South African Reserve Bank Working Paper Series WP/25/12

Climate risk and bank lending in South Africa

Helen Chiappini, Laura Nieri and Stefano Piserà

Authorised for publication by Konstantin Makrelov

18 August 2025

SOUTH AFRICAN RESERVE BANK

South African Reserve Bank Working Papers are written by staff members of the South African Reserve Bank and, on occasion, by consultants under the auspices of the South African Reserve Bank. The papers deal with topical issues and describe preliminary research findings and develop new analytical or empirical approaches in their analyses. They are solely intended to elicit comments and stimulate debate.

South African Reserve Bank Working Papers are externally refereed.

Information on South African Reserve Bank Working Papers can be found at
https://www.resbank.co.za/en/home/publications/Papers/working-papers.

Enquiries relating to the Working Paper Series can be addressed to:
Head: Economic Research Department
South African Reserve Bank
P O Box 427
Pretoria 0001

Tel. +27 12 313 3911

Climate risk and bank lending in South Africa

Helen Chiappini,[*] Laura Nieri[†] and Stefano Piserà[‡]

Abstract

This study investigates whether physical risk and transition risk factors affect South African bank lending behaviour. Results of baseline analysis suggest that physical climate risk negatively affects South African bank lending behaviour. Similarly, we find consistent results when considering climate transition risk proxied by the adoption of South Africa's carbon tax in 2019. Finally, we find that the physical climate risk effect is stronger for commercial banks and tends to assume a non-linear U-shape effect. Our research provides one of the first empirical assessments of climate risk effects on the South African banking industry and includes useful suggestions for practitioners, policymakers and regulators.

JEL classification

G00, G20

Keywords

Bank, bank lending, climate risk, physical risk, transition risk, South Africa

* University of Chieti-Pescara, Italy.

† University of Genoa, Italy. Corresponding author. Email: Laura.Nieri@unige.it.

‡ University of Genoa, Italy.

1. Introduction

Climate change has become a prominent topic on the global public agenda as it poses a risk to human life and economic development (Chalabi-Jabado and Ziane 2024). Since the Paris Agreement on Climate Change in 2015, governments worldwide have started to identify policies and plans to mitigate the effects of climate change and foster a green economy, which has implications for public expenditure. Financial institutions, and specifically banks, play a big role in financing the transition towards a climate-resilient economy and supporting the recovery of firms and households hit by climate-related events. For example, the United Nations Environment Programme Finance Initiative (UNEP FI) recently mapped cases where banks (e.g. Banco Bilbao Vizcaya Argentaria and National Australia Bank) launched a series of ad hoc financing programmes to support people after physical climate risk events (e.g. floods and hurricanes) (UNEP 2024).

At the same time, the economic and financial consequences of climate-related events, along with the risks associated with the need to manage the climate transition and comply with environmental regulations, represent significant challenges for firms and households, while emerging as a new driver of credit risk for banks. In this regard, climate-related risks could serve as a potential disincentive for banks, leading to a reduction in credit supply.

In line with this hypothesis, the relevant scientific literature provides evidence that physical risk may negatively affect bank lending behaviour, leading to a contraction of loans after a set of climate events, including temperature shifts (Conlon et al. 2024; Chalabi-Jabado and Ziane 2024; Duan and Li 2024).

On the other hand, the effects of climate transition risk on bank lending are conflicting (e.g. Chalabi-Jabado and Ziane 2024; Miguel, Pedraza and Ruiz-Ortega 2024; Reghezza et al. 2022) and related to the bank size (Miguel, Pedraza and Ruiz-Ortega 2024) or level of polluters (Reghezza et al. 2022). Climate transition risk may affect bank lending behaviour in two opposite directions. By complying with national or international regulations aimed at greening economic and financial systems, banks could either reduce their exposure to brown firms and sectors or choose to support these firms in their green transition by financing green innovations and new productions. In contrast, although physical risk has been shown to lead to the creation of ad hoc financing lines (UNEP FI 2024), it generally appears to have negative effects on bank lending (Conlon et al. 2024; Chalabi-Jabado and Ziane 2024; Duan and Li 2024).

Like many other countries, South Africa faces significant risks from climate change. According to the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC 2021), “Climate change will influence the growth rate and overall economic performance of the country. By mid-century, costs could reach between 8 and 12 billion EUR (or 3% to 5% of GDP) under low and high emissions scenarios, respectively. By the end of the century, South Africa could stand to lose up to 13.5% of GDP, or 33 billion EUR under a high emissions scenario”.

Despite the centrality of the climate issue, the impact of climate change risk on bank lending behaviour has not generated country-focused research in South Africa. Country-focused studies have, for instance, found a positive relationship between the increase of bank loans in South Africa and CO_2 emissions (Samour, Moyo and Tursoy 2022), showing that there is an increase in environmental degradation when the loans to firms grow without considering climate issues. In addition, a qualitative study analyses the banking commitment towards climate change using cases of South African banks and identifies huge differences in the banking approaches to climate change (Elsner and Neumann 2023). The international study by Chalabi-Jabado and Ziane (2024) includes South Africa in the sample of countries, confirming that physical risk hurts bank loan growth.

This research aims to fill the gap of studies that provide international evidence on the relationship between climate risk and bank lending, without a specific focus on South Africa, by investigating whether physical and transition risk affect South African banks’ lending behaviour. Our empirical analysis relies on a sample of 38 South African banking institutions over the period 2008–2024 and uses a highly granular dataset containing monthly bank-specific data sourced from the South African Reserve Bank (SARB) website.

Preliminary results suggest that physical climate risk negatively affects South African bank lending behaviour, proxied by the growth rate of bank loans to both non-financial firms and households. Similar results are obtained when we consider climate transition risk, proxied by the adoption of the 2019 carbon tax. We thus provide one of the first empirical assessments of the impact of adopting a carbon tax on bank lending in developing countries. More specifically, our findings show that transition risk has a negative effect mainly on loans to non-financial firms. We also observe that physical climate risk seems to have a greater (negative) impact on the growth of overdrafts compared to mortgages, with the overall impact statistically significant only for commercial banks. Finally, we demonstrate the existence of a non-linear relationship between climate change risk and lending behaviour, revealing a U-shaped effect in bank lending, previously observed only in firm production (Burke, Hsiang and Miguel 2015).

Robust to additional tests and specifications, these findings contribute to advancing the overall understanding of climate risk effects on South African bank lending behaviour and include relevant policy implications.

First and foremost, the results highlight the need for policymakers and regulators to address the decline in bank lending, which threatens the ability of South African firms and households to recover after physical climate risk events. This will allow banks to maintain their centrality in managing the transition to a green and resilient South African economy, without impairing their stability. In this context, the example of the European banking supervisor is particularly relevant. In 2020, the European Central Bank (ECB) published guidelines encouraging banks to adopt virtuous practices by incorporating climate risk governance into their strategies and business models (ECB 2020). Furthermore, banks are required to develop a robust framework to assess these risks and evaluate their impact on performance and, ultimately, on financial stability.

Our evidence of a negative reaction of banks to climate change risks also suggests a possible rebalancing of portfolios towards sectors less exposed to climate-related risks. While such behaviour may be justified as a strategy to contain banks' risk exposure, it could have negative implications for the real economy, potentially leading to reduced financing for counterparties that require funds for the transition. Therefore, targeted economic and financial policies are needed to enable banks to play a crucial role in financing the climate and environmental transition.

This study confirms that a comprehensive understanding of how banks respond to climate events and regulations requires access to data on credit lines dedicated to transition goals and physical risk recovery, as well as data on bank financing for both green and brown sectors. Disclosing such data would promote greater transparency, enhance market discipline, empower stakeholders to make better-informed decisions and ultimately motivate financial institutions to align their practices with sustainability objectives.

The rest of the paper is organised as follows. Section 2 presents the background and the literature review. Section 3 describes the data and method. Section 4 and 5 summarise the econometric approach and main results, while section 6 concludes and presents policy implications and avenues for future research.

2. Background, literature review and hypotheses

The aim of this section is to define climate-related risk, summarise the literature on climate-related risk and bank lending, and present the main hypotheses of our research.

