affected (Brei M. et al., 2019; Faiella I. et al., 2018; Rehbein O. et al., 2022). This study besides adding on a more geographical and temporal perspective, specifically on flood events, also, contributes to the literature on the interplay between insurance and banking sector, and the important role of insurance in international credit reallocation (S. V. Prabhakar et al., 2015; Lamond J. et al., 2014).

Appendix

Table A1: Variables description 1

Variable name	Variable definition	Source
Unemployment Rate (%)	Number of unemployed persons as a percentage of the labor force.	IMF Outlook Database
Population Growth (%)	Annual population growth calculate as [[Population(t) - Population(t-1)]/Population(t-1)].	IMF Outlook Database
GDP Change (% Real)	Annual percentages of constant price GDP are year-on-year changes; the base year is country-specific.	IMF Outlook Database
Gov. Gross Debt (%)	Gross debt consists of all liabilities that require payment or payments of interest and/or principal by the debtor to the creditor at a date or dates in the future, in percentage of GDP.	IMF Outlook Database
Common Language	Dummy variable that is equal to one if the two countries share the same language or have a former colonial relation.	Rose (2004)
Log (Distance)	Log of geographic distance borrower-Lender's country.	Rose (2004)
Cross-border	Dummy variable equal to 1 if the lender parent and lender operate in a different country from the borrower; 0 otherwise This variable indicates a loan granted cross bordered.	LPC's DealScan
Cross-border Lending	Log change in the amount of cross-border lending value-weighted by country i to destination country j. The variable is constructed as log(1+ the amount of cross-border lending*LenderShare).	LPC's DealScan

Table A1: Variables description (cont.)

Variable name	Variable definition	Source
Number of Lenders	Number of different LenderId's per LPCDealId and LPCTrancheId.	LPC's DealScan
Total Damages	Losses caused by flood events, expressed in thousands of US dollars ('000 US$).	EM-DAT
Damage-to-GDP (%)	Losses caused by flood events, expressed in thousands of US dollars ('000 US$), adjusted to GDP in percentage terms.	EM-DAT
Uninsured Damages-to-GDP (%)	Uninsured Damages represents the portion of total flood-related losses not covered by insurance, adjusted to GDP, in percentage terms.	EM-DAT
Total People Affected	Individuals impacted by flood events, including deaths, injuries, directly affected, and homeless.	EM-DAT

Table A2: European Countries Sample

Variable name	Countries
Borrower Country	France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine and United Kingdom
Lender Operating Country	Austria, Belarus, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine and United Kingdom

Table A3: Robustness Checks – Insurance Coverage

This table presents the estimates derived from an adaptation of Equation 1 and Equation 2, respectively, where the independen t variable is Physical Risk in the Borrower's Country, measured as uninsured damages normalized by GDP (%) in Column (1), while in Column (2) the independent variable is Physical Risk in Lender's Country, measured as uninsured damages by GDP (%). The dependent variable in both equations is the Cross-border Lending, constructed as log(1+loan amount × share of cross-border lenders). The sample covers the period 1985-2024. Column (1) reports the equation including country macro-economic controls and lender and borrower fixed effects. Column (2) reports the equation including country macro-economic controls and borrower fixed effects. Country macro-economic control variables are Unemployment Rate (%), GDP Change (% Real), Population Growth and Government Gross Debt (%). Borrower and lender fixed effects are indicated at the bottom of each column with "Yes" or "No". Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Cross-border Lending	
	(1)	(2)
Physical Risk in Borrower's Country	-0.770***	
	(0.105)	
Physical Risk in Lender's Country		0.202***
		(0.072)
GDP Change (% Real)	0.003	0.002
	(0.003)	(0.004)
Unemployment Rate (%)	-0.019***	-0.023***
	(0.003)	(0.003)
Population Growth (%)	-2.965	-8.477
	(8.462)	(9.439)
Government Gross Debt (%)	0.003***	0.005***
	(0.001)	(0.001)
Borrower FE	Yes	Yes
Lender FE	Yes	No
N	62001	62499
adj. R-sq	0.567	0.444

