



UNIVERSIDADE CATÓLICA PORTUGUESA

# Climate risk and bank lending to firms: a literature review

Mariana de Oliveira Alves

Católica Porto Business School  
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by

Mariana de Oliveira Alves

supervised by  
Professor Doutor Bernardo P. Marques

Católica Porto Business School  
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# Abstract

Climate change poses a challenge to the global economy, with the banking sector and corporate borrowers at the vanguard of managing related risks. Against this backdrop, this thesis investigates the state-of-the-art of the literature on the impact of climate risk on bank lending to corporations, focusing both on physical and transition risks. To do so, a systematic literature review is performed that covers papers published in top Finance journals (ABS 3 or above), between 2000 and 2024, available in the "Web of Science" database, and which meet certain climate-related keywords. By analysing in detail the 23 papers that resulted from the systematic review, we find a large number of results and potential gaps in the literature, including, for instance, that (i) there is some concentration of climate risk measures (physical risks: natural disasters, transition risk: carbon emissions), (ii) studies on climate physical risks are concentrated on the impact of climate risk on borrower creditworthiness, whereas papers on transition risks are almost exclusively focused on regulatory changes as the transmission channel, (iii) only a few studies have studied borrowing firm's exposure to physical risks in Europe and the Emerging Markets; and (iv) physical risks generally exhibit a positive correlation with bank lending measures, while less consensus is found for transition risks. Overall, we view the results presented in this thesis as showcasing that the intersection between climate risks and bank intermediation is a vibrating field of study and we hope that researchers find this review interesting to guide future contributions for research.

Keywords: climate change, physical risk, transition risk, bank lending practices, corporate borrowing, literature review.

Number of words in the main body of the Thesis: 8,494.



# Resumo

As alterações climáticas representam um desafio para a economia global, com o setor bancário e as empresas na vanguarda da gestão dos riscos climáticos. Neste contexto, a presente tese tem como objetivo investigar o impacto do risco climático nas práticas de empréstimo bancário a empresas, focando-se nos riscos físicos e de transição. Para o efeito, foi conduzida uma revisão da literatura de publicações em revistas científicas de topo na área de Finanças (ABS 3 ou superior), entre 2000 a 2024, disponível na base de dados *Web of Science*, e que cumpre um conjunto de palavras-chave relacionadas com clima. Através da análise detalhada dos 23 artigos que resultaram da revisão sistemática, foi identificado um conjunto vasto de resultados e potenciais lacunas na literatura, incluindo, por exemplo, o entendimento de que (i) existe alguma concentração nas medidas de risco climático utilizadas (risco físico: desastres naturais, risco de transição: emissões de carbono), (ii) os estudos sobre riscos físicos encontram-se focados no impacto do risco climático na qualidade creditícia dos devedores, enquanto trabalhos sobre risco de transição dedicam-se quase exclusivamente às alterações regulatórias como canal de transmissão, (iii) existe apenas um número reduzido de artigos que analisam a exposição de empresas a risco físico na Europa e Mercados Emergentes; e (iv) os riscos físicos tendem a exibir uma correlação positiva com medidas de financiamento bancário, por contraposição aos riscos de transição, que revelam um menor grau de consenso. Em geral, estes resultados podem ser entendidos como reveladores de que a intersecção entre risco climático e intermediação bancária trata-se de uma área de estudo vibrante, esperando-se que esta revisão de literatura possa ser útil como guia para futuras trabalhos de investigação neste domínio.

Palavras-chave: alterações climáticas, risco físico, risco de transição, práticas de empréstimos bancários, revisão de literatura.

Número de palavras no corpo da Tese: 8,494.

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## 1. Introduction

The interplay between climate change and the banking sector has emerged as a pivotal area of research, with significant implications for global economic stability and sustainable development (Garmaise and Moskowitz, 2009; Javadi and Masum, 2021; Delis *et al.*, 2019; BCBS, 2021; Degryse *et al.*, 2023). Climate change, as reported by the World Economic Forum (2017) and the Intergovernmental Panel on Climate Change (IPCC, 2018), materializes in physical risks and transition risks that directly affect the banking sector's lending practices. Against this backdrop, there has been a growing interest by academia in the interaction between climate risk and the banking sector, leading to a significant volume of new papers addressing this topic. Moreover, while there have been some relevant studies performing literature review on related topics (Dafermos *et al.* 2018; Giglio *et al.*, 2021; BCBS, 2021), these have become relatively outdated, given the pace of new research in this field.

In this context, the goal of this thesis is to update the literature review on the impact of climate risk on the banking sector, with emphasis on corporate lending. To achieve this, a systematic literature review was conducted on papers published between 2000 and 2024, in the main Finance academic journals, and using a dictionary of climate related keywords. This process resulted in the identification of 23 articles that study the impact of climate risks (physical and transition) on bank lending to firms. Furthermore, the sample was subject to a bibliometric analysis and four papers were selected for a detailed review.

The main findings in this thesis may be summarized in the following way. First, we find that (i) physical and transition risks are evenly covered in the literature, (ii) there has been a surge in research on climate risk since 2019 (20 out of 23 papers being published in this period), (iii) there is some concentration of climate risk measures (physical risks: natural disasters, transition risk: carbon emissions),

and (iv) there are relatively few papers published in high-ranking journals (only 8 papers are published in ABS 4 journals), indicating potential barriers to entry to this topic. Second, with respect to the transmission channels, our findings suggest that studies on climate physical risks are concentrated on the impact of climate risk on borrower creditworthiness, with only a few exceptions exploring the impact on asset (collateral) valuation, loan demand (disaster lending) or bank funding costs; whereas, papers on transition risks are almost exclusively focused on regulatory changes as the transmission channel, suggesting the presence of a potential literature gap regarding the remaining two channels (technological change and consumer sentiment).

Thirdly, among other findings regarding the sample and econometric approach, we find that (i) studies have been concentrated on credit supply (physical risks) and loan pricing (transition risk), indicating the existence of research opportunities in less well-covered bank lending measures such as loan pricing and covenants (for physical risk); (ii) only a few studies have studied borrowing firm's exposure to physical risks in Europe and the emerging markets; (iii) a significant share of the studies does not explicitly mention their approach to mitigate endogeneity concerns, which could be seen as a limitation in their methodology, and an important gap in the literature; and (iv) none of the studies explores scope 2 or scope 3 CO<sub>2</sub> emissions, likely due to lack of data availability, which can be seen as a potential research opportunity, given that the upcoming tightening of CO<sub>2</sub> reporting requirements is likely to increase the availability of data (e.g., EU Taxonomy). Fourth and final, concerning the main results of the papers, we find that physical risks generally exhibit a positive correlation with lending measures, suggesting an increased demand for financial support during recovery and reconstruction phases; while, conversely, studies on the impact of transition risks on bank lending to firms show less consensus.