2.1 Background on climate-related financial risk and bank lending

It is widely accepted that climate change has direct and indirect consequences for human life and economic institutions, such as banks. On the one hand, climate change causes acute or chronic physical events, such as droughts, floods and storms (acute events) or an increase in temperature or sea level (chronic events). On the other hand, political actions aimed at reducing climate change (such as the adoption of climate legislation or policies), new technological innovations to make production processes more environmentally friendly, and changes in consumer and investor preferences in favour of green products may generate transition risk (Taskforce on Climate-Related Risk 2019).

Both physical and transition risks can affect bank operations and the overall balance sheet directly or indirectly. The Taskforce on Climate-Related Risk (2019) and the ECB

(2020), among others, have provided insightful examples of the channels through which climate change may affect banks' operations and performance. For the purposes of our study, we focus on how physical and transition risks may affect lending behaviour and credit risk, excluding other risks (e.g. market risk, liquidity risk and operational risk).

Physical climate risk events, such as flooding, may indirectly affect credit risk by increasing the probability of borrower default or loss given default due to a reduction in the value of loan collateral (e.g. flooding can damage buildings used as loan collateral). Overall, the effects on probability of default and loss given default may result in increased bank losses and reduced profitability (ECB 2020). Consequently, the threat of physical risk may discourage lending in areas affected by past physical events or, more generally, in areas exposed to acute or chronic climate events.

Similarly, climate transition risk events such as the adoption of green legislation by a country (e.g. the South African carbon tax in 2019) may require corporate adaptation costs and generate lower corporate profitability. This could increase borrowers' probability of default and lower collateral value (ECB 2020), affecting bank losses and performance. In other words, the complete and proactive incorporation of transition risks into bank strategies and operations, or the incomplete incorporation of such aspects, may have positive or negative consequences for banks. Bank policies aimed at financing polluter firms may "positively affect commercial bank performance because banks can charge higher-risk premiums to higher-risk companies" (Chalabi-Jabado and Ziane 2024: 2). However, banks' failure to integrate transition risks into their strategies and policies "adversely affects their performance through increased default rates of high-risk firms and losses in financial assets" (Chalabi-Jabado and Ziane 2024: 2).

Worldwide, bank supervisors are working to raise awareness in the banking industry of climate-related risk and improve preparedness for managing such risk. The ECB is one of the most active bodies in this area, having implemented a wide range of guidelines to encourage banks to disclose information on climate-related risks, as well as conducting ad hoc stress tests to identify vulnerabilities in banks relating to climate change issues (see e.g. ECB (2020, 2022)). Recently, the SARB introduced similar guidelines for banks, including branches of foreign institutions and controlling companies, on integrating climate-related risks into their governance and risk management frameworks (SARB 2024).

With specific reference to South Africa, the World Bank's Sovereign ESG Data Portal states that the country is one of the world's top 15 emitters of greenhouse gases. South Africa's Department of Forestry, Fisheries and the Environment (2021) also reports that extreme weather events are becoming more frequent and intense than in the past. South Africa's overall climate vulnerability is high, with the World Bank (2021) ranking the country 92 out of 181. The outlook is not optimistic. Temperatures are expected to rise across all emission scenarios, with more than 120 hot days per year expected by the end of the century. In addition, droughts, floods and storm-related events such as high winds, coastal storm surges and hail are currently affecting South Africa and could be exacerbated by climate change.

Such climate events are likely to have dramatic effects on living conditions, health and the economy (World Bank 2021). Therefore, climate-related risk is a pertinent issue for South Africa, where there is an urgent need to enhance the resilience of financial systems to climate-related shocks and to maintain robust monetary policy credibility to address larger and more persistent price shocks (SARB 2024).

As a result, the SARB joined the Network for Greening the Financial System in 2019 and committed itself to:

- "ensuring that financial institutions and markets consider climate-related risks in their operations;
- understanding the impacts of climate change on inflation and financial stability and taking appropriate actions to mitigate against these risks; and
- greening its own operations" (SARB 2024).

2.2 Literature review

A growing body of literature has analysed the effects of climate risk on the behaviour of banks, paying particular attention to stability (Le, Tran and Mishra 2023; Liu et al. 2024; Roncoroni et al. 2021), liquidity (Lang et al. 2023; Lee et al. 2022; Xu, Ren and He 2024), performance (Caby, Ziane and Lamarque 2022; Lee, Zhang and Lee 2024) and lending behaviour (Chalabi-Jabado and Ziane 2024; Conlon et al. 2024; Duan and Li 2024). However, focusing specifically on lending, only a few studies have thus far investigated the effect of both physical and transition risks on banks' lending behaviour.

Studies have recognised that physical risk negatively affects bank lending behaviour. For example, Duan and Li (2024) demonstrated that in the United States (US), a temperature increase of 1°F over the past 36 months was associated with a 6.65% reduction in bank lending, as well as a 0.88% reduction in the loan approval rate. Another study of the US banking system found that banks reduced their lending when experiencing unexpected climate-related events such as floods, storms and heatwaves (Conlon et al. 2024). Finally, a study of 147 banks worldwide (including 40 banks in South Africa) confirmed that physical risk negatively affects bank loan growth (Chalabi-Jabado and Ziane 2024).

Conversely, literature analysing the impact of transition risk on banks' lending behaviour yields mixed results. According to Chalabi-Jabado and Ziane (2024), transition risk factors positively affected the loan growth of international banks on average, while Miguel, Pedraza and Ruiz-Ortega (2024) found positive effects for small banks and negative effects for large Brazilian banks. Another context-dependent study by Reghezza et al. (2022) showed that European banks reduce lending to polluting firms after the passage of the 2015 Paris Agreement. Focusing on South Africa, Monnin, Sikhosana and Singh (2024) identify and explore the primary transition risks facing the banking sector, with particular emphasis on the coal value chain. The authors provide a detailed assessment of the banking system's exposure to transition risks in the corporate sector, demonstrating that these risks are both significant in scale and broadly distributed across industries. They outline a range of macroprudential policy measures that could mitigate these risks and strengthen the resilience of the financial system in the transition to a low-carbon economy.

Although climate risk is a critical factor for banks in South Africa, the relationship between physical and transitional climate risk and bank lending behaviour is largely unexplored in climate finance literature. Understanding the impact of climate-related risk on South African bank lending is important because it enables effective regulations and targeted macroprudential policies to be developed to manage climate risks in the financial system. This would also help prevent climate-related financial crises, ensuring economic stability and supporting the transition to a sustainable economy by directing credit towards low-impact activities.

2.3 Hypotheses

Drawing on the literature review and the background on climate-related risks for banks, we aim to examine the impact of climate risks on the lending behaviour of South African banks. To this end, this paper empirically tests the following hypotheses:

H1: Physical risk negatively affects bank lending behaviour.

This first hypothesis is based on unambiguous evidence from empirical studies on the relationship between physical risk and bank lending. According to Chalabi-Jabado and Ziane (2024), exposure to physical risk events leads to a more conservative lending approach by banks due to the increased likelihood of borrowers being unable to repay their loans. Consequently, banks tend to shift their lending to less risky areas, impose more stringent loan terms and increase loan spreads.

H2a: Transition risk positively affects bank lending behaviour.
H2b: Transition risk negatively affects bank lending behaviour.

These two alternative hypotheses regarding the relationship between transition risk and bank lending behaviour are motivated by a mixture of findings in previous literature and underlying mechanisms that could justify similar results. Indeed, transition risk can create opportunities to expand or reduce lending, as banks may decide to increase lending to finance firms' transition to a green economy, or reduce lending to mitigate the credit risk associated with brown firms.

3. Data source and descriptive statistics

3.1 Data description

To explore the effect of climate change risk on the lending behaviour of South African banks, we gathered detailed data from all banks registered in the country, including both foreign and domestic institutions. Using data for both domestic and foreign banks enables a comprehensive assessment of the effect of climate change on the overall bank credit offered by banks operating in South Africa, which may vary depending on banks' distinctive features. Especially for foreign banks, the effect of climate risks on lending behaviour may be influenced by the policies set at the group level and regulations that apply to other countries where the banking group operates. Domestic banks, on the other hand, may be more sensitive to local climate policies and regional climate impacts. Studying both types of institution helps capture the heterogeneity in how banks perceive and react to climate-related financial risks. Consequently, we chose to account for the intrinsically different nature of domestic and foreign institutions by incorporating it as a dummy variable in our regression model. This approach allows us to fully understand the lending dynamic of all available banks operating in South Africa.

