Policy Research Working Paper

Climate Change Regulations

Bank Lending and Real Effects

Faruk Miguel Alvaro Pedraza Claudia Ruiz-Ortega



WORLD BANK GROUP

Finance, Competitiveness and Innovation Global Practice & Development Research Group December 2022

Abstract

This paper analyzes how capital requirements from environmental risk exposure affect bank lending to the corporate sector, and how these effects transmit to real economic activity and greenhouse gas emissions. It exploits the introduction of a policy in Brazil that required banks to incorporate environmental risks into their capital assessments. Using comprehensive credit data, the paper finds that the policy induces large banks to reallocate their lending away from exposed sectors. The credit contraction has no substantial impact on the real activity and greenhouse gas emissions of these sectors, as smaller banks expand their lending. However, the policy triggers a moderate labor reallocation from small firms (those with higher costs of switching lenders) to large firms in environmentally exposed sectors.

This paper is a product of the Finance, Competitiveness and Innovation Global Practice and the Development Research Group, Development Economics. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at fmiguelliriano@worldbank.org, apedrazamorales@worldbank.org, and cruizortega@worldbank.org.

The Policy Research Working Paper Series disseminates the findings of work in progress to encourage the exchange of ideas about development issues. An objective of the series is to get the findings out quickly, even if the presentations are less than fully polished. The papers carry the names of the authors and should be cited accordingly. The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the International Bank for Reconstruction and Development/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent.

Climate-Change Regulations: Bank Lending and Real Effects

Faruk Miguel

Alvaro Pedraza

Claudia Ruiz-Ortega

Originally published in the <u>Policy Research Working Paper Series</u> on *December 2022*. This version is updated on *December 2023*. To obtain the originally published version, please email <u>prwp@worldbank.org</u>.

JEL classification: G21, G28, D62, Q54

Keywords: capital requirements, climate change, bank lending, real effects

1. Introduction

Climate risks and climate policies are expected to have a major impact on the financial system. In recent years, financial authorities have required banks to embed climate risks into their risk management frameworks, including in their Internal Capital Adequacy Assessment Process, the so-called ICAAP.^{1,2} The expectation is for banks to have sufficient capital to cover climate-related risks, which in the context of capital constraints, implies adjustments in their lending behavior. Despite the use of prudential regulation to address climate risks, little is known about the effects of these policies on credit supply to firms, and more broadly, on real economic activity, including the potential implications for greenhouse gas emissions (GHG) reduction. In this paper, we evaluate a policy introduced in Brazil in September 2017 requiring banks to incorporate social and environmental risks in their capital adequacy assessments and the impact on firms' credit and firms' real outcomes.

While some policymakers are exploring the explicit use of prudential measures to direct funds away from high-carbon activities and into green sectors (Monasterolo, et al., 2022), the main objective of prudential capital requirements is to enhance the soundness and stability of financial institutions. Whether newly implemented climate-related prudential measures affect bank lending and firm activity is an open empirical question with important policy implications. For instance, negative effects on bank lending would imply that there are costs associated with bank capital that curb the ability of banks to support firms in climate-exposed sectors. It is possible that such outcomes, even if unintended, might be desirable to the extent that they promote the divesting in some high-carbon activities. However, constraining the supply of credit to firms with significant exposure to climate change risk might be detrimental as it limits their ability to finance the transition to a less-carbon intensive economy.

We use the uneven implementation of the 2017 ICAAP in Brazil to identify the effects of the policy on bank lending. Following principles of proportionality, the capital assessment was

¹ The ICAAP is the core component of Pillar 2 in the Basel banking regulations. It captures the banks' own assessment of the additional capital, over and above the regulatory minimum (Pillar 1), to cover the risks for which the bank is exposed over the next three to five years.