The remaining of this thesis is organized into four sections. **Section 2** presents a brief overview of climate change and its impact on the banking sector, with highlight to the challenges and risks posed by physical and transition factors. In **Section 3**, we detail the methodological approach followed in the thesis, namely the bibliometric analysis and detailed analysis of selected papers. **Section 4** presents the results of the bibliometric analysis, i.e., a quantitative perspective on the current state-of-the-art of the literature. **Section 5** provides a critical analysis of selected papers. In **Section 6** we provide a discussion of the main results, which can be seen as a summary of the previous sections; before concluding in **Section 7**.

## 2. Overview of climate change and the impact of climate risk on the banking sector

### 2.1. Climate change

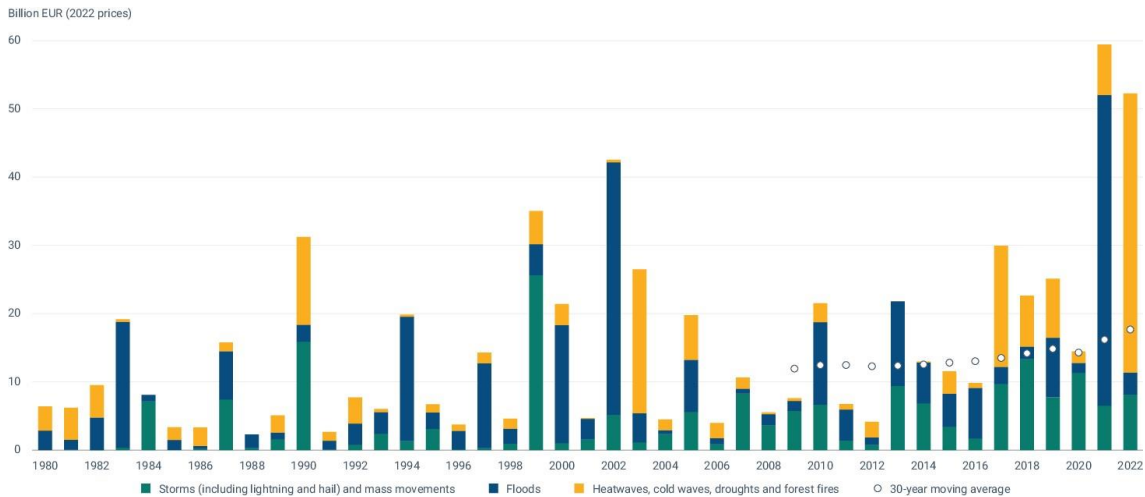
Climate change poses significant risks to the world economy (World Economic Forum, 2017). It affects the availability of resources, influencing the price of energy and the value of companies. The Intergovernmental Panel on Climate Change (IPCC) has concluded that the level of emissions observed since the mid-20th century is likely to lead to global warming of 1.5°C above pre-industrial levels between 2030 and 2052 (IPCC, 2018). This would cause lasting changes, increasing the likelihood of serious, far-reaching, and irreversible impacts on ecosystems and people. Effectively, over the last forty years, the number of natural disasters worldwide and the resulting economic losses (insured and uninsured) have increased significantly (**Figure 1**).

As a result, policymakers have begun to recognize that climate change represents a major and urgent threat (Reghezza *et al.* 2022). More precisely, the Paris Agreement (COP21), signed in December 2015, marks a significant turning point, with nations accounting for 97 percent of global greenhouse gas emissions pledging to implement actions to limit the rise in global temperatures to below 2°C compared to pre-industrial levels. Furthermore, COP21 called upon countries to outline their strategies for mitigating emissions in the medium and long term through 'Intended Nationally Determined Contributions' (INDCs) (Reghezza *et al.* 2022). This agreement is the first of its kind to acknowledge the importance of aligning financial flows with objectives that support low-emission and climate-resilient development.

For the financial industry, this agreement signals a shift towards the redirection of capital to support these goals. Additionally, it reinforces mutual accountability among signatories to achieve the agreed-upon climate objectives, with a

commitment to a substantial reduction in CO2 emissions and the pursuit of net-zero emissions by the latter half of the 21st century (Reghezza *et al.*, 2022).

**Figure 1. Economic losses from extreme climate-related events in Europe over the 1980–2017 period (EUR billions, 2017 values).**



*Note: The moving average is calculated over a ten-year period. The stacked bars are divided into different segments indicating the economic losses by type of event. Source: EEA (2023)*

As one of the main providers of credit, the banking sector is a key player in these efforts (ECB, 2022). The momentum established by COP21 expanded the range of investment opportunities available to finance green projects and renewable energy. In fact, investments in renewable energy have increased sharply in recent years and are expected to grow enormously in terms of market share as well (Reghezza *et al.* 2022). This increase is driven by a growing consensus towards a low-carbon economy and technological improvements that lead to cost reductions in renewable energy, making alternatives to fossil fuels more attractive (Reghezza *et al.* 2022).

The exploration of climate change has highlighted the profound implications for the global economy and the emerging role of the banking sector in mitigating these effects. As we navigate the complexities of the transition to a sustainable future, the financial sector's strategies and responses become increasingly

significant (ECB, 2022). With the stage set for further investigation, the next section examines the specific risks that climate change poses to banks – which are now facing mounting regulatory and supervisory pressure to enhance the management and disclosure of climate related risks (ECB, 2022).

## 2.2. Impact of climate risk on the banking sector

As discussed by the Basel Committee for Banking Supervision (BCBS, 2021), the climate-related risks faced by banks can be split into two main categories: physical risks and transition risks – which we detail in the next sub-sections.

### 2.2.1. Physical risks

Physical risks in the banking sector are defined as the direct impact of extreme weather events, such as increasingly frequent or severe storms, floods, and droughts (ECB, 2021), which can dramatically raise the financial value at risk by destroying assets like homes, offices, and factories, leading to substantial economic losses and heightened compensation for loss or liability risk (Beau, 2019). The escalation of these physical risks prompts the introduction of a wide range of new environmental rules and regulations, which may tighten existing standards or impose entirely new environmental obligations on businesses, giving rise to transition risks.

The vulnerability of the banking sector to hurricanes is a critical aspect of physical risks that has been thoroughly examined in the literature. Brei *et al.* (2019) provide a clear picture of how banks adjust their lending practices immediately following hurricane strikes, demonstrating a reactive approach to

borrower quality in disaster-stricken regions, underscoring the importance of borrower quality in the face of climatic challenges.

The impact of extreme weather events extends beyond immediate disaster response and into the broader credit markets. For instance, Garmaise and Moskowitz (2009) reveals the intricate ways in which banks incorporate natural disaster risks into their loan pricing strategies, affecting both borrower quality and loan demand. In a similar vein, Massa and Zhang (2021) examine the repercussions of insured losses from Hurricane Katrina on institutional bonds, thus shedding light on how asset valuation and bank funding costs are influenced by climate-related physical risks.

Long-term climate phenomena, such as droughts, also have profound implications for the banking sector. Furthermore, Faiella and Natoli (2018), and Koetter *et al.* (2020) explore the indirect effects of climate-related physical risks on credit supply, emphasizing regional disparities and the challenges faced by banks in managing recovery lending, which ultimately affects bank funding costs.