To this end, we retrieved data from the SARB website and publicly available databases like the Organisation for Economic Co-operation and Development (OECD) database. This comprehensive data collection allows for a thorough analysis of the broader banking landscape, including households, and financial and non-financial corporation loans.

Our study concentrates on a sample of 32 banks headquartered in South Africa, of which 13 are foreign-owned banks and 6 are branches of foreign banks operating in South Africa, for the period from 2008 to 2024.[1] As in previous research (see Casu, Chiaramonte and Cucinelli 2024), we use monthly bank-specific data retrieved from the BA900 economic returns, which are publicly available on the SARB website.

To measure physical climate change risk, we follow the literature using the country's welfare cost caused by climate change (CCrisk) and annual abnormal surface temperature (Abn_temperature) as a robustness test (Wang, Wang and Liu 2024). To capture the transitional side of climate change risk, we disentangle the effect of the adoption of the 2019 carbon tax (CT) in a difference-in-difference (DID) regression setting. Finally, to explore the effect of country perception of climate change risk

1 Some of these institutions may no longer be in operation due to mergers or liquidation; nonetheless, the relevant data pertaining to the periods during which they were active have been retained in our dataset.

(CCperc), we collect data on climate change risk perception from the Google trend database, aggregating it as a mean of a principal component analysis technique. Table 1 shows the data description and source, while Table 2 reports their descriptive statistics.

Table 1: Data description and source

Variables	Description	Source
Loans_Grwt	Monthly growth rate of loans and advances	Authors' estimations based on data available on the SARB website
House_loans_Grwt	Monthly growth rate of household loans	
FinCorp_loans_Grwt	Monthly growth rate of financial corporation loans	
NonFinCorp_loans_Grwt	Monthly growth rate of non-financial corporation loans	
CCrisk	Annual welfare costs caused by climate change scaled by total gross domestic product	OECD.stat, EXP_MORSC dataset
Abn_Temp	Annual surface temperature change	OECD.stat, GREEN_GROWTH dataset
CCperc	Monthly country climate change risk perception	Authors' estimation based on Google trend analysis
CT	Dummy variable equal to 1 for years after the introduction of the carbon tax (2019) and 0 otherwise	Authors' estimation
Size	Monthly natural logarithm of bank total assets	Authors' estimations based on data available on the SARB website
Eta	Monthly banks' total equity to total asset ratio	
Impairment_loans	Monthly loan impairments to total loans ratio	
Dep_Grwt	Monthly growth rate of deposits	
Gdp	Monthly gross domestic product growth rate	OECD data
Infl	Monthly consumer price index growth rate	
Shortint_Grwt	Monthly short-term government securities interest rate	
Covid	Dummy variable equal to 1 for 2020–2022 years and 0 otherwise	Authors' estimation

Table 2: Descriptive statistics

Variables	Mean	P.50	S.D	P.25	P.75
Loans_Grwt	0.0247	0.0052	0.1994	-0.0140	0.0293
House_loans_Grwt	0.0103	0.0028	0.1504	-0.0102	0.0158
FinCorp_loans_Grwt	0.3561	0.0001	0.234	-0.0462	0.0599
NonFinCorp_loans_Grwt	0.0114	0.0036	0.1311	-0.0207	0.0301
CCrisk	0.0445	0.0441	0.0156	0.0279	0.0570
Abn_Temp	1.120	1.083	0.388	0.815	1.415
Ccperc	-0.0079833	-0.1134	0.139	-0.9635	0.8225
Size (logarithm)	16.329	16.053	2.819	14.535	17.582
Eta	0.1721	0.1204	0.1604	0.0778	0.1969
Impairment_loans	0.0335	0.0170	0.0475	0.0062	0.0348
Dep_Grwt	0.014	0.077	0.0975	0.009	0.034
Gdp	0.003	0.004	0.0281	0.001	0.007
Infl	0.0561	0.0540	0.0175	0.0443	0.064
Shortint_Grwt	-0.001	0	0.0026	-0.001	0.001
Covid	0.1740	0	0.379	0	0

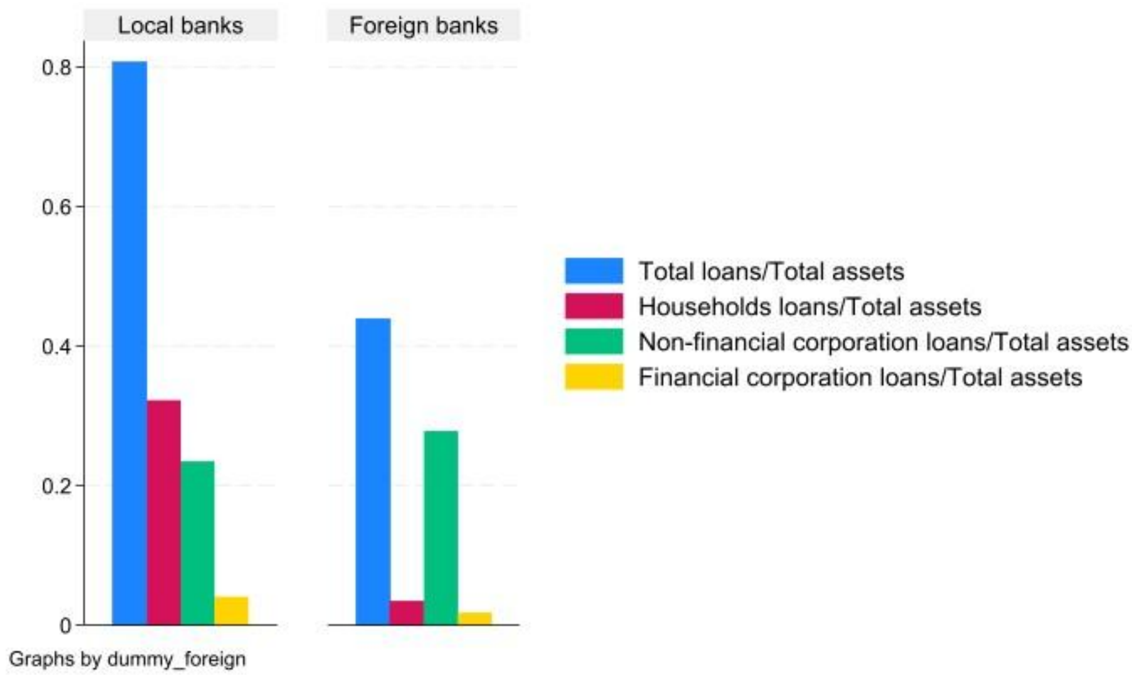
Note: This table shows the descriptive statistics of all variables used. All variables are winsorised at 99% of each tail.

3.1.1 Bank lending behaviour in South Africa

To fully capture the dynamic between climate change risk and bank lending behaviour, we collect data related to bank loans, distinguishing them based on the type of borrower: total loans, household loans, and loans to financial and non-financial corporations. To provide a more granular analysis, we further disaggregate total loans into two categories: mortgage loans and overdraft loans. As a proxy of bank lending behaviour, we use the monthly growth rate of these loan aggregates.

While it is true that many banks in the BA900 report limited lending activity, others present a remarkable weight of loans compared to total assets. Overall, our total sample of banks includes institutions with significant lending and others that may have smaller or more specialised lending operations. We decided to include all institutions that report any level of lending activity, even if minimal, as they contribute to the overall lending landscape and are relevant to our analysis. Additionally, our analysis includes banks engaged in niche lending markets that may not be immediately apparent from headline figures. As shown in Figure 1, despite heterogeneity in the absolute volume of loans across banks, the distribution of loans to assets ratios remains relatively balanced within the sample. This validates the inclusion of both domestic and foreign banks in the analysis.

Figure 1: Foreign vs domestic banks



Note: This figure shows total loans, households loans, non-financial corporation loans and financial corporation loans to asset ratios for domestic and foreign banks. The x-axis shows the domestic vs foreign banks group, while the y-axis accounts for selected loans to assets ratios.