² For example, in the UK and Europe (Bank of England, 2019; ECB, 2020). More recently, the newly introduced Basel Principles on Effective Management and Supervision of Climate Risk (BIS, 2022) give further guidance to banks to introduce climate risks into their ICAAP (Principle 5) as well as how supervisors should deal with this aspect (Principle 14). By the end of 2024, banks governed by ECB regulations are expected to fulfill all supervisory expectations related to climate and environmental risks as delineated in 2020 (ECB, 2020), including full integration in the ICAAP.

mandatory for large banks, those with assets greater than 10% of GDP. We refer to this group as *treated banks*. Banks with assets between 1% and 10% of GDP were required to assess their capital based on a simplified ICAAP framework (*partially treated banks*), while smaller banks were exempt from the policy, *control banks* in our setting. The regulation required, for the first time, that banks measure and report the capital required to cover their exposure to socio-environmental risks, in addition to other business risks (e.g., credit, market, operational, and liquidity risks). We conjecture that the policy might impact the supply of credit for several reasons. For instance, banks with extensive exposure to firms in sectors with high socio-environmental risks could be required to hold additional capital above their mandatory minimum. Instead of raising additional capital, banks might contract their lending to these sectors or adjust the risk profile of the loans (e.g., firm rating, size, or loan maturity). Also, expanding their lending to environmentally risky sectors might enhance the regulatory oversight, increase the media scrutiny, and have negative reputational considerations. Thus, the requirement to disclose the exposure to borrowers with high socio-environmental risk might deter banks from lending to firms in these sector.

Using a taxonomy developed by the Brazilian Federation of Banks (FEBRABAN) in 2014, we identify sectors with high and low social and environmental risks, that is, exposed and nonexposed sectors. We combine monthly bank lending data with the FEBRABAN taxonomy of environmentally exposed sectors to evaluate the incidence of the regulation. To identify the effects from the ICAAP on bank lending, we follow a triple difference-in-differences methodology that compares: (i) the lending behavior from treated banks to exposed sectors vis-à-vis non-exposed sectors before and after the policy; (ii) relative to the change in credit from control banks in these sectors.

We find that the introduction of the new 2017 ICAAP led to a credit reallocation by treated banks away from firms in exposed sectors, and more specifically to small borrowers: lending to small firms in environmentally risky sectors declined between 2.7% and 3.1%. The change in credit to exposed sectors by large banks was also in the form of shorter loan maturity. There is a 1.0% increase in the proportion of short-term credit extended by treated banks to small and exposed firms after the policy change. In contrast, control banks—those not subject to the ICAAP exercise—raised their overall credit volume to companies in both exposed and non-exposed sectors after the regulation, while keeping the maturity of these loans unchanged.

A major challenge of our analysis is how to isolate adjustments in the supply of credit to exposed sectors from changes in their credit demand. This is especially relevant in our context since Brazil experienced a protracted economic recession from 2014 to 2016. To control for the business cycle, we include sector \times month fixed effects in our specifications. By doing so, we compare the lending obtained by the same 5-digit sector at a given period between treated and control banks. With this strategy, we measure the impact of the regulation by the relative difference in lending to a given sector between treated and control banks, before and after the regulation. One limitation of our approach is that within a sector, firms that borrow from large and small banks may be different. For instance, within a given sector, large banks may specialize in lending to the largest firms or to firms more connected to international trade. If the business cycle affects these firms differently, our results may be biased. We include in our specifications fixed effects at the sector \times bank level, which control for all time-invariant factors of a sector-bank pair, such as the sectoral focus of lenders. To the extent that the lending specialization of banks does not vary over time, these fixed effects help us mitigate this concern.