### 2.2.2. Transition risks

Transition risks arise from adjustments made to develop a green economy and depend on the timing and speed of this process (BCBS, 2021). Unanticipated changes in climate policies, regulations, technologies and/or market sentiment can trigger a rapid reassessment of the value of broad categories of assets (Batten *et al.* 2017), leading banks to revalue the assets given as loan collateral (Piero, 2024). Consequently, banks exposed to climate-sensitive sectors could be forced to make quick sales of carbon-intensive assets, leading to liquidity problems (Pereira da Silva, 2019).

On the other hand, these risks are likely to produce significant and systematic impacts on financial stability and macroeconomic conditions (Allen *et al.*, 2020). A disorderly transition to a low-carbon economy, characterized by the sudden introduction of climate policies and a lack of full anticipation by investors, could lead to a swift revaluation of carbon-intensive assets and thus affect portfolio performance (Battiston *et al.*, 2017).

There is a growing awareness that investors are not yet pricing climate risks into the value of financial contracts, potentially increasing their exposure to such risks (Morana and Sbrabana, 2019; Dunz, 2021). The main barriers to aligning investments with the low-carbon transition are the deep uncertainty surrounding the introduction of climate policies and the characteristics of climate risks, which present a new type of risk for economic analysis (Dunz, 2021).

Moreover, transition risks could also affect banks' credit risk if new technologies or changes in consumer behaviour towards 'environmentally friendly' sectors reduce the profitability of carbon-intensive companies, further increasing their default risk (Krueger *et al.*, 2020).

Although transition risks are difficult to quantify, the market valuation of the main US coal producers fell by 95 per cent in the period 2010-2017, highlighting that disruptive changes in technology can cause sharp fluctuations in the valuation of 'stranded assets' (Longwell *et al.*, 1995).

### 3. Methodology

#### 3.1. Bibliometric analysis

To perform the bibliometric analysis, we start by establishing a set of selection criteria that capture the complex relationship between climate risk and the banking sector's lending practices to firms. Namely:

1. **Period of publication:** This step defines the period of the review, spanning the period from 2000 to 2024, to include both the fundamental and the most recent contributions in the field;
2. **Relevance of the academic journal:** In this step, leading academic journals are identified, using methodologies inspired by seminal works such as Brocke *et al.* (2009), to ensure the inclusion of articles from reputable and relevant academic sources. The ABS ranking serves as an indicator of the journal's prestige and the perceived quality of the research it publishes (Hussain, 2010). The criterion used was to exclusively consider journals with an ABS ranking greater or equal to 3 (3, 4 and 4\*).
3. **Keyword analysis:** Using the Web of Science database, we apply the criteria identified above (1 and 2) as well as the following dictionary of climate-related keywords: climate risk, wildfire, forest fire, drought, temperature, heat stress, water stress, hurricane, typhoon, sea level rise, sea, transition risk, CO2 emissions, Paris agreement, stranded assets, electric vehicle, pricing, cost of debt, debt pricing, debt cost, financing cost, loan pricing, loan spread, credit risk, credit pricing, bank debt, bank lending, credit rationing loan rationing, and recovery lending. Applying criteria 1,2 and 3 resulted in the identification of 785 articles.
4. **Detailed analysis and additional criteria:** Finally, an in-depth analysis of the paper abstracts was performed, to screen papers that cumulatively meet the following criteria: (i) the unit of analysis is a non-financial firm,

(ii) the debt instrument is a bank loan, and (iii) climate-related measures are used as causal or moderating mechanisms of bank lending. Articles that did not fully meet these criteria were excluded, resulting in a refined selection for further analysis.

Furthermore, after applying the abovementioned criteria, a set of papers was added based on their impact within the scientific community, as indicated by the number of citations on Google Scholar. Effectively, this step was taken to ensure that the final sample included significant papers and working papers that, despite not being published in journals with an ABS ranking above 3, are considered influential and contribute with valuable insights to the field.

Finally, after reaching the final sample, the papers were systematically categorized, based on four dimensions: (i) the overall identification (which includes the year of publication, journal/ABS ranking, typification of the main climate risks, and citations), (ii) the transmission channels (i.e., the mechanisms via which climate risks are expected to influence the bank lending measures), (iii) the sample and econometric approach (comprising the sample period, countries, climate and bank lending measures, econometric methods used, and endogeneity mitigation strategies), and (iv) key findings (namely, the sign and statistical significance of the main coefficient of interest).

### 3.2. Detailed review of selected papers

To further understand the state-of-the-art of the literature on climate risk and the banking sector, a second method was applied, related to the detailed analysis of two papers in each strand (physical and transition risks).

The selection of the papers was performed with the goal of diversifying across a set of dimensions, including the type of climate sub-risk but also the sample

composition (country/period), the type of measures and methods used, and the impact on the field of study (i.e., number of citations).

In sum, this part of the analysis aims to augment the bibliometric analysis by performing a qualitative, in-depth review of a variety of key contributions to the literature.

## 4. Results of the bibliometric analysis

### 4.1. General overview

**Table 1** provides a global perspective of the list of 23 papers that study the impact of climate-related risks in the bank lending to the corporate sector, of which 11 papers study only physical risks, 11 papers study only transition risks, and 1 paper studies both types of risk – indicating that both types of risk are evenly covered in the literature. The table is organized into two panels, with **Panel A** focusing on physical risks and **Panel B** addressing transition risks.

The analysis of the column (1) of **Table 1** reveals that research on climate-related risks within the banking sector are concentrated after 2019 (20 out of 23). This trend underscores the escalating importance and urgency of understanding the financial implications of climate change, especially after the Paris agreement.

In column (3) of **Table 1**, we can observe that 7 out of the 11 papers addressing physical risk are focused on natural disasters, whereas all transition related risks are somehow related to potential losses arising from adverse changes in the regulatory landscape. On the other hand, the underrepresentation of certain sub-types, such as wildfire risk (physical risks) or technology and reputation risks (transitions risks), suggests the presence of potential gaps in the literature and opportunities for future research.

Additionally, column (4) shows that most papers have been published in journals with an ABS rank of 3 or 4, reflecting the criteria used to identify the papers and underscoring the scholarly rigor of the research. However, it is noteworthy that only 8 papers have been published in journals with the highest ABS rank of 4 within this specialized topic. This observation may suggest some resistance to embracing highly specialized topics like climate risk in finance journals, which often have a more generalist nature. The limited number of publications in top-tier journals could be indicative of the challenges researchers face in aligning the

nuanced aspects of climate risk with the broader themes traditionally explored in finance literature.

Finally, the citation counts in the last column provide a measure of the impact and recognition of the research within the academic community. Papers with high citation counts, such as Javadi *et al.* (2021) with 211 citations, demonstrate significant influence and contribution to subsequent studies. On the other hand, papers with fewer citations may represent emerging research areas or underexplored topics within the field.