3.1.2 Physical climate change risk measures

We follow the literature (Roy and Braathen 2017; Chiaramonte et al. 2024a) measuring country-level climate change costs using data on mortality, morbidity and welfare costs resulting from exposure to environmental risks, sourced from the OECD.stat database (dataset code: EXP_MORSC). This dataset has been widely used in recent empirical studies, such as those by Roy and Braathen (2017), as it provides comparable metrics on the welfare costs of climate change. The data are presented in terms of welfare expenses (e.g. deaths, infrastructure) scaled by the country's gross domestic product (GDP) in US dollars, allowing for cross-country comparisons and facilitating the analysis of the economic impact of climate-related health and welfare risks.

To ensure robustness in our analysis, we also use an alternative proxy for climate change costs by examining abnormal surface temperature data. This dataset, provided by the OECD Green Growth (dataset code: GREEN_GROWTH), allows us to assess the physical climate impacts associated with temperature deviations, strengthening our understanding of the economic and welfare effects of climate change. By employing both welfare cost data and temperature anomalies, we can triangulate the relationship between climate risks and their economic consequences, providing a more comprehensive view of the costs associated with climate change at the national level. However, because data for welfare cost and temperature anomalies are available until 2019, the period considered in our first regression is 2008–2019.

3.1.3 Climate change transition risk

Transition risk refers to the financial and operational challenges that arise as economies move towards a low-carbon or more climate-resilient future. Unlike physical risks, which stem from climate-related events like floods or droughts, transition risks emerge from the policies, technologies, market shifts and social pressures associated with mitigating climate change. As governments introduce new regulations, such as carbon pricing, emissions caps or stricter environmental standards, businesses – especially those in carbon-intensive industries – face higher operating costs and compliance burdens. Thus, the regulatory changes can affect firms' profitability, competitiveness and long-term viability. At the same time, technological innovation (such as renewable energy or electric vehicles) can disrupt traditional industries, making some business models obsolete or uncompetitive.

In the financial sector, and particularly for banks, transition risk is a concern because it can lead to a deterioration in the creditworthiness of borrowers, a decline in the value of certain types of collateral or a reassessment of the risk profile of entire sectors. If banks continue lending to companies that are not aligned with the low-carbon transition, they may face increased defaults, write-downs and reputational damage. Conversely, failing to support climate-aligned innovation may result in lost opportunities and strategic obsolescence. Therefore, the adoption of a carbon tax by a country is a classic example of transition risk, because it reflects the regulatory, economic and societal shifts required to achieve climate commitments.

However, unlike the physical dimension of climate change risk, measuring transition risk is not a trivial process. In line with the definition of transition risk as a "risk causing losses occurring after regulatory changes" (Dunz, Naqvi and Monasterolo 2017), we consider South Africa's environmental policy shifts – most notably the introduction of a carbon tax in 2019 – as a useful shock for analysing how businesses, financial institutions and government may be affected by the transition to a low-carbon economy.

According to regulators, the carbon tax will play a crucial role in helping South Africa meet the objectives outlined in the National Climate Change Response Policy (NCCRP)[2] and in fulfilling its commitments to reducing greenhouse gas emissions. Specifically, the NCCRP provides a comprehensive policy framework designed to facilitate a just and equitable transition to a low-emissions, climate-resilient economy. This transition will be supported by a combination of incentives and disincentives, including regulatory, economic and fiscal measures, all aimed at guiding the country towards sustainable growth.

Furthermore, following the ratification of the Paris Agreement, South Africa is committed to producing Nationally Determined Contributions every five years, detailing its efforts to reach a "peak, plateau and decline" trajectory for greenhouse gas emissions. As part of this commitment, South Africa aims to reduce emission levels between 398 and 614 million tons of carbon dioxide equivalent during the 2020–2035 period, with emissions set to decrease in absolute terms from 2036 onwards.

The carbon tax will be rolled out in two phases:

- Phase one: From 1 June 2019 to 31 December 2022, the tax will apply exclusively to direct emitters (scope 1 emitters).
- Phase two: From 1 June 2023 to 31 December 2030, the tax will continue to evolve, potentially expanding its scope and coverage.

Therefore, we empirically test the tax's effects on bank lending policies as a mean of a dummy variable taking the value of 1 for months after June 2019 and 0 otherwise. As a rule of thumb, a DID regression must include three or four time periods before the shock and three or four periods after. Therefore, we restrict the period of analysis from 2017 to 2024 to capture the causal effect of adopting the 2019 carbon tax.

---

2 The National Climate Change Response Policy came into effect in 2011. It provides a comprehensive plan to mitigate and adapt to climate change impacts in the short, medium and long term (up to 2050). According to this document, greenhouse gas emissions are expected to begin to decrease by 2020–2025 and then stabilise for up to 10 years before declining in absolute terms.

3.1.4 Climate change risk perception

While exploring the effect of climate change risk on bank lending behaviour, it is also relevant to investigate the role played by another dimension of such risk: its 'social' perception. To this end, we create an index based on Google Trends data in South Africa capturing the monthly public interest in and awareness of the topic of climate change, as measured by the relative frequency of online searches. The index indicates how much attention climate change is receiving from the public, businesses, banks (for our purposes), policymakers, media and other stakeholders at any given point in time.

As widely used in the literature (e.g. Aslanidis et al. 2022; Birindelli, Chiappini and Jalal 2023; Chiaramonte et al. 2024a), Google Trends is a good proxy of the social perception of a risk, fear or crisis. With reference to our research question, a rising Google Trend index may indicate increasing social or political attention on climate change, prompting banks to align lending portfolios with public expectations or anticipated regulation. Similarly, a higher level of public concern may pressure banks to show that they are actively managing these risks – leading to the formal integration of climate metrics into risk models.

Therefore, we create the Climate Change Perception Index by following the literature using Google Trends as a tool to capture stakeholders' perceptions (e.g. Birindelli, Chiappini and Jalal 2023; Chiaramonte et al. 2024a) and researchers previously using text analysis to build new climate risk indexes (e.g. Gavriilidis 2021). We search on Google Trends for the frequency of searches in South Africa between January 2008 and 2024 using the following keywords: 'carbon dioxide', 'climate risk', 'greenhouse gas emissions', 'CO_2' and 'global warming'. Then, we use the principal component analysis technique to aggregate the score and provide a final index of South African stakeholders' perceptions/awareness of climate change risk.

4. Empirical analysis

To assess the impact of physical and transition climate change risk on bank lending policies, we employ a two-step empirical approach. In the first step, we examine how the escalating country-level costs associated with climate change – that is, our proxy of physical risk – may affect bank lending behaviour. To test this hypothesis, we employ an ordinary least squares regression model with Bank*time fixed effects, which allows us to isolate the effects of country-level climate costs on the loan growth rate at the bank level, as follows:

$$Y_{i,t} = c + \beta_1 CCRisk_{i,t} + \boldsymbol{\gamma}'\boldsymbol{X}_{i,t} + Bank_i * time_t + \varepsilon_{i,t}$$

Where *Y* measures the monthly growth rate of total loans (Loans_Grwt), household loans (House_Grwt), loans to financial corporations (FinCorp_Grwt) and loans to non-financial corporations (NonFinCorp_Grwt) respectively. $CCRisk_{i,t}$ is the annual country measure of climate costs to GDP; *X* is a vector of control variables. In line with the relevant literature using a similar dataset (e.g. Casu, Chiaramonte and Cucinelli 2024), we control for bank *Size* (natural logarithm of total assets), equity to total assets (Eta), loan impairments to total loans (Impairments_loans), monthly growth rate of deposits (Dep_Grwt), monthly short-term government bond rate change (Shortint_Grwt), country-level GDP growth rate (*Gdp*) and monthly inflation rate (*Infl*). $Bank_i, * \ time_t$, and $\varepsilon_{i,t}$ represent bank interacted with time fixed effects and the error terms respectively.

In the second step, we investigate the effect of transition risk (proxied by the 2019 carbon tax regulation) on banks' lending policies employing a DID regression framework built around the adoption of the 2019 South African carbon tax policy. Using a DID regression allows us to test the effect of the 2019 carbon tax passage in South Africa and to estimate a causal impact by comparing how lending behaviour changes over time between a treated group and a control group.