Even though we find that control banks expand their credit, perhaps offsetting some of the contraction by treated banks, one remaining question is whether firms in these sectors are able to switch lenders and fully substitute loans from large to small banks, or if the credit contraction they experience leads to lower real outcomes, including their capacity to reduce their carbon footprint. To shed light on this issue, we use the Brazilian census of the formal labor market (RAIS) and a comprehensive dataset on greenhouse gas emissions (The Greenhouse Gas Emission and Removal Estimating System, SEEG). Specifically, we test whether there are any changes in employment, number of active firms, distribution of firm size, and emissions, in municipalities with a greater presence of treated banks; we refer to these locations as treated municipalities. We compare firms in these municipalities to firms in municipalities with a smaller presence of banks subject to the ICAAP rule (i.e., control municipalities) and estimate the changes before and after the policy. A key concern in this exercise is that if control municipalities are significantly different from treated municipalities in the pre-regulation period, our estimates would likely be biased, as we do not have a valid counterfactual with which to identify the impact of the policy. To address this issue, we conduct a matching exercise where we refine the control group exclusively to municipalities that during the pre-policy period are similar (both in levels and trends) to treated municipalities -with respect to their GDP, population, employment, number of firms, and emissions in exposed sectors.

Effectively, the methodology we use to identify the real effects of firms in exposed sectors consists of a difference-in-difference matching estimator.

We find a moderate impact of the policy on real economic activity. For instance, we do not find any differences in the level of employment and total GHG emissions of exposed firms in treated and control municipalities. There is evidence, however, of some labor reallocation between small and large firms within exposed sectors. In particular, the results suggest than in treated municipalities, there is a decline in the number of formal firms, and the average firm size increases after the policy. Consistent with this finding, we show that the employment share and the share of micro firms³ within exposed sectors declines after the policy in municipalities with more incidence of banks subject to the ICAAP rule. Overall, the evidence suggests that the contraction in credit to environmentally exposed firms by treated banks is largely offset by the increase in supply from banks not subject to the policy. The negative effects from the contraction in credit appears to concentrate in smaller firms, those that are less able to substitute borrowing across lenders.

Our analysis sheds light on the role of prudential policies that account for climate-related risks. The uneven implementation of the policy in Brazil –requiring only large banks to perform the ICAAP exercise– seems to generate a redistribution in the supply of credit where small banks disproportionally increase their lending, with potentially important implications for their soundness. Additionally, while the substitution in credit seems to mitigate the effect from the contraction in credit, this raises the question of whether in other contexts, capital requirement policies might have a stronger impact on firms' activity and on GHG emissions if these policies are applied to all lenders simultaneously.

Our paper is most closely related to the literature examining the effect of banks' capital regulation on bank lending. For example, a number of recent papers have analyzed the effects of capital requirement changes (Imbierowicz, et al., 2018; Gropp, et al., 2019; De Jonghe, et al., 2020; Fraisse, et al., 2020) or macro-prudential tools (Jimenez, et al., 2017) on lending and firm-level outcomes, such as investment and employment. Similar to Gropp, et al. (2019), we use a quasi-natural experiment and difference-in-differences matching estimator to measure the response in credit and economic activity to changes in bank capital requirements. We contribute to the literature by examining the role of prudential measures that require capital to address the impact from climate-change risks.

³ Firms with less than 2.4 million Reais of yearly revenue.

We also add to a growing literature that studies how climate risks affect the financial sector.⁴ For example, due to firms' exposure to climate-change risks, investors and banks might ask for higher returns (Atanasova & Schwartz, 2019; Delis, et al., 2019; Bolton & Kacperczyk, 2021). While some financial sector initiatives direct funds to projects that support the transition to a low-carbon economy (e.g., via the preferential purchase of green bonds, Oustry, et al., 2020), most of the current prudential regulation seeks to limit the impact from climate-change risks on the financial sector in line with their mandate. However, since climate-related and environmental risk management were only introduced in the banking sector in recent years (and in many cases only partially, see ECB 2020), there are no comprehensive analysis on the effect of these policies. To the best of our knowledge, we are the first to examine how climate-related prudential regulations affect banks' lending behavior and transmit to the real economy. In a recent paper, Kacperczyk & Peydró (2022) study how changes in banks' green preferences affect bank lending, credit allocation, and economic activity. The authors examine the credit channel after banks announce their committment to decarbonization, as opposed to the response to climate-related prudential regulations which is the focus of our work.