**Table 1.** General overview

Reference (1)	Title (2)	Climate risk sub-type (3)	Journal (ABS rank) (4)	# Citations (5)
<i>Panel A. Physical risk</i>				
Benincasa <i>et al.</i> (2024)	How do firms cope with losses from extreme weather events?	Hydrogeological risk	JCF (4)	16
Miguel <i>et al.</i> (2024)	Climate-change regulations: Bank lending and real effects	Regulatory risk	JFS (3)	5
Ivanov <i>et al.</i> (2022)	Bank lending networks and the propagation of natural disasters	Natural disasters on borrower credit	FM (3)	47
Javadi and Masum (2021)	The impact of climate change on the cost of bank loans	Climate change (drought)	JCF (4)	211
Massa and Zhang (2021)	The Spillover Effects of Hurricane Katrina on Corporate Bonds and the Choice Between Bank and Bond Financing	Natural disasters (hurricanes)	JFQA (4)	73
Koetter <i>et al.</i> (2020)	Borrowers under water! Rare disasters, regional banks, and recovery lending	Climate change (flood)	JFI (4)	160
Brei <i>et al.</i> (2019)	The impact of natural disasters on the banking sector: Evidence from hurricane strikes in the Caribbean	Natural disasters (hurricanes)	QREF (2)	114
Schüwer <i>et al.</i> (2019)	How do banks react to Catastrophic Events? Evidence from Hurricane Katrina	Natural disasters	RoF (4)	145
Collier <i>et al.</i> (2019)	Firms' Management of Infrequent Shocks	Natural disasters (hurricanes and volcanic eruption)	JMCB (4)	41
Faiella and Natoli (2018)	Natural catastrophes and bank lending: the case of flood risk in Italy	Hydrogeological risk	Not applicable	40

Reference (1)	Title (2)	Climate risk sub-type (3)	Journal (ABS rank) (4)	# Citations (5)
Cortés (2014)	Rebuilding after disaster strikes how local lenders aid in the recovery	Natural disasters	Not applicable	96
Garmaise and Moskowitz (2009)	Catastrophic Risk and Credit Markets	Natural disasters (earthquakes and hurricanes)	Not applicable	138
<i>Panel B. Transition risk</i>				
Miguel <i>et al.</i> (2024)	Climate-change regulations: Bank lending and real effects	Regulatory risk	JFS (3)	5
Bruno and Lombini (2023)	Climate transition risk and bank lending	Regulatory risk	JFR (3)	4
Degryse <i>et al.</i> (2023)	When green meets green	Regulatory risk	JCF (4)	116
Ding <i>et al.</i> (2023)	Does carbon emission of firms matter for Bank loans decision? Evidence from China	Regulatory risk	IRFA (3)	24
Haas and Kempa (2023)	Low-Carbon Investment and Credit Rationing	Financial and market risk	ERE (3)	19
Ivanov <i>et al.</i> (2024)	Banking on Carbon: Corporate Lending and Cap-and-Trade Policy	Regulatory risk	Not applicable	92
Ho and Wong (2022)	Effect of climate-related risk on the costs of bank loans: Evidence from syndicated loan markets in emerging economies	Regulatory and technology risk	EMR (2)	21
Ehlers <i>et al.</i> (2022)	The pricing of carbon risk in syndicated loans: Which risks are priced and why?	Regulatory risk and market risk	JBF (3)	182
Dunza <i>et al.</i> (2021)	Climate sentiments, transition risk, and financial stability in a stock-flow consistent model	Regulatory risk	JFR (3)	112
Huang <i>et al.</i> (2021)	Do banks price environmental transition risks? Evidence from a quasi-natural experiment in China	Regulatory risk	JCF (4)	68
Delis <i>et al.</i> (2019)	Being Stranded the Carbon Bubble? Climate Policy Risk and the pricing of Bank Loans	Regulatory risk	Not applicable	85
Kleimeier and Viehs (2018)	Carbon disclosure, emission levels, and the cost of debt	Regulatory and reputation risk	Not applicable	140

Note: JCF – Journal of Corporate, JFS – Journal of Financial Stability, FM – Financial Management Association International, JFQA – Journal of Financial and Quantitative Analysis, JFI – Journal of Financial Intermediation, QREF – Quarterly Review of Economics and Finance, RoF – Review of Finance, JMCB – Journal of Money, JFR – The Journal of Financial Research, IRFA – International Review of Financial Analysis, ERE – Environmental and Resource Economics, EMR – Journal Pre-proof, JBF – Journal of Banking and Finance, JFR – Journal of Financial Stability.

## 4.2. Transmission channels

**Table 2** outlines the transmission channels via which physical risks impact bank lending to corporations. Specifically, the table categorizes the papers in four channels: borrower quality, loan demand, asset valuation and bank funding costs.

Overall, the results in **Table 2** show that 8 out of the 12 papers on physical risks examine the impact of climate risk on borrower quality, understood as the ability and willingness of firms to repay a loan, assessed through a combination of standard financial information like credit scores, income, and past delinquencies (Iyer, 2016; Miguel *et al.*, 2024; Massa and Zhang, 2021; Brei *et al.*, 2019). This result suggests that the academic community has invested significant resources into the investigation of the impact of climate risk on the creditworthiness of borrowers, indicating that this channel is relatively exhausted in the literature.

On the other hand, asset valuation, which can be understood as “the fair monetary measure of the desirability of ownership of specific properties for a specific purpose” (Cowe-Falls *et al.*, 2023) is explored only by 2 papers in our sample (Benincasa *et al.*, 2024; Garmaise and Moskowitz, 2009). This suggests that there is still ample room in the literature to examine how extreme weather events and other physical risks can impact the value of assets, both for individual borrowers. We also note that this channel can be particularly useful to analyse for SME financing, which critically depends on the existence of collateral, due to the prevalence of asymmetric information issues (Duarte *et al.*, 2017).

Finally, regarding the two least studied channels, loan demand can be understood as the need or desire for loans by entities, influenced by economic conditions, interest rates, and borrowers’ financial situations; while bank funding costs, can be seen as the total expense a bank incurs to obtain funds, including components such as risk-free rates, credit risk premiums and liquidity risk

premiums (Beau, 2014). More specifically, Cortés (2014) examines how such risks influence demand for borrowing (disaster lending), while Ivanov *et al.* (2022) and Javadi *et al.* (2021) explore their effects on banks' cost of funding, which can alter lending practices and profitability. In sum, both topics (loan demand and bank funding costs) can be seen as showing substantial gaps in the literature that should be addressed.

**Table 2.** Transmission channels: physical risk

Reference	Borrower quality	Loan demand	Asset valuation	Bank funding costs
Benincasa <i>et al.</i> (2024)			✓	
Miguel <i>et al.</i> (2024)	✓			
Ivanov <i>et al.</i> (2022)	✓			✓
Javadi and Masum (2021)				✓
Massa and Zhang (2021)	✓			
Koetter <i>et al.</i> (2020)	✓			
Brei <i>et al.</i> (2019)	✓			
Schüwer <i>et al.</i> (2019)	✓			
Collier <i>et al.</i> (2019)	✓			
Faiella and Natoli (2018)	✓			
Cortés (2014)		✓		
Garmaise and Moskowitz (2009)			✓	

**Table 3** shows the results of categorizing the transition risks' papers into three channels via which the shift towards a low-carbon economy can influence bank lending to firms: regulatory change, technological innovation, and consumer sentiment.