Therefore, we run the following DID regression:

$$Y_{i,t} = c + \beta_1 TREATED * CT_{i,t} + \beta_2 TREATED + \beta_3 CT + \boldsymbol{\gamma}'\boldsymbol{X}_{i,t} + Bank_i + \varepsilon_{i,t}$$

where *Y* measures the monthly growth rate of the different aggregates of loans, *TREATED* is a dummy variable equal to 1 for local banks and 0 for foreign banks, and *CT* is a dummy variable equal to 1 for months after June 2019 and 0 otherwise. *TREATED*CT* is their interactions and our target variable, representing the effect of the carbon tax on banks' lending policies for local banks.

The rationale for using local banks as the treated group and foreign ones as a control group lies in the intrinsic characteristics of domestic banks, whose assets are more exposed to the local economy, as shown by a higher loans to total assets ratio (Figure 1). First, local banks might have higher exposure to local industries like energy or manufacturing that are more sensitive to carbon taxation, while foreign banks may have a more diversified asset portfolio that might shield them from the tax's direct impacts.

Second, using foreign banks as a control improves the econometric strength of our test because we can isolate the effect of the carbon tax on the credit provision of local banks. The idea is that foreign banks, whose domestic operations are assumed to be less affected by the carbon tax, will help control for other factors affecting credit provision (e.g. global economic conditions and interest rates). Any observed difference in credit provision between the local and foreign banks could thus be more likely attributed to the carbon tax rather than other factors.

Finally, we include the same set of control variables used in our first equation, along with the 'Covid' dummy (to capture possible confounding effects), as well as bank fixed effects and standard errors clustered at the bank level.

5. Results

5.1 Baseline analysis results

Table 3 shows the results of our baseline analysis, where we explore the effect of physical risk on the growth rate of total loans, household loans, and financial and non-financial corporation loans.

Table 3: Baseline results

Variables	Loans_Grwt	House_loans_Grwt	FinCorp_loans_Grwt	NonFinCorp_loans_Grwt
CCrisk	-0.0372***	-0.102***	-1.011***	-0.0309***
	(0.0102)	(0.0374)	(0.0788)	(0.00597)
Size	0.000290	0.000839**	-0.00493	0.000186
	(0.000454)	(0.000390)	(0.00587)	(0.000348)
Eta	0.00208	0.00449**	-0.0142	0.000641
	(0.00222)	(0.00204)	(0.0389)	(0.00138)
Impairment_loans	-0.0125*	-0.00353	-0.0453	-0.00695**
	(0.00654)	(0.00670)	(0.0296)	(0.00345)
Dep_Grwt	0.00261***	0.000160	0.00881	0.00179***
	(0.000561)	(0.000480)	(0.00716)	(0.000346)
Gdp	0.00295	0.00553	0.0939	-0.00615
	(0.00588)	(0.00575)	(0.0869)	(0.00548)
Infl	-0.00527	0.000807	-0.0133	-0.00197
	(0.00427)	(0.00426)	(0.0710)	(0.00336)
Shortint_Grwt	-0.0242	0.00589	-0.411	0.0106
	(0.0230)	(0.0134)	(0.317)	(0.0158)
D_Foreign	Yes	Yes	Yes	Yes
Bank*time FE	Yes	Yes	Yes	Yes
Observations	4 205	3 216	2 660	3 695
R-squared	0.144	0.212	0.166	0.138

Note: This table reports the estimates of the baseline model during the period 2008–2019. The dependent variables are loans growth rate (Loans_Grwt), household loans growth rate (House_loans_Grwt), financial corporation loans growth rate (FinCorp_loans_Grwt) and non-financial corporation loans growth rate (NonFinCorp_loans_Grwt), which measure banks' lending policies. The target variable is country-level climate change risk (CCrisk). Variable definitions are provided in Table 1. The superscripts ***, ** and * denote coefficients statistically different from zero at the 1%, 5% and 10% levels, respectively, in two-tailed tests.

As shown, *CCrisk* is always negative and statistically significantly correlated with all kinds of types of bank loans, supporting the hypothesis of the economic relevance of climate change costs for bank business activity. As shown in the literature (see e.g. Monasterolo and Raberto (2017)), climate-related costs exert a downward pressure on the broader economy, causing significant disruptions that negatively affect businesses and individuals alike. Companies may face reduced revenues and lower profitability, which increase the likelihood of financial distress or default, particularly in industries most vulnerable to climate impacts, such as agriculture, energy and manufacturing. The increasing frequency of extreme weather events, shifts in resource availability and disruptions to supply chains can exacerbate these challenges, making it more difficult for businesses to maintain their operations and meet financial obligations. At the individual/household level, these pressures can reduce consumers' ability to repay loans, increasing the likelihood of defaults.

In this context of heightened economic uncertainty and financial strain, banks are exposed to higher credit risks (Wu et al. 2024) from both corporate and individual borrowers, so they may adopt more conservative lending policies to mitigate these risks and safeguard their balance sheets. These policies can include tightening credit standards, such as requiring higher credit scores or stricter collateral requirements for loan approvals. Banks may also raise interest rates to compensate for the increased risk of default, making borrowing more expensive and further restricting access to credit. In terms of statistical coefficients, the largest effect seems to be related to the slowdown of loans to financial corporations, followed by loans to households and non-financial firms.

We observe qualitatively similar results for transition risk (Table 4), although they are less statistically significant than those for physical risk. Specifically, after the passage of the 2019 carbon tax, local banks (TREATED group) experienced a slowdown of total loans, which seems to be mainly explained by the decline of non-financial corporation loans. We interpret these results based on higher exposure to local economic conditions, regulatory environments and market dynamics of domestic banks. Domestic banks tend to have a more concentrated portfolio in their home market, which makes them more vulnerable to the economic effects of a carbon tax. After the adoption of a carbon tax, businesses in carbon-intensive industries (such as manufacturing, energy or transportation) face higher operating costs and, other things being equal, a reduction in their creditworthiness, which may result in lower credit provision.

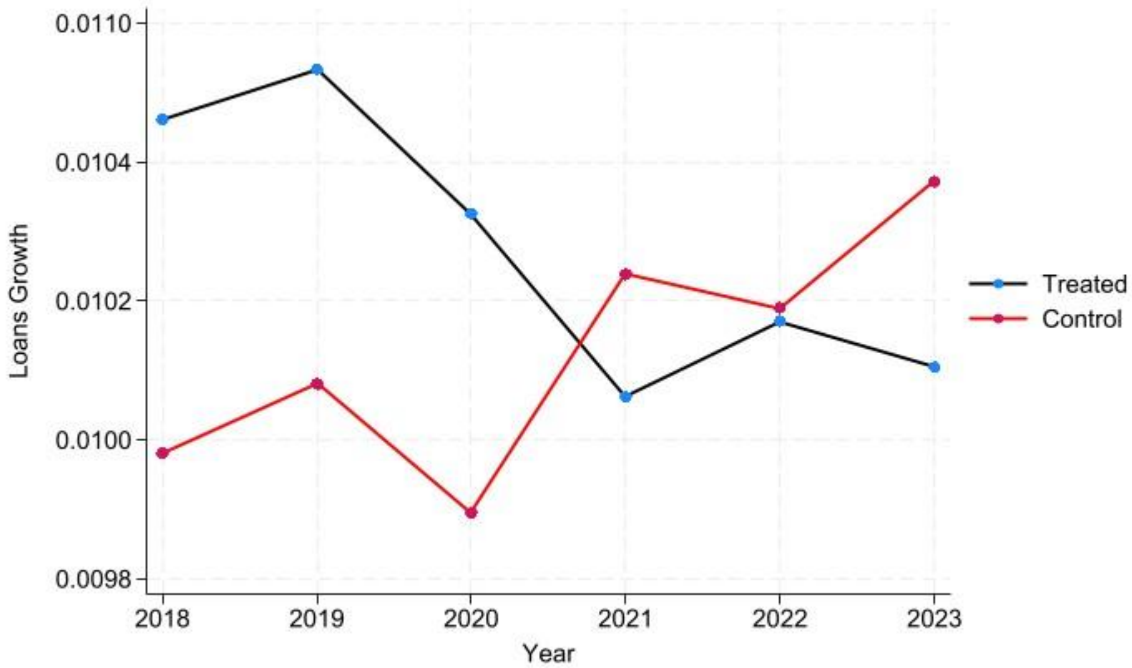
Table 4: DID results

Variables	Loans_Grwt	House_loans_Grwt	FinCorp_loans_Grwt	NonFinCorp_loans_Grwt
Treated*CT	-0.000212*	-0.000176	1.29e-06	-0.000166**
	(0.000112)	(0.000327)	(0.00396)	(7.45e-05)
CT	0.000200*	0.000295	-0.00156	9.01e-05
	(0.000101)	(0.000365)	(0.00344)	(8.88e-05)
Treated	-0.00218***	-0.000703***	-0.0155	0.000300
	(0.000735)	(0.000245)	(0.0114)	(0.000253)
Controls	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Observations	2 037	1 594	1 219	1 729
R-squared	0.145	0.195	0.082	0.054

Note: This table reports the estimates of DID regression during the period 2017–2024. The dependent variables are loans growth rate (Loans_Grwt), household loans growth rate (House_loans_Grwt), financial corporation loans growth rate (FinCorp_loans_Grwt) and non-financial corporation loans growth rate (NonFinCorp_loans_Grwt), which measure banks' lending policies. The superscripts ***, ** and * denote coefficients statistically different from zero at the 1%, 5% and 10% levels, respectively, in two-tailed tests.