Table A4: Robustness Checks – Cumulative Damages

This table presents the estimates derived from an adaptation of Equation 1 and from Equation 2, respectively, where the independen t variable is Physical Risk in the Borrower's Country 3 Column (1) or Lender's Country 3 Column (2) , measured as cumulative total damages normalized by GDP, for four previous periods. The dependent variable is the Cross-Border Lending, constructed as log(1+loan amount × share of cross-border lenders). The sample covers the period 1985-2024. Column (1) reports that equation including country macro-economic controls and lender and borrower fixed effects. Column (2) reports that equation including country macro-economic controls and lender fixed effects. Country macro-economic control variables are Unemployment Rate (%), GDP Change (% Real), Population Growth and Government Gross Debt (%). Borrower and lender fixed effects are indicated at the bottom of each column with "Yes" or "No". Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Cross-border Lending	
	(1)	(2)
Physical Risk in Borrower's Country	-0.403***	
	(0.071)	
Physical Risk in Lender's Country		0.149***
		(0.031)
GDP Change (% Real)	0.002	0.002
	(0.003)	(0.004)
Unemployment Rate (%)	-0.020***	-0.023***
	(0.003)	(0.003)
Population Growth (%)	-2.782	-8.684***
	(8.580)	(9.438)
Government Gross Debt (%)	0.003***	0.005***
	(0.001)	(0.001)
N	61904	62499
adj. R-sq	0.567	0.443

Table A5: Additional check in Borrower's Country Industries

This table presents the estimates derived from Equation 1, where the independent variable is Physical Risk in the Borrower's Country, measured as total damages normalized by GDP. The dependent variable is the Cross-border Lending, constructed as log(1+loan amount × share of cross-border lenders). The sample covers the period 1985-2024. Column (1) reports Equation 1, including country macro-economic controls and lender and borrower fixed effects. The regressor in the table is from Borrower's Country Physical Risk within each industry. There are 34 industries in the sample. Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Cross-border Lending		
Physical Risk in Borrower's Country			
	(1)	N	adj. R-sq
Aerospace and Defence	-4.280***	682	0.598
	(1.102)		
Agriculture	-1.668	945	0.687
	(3.446)		
Automotive	-0.824***	2699	0.601
	(0.256)		
Beverage, Food, and Tobacco Processing	-0.109	4031	0.710
	(0.570)		
Business Services	-0.913	3087	0.603
	(0.564)		
Chemicals, Plastics and Rubber	-0.914**	2718	0.579
	(0.355)		
Construction	0.095	7495	0.640
	(0.779)		
General Manufacturing	-0.119	6789	0.681
	(0.392)		
Healthcare	-1.446***	2989	0.638
	(0.281)		
Hotel and Gaming	-0.473	776	0.613
	(1.931)		
Leisure and Entertainment	-0.727	1219	0.641
	(0.675)		
Mining	0.713**	1369	0.594
	(0.349)		
Oil and Gas	-0.174	3782	0.467
	(0.192)		
Paper and Packaging	-0.582	1105	0.775
	(8.554)		
REITS	0.885	319	0.645
	(1.559)		
Real Estate	-0.429	3303	0.668
	(0.751)		

Restaurants	1.170	707	0.747
	(2.015)		
Retail and Supermarkets	0.578	3094	0.503
	(0.599)		
Services	1.780	2312	0.689
	(1.122)		
Shipping	-0.329	2343	0.569
	(1.008)		
Technology	-9.601***	1417	0.513
	(1.974)		
Textiles and Apparel	0.015	460	0.808
	(0.710)		
Transportation	-0.242	3248	0.558
	(0.179)		
Wholesale	3.890***	2681	0.578
	(0.697)		

Table A6: Additional check in Lender's Country Industries

This table presents the estimates derived from Equation 1, where the independent variable is Physical Risk in the Lender's Country, measured as total damages normalized by GDP. The dependent variable is the Cross-border Lending, constructed as log(1+loan amount × share of cross-border lenders). The sample covers the period 1985-2024. Column (1) reports Equation 1, including country macro-economic controls and lender fixed effects. The regressor in the table is from Lender's Country Physical Risk within each industry. There are 34 industries in the sample. Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