Finally, there has been growing support for the use of micro-prudential measures to direct capital towards green sectors.⁵ Whether it is by giving preferential capital treatment to clean loans –the Green Supporting Factor⁶– or by requiring financial institutions to hold more capital for high-carbon assets, the Dirty Penalizing Factor (DPF).⁷ In this context, the ICAAP rule in Brazil resembles the latter type of regulation by requiring banks to allocate sufficient internal capital to cover the environmental exposure of their portfolios. In turn, our results contribute to understanding the intended and unintended consequences of micro-prudential measures that address climate-change risks.

The rest of the paper is organized as follows. Section 2 discusses the Brazilian institutional background and outlines the primary channels that explain how the capital assessment rule may impact bank lending. In section 3, we discuss the impact of the policy on bank lending. Section 4 sumarizes our findings on the impact of the regulation on the real outcomes and GHG emissions

⁴ See Giglio, et al., (2021) for a review of this literature.

⁵ See Monasterolo et al., (2022) for a comprehensive review of financial sector initiatives to support the low-carbon transmission.

⁶ Oehmke & Opp, (2022) introduces a theoretical framework to evaluate this idea.

⁷ See NGFS (2022) for a summary of survey findings from a large pool of financial institutions identifying practices in the areas of green/non green classification and the assessment of risk differentials.

of firms. In section 5, we discuss the main limitations of our analysis and potential extensions. Section 6 concludes.

2. Institutional background

Over the years, financial authorities in Brazil have introduced multiple regulations to promote socio-environmental sustainability and address climate risks. Following the introduction of an environmental regulation on rural finance and financing in the Amazon Region in 2008, the National Monetary Council introduced the Social and Environmental Responsibility Policy (PRSA) in 2014. These were guiding principles to define and identify social and environmental risks –"the possibility of loss to the institution arising from social and environmental damage." The exact definitions of what constitutes a social and environmental risk were left for financial institutions. FEBRARAN, the Brazilian Federation of Banks coordinated the response from the banking industry and in partnership with the Center for Sustainability Studies of the Getulio Vargas Foundation, developed a methodology that identified economic activities potentially causing social and environmental impacts.⁸ Since 2015, banks have been using the taxonomy to track and report their lending to exposed sectors (although at aggregate levels).

In February 2017, the CMN introduced a new risk management framework.⁹ The directive required, for the first time, the explicit identification, monitoring and mitigation of socioenvironmental risks, in addition to credit, market, operational, and liquidity risk. In September that year, the Central Bank of Brazil (BCB) established the parameters and procedures for the Internal Capital Adequacy Assessment Process –the policy intervention that we examine. The BCB required that banks assess and measure the need for capital over a three-year horizon period to cover for social and environmental risks (Circular BCB No. 3846, September 13, 2017).¹⁰ Following principles of proportionality, the implementation of the new ICAAP was mandatory for larger banks, those with assets greater than 10% of GDP or *S1 group* per BCB rule –treated banks.

⁸ The methodology also identified green sectors. The strategy to address the PRSA was established under the umbrella of a self-regulation system introduced by FEBRABAN (SARB Directive No. 14, August 28, 2014).
⁹ CMN Resolution 4,557, February 23, 2017.

¹⁰ Article 3 of the regulation states: "Icaap must allow for the assessment of the sufficiency of the capital held by the institution over a three-year horizon, considering... II.c) socio-environmental risk in accordance with Resolution No.4,327 of April 25, 2014 [PRSA]."