Overall, our results seem to support hypothesis 2b: the negative effect of climate transition risk on bank lending behaviour. Moreover, Figure 2 shows the validity of DID assumptions, showing no differences between treated (domestic) and controlled (foreign) banks during the period before the adoption of the carbon tax.

Figure 2: Parallel trend result



Note: This figure shows the parallel trend results of Loans_Grwt for treated (domestic) and control (foreign) banks before and after the adoption of the 2019 carbon tax.

5.2 Further analysis

We are interested in understanding if the effects of climate change risk stem from the 'perception' of its negative impact or from actual losses and risks affecting a bank's balance sheet and, consequently, its lending behaviour. To provide insights into this issue, we run equation 1 by replacing the OECD physical climate risk (CCrisk) with our Google Trends sentiment analysis estimation of climate risk perception (CCperc), testing its statistical significance with bank lending (Table 5).

Table 5: Testing the effect of climate change risk perception

Variables	Loans_Grwt	House_loans_Grwt	FinCorp_loans_Grwt	NonFinCorp_loans_Grwt
CCperc	-1.38e-05	-0.000562	0.0290	-0.000733
	(0.00207)	(0.00172)	(0.0355)	(0.00154)
Dummy foreign	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Bank*time FE	Yes	Yes	Yes	Yes
Observations	5 649	4 340	3 548	4 961
R-squared	0.149	0.202	0.176	0.140

Note: This table reports the estimates of the baseline model during the period 2008–2024. The dependent variables are loans growth rate (Loans_Grwt), household loans growth rate (House_loans_Grwt), financial corporation loans growth rate (FinCorp_loans_Grwt) and non-financial corporation loans growth rate (NonFinCorp_loans_Grwt), which measure banks' lending policies. The target variable is country-level perception of climate change risk (CCperc). Variable definitions are provided in Table 1. The superscripts ***, ** and * denote coefficients statistically different from zero at the 1%, 5% and 10% levels, respectively, in two-tailed tests.

Table 5 shows that CCperc is almost always negatively correlated with bank lending behaviour, though the correlation is not statistically significant. This suggests that the detrimental consequences of climate change on loans supply do not depend on stakeholders' pressure or fear, but rather on a concrete impact on bank balance sheets.

In Table 6 we explore the different effects of CCrisk on different types of loans, namely mortgages and overdraft credit lines, finding that the stronger effect appears to be associated with the overdrafts. This result is probably explained by two technical features of these lending techniques. First, in contrast to mortgages, overdraft lines of credit are usually more risky because they do not require collateral; therefore, in a riskier scenario, banks may prefer mortgages. Second, mortgages are usually mid/long-term loans, so an adverse climate event will only affect the flow of new loans, whereas overdraft lines are shorter term and more flexible and can be more easily reduced in response to changing risk conditions. Besides, there might be an economic reason for mortgages being used to finance capital expenditures, which could result from a recovery or transition plan adopted by businesses and households after a climate event. In contrast, overdrafts are typically used to finance working capital that usually is less involved in the climate change recovery/transition process.

Table 6: Mortgage vs overdraft

Variables	Mortgage_Grwt	Overdraft_Grwt
CCrisk	-0.0197***	-0.0318***
	(0.00596)	(0.00714)
Controls	Yes	Yes
Dummy foreign	Yes	Yes
Bank*time FE	Yes	Yes
Observations	2 312	4 204
R-squared	0.228	0.121

Note: This table reports the estimates of the baseline model during the period 2008–2019. The dependent variables are mortgage and overdraft growth rate. The target variable is country-level climate change risk (CCrisk). Variable definitions are provided in Table 1. The superscripts ***, ** and * denote coefficients statistically different from zero at the 1%, 5% and 10% levels, respectively, in two-tailed tests.

In Table 7 we further scale the details of our database by running a subsample analysis according to the banks' specialisation (commercial, financial services, government owned, mutual, retail). As shown, the effect of climate change risk on lending behaviour appears to be statistically significant only for commercial banks. This result may be explained by the large number of observations for commercial banks in our sample, as well as by the fact that commercial banks' goal is to maximise shareholder returns given the risk embodied in the bank assets. As such, they are more likely to adjust their lending practices to the riskiness of the economic scenario, which may also deteriorate because of climate change risk. In contrast, mutual banks, as well as government-owned banks, tend to be less focused on short-term profits and more committed to serving their stakeholders and communities. This is why they might be less reactive to climate change risks in their lending policies.

Table 7: Subsample analysis of bank specialisation

	Loans_Grwt				
Variables	**Commercial**	**Financial services**	**Government owned**	**Mutual**	**Retail**
CCrisk	-0.0562***	-0.0334	-0.0129	-0.000275	-0.00703
	(0.0159)	(0.0783)	(0.0155)	(0.0332)	(0.0146)
Controls	Yes	Yes	Yes	Yes	Yes
Dummy foreign	Yes	Yes	Yes	Yes	Yes
Bank*time FE	Yes	Yes	Yes	Yes	Yes
Observations	2 553	143	577	361	571
R-squared	0.143	0.162	0.271	0.238	0.115

Note: This table reports the estimates of the banks' specialisation subsample model during the period 2008–2019. The dependent variable is the loans growth rate (Loans_Grwt), which measures banks' lending behaviour. The target variable is country-level climate change risk (CCrisk). Variable definitions are provided in Table 1. The superscripts ***, ** and * denote coefficients statistically different from zero at the 1%, 5% and 10% levels, respectively, in two-tailed tests.

As the risks associated with climate change continue to intensify, their potential impact on financial performance and risk perception may increase in a non-linear manner. Extreme weather events, along with evolving regulatory frameworks, have the capacity to cause sudden and significant shifts in corporate risk management practices and financing decisions (Chiaramonte et al. 2024b). Firms may experience abrupt adjustments in their strategies as the severity of climate-related risks surpasses established thresholds. For example, Liu et al. (2023) highlight a threshold effect in climate risk, particularly concerning the demand for non-life insurance. Their findings suggest a U-shaped correlation with life insurance demand and an inverse S-shaped relationship for non-life insurance. Similarly, Burke, Hsiang and Miguel (2015) illustrate a non-linear relationship between economic productivity and temperature across all nations, showing that productivity peaks at an average annual temperature of 13°C.

Together, these studies point to the importance of understanding the non-linear and threshold-driven dynamics that influence financial markets and economic outcomes in the face of climate change. Therefore, in Table 8 we explore the existence of a non-linear relationship between CCrisk and bank lending behaviour by adding the square root of CCrisk to equation 1 and testing if the related coefficients take different values or statistical significance compared to the hypothesis of a linear relationship.