The first channel, regulatory change, refers to modifications or updates in laws, rules, and guidelines that govern corporate behaviour, particularly in financial

reporting and corporate governance (Abdulmalik *et al.*, 2019). This channel is by far the most extensively studied (10 out of 12).

Regarding the remaining channels, technological innovation is understood as the implementation of an idea for a new product or a new service or the introduction of new elements in an organization’s production process or service operation. In this regard, the study by Haas and Kempa (2023) explicitly acknowledges the role that advancements in green technology play in driving economic and financial change. As for consumer sentiment, it has been addressed by Dunza *et al.* (2021), who recognize that public perception and behaviour related to climate change can significantly influence market dynamics and financial decisions.

In sum, the existing literature on transition risks is almost exclusively focused on regulatory changes as the transmission channel, indicating a relevant literature gap on the remaining two channels (technological change and consumer sentiment).

**Table 3.** Transmission channels: transition risk

Reference	Regulatory change	Technological innovation	Consumer sentiment
Miguel <i>et al.</i> (2024)	✓		
Bruno and Lombini (2023)	✓		
Degryse <i>et al.</i> (2023)	✓		
Ding <i>et al.</i> (2023)	✓	✓	
Haas and Kempa (2023)		✓	
Ivanov <i>et al.</i> (2024)	✓		
Ho and Wong (2022)	✓		
Ehlers <i>et al.</i> (2022)	✓		
Dunza <i>et al.</i> (2021)	✓		✓
Huang <i>et al.</i> (2021)	✓		
Delis <i>et al.</i> (2019)	✓		
Kleimeier and Viehs (2018)			✓

### 4.3. Sample and econometric approach

Next, we analyze the composition of the sample, climate and bank measures and econometric methods applied in each paper, organized by type of risk (physical and transition risk).

Starting with **Panel A** of **Table 4**, columns (2) and (3), we can observe that the proxies used to measure exposure to physical risks are very diverse (e.g., damages from natural disasters, the Palmer Drought Severity Index, the Hurricane Destruction Index) and seem to depend both on private and public sources of weather or disaster related data – for instance, only 3 of the 6 papers focused on the US use data from public sources, namely, the Federal Emergency Management Agency (FEMA) and the National Oceanic and Atmospheric Administration (NOAA).

With respect to the lending measures –columns (4) and (5) –, 7 out of the 12 papers test the impact of climate risk on credit supply, with data drawn from a variety of databases such as Amadeus (firm-level), the Federal Financial Institutions Examination Council (FFIEC), and national credit registers (loan-level) – making the study of this measure less attractive for prospective researchers. Conversely, the study of the impact of physical risks on loan pricing and loan covenants has only been analyzed by a smaller set of papers (3 and 2, respectively), representing a potential gap in the literature.

The geographic scope of the sample's studies, presented in column (6), shows a predominance of interest in the United States (6 out of 12 articles). Effectively, only three studies address emerging markets, such as the work by Miguel et al (2024) in Brazil, and only two consider the European context. This disparity highlights a significant research gap and suggests a potential area for further study, particularly in understanding how climate risks affect banking practices in different regions, especially in Europe.

Regarding the sample periods, column (7), the studies vary from short-term analyses, such as the post-Hurricane Katrina environment by Massa and Zhang (2021), to long-term historical data assessments like the multi-decade analysis by Ivanov *et al.* (2022). The most recent paper in the sample is by Miguel *et al.* (2024), indicating the ongoing relevance of this research area. The duration of the sample periods in these studies is crucial for capturing the immediate and long-term effects of climate risks on the banking sector.

With respect to the econometric methods employed, presented in column (8), 5 of the 12 papers employ Differences-In-Differences (DID) approach, wherein exposed firms in the period of the disaster/event are compared to two control groups: non-exposed firms and exposed firms prior to the extreme weather event; while the remaining papers use standard panel regression analysis.

Finally, addressing endogeneity is a crucial part of econometric analysis. Namely, the main point of concern is that there may be omitted factors that may simultaneously determine the exposure of the firm to climate risk and influence their credit worthiness (e.g., firms located in the rural countryside may lack managerial skills which simultaneously impair their ability to mitigate the exposure to wildfire risk, while also limiting their profitability potential). In this sense, as shown in column (9), some studies, such as Brei *et al.* (2019), have taken explicit steps to mitigate this issue using instrumental variables and a battery of fixed effects. A significant share of the studies, however, does not explicitly mention their approach to mitigate endogeneity concerns, which could be seen as a limitation in their methodology, and an important gap in the literature.

**Panel B of Table 4** shows the details of the sample and econometric approach of transition risks' studies. Namely, unsurprisingly column (2) shows that the majority of measures (7 out of 12) are related to the carbon intensity of borrowing firms, stemming from a set of different sources, such as the Carbon Disclosure

Project (CDP) and S&P Trucost. However, as noted in the table, none of the studies explores scope 2 or scope 3 CO<sub>2</sub> emissions, likely due to lack of data availability, which can be seen as a potential research opportunity, given that the upcoming tightening of CO<sub>2</sub> reporting requirements is likely to increase the availability of data (e.g., EU Taxonomy). On the other hand, some studies examine the implications of less well-known measures such as climate protection performance index (Bruno *et al.*, 2023) and climate-related risks for internal bank capital assessments, i.e., ICAAP (Miguel *et al.*, 2024).

In contrast to physical risks, the main measure of bank lending in transition risks' studies – column (4) – is loan pricing (9 out of 12). This seems to indicate that the literature is more inclined to test the narrative that banks are imbedding transition risk into the credit risk models of polluting firms, than they are to test the 'physical risk exposure-loan pricing' hypothesis. Importantly, this suggests that there is a potential gap in the literature for studies relating carbon intensity and access to bank credit.

With respect to geographical scope, column (6) shows that the studies addressing transition risks seem to have a more disperse focus than the physical risks' studies did, which may reflect the fact that carbon intensity is a relatively harmonized measure across countries.

Finally, regarding the econometric approach and endogeneity, columns (8) and (9) of **Table 4 (Panel B)** show that the majority of papers either employ panel regressions or DID, and have relatively poor endogeneity mitigation strategies, confirming the literature gap found for the physical risks' studies.