A simplified ICAAP would apply to banks with assets between 1% and 10% of GDP or *S2 group* –partially treated banks. The regulation excluded smaller lenders, *groups S3-S4* –control banks.¹¹

After the Paris Aggreement, and as a member of the Network of Greening the Financial System (NGFS), the BCB further alligned its policies with international standards. In September 2020, the BCB launched a new sustainable agenda. In addition to the socio and environmental risks that were addressed since the 2014 PRSA, the new risk and capital management frameworks would explicitly include climate-related risks. That year, FEBRABAN, carried out a review of the methodology for classifying activities. The new taxonomy has three modalities: Green Economy, Climate Change Exposure and Environmental Risk Exposure. Figure C1 in the Appendix presents the timeline of green financial sector initiatives in Brazil. Even thoguh the 2017 ICAAP did not explicitly refer to climate-reated risks (e.g., from physical and transition risks), there are major similarities with how social and environmental risks were defined. For instance, economic activities with large contributions to GHG emissions were identified as 'environmentally risky' in the 2014 FEBRABAN taxonomy. In fact, there was an extensive overlap between sectors first classified as having high environmental risk and sectos with climate change exposure in the 2020 updated taxonomy. Therefore, we interprent our findings more broadly in the context of prudential measures that are aimed to address climate change risks.

While the September 2017 ICAAP did not explicitly restrict S1 and S2 banks from lending to firms in exposed sectors, there are several channels through which this rule might impact credit supply. First, banks that lend to firms with high social and environmental risks might be required to hold additional capital to cover for risks not adequately addressed by Pillar 1 capital requirements. To the extent that capital is costly, large banks could limit their exposure to firms in exposed sectors, either by contracting their total lending (extensive margin) or by adjusting the risk profile of their loans (intensive margin); for example, by focusing on safer borrowers such as larger rather than smaller firms, or by adjusting loan conditions, such as shortening the maturity of the loans or requiring more collateral.

Second, even if a bank is not capital constrained, expanding its loan portfolio to exposed firms might enhace the regulatory oversight, through increased supervisory scrutiny. For example,

¹¹ While the February Resolution (CMN Resolution 4,557) established the timeline to implement the risk and capital management regulation for all banks (S1 through S4), the ICAAP was set to apply exclusively to lenders in the S1 and S2 group.

if a bank broadens its credit exposure to clients involved in activities with negative environmental impact (e.g., deforestation, burning of fossil fuels, etc.), the BCB might increase its supervisory actions; resulting in on-site examinations evaluating the bank's operations or in the requirement of additional capital allocations on top of the bank's self-imposed capital (Bonfim et al, 2022; Ivanov and Wang, 2019).¹² Moreover, the publication of capital requirements, even if these are self-assessed, can have a disciplinary effect on banks and result in credit reallocation (Konietschke, et al., 2022).

Finally, large banks may have more incentives to adjust their lending portfolio to signal green commitments (Demirguc-Kunt, et al., 2023) due to their heavier reliance on market funding, which tends to be more sensitive to environmental performance. Moreover, their greater exposure to media scrutinity may also increase their compliance with environmental policies such as the 2017 ICAAP (Borghesi, et al., 2014).

3. Bank lending

In this section, we examine how the ICAAP regulation affects bank lending. To do so, we first present the data, then we explain our empirical methodology, and present our results.

3.1 Data

We use data from the BCB Sistema de Informações de Créditos (SCR). This dataset includes monthly information from January 2017 to December 2019 on the outstanding credit for each 5-digit sector of the CNAE classification (Classificaçao Nacional de Atividade Economica), funding source (earmarked vs. non-earmarked credit), tenor, borrower size, and lender size. One limitation with this dataset is that we do not observe the outstanding lending volumes of each bank. Instead, banks are classified based on their size into four groups (i.e., S1, S2, S3 and S4). We exclude from the analysis lenders in the S5 group, which are mostly credit unions and credit cooperatives. In line with the ICAAP framework, we refer to S3 and S4 as control banks and S1 banks as treated. We focus on these three groups for most of the analysis in the text and use the partially treated banks, S2 group, in robustness exercises. We also restrict the data to outstanding

¹² In a survey of climate-related and environmental actions, the BCB reported that it often "conducts specific on-site examinations evaluating institutions with high credit exposure to clients involved in illegal deforestation (largest Brazilian driver of GHG emissions)."

volumes funded in the non-earmarked credit market, as government-sponsored loans tend to be subject to especial rules and are typically restricted to especific programs.