Table 8: Testing the non-linear effect of CCcost_Gdp

Variables	Loans_Grwt	House_loans_Grwt	FinCorp_loans_Grwt	NonFinCorp_loans_Grwt
CCrisk	0.122**	0.209***	7.078***	0.0509*
	(0.0585)	(0.0786)	(0.284)	(0.0304)
CCrisk^2	-1.507**	-2.169***	-76.45***	-0.773**
	(0.645)	(0.808)	(3.280)	(0.337)
Controls	Yes	Yes	Yes	Yes
Dummy foreign	Yes	Yes	Yes	Yes
Bank*time FE	Yes	Yes	Yes	Yes
Observations	4 205	3 216	2 660	3 695

Note: This table reports the estimates of the non-linear relationship between CCrisk and bank lending policies during the period 2008–2019. The dependent variables are loans growth rate (Loans_Grwt), household loans growth rate (House_loans_Grwt), financial corporation loans growth rate (FinCorp_loans_Grwt) and non-financial corporation loans growth rate (NonFinCorp_loans_Grwt), which measure banks' lending policies. The target variables are country-level climate change risk (CCrisk) and its square root (CCrisk^2). Variable definitions are provided in Table 1. The superscripts ***, ** and * denote coefficients statistically different from zero at the 1%, 5% and 10% levels, respectively, in two-tailed tests.

Table 8 demonstrates the existence of a U-shape relationship between CCrisk and bank lending policies, in line with the existing literature. Specifically, our results show that for low levels of CCrisk, South African banks increase their loans supply, probably because at lower levels of physical climate change risk, banks tend to expand credit provision as the associated risks are assessed to be manageable. In such an environment, climate-related exposures do not materially impair borrower creditworthiness or collateral valuations. Moreover, moderate climate variability may stimulate demand for financing targeted at adaptive investments – such as infrastructure resilience, energy efficiency and supply chain reinforcement – which banks can support under existing risk appetites. These loans are typically underwritten with a view towards strategic opportunity rather than crisis mitigation. Pricing can reflect a modest risk premium without materially affecting credit performance metrics such as probability of default or loss given default.

Conversely, when physical climate risks intensify and become more systemic (the U-shape of CCrisk) banks tend to adopt more conservative lending behaviour. Under these conditions, climate-related disruptions begin to significantly affect asset quality, impair collateral values and raise counterparty credit risk.

Finally, we run the following robustness tests to strengthen our inference: in Table 9 we replaced the CCrisk measure with annual surface temperature (Abn_temperature), and in Table 10 we replaced our baseline model by lagging all control variables by one period. Results confirm our baseline results.

Table 9: Alternative measure of physical risk: annual abnormal surface temperature

Variables	Loans_Grwt	House_loans_Grwt	FinCorp_loans_Grwt	NonFinCorp_loans_Grwt
Abn_temperature	-0.000436***	-0.00276***	-0.0118***	0.000423
	(7.57e-05)	(0.000782)	(0.000729)	(0.000961)
Dummy foreign	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Bank*time FE	Yes	Yes	Yes	Yes
Observations	4 205	3 216	266	3 695
R-squared	0.144	0.212	0.166	0.138

Note: This table reports the estimates of the baseline model during the period 2008–2019. The dependent variables are loans growth rate (Loans_Grwt), household loans growth rate (House_loans_Grwt), financial corporation loans growth rate (FinCorp_loans_Grwt) and non-financial corporation loans growth rate (NonFinCorp_loans_Grwt), which measure banks' lending policies. The target variable is country-level surface abnormal temperature (Abn_temperature). Variable definitions are provided in Table 1. The superscripts ***, ** and * denote coefficients statistically different from zero at the 1%, 5% and 10% levels, respectively, in two-tailed tests.

Table 10: Lagged baseline model

Variables	Loans_Grwt	House_loans_Grwt	FinCorp_loans_Grwt	NonFinCorp_loans_Grwt
CCrisk	-0.0215***	-0.111***	-0.973***	-0.0166***
	(0.00776)	(0.0272)	(0.0784)	(0.00491)
Dummy foreign	Yes	Yes	Yes	Yes
Controls (-1)	Yes	Yes	Yes	Yes
Bank*time FE	Yes	Yes	Yes	Yes
Observations	4 166	3 184	2 641	3 664
R-squared	0.132	0.211	0.166	0.126

Note: This table reports the estimates of the baseline model during the period 2008–2019 with control variables lagged of one period. The dependent variables are loans growth rate (Loans_Grwt), household loans growth rate (House_loans_Grwt), financial corporation loans growth rate (FinCorp_loans_Grwt) and non-financial corporation loans growth rate (NonFinCorp_loans_Grwt), which measure banks' lending policies. The target variable is country-level climate change risk (CCrisk). Variable definitions are provided in Table 1. The superscripts ***, ** and * denote coefficients statistically different from zero at the 1%, 5% and 10% levels, respectively, in two-tailed tests.

6. Conclusion

We have explored the effects of climate change risk – both physical and transition-related – on South African bank lending policies during the period 2008–2024. Consistent with the literature identifying climate change as one of the most relevant risks for financial institutions, we find that country climate change cost reduces the growth of total loans, household loans, financial corporation loans and non-financial corporation loans. This effect also seems to be confirmed when considering the transition side of climate change risk, with loans to non-financial corporations slowing down after the passage of the 2019 carbon tax policy. We observe a major effect of climate change risk on commercial banks, which are probably more risk averse and profit-oriented than other banking institutions more connected and engaged with local communities and thus more willing to support their communities when affected by climate change. We also find that the effect of climate change risk is non-linear, with the relationship between climate risk and bank loans assuming a U-shape function. Robust to several tests and an additional econometric approach, the findings provide relevant and new insights into the complicated relationship between climate change risk and its detrimental effects on financial intermediaries in an emerging economy like South Africa.

Overall, our findings provide clear evidence that climate change poses potentially significant threats not only to the banking system but also to businesses and the broader South African economy. These results carry important implications for regulators, financial institutions and the private sector. For regulators and supervisory authorities, our analysis highlights the urgent need to strengthen the integration of climate-related risks into financial regulation. This includes the development of robust climate stress-testing frameworks, the incorporation of climate risks into banks' internal risk management systems and capital requirements, and the adoption of differentiated supervisory approaches tailored to the size, mandate and risk profile of financial institutions. Such measures would help contain systemic vulnerabilities without disproportionately constraining credit flows.

For banks, the findings point to the necessity of improving internal risk assessment models to better capture both physical and transition risks associated with climate change. Commercial banks, in particular, seem more reactive to these risks, likely reflecting their profit-maximising orientation. It will be essential to strike a balance between sound risk management and the continuation of sustainable and inclusive lending practices.

Finally, these dynamics have significant implications for firms – especially non-financial corporations operating in carbon-intensive sectors or in regions particularly vulnerable to climate impacts. A more cautious approach to lending may reduce firms' access to finance at a time when investments in adaptation and decarbonisation are most needed. This could delay progress in transitioning to a low-carbon economy and increase companies' exposure to future climate-related disruptions. To mitigate these effects, policymakers should consider targeted financial instruments – such as green credit guarantees, concessional loans or blended finance schemes – to support sustainable investments and reduce the perceived risk for lenders. Particular attention should be paid to small and medium-sized enterprises, which are often most constrained in accessing finance despite playing a crucial role in the green transition.

Achieving a careful balance between prudential oversight and the provision of adequate credit will be critical to ensure that climate resilience and economic growth proceed hand in hand, particularly in emerging economies such as South Africa.

Annexure

Table A.1: List of banks and average total assets

Bank name	D_Foreign (1 foreign; 0 local)	Total assets (average value period 2008–2024, millions)
MEEG BANK LIMITED	0	1244769
AFRICAN BANK LIMITED	0	4.54e+07
SOCIETE GENERALE – JOHANNESBURG BRANCH	1	9176359
BIDVEST BANK LIMITED	0	5017765
ABSA BANK LTD	0	8.29e+08
HABIB OVERSEAS BANK LTD	1	999912.7
BANK OF TAIWAN – SOUTH AFRICA BRANCH	1	1498208
CANARA BANK	1	356867.1
GRINDROD BANK LTD	0	7560514
ICICI BANK LIMITED	1	432622.4
COMMERZBANK AKTIENGESELLSCHAFT	1	9197806
TYME BANK LIMITED	0	1058954
DISCOVERY BANK LIMITED	0	2862743
CITIBANK N.A.	1	5.42e+07
THE ROYAL BANK OF SCOTLAND	1	1.47e+07
HBZ BANK LTD	1	3416825
IMPERIAL BANK LTD	0	4.95e+07
STATE BANK OF INDIA	1	4716663
VBS MUTUAL BANK	0	698015.3
REGAL TREASURY PRIVATE BANK LTD	0	1521813
BANK OF BARODA	1	1399970
CAPITEC BANK	0	4.72e+07
DEUTSCHE BANK AG	1	1.99e+07
SASFIN BANK LTD	0	4549130
BANK OF CHINA LTD – JOHANNESBURG BRANCH	1	2.15e+07
CHINA CONSTRUCTION BANK CORPORATION – JOHANNESBURG BRANCH	1	2.09e+07
UBANK LIMITED	0	4257613
FIRSTRAND BANK LIMITED	0	8.34e+08
THE STANDARD BANK OF SA LTD	0	1.03e+09
NEDBANK LTD	0	7.03e+08
MERCANTILE BANK LTD	0	8863559
THE SA BANK OF ATHENS LTD	1	2020325
GBS MUTUAL BANK	0	1044686
FINBOND MUTUAL BANK	0	1387715
BANK OF INDIA – JOHANNESBURG BRANCH	1	431773.6
BNP PARIBAS SA	1	1.15e+07
THE HONGKONG AND SHANGHAI BANKING CORPORATION LIMITED – JOHANNESBURG BRANCH	1	3.60e+07
STANDARD CHARTERED BANK	1	2.57e+07