**Table 4.** Sample and econometric approach

Reference (1)	Climate measure (2)	Climate database (3)	Lending measure (4)	Lending database (5)	Sample country (6)	Sample period (7)	Econometric method (8)	Endogeneity mitigation (9)
<i>Panel A. Physical risk</i>								
Benincasa <i>et al.</i> (2024)	Self-reported monetary losses from extreme weather	EM-DAT	Credit supply	Amadeus database	41 economies in Central, Eastern, South-East Europe, Central Asia, the Middle East, and North Africa	2018-2020	Panel data regression	Not mentioned
Miguel <i>et al.</i> (2024)	Environmental risks ICAAP	Not applicable	Loan maturity, firm rating or size	BCB Sistema de Informações de Créditos (SCR)	Brazil	2017-2019	DID regression	DID matching estimator
Ivanov <i>et al.</i> (2022)	Damages from natural disasters	NOAA	Credit supply	Call Reports from FFIEC	United States	2000-2020	Panel regression analysis	Not mentioned
Javadi and Masum (2021)	Palmer Drought Severity Index (PDSI)	AIR database	Loan pricing	Comps database	United States (48 states)	1986-2017	Regression analysis	Not mentioned
Massa and Zhang (2021)	Insured losses from Hurricane Katrina	Bank of America Merrill Lynch U.S. Corporate and High Yield Master bond index	Institutional bond	Lipper's eMAXX fixed income	United States	2005	Regression analysis	Leveraging Hurricane Katrina as exogenous shock to the capital habitat of firms

Reference (1)	Climate measure (2)	Climate database (3)	Lending measure (4)	Lending database (5)	Sample country (6)	Sample period (7)	Econometric method (8)	Endogeneity mitigation (9)
Koetter <i>et al.</i> (2020)	County exposure to floods	DWDy	Credit supply	Deutsche Bundesbank's credit register	Germany	2003-2014	DID regression	Not mentioned
Brei <i>et al.</i> (2019)	Hurricane destruction index	Hurricane strike data	Credit supply	Bank financial statements and reports	Caribbean	1970-2016	Panel regression analysis	IVs, FE, and control variables for macroeconomic conditions
Schüwer <i>et al.</i> (2019)	Likelihood and severity of natural disasters	NOAA	Credit supply	FFIEC	United States	2000-2007	DID regression and Panel regression	Not mentioned
Collier <i>et al.</i> (2019)	Financial losses from Hurricane Sandy	NOAA	Loan pricing	Dun & Bradstreet and Call Reports from FFIEC	Areas by FEMA	2013	Panel data regression and DID	Not mentioned
Faiella and Natoli (2018)	Share of firms located in high-flood risk areas	Italian Civil Protection Department and Italian National Institute of Statistics	Credit supply	Bank of Italy supervisory reports	Italy	1995-2015	Panel regression analysis	FE, control variables, matching techniques
Cortés (2014)	Shocks in temperature	FEMA disaster declarations	Credit supply	FDIC and reports	United States	1999-2010	DID regression	Control group non-disaster areas, FE, IV
Garmaise and Moskowitz (2009)	Micro-level earthquake risk data	AIR database	Loan pricing	Comps database	United States (11 states)	1992-1999	Regression analysis	Addressed bias with census tract FE and loan analysis

Reference (1)	Climate measure (2)	Climate database (3)	Lending measure (4)	Lending database (5)	Sample country (6)	Sample period (7)	Econometric method (8)	Endogeneity mitigation (9)
<i>Panel B. Transition risk</i>								
Miguel <i>et al.</i> (2024)	Environmental risks ICAAP	Not mentioned	Credit supply	BCB-SCR	Brazil	2017-2019	DID regression	Not mentioned
Bruno and Lombini (2023)	Climate protection performance index	Eikon, Germanwatch	Credit supply (bank loan) + Loan pricing (bank loan)	DealScan	Around the world	2010-2021	OLS	Not mentioned
Degryse <i>et al.</i> (2023)	Carbon emissions and environmental disclosure factors	CDP	Loan pricing + Loan maturity + Other loan conditions (covenants)	Thomson Reuters LPC DealScan Database	Around the world	2010-2018	DID regression	FEs, Hausman Specification Test, Matching Procedures
Ding <i>et al.</i> (2023)	Carbon emissions (industry level)	CSMAR	Loan pricing	CSMAR	China	2008-2018	Regression	Lagged variables, excl. certain companies, Industry FE
Haas and Kempa (2023)	Climate risk factors	N/A	Loan pricing	N/A	Not specified	N/A	N/A	N/A
Ivanov <i>et al.</i> (2024)	Carbon pricing policies	EPA	Loan pricing + Loan maturity	Y14 and SNC - Shared National Credit	United States	2011-2023	DID regression	Not mentioned
Ho and Wong (2022)	Scope 1 emissions	S&P Trucost	Loan maturity	Thomson Reuters LPC DealScan Database	Emerging market economies	2010-2021	Panel regression	IVs and FE
Ehlers <i>et al.</i> (2022)	Carbon intensity	S&P Trucost	Loan pricing	Dealogic	31 countries	2005-2018	Regression	Not mentioned
Dunza <i>et al.</i> (2021)	Green Supporting	N/A	Credit supply	N/A	Not specified	N/A	N/A	N/A

Reference (1)	Climate measure (2)	Climate database (3)	Lending measure (4)	Lending database (5)	Sample country (6)	Sample period (7)	Econometric method (8)	Endogeneity mitigation (9)
	Factor and Carbon Tax							
Huang <i>et al.</i> (2021)	Theoretical Modeling (E- DSGE Model)	CBIRC	Loan pricing + Loan spread	CBIRC Jiangsu Office	China	2010- 2016	DID regression	Diff. sectors, Pre- and post- Action loans, Loans from same bank
Delis <i>et al.</i> (2019)	Risk of stranded fossil fuel reserves	C3I and CCPI	Loan pricing	Dealscan	59 different countries	2007- 2016	Regression	Control for FE, variable interactions, sensitivity to commodity price controls, proven reserves data
Kleimeier and Viehs (2018)	Carbon emissions	CDP	Loan pricing	Dealscan	United States ( 58 states)	2009- 2016	OLS	Lagged Independent Variables, FE

*Note: AIR - BCB-SCR – Brazil Central Bank Credit Register, C3I - Climate Change Cooperation Index, CCPI - Climate Change Policy Index, CDP – Carbon Disclosure Project, CBIRC – China Banking and Insurance Regulatory Commission, CSMAR - China Stock Market and Accounting Research Database, DID – differences in differences, EM-DAT - Emergency Events Database, DWDy – German Weather Service - Deutscher Wetterdienst, FFIEC – Federal Financial Institutions Examination Council, FE – fixed effects, FEMA - Federal Emergency Management Agency, ICAAP – Internal Capital Adequacy Assessment, IV – instrumental variables, NOAA - National Oceanic and Atmospheric Administration, OLS – Ordinary Least Squares.*

#### 4.4. Main results

The sign and statistical significance of the main relationship of interest, i.e. the impact of the climate proxy on the bank lending measure, is summarized in **Table 5**.

Overall, **Panel A** shows that physical risks generally exhibit a positive correlation with lending measures, suggesting an increased demand for financial support during recovery and reconstruction phases. For instance, Benincasa *et al.* (2024) found that self-reported monetary losses from extreme weather positively affect loan volumes, indicating a proactive response from financial institutions to facilitate recovery efforts.