We merge the credit data to the taxonomy at the 5-digit CNAE sectoral level developed by FEBRABAN in 2014. Of the 658 sectors in the credit data, 332 are classified as having high socioenvironmental risk (i.e., treated sectors). Notably, while this first clasification preceeds the 2020 FEBRABAN taxonomy which included climate-change exposure, there is a large overlap between the two; 312 sectors are classified as having both exposure to socio-environmental and to climate change risk in our dataset.¹³ The major focus on environmental risks in the 2014 FEBRBAN taxonomy is due to the potential ambiguity about social risks, as these "are associated with a contextual aspect, not necessarily related to the nature of economic activities" (FEBRABAN, 2019). For this reason, we refer to environmental exposure interchangeably with socio-environmental risks. In summary, we have large S1-banks and smaller S3- and S4-banks operating in 332 and 326 exposed and non-exposed sectors respectively, with monthly lending information desaggregated by: federal unit (27 states), maturity (below or above one year), and firm size (large, medium, small and micro).

Treated banks are the largest six banks in the country, which include two stated-owned banks (Caixa Economica and Banco do Brasil), three domestic private banks (Bradesco, Itau and BTG Pactual) and one foreign bank (Santander). The combined market share of these banks in terms of total loans was 84% in January 2017. In that year, in the eight months prior to the introduction of the ICAAP, 54% of the total lending volume was directed to firms in sectors with high environmental risk. For these firms, 69% of the credit was short-term (i.e., with maturity of less than one year) and the share of short-term credit to non-exposed firms was 67% (Table 1). In Figure 1, we illustrate graphically and for a symetric 8-month window before-and-after the ICAAP rule the relative growth of total lending from large banks to exposed vis-à-vis non-exposed sectors and the share of short term credit in each case. As shown in the figure, both the size and share of short-term credit to exposed and non-exposed sectors followed similar paths prior to the regulation. After the ICAAP was introduced, there appears to be a relative decline in the credit to firms in environmentally risky sectors, with total credit growth 2.3 percentage points below those of non-exposed firms in the same time window. Also, for exposed sectors, the share of short term credit to redit growth 2.3 percentage points below those of non-exposed firms in the same time window. Also, for exposed sectors, the share of short term credit to redit growth 2.3 percentage points below those of non-exposed firms in the same time window. Also, for exposed sectors, the share of short term credit to redit growth 2.3 percentage points below those of non-exposed firms in the same time window. Also, for exposed sectors, the share of short term credit to redit growth 2.3 percentage points below those of non-exposed firms in the same time window. Also, for exposed sectors, the share of short term credit to redit to firms in the same time window. Also, for exposed sectors, the share of

¹³ For example, extraction sectors, such as coal, oil, and natural gas were classified as exposed to socio-environmental risk and to climate-change risks.

seems to increase at a faster pace than the share of short term loans to non-exposed sectors after the ICAAP framework. Although only suggestive, the evidence highlights potential changes in credit allocation induced by the regulation.