References

Aslanidis, N, Aurelio F B, López, O G. 2022. 'The link between cryptocurrencies and Google Trends attention'. *Finance Research Letters* 47: 102654.

Birindelli, G, Chiappini, H and Jalal, R N. 2023. 'SFDR, investor attention, and European financial markets'. *Finance Research Letters* 56: 104135.

Burke, M, Hsiang, S and Miguel, E. 2015. 'Global non-linear effect of temperature on economic production'. *Nature* 527: 235–239.

Caby, J, Ziane, Y and Lamarque, E. 2022. 'The impact of climate change management on banks' profitability'. *Journal of Business Research* 142: 412–422.

Casu, B, Chiaramonte, L and Cucinelli, D. 2024. 'The impact of liquidity on bank lending in South Africa'. South African Reserve Bank Working Paper Series, WP/24/10.

Chalabi-Jabado, F and Ziane, Y. 2024. 'Climate risks, financial performance and lending growth: evidence from the banking industry'. *Technological Forecasting and Social Change* 209: 123757.

Chiaramonte, L, Dreassi, A, Girardone, C and Piserà, S. 2024a. 'Socially responsible banking: weathering the Covid-19 storm'. *Journal of International Financial Markets, Institutions and Money* 95: 102029.

Chiaramonte, L, Dreassi, A, Goodell, J W, Paltrinieri, A and Piserà, S. 2024b. 'Banks' environmental policies and banks' financial stability'. *Journal of International Financial Markets, Institutions and Money* 91: 101927.

CMCC. 2021. *G20 climate risk atlas: impacts, policy, economics: South Africa*. https://files.cmcc.it/g20climaterisks/SouthAfrica.pdf

Conlon, T, Ding, R, Huan, X and Zhang, Z. 2024. 'Climate risk and financial stability: evidence from syndicated lending'. *The European Journal of Finance* 30(17): 1–31.

Department of Forestry, Fisheries and the Environment, Republic of South Africa. 2021. 'National climate change adaption strategy'. https://unfccc.int/documents/307117

Duan, T and Li, F W. 2024. 'Climate change concerns and mortgage lending'. *Journal of Empirical Finance* 75: 101445.

Dunz, N, Naqvi, A and Monesterolo, I. 2017. 'Climate sentiments, transition risk, and financial stability in a stock-flow consistent model'. *Journal of Financial Stability* 54: 100872.

ECB. 2020. 'Guide on climate-related and environmental risks: supervisory expectations relating to risk management and disclosure'. https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.202011finalguideonclimate-relatedandenvironmentalrisks~58213f6564.en.pdf

ECB. 2022. 'Climate risk stress test'. https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.climateriskstresstest2021~a4de107198.en.pdf

Elsner, C and Neumann, M. 2023. 'Caught between path-dependence and green opportunities – assessing the impetus for green banking in South Africa'. *Earth System Governance* 18: 100194.

Gavriilidis, K. 2021. 'Measuring climate policy uncertainty'. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3847388

Lang, Q, Ma, F, Mirza, N and Umar, M. 2023. 'The interaction of climate risk and bank liquidity: an emerging market perspective for transitions to low carbon energy'. *Technological Forecasting and Social Change* 191: 122480.

Le, A T, Tran, T P and Mishra, A V. 2023. 'Climate risk and bank stability: international evidence'. *Journal of Multinational Financial Management* 70: 100824.

Lee, C C, Wang, C W, Thinh, B T and Xu, Z T. 2022. ‘Climate risk and bank liquidity creation: international evidence’. *International Review of Financial Analysis* 82: 102198.

Lee, C C, Zhang, X and Lee, C C. 2024. ‘Does climate change matter for bank profitability? Evidence from China’. *The North American Journal of Economics and Finance* 74: 102257.

Liu, B, Yin, W, Chen, G and Yao, J. 2023. ‘The threshold effect of climate risk and the non-linear role of climate policy uncertainty on insurance demand: evidence from OECD countries’. *Finance Research Letters* 55: 103820.

Liu, Z, He, S, Men, W and Sun, H. 2024. ‘Impact of climate risk on financial stability: cross-country evidence’. *International Review of Financial Analysis* 92: 103096.

Miguel, F, Pedraza, A and Ruiz-Ortega, C. 2024. ‘Climate-change regulations: bank lending and real effects’. *Journal of Financial Stability* 70: 101212.

Monasterolo, I and Raberto, M. 2017. ‘Is there a role for central banks in the low-carbon transition? A stock-flow consistent modelling approach’. SSRN Working Paper (21 November).

Monnin, P, Sikhosana, A and Singh, K. 2024. ‘Transition and systemic risk in the South African banking sector: assessment and macroprudential options’. South African Reserve Bank Working Paper Series, WP/24/12.

Reghezza, A, Altunbas, Y, Marques-Ibanez, D, d’Acri, C R and Spaggiari, M. 2022. ‘Do banks fuel climate change?’ *Journal of Financial Stability* 62: 101049.

Roncoroni, A, Battiston, S, Escobar-Farfán, L O and Martinez-Jaramillo, S. 2021. ‘Climate risk and financial stability in the network of banks and investment funds’. *Journal of Financial Stability* 54: 100870.

Roy, R and Braathen, N. 2017. ‘The rising cost of ambient air pollution thus far in the 21st century: results from the BRIICS and the OECD countries’. OECD Environment Working Papers, No. 124.

Samour, A, Moyo, D and Tursoy, T. 2022. ‘Renewable energy, banking sector development, and carbon dioxide emissions nexus: a path toward sustainable development in South Africa’. *Renewable Energy* 193: 1032–1040.

SARB. 2024. ‘Climate change’. https://www.resbank.co.za/en/home/about-us/climate-change#:~:text=The%20SARB%20is%20focused%20on,greening%20its%20own%20operations

SARB. 2024. ‘Guidance on climate-related governance and risk practices for banks’. https://www.resbank.co.za/en/home/publications/publication-detail-pages/prudential-authority/pa-deposit-takers/banks-guidance-notes/2024/G2-2024-Climate-Guidance-Risk-Banks

Taskforce on climate related financial risk. 2022. ‘Recommendations of the Task Force on Climate-related Financial Disclosures’. https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf

UNEP FI. 2024. ‘Managing physical climate-related risks in loan portfolios’. https://www.unepfi.org/themes/climate-change/managing-physical-climate-related-risks-in-loan-portfolios/

Wang, D, Wang, Y and Liu, Y. 2024. ‘Temperature variability, natural disasters and bank systemic risk: evidence from Chinese city commercial banks’. *Economics Letters* 242: 111846.

World Bank. 2021. ‘Climate risk country profile: South Africa’. https://climateknowledgeportal.worldbank.org/sites/default/files/country-profiles/15932-WB_South%20Africa%20Country%20Profile-WEB.pdf

Wu, B, Wen, F, Zhang, Y and Huang, Z (J). 2024. ‘Climate risk and the systemic risk of banks: a global perspective’. *Journal of International Financial Markets, Institutions and Money* 95: 102030.

Xu, X, Ren, X and He, F. 2024. ‘Climate policy uncertainty and bank liquidity creation’. *Finance Research Letters* 65: 105403.