	Cross-border Lending		
Physical Risk in Lender's Country			
	(1)	N	adj. R-sq
Aerospace and Defence	-0.666***	744	0.382
	(0.278)		
Agriculture	0.638	1045	0.409
	(0.598)		
Automotive	-0.979***	2835	0.394
	(0.239)		
Beverage, Food, and Tobacco Processing	0.159	4196	0.540
	(0.204)		
Business Services	0.774***	3205	0.407
	(0.564)		
Chemicals, Plastics and Rubber	0.307	2839	0.394
	(0.260)		
Construction	1.647***	7686	0.346
	(0.252)		
General Manufacturing	0.797***	7025	0.560
	(0.182)		
Healthcare	-1.080***	3118	0.440
	(0.279)		
Hotel and Gaming	-2.136**	875	0.291
	(1.061)		
Leisure and Entertainment	0.007	1282	0.418
	(0.307)		
Mining	-1.086***	1469	0.414
	(0.337)		
Oil and Gas	-1.102	3952	0.288
	(0.301)		
Paper and Packaging	0.807*	1200	0.545
	(0.433)		
REITS	1.513	380	0.399
	(0.937)		
Real Estate	-1.032***	3476	0.419
	(0.351)		

Restaurants	1.428*** (0.530)	755	0.294
Retail and Supermarkets	0.845*** (0.239)	3239	0.275
Services	0.447 (0.341)	2424	0.484
Shipping	0.909** (0.430)	2498	0.416
Technology	0.364 (0.479)	1525	0.368
Textiles and Apparel	0.442 (0.400)	517	0.536
Transportation	0.633** (0.314)	3411	0.350
Wholesale	0.711*** (0.251)	2802	0.424

Figure A1: Cumulative distribution of flood events across Europe

This figure reports the cumulative events across the European Countries presented in EM-Dat dataset, over the period 1985-2024. The maximum number of recorded events account for 70 as the lower value accounts for 0. The map report strong colours for the countries that report higher number of flood events across this period of time and neutral colours otherwise.

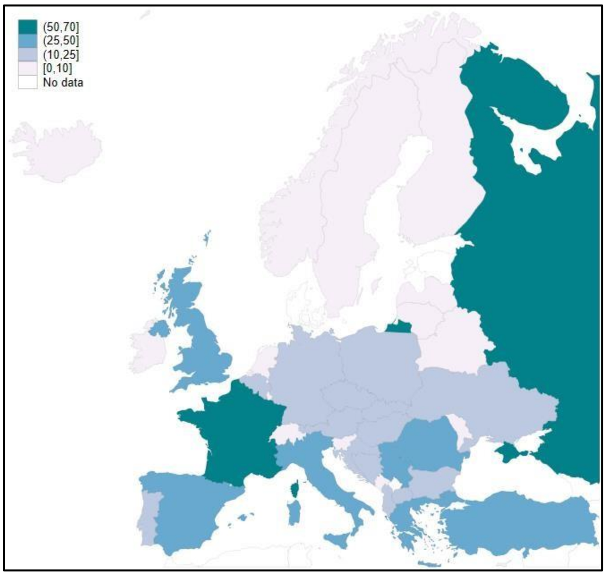


Figure A2: Total Damages by GDP of flood events across Europe

This figure reports the cumulative damages to GDP across the European Countries presented in EM-Dat dataset, over the period 1985-2024. The maximum number of recorded cumulative damages to GDP account for 0.3 as the lower value accounts for 0. The map report strong colours for the countries that report higher cumulative damages on flood events across this period of time and neutral colours otherwise.