Comparing credit between exposed and non-exposed sectors within treated banks, however, might mask underlying sectorial trends, since each of these industries represent different economic activities. In turn, we present the summary statistics on the lending from control banks, S3 and S4 groups, to sectors with high and low socio-environmental risks.¹⁴ Control banks include foreign banks such as Societe Generale, BNP Paribas, and Scotiabank, as well as stated owned banks (e.g., Banco da Amazonia) and many private commercial banks. As expected, total credit from these banks to both exposed and non-exposed firms is significantly smaller than lending from treated banks (e.g., total lending volume by control banks is on average 6.9% and 8.4% of the total volume of S1 banks to exposed sectors and non-exposed sectors respectively). Pior to the capital policy, 58% of the total lending volume from control banks was directed to firms in sectors with high environmental risk. For these exposed firms, 75% of the credit was short-term and 73% for non-exposed sectors

Importantly, the sectoral and geographical distribution of credit between treated and control banks are similar. According to Figure 2 (Panels A and B), both S1 and S3-S4 banks tend to allocate a similar share of their credit towards each economic acitivity, measured at the most aggregated CNAE level (listed in Table C2 of the Appendix). Similarly, according to Table 1, the share of credit by region among treated and control banks is similar prior to the ICAAP policy. Furthermore, within exposed and non-exposed sectors, the size distribution of borrowers is similar across treated and control banks. In sectors with high socio-environmental risks, large firms represent 68% of the total treated banks' credit before the policy and 65% for the control group. For non-exposed sectors, the share of credit to large firms is significantly smaller due to the nature of firm size and demand for credit in extractive industries relative to sectors with low environmental risks. The key aspect for our analysis is that the share of credit to firms with different sizes is similar for treated and control banks, 41% and 39% respectively for large firms.

3.2 Methodology

¹⁴ The average assets, deposits, and capital ratios of S1 and non-S1 banks prior to the reform are displayed in Table C1 of the Appendix.

To evaluate the impact of the ICAAP on bank lending, we follow a difference-indifferences methodology where we compare the lending of treated banks to exposed sectors vis-àvis non-exposed sectors before and after the policy. The baseline specification is as follows:

$$y_{s,m,l,f} = \alpha_0 + \alpha_1 Post_m + \alpha_2 Exp_s + \alpha_3 Exp_s * Post_m + \gamma_{s,l,f} + \delta_{m,l,f} + \varepsilon_{s,m,l,f}$$
(1)

where $y_{s,m,l,f}$ is an outcome variable of treated banks measured at the sector *s* level, during year-month *m*, in location *l*, and for firms with size *f*. In line with the discussion in Section 2, we examine the total lending volume in logs and the share of short-term credit (i.e., short term credit divided by total credit) of treated banks. *Post_m* is an indicator variable that equals one from September 2017 onwards and zero otherwise. *Exp_s* is an indicator variable equal to one for sectors with high socio-environmental risks and equal to zero for non-exposed sectors according to the FEBRABAN taxonomy. The coefficient α_3 represents the effect of the ICAAP regulation on outcome $y_{s.m.l.f}$ to exposed sectors.

We include a series of fixed effects to control for time unvarying characteristics of borrowers and sectors, as well as for time varying factors (e.g., the business cycle) affecting credit demand. More precisely, we use Sector*Federal Unit*Borrower Size fixed effects ($\gamma_{s,l,f}$) to capture borrower characteristics that affect the demand for credit and that are constant over time. In addition, Equation (1) includes Year-Month*Federal Unit*Borrower Size fixed effects ($\delta_{m,l,f}$) which capture time-varying factors that affect the demand at a given location and for borrowers of different sizes. The last term in equation (1), $\varepsilon_{s,m,l,f}$, is an error term clustered at the sector*yearmonth level. In Appendix A, we show that the lending of treated banks to exposed and non-exposed sectors followed a parallel trend in the pre-regulation period.