Conversely, the studies on transition risks present a more nuanced picture, as shown in **Panel B**. While some studies, such as Bruno *et al.* (2023), report a positive relationship between climate protection performance and syndicated loan activity, others, such as Ding *et al.* (2023), observe a negative correlation between carbon emissions and bank loan access. One possible explanation for this dichotomy is the complex interplay between proactive climate policies that encourage green investment and the increasing incorporation of climate risk assessments in lending decisions, which may penalize carbon-intensive industries.

The robustness of these findings is reinforced by the high level of statistical significance between the studies, denoted by '\*\*\*', indicating a strong relationship between climate risks and bank lending practices.

**Table 5. Main results**

Reference	Climate measure (X)	Lending measure (Y)	Coefficient sign	Statistical significance
<i>Panel A. Physical risk</i>				
Benincasa <i>et al.</i> (2024)	Self-reported monetary losses from extreme weather	Credit supply	+	***
Miguel <i>et al.</i> (2024)	Environmental risks from bank capital assessments	Loan maturity, firm rating or size	-	***
Ivanov <i>et al.</i> (2022)	Damages from natural disasters	Credit supply	+	***
Javadi and Masum (2021)	Palmer Drought Severity Index (PDSI)	Loan pricing	+	***
Massa and Zhang (2021)	Insured losses from Hurricane Katrina	Institutional bond	-	***
Koetter <i>et al.</i> (2020)	County × Time Fixed Effects	Credit supply	+	***
Brei <i>et al.</i> (2019)	Hurricane destruction index	Credit supply	+	***
Schüwer <i>et al.</i> (2019)	Likelihood and severity of natural disasters	Credit supply	+	***
Collier <i>et al.</i> (2019)	Financial losses from Hurricane Sandy	Loan pricing	+	***
Faiella and Natoli (2018)	Share of firms located in high-flood risk areas	Credit supply	+	***
Cortés (2014)	Shocks in temperature	Credit supply	+	***
Garmaise and Moskowitz (2009)	Micro-level earthquake risk data	Loan pricing	-	***
<i>Panel B. Transition risk</i>				
Miguel <i>et al.</i> (2024)	Environmental risks in ICAAP	Credit supply	-	***
Bruno and Lombini (2023)	Climate protection performance index	Credit supply + Loan pricing	+	***
Degryse <i>et al.</i> (2023)	Carbon emissions and environmental disclosure factors	Loan pricing + Loan maturity + Other loan conditions (covenants)	+	***

Reference	Climate measure (X)	Lending measure (Y)	Coefficient sign	Statistical significance
Ding <i>et al.</i> (2023)	Impact of carbon emissions on bank loan access	Loan pricing	-	***
Haas and Kempa (2023)	Determination of climate risk factors	Loan pricing	-	***
Ivanov <i>et al.</i> (2024)	Carbon pricing policies	Loan pricing + Loan maturity	+	***
Ho and Wong (2022)	Scope 1 emissions	Loan maturity	-	***
Ehlers <i>et al.</i> (2022)	Analysis of syndicated loans and carbon intensity	Loan pricing	-	***
Dunza <i>et al.</i> (2021)	Green Supporting Factor and Carbon Tax	Loan	-	***
Huang <i>et al.</i> (2021)	Theoretical Modeling (E-DSGE Model)	Loan pricing + Loan spread	-	***
Delis <i>et al.</i> (2019)	Risk of stranded fossil fuel reserves	Loan pricing	+	***
Kleimeier and Viehs (2018)	Carbon emissions as environmental performance measure	Loan pricing	+	***

Note: # citations taken from Google scholar (accessed: July 6, 2024). The last column presents the statistical significance of the main coefficient of interest, wherein \*, \*\* and \*\*\* represent statistical significance at the 1%, 5% and 10% thresholds, respectively.

## 5. Detailed review of selected papers

The four papers selected for the detailed review were:

- Physical risks: Garmaise and Moskowitz (2009), Javadi and Masum (2021);
- Transition risks: Delis *et al.* (2019), and Degryse *et al.* (2023).

Each selected paper offers a unique perspective on the different aspects of climate risk, from the immediate effects of natural disasters to the long-term implications of regulatory changes for a low-carbon economy. The selection reflected a balance between studies that examine the direct financial impacts of climate-related events and those that explore the broader economic transitions required to mitigate climate change.

### 5.1. Garmaise and Moskowitz (2009)

The study by Garmaise and Moskowitz (2009) provides a detailed examination of how catastrophic risks, specifically earthquakes, impact loan pricing and credit supply.

The authors investigate the effects of earthquake risks on loan pricing using data from 11 U.S. states. By integrating earthquake risk data from the AIR database with loan pricing information from the Comps database, the regression results reveal that higher catastrophic risks lead to increased loan spreads and stricter loan conditions.

The study employs regression models that control for firm-specific and macroeconomic factors, ensuring the robustness of the results. The use of detailed earthquake risk data and comprehensive loan pricing information allows for a precise assessment of how physical risks influence credit markets.

The findings suggest that banks proactively adjust loan spreads in response to higher catastrophic risks, reflecting the increased likelihood of default and

potential losses. This signals that most banks in the sample have already a risk management approach that integrates physical risk assessments and possibly a strategic shift towards geographic diversification and disaster recovery lending. Compared to the study by Delis, de Greiff, and Ongena (2019), which focuses on climate policy risks, Garmaise and Moskowitz (2009) highlight the immediate financial impacts of natural disasters. Both studies underscore the importance of risk-based loan pricing but differ in the nature of the risks examined. Nonetheless, the paper's main contribution lies in its pioneering analysis of the direct impact of natural disasters on credit markets, paving the way for subsequent research on physical risk management in banking.

## 5.2. Javadi and Masum (2021)

The paper by Javadi and Masum (2021) provides a comprehensive analysis of how persistent climatic changes, specifically drought conditions, impact loan pricing and credit availability.

More specifically, the authors investigate the effects of climate change on the cost of bank loans across 48 U.S. states. Using the Palmer Drought Severity Index (PDSI) to measure drought conditions, their regression models reveal that worsening droughts lead to higher loan spreads, reflecting the increased risks associated with climate change.

The study employs regression models that control for firm-specific, regional, and temporal factors to ensure robust results. The use of PDSI data and detailed loan information allows for a precise assessment of the impact of long-term climatic conditions on loan pricing.

The findings suggest that banks adjust loan spreads to account for the heightened risks of default due to adverse climatic conditions. In line with Garmaise and Moskowitz (2009), this results suggests that banks are integrating climate risk

assessments into their credit evaluation processes and developing strategies for climate-resilient investments.

However, in contrast to Garmaise and Moskowitz (2009), which focus on immediate catastrophic risks, Javadi and Masum (2021) provide insights into the long-term impacts of climate change. Both studies highlight the importance of risk-based loan pricing, with Javadi and Masum (2021) emphasizing the persistent nature of climate-related risks.

The paper's main contribution is its forward-looking approach to quantifying the long-term financial impacts of climate change on loan pricing, highlighting the critical need for the banking sector to adapt to an evolving risk landscape.