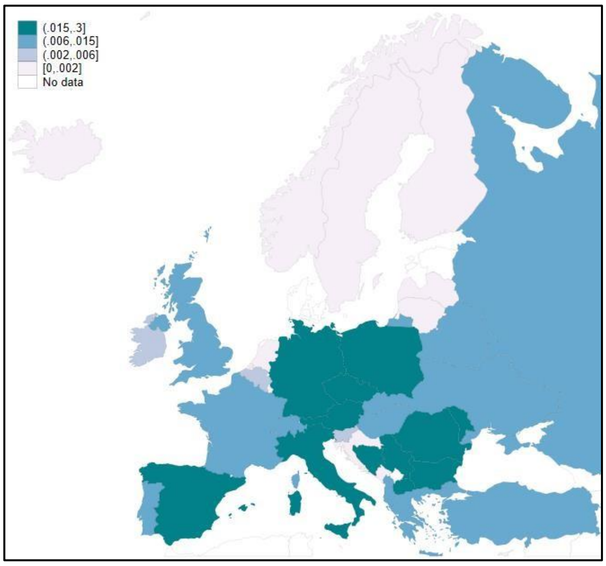


Figure A3: Insured Damages by GDP of flood events across Europe

This figure reports the cumulative insured damages to GDP across the European Countries presented in EM-Dat dataset, over the period 1985-2024. The maximum number of recorded cumulative damages to GDP account for 0.03 as the lower value accounts for 0. The map report strong colours for the countries that report higher cumulative insured damages on flood events across this period of time and neutral colours otherwise.

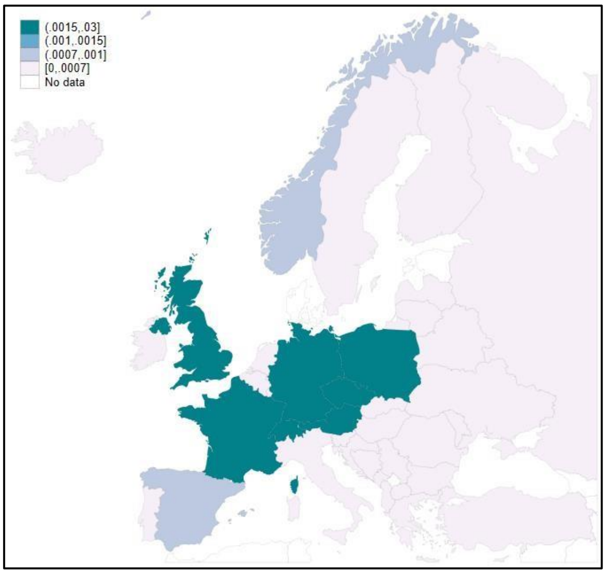


Figure A4: Cross-border syndicated loans across Europe

This figure reports the cross-border syndicated loan amounts across the borrowers' Countries, over the period 1985-2024. The map report strong colours for the countries that report higher cumulative damages on flood events across this period of time and neutral colours otherwise.

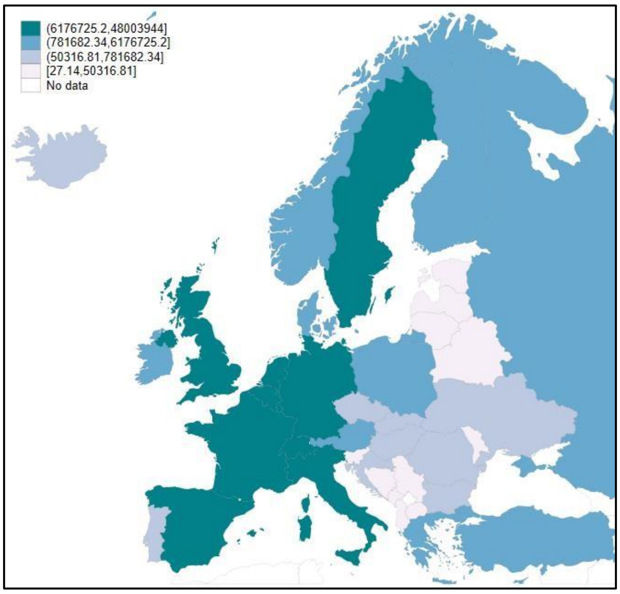


Figure A5: Evolution over time and changes on Flood events and Syndicated Loans

This figure shows the evolution on number of flood events and cross-border syndicated loan amounts over the period 1985-2024 for the all sample of countries. The x-axis shows the sample period. On the left-side, the y-axis shows the number of flood events by each year; on the right-side, the y-axis shows the cross-border syndicated loans amount lent.