Given that our empirical strategy compares the lending of treated banks across sectors over time, one concern is if the Difference-in-Difference effect captures a change in the credit demand of exposed sectors, rather than a lending adjustment of banks due to the ICAAP. To rule out this possibility, we compare the credit dynamics to exposed and non-exposed sectors by other lenders that were not subject to the ICAAP policy. More concretely, we estimate a triple difference-indifferences regression to identify the change in lending from treated banks to exposed sectors vs. non-exposed sectors around the ICAAP introduction relative to the change in credit from control banks in these sectors. We estimate the following equation:

$$y_{g,s,m,l,f} = \alpha_0 + \alpha_1 Post_m + \alpha_2 TB_g + \alpha_3 Exp_s + \alpha_4 TB_g * Post_m + \alpha_5 TB_g * Exp_s + \alpha_6 Exp_s * Post_m + \alpha_7 TB_g * Exp_s * Post_m + \gamma_{s,l,f} + \delta_{m,l,f} + \kappa_{g,s} + \mu_{s,m} + \varepsilon_{g,s,m,l,f}.$$
(2)

The dependent variable is now calculated at the bank group level g (S1, S3 or S4) for each sector, month, location, and firm size. The indicator variable TB_g is equal to one for treated banks, those classified as S1, and is zero otherwise. The coefficient α_7 captures the impact of the ICAAP on bank lending by treated banks to exposed sectors. In addition to the controls discussed above, Equation (2) includes Sector*Year-month fixed effects ($\mu_{s,m}$), which help us control for time-varying factors that impact the demand of credit of each 5-digit sector, and Bank Group*Sector fixed effects ($\kappa_{g,s}$) which capture potential lending especialization among banks towards firms in certain sectors.

3.3 Results

Columns 1 and 3 of Table 2 display the results of estimating Equation (1) on our outcomes of interest using a symmetric 8-month window before-and-after the ICAAP policy (i.e., between January 2017 and April 2018). According to column 1, total credit to exposed sectors from treated banks decreased by 1.5% after the regulation. The decline in lending to firms with high environmental risks seems to be more pronounced in long-term credit; the share of short-term credit from treated banks to exposed sectors increases by 0.5% after the ICAAP.

As an extension of Equation (1), we examine the heterogeneity of the findings across firms. For instance, in response to the ICAAP, banks could reallocate credit away from riskier borrowers, as documented by Konietschke et al. (2022) when they are required to disclose the results of their stress tests. Since firm rating is not available in our lending data, we instead examine the changes in credit by borrower size. To be precise, we include an additional interaction term in Equation (1), $Exp_s * Post_m * Small_f$, where $Small_f$ is an indicator variable equal to one for small and micro firms and zero otherwise. In this exercise, we also include Sector*Year-month fixed effects to capture time varying factors that impact the demand of credit at the sector level. Results are presented in columns 2 and 4 of Table 2. We find that the credit contraction is more pronounced among smaller firms in exposed sectors; –treated banks reduce their credit by 3.1% after the

introduction of the ICAAP- and loans tend to have shorter duration. For these borrowers, the share of short-term credit from treated banks increases by an additional 0.5% after the policy.

To corroborate our results, we interact the treated sector variable (Exp_s) with year-month dummies to estimate the monthly evolution of each of the four dependent variables around the introduction of the ICAAP rule. Figure 3-Panel A presents the coefficient plots of these interactions with the associated confidence intervals. The figure, which presents the dynamic impact of the ICAAP policy on treated banks' lending when we restrict the sample to small firms, offers at least three main insights. First, it further validates the parallel trend assumption in a nonlinear framework. That is, before the policy, treated banks' credit growth was similar between small firms in exposed and non-exposed sectors. Second, after the ICAAP policy, total lending to small firms in exposed sectors declines relative to non-exposed firms and the credit contraction is more pronounced for long-term credit. As a result, the share of short-term credit to small firms in exposed sectors rises following the ICAAP. Third, Panel B of the figure presents the coefficient plots for the credit outcomes from control banks. For this group, there are no changes in lending between exposed and non-exposed firms after the policy. The evidence for our control group, banks not subject to the ICAAP rule, suggests that the documented changes in the credit dynamics between exposed and non-exposed firms after September 2017 are not a result from sectoral trends, but rather these effects are exclusive to treated banks. To formally test this idea, we estimate Equation (2), which uses S3