### 5.3. Delis *et al.* (2019)

The study by Delis *et al.* (2019) investigates how banks price loans in response to climate policy risks. Namely, by analysing syndicated loan data alongside climate policy measures, the authors show that banks impose higher loan spreads on firms facing elevated climate policy risks, indicating a precautionary approach to potential regulatory costs.

Specifically, the authors use syndicated loan data from various countries, combined with climate policy indices to measure the exposure of firms to regulatory risks. Their regression results, which control for firm-specific and macroeconomic factors, demonstrate a clear relationship between climate policy risk and loan pricing.

In line with the previous two studies on physical risks for US banks, the findings by Delis *et al.* (2019) suggest that banks worldwide are proactively incorporating climate policy risks into their lending decisions. Such pricing strategy serves as a risk management tool, reflecting the anticipated costs associated with transitioning to a low-carbon economy. Consequently, banks may strategically

adjust their portfolios, reducing exposure to high-carbon industries and favouring investments in green technologies.

However, when compared to Garmaise and Moskowitz's (2019) study on earthquake risk and loan pricing, it becomes evident that banks similarly adjust loan spreads in response to both physical and transition risks, albeit through different mechanisms. Meanwhile, the impact of anticipated policy changes differs from the immediate effects of insured losses examined by Massa and Zhang (2021).

The study's main contribution lies in its seminal exploration of the intersection between climate policy and financial decision-making, offering crucial insights into how banks are adapting their lending practices in anticipation of a low-carbon future.

#### 5.4. Degryse *et al.* (2023)

The work by Degryse *et al.* (2023) investigates the impact of green regulations on bank loan spreads, using a comprehensive dataset that includes loan information, firm-specific characteristics, and green regulation indicators. By employing a DID approach, the authors find that banks impose higher loan spreads on firms facing stricter green regulations, reflecting the anticipated costs and risks of environmental compliance.

The study employs a DID methodology to control for potential confounding factors, ensuring the robustness of their findings. The dataset combines detailed loan information with firm-specific data and green regulation indicators, providing a comprehensive view of how regulatory risks are priced into bank loans.

The findings indicate that banks are proactively adjusting loan spreads to account for the costs associated with green regulations. This risk management

strategy involves integrating environmental compliance costs into credit risk assessments and potentially favouring firms with strong environmental performance or investments in green technologies.

When compared to Delis, de Greiff, and Ongena (2019), which examines broader climate policy risks, Degryse *et al.* (2023) provide a focused analysis on green regulations. Both studies highlight the role of regulatory risks in shaping bank lending practices, but Degryse *et al.* (2023) offer specific insights into the financial implications of environmental compliance.

The study's principal contribution is its meticulous dissection of the direct relationship between green regulations and bank lending, enriching the discussion on how financial institutions are adapting to the evolving landscape of environmental sustainability.

## 6. Discussion

This thesis has systematically explored the intricate relationship between climate change and the banking sector, particularly focusing on the impact of climate risks on corporate lending.

The literature on climate risks within the banking sector has been evenly distributed between physical and transition risks, reflecting a balanced academic interest in both dimensions. Notably, there has been a pronounced increase in research since 2019, with most of the identified papers published in this period. This trend likely reflects the growing recognition of climate change as a pressing financial risk and the urgency to understand its implications following the Paris Agreement.

A significant concentration of studies on physical risks has utilized natural disasters as a proxy, which may indicate a research gap in other types of physical risks such as wildfires, droughts, and sea-level rise. This observation aligns with the finding that studies on physical risks are primarily focused on borrower creditworthiness, with less attention given to other transmission channels like asset valuation, loan demand, and bank funding costs. This suggests potential avenues for future research to explore these underrepresented areas.

The relatively few papers published in top-tier ABS 4 journals suggest barriers to entry for this specialized topic. This could be due to the complexity of integrating climate risk into traditional financial research frameworks or the nascent nature of this field. Moreover, a significant share of studies does not explicitly address endogeneity concerns, which may limit the methodological robustness of their findings and presents an opportunity for methodological advancements in future research.

The presence of well-cited papers in the field indicates that certain studies have had a substantial impact on the academic community and potentially on practice.

However, none of the studies explores scope 2 or scope 3 CO2 emissions, likely due to data constraints. This gap is poised to become an important research opportunity, especially as CO2 reporting requirements become more stringent, potentially providing richer datasets for analysis.

The focus on credit supply in the study of physical risks and loan pricing in transition risks' studies reveals potential gaps in the literature regarding the effects on loan pricing and covenants for physical risks, and credit supply for transition risks. This indicates that future research could benefit from a more diverse set of lending measures to fully understand the multifaceted impacts of climate risks.

The main results underscore a positive correlation between physical risks and lending measures, suggesting a reactive demand for financial support during recovery phases. In contrast, the relationship between transition risks and bank lending is less consensual, reflecting the complexity of integrating forward-looking transition risks into current lending practices. This dichotomy underscores the need for banks to develop sophisticated risk assessment models that can accommodate the dynamic nature of climate risks.

## 7. Conclusions

This thesis has undertaken a comprehensive literature review to elucidate the impact of climate risks on bank lending to firms, a subject of growing importance in the face of global climate change. Through a meticulous bibliometric analysis and detailed examination of selected papers, this research has provided an updated synthesis of the current state-of-the-art in this field, focusing on the period from 2000 to 2024.

The findings of this thesis underscore the balanced academic coverage of both physical and transition risks, reflecting the dual nature of climate risks that banks must navigate when lending to firms. The surge in research post-2019 indicates an accelerating interest and urgency in understanding these risks, likely spurred by heightened regulatory focus and societal awareness following key international agreements on climate action.

A notable gap has been identified in the literature regarding the study of certain physical risks, such as wildfires, droughts, and sea-level rise, and their transmission channels beyond borrower creditworthiness. This presents an opportunity for future research to broaden the scope and deepen the understanding of how diverse physical risks affect bank lending practices.

The limited presence of high-tier journal publications within this specialized topic suggests potential barriers to entry, possibly due to the interdisciplinary nature of climate finance. Additionally, the methodological limitations highlighted by the absence of explicit endogeneity mitigation strategies in some studies call for more robust econometric approaches in future research.

Despite data constraints, particularly the lack of exploration into scope 2 and scope 3 CO<sub>2</sub> emissions, we anticipate that the evolving regulatory landscape will soon provide richer datasets, enabling more comprehensive analyses of climate risks in bank lending.

The main results of the reviewed papers reveal a generally positive correlation between physical risks and lending measures, indicative of a demand-driven response to support recovery and reconstruction efforts. In contrast, the relationship between transition risks and bank lending is characterized by a lack of consensus, reflecting the complexity of integrating these risks into current financial models and practices.

We view the results in this thesis as reaffirming the critical role of the banking sector and corporations in addressing climate risks through lending practices. As banks and corporations continue to adapt to a changing climate landscape, we hope that the insights garnered from this literature review can help pave the way for future research contributions.

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