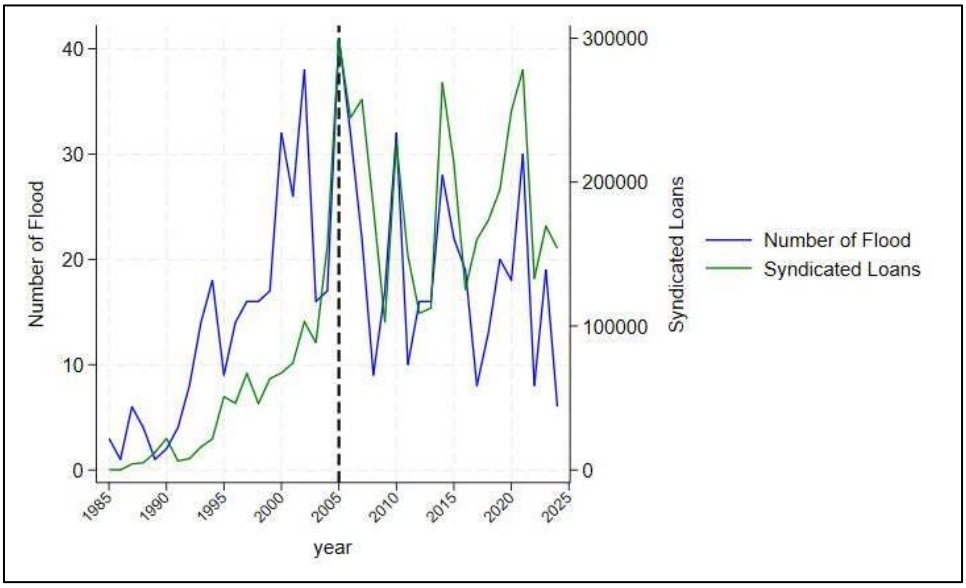
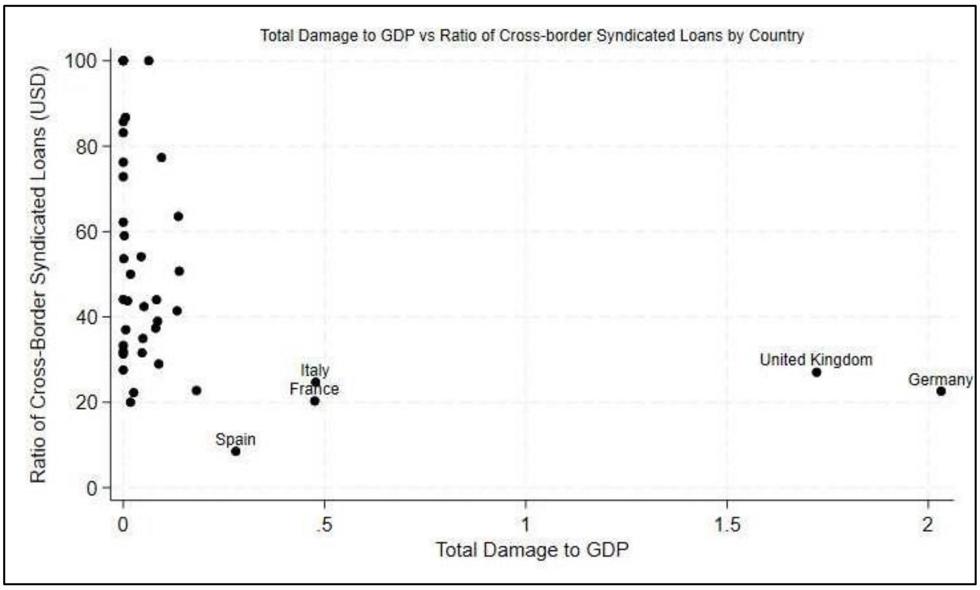


Figure A6: Total damages over syndicated loans share weighted ratio

This graph plots the relation between Cumulative Damages-to-GDP for each country over the sample period and the Ratio of Cross-Border Syndicated Loans (USD). The variable on the y-axis is calculate as the share of cross-border lending on total lending that each operating bank in the sample has financed in the syndicated loan market over the period 1985-2024. For variable definitions, see Table A1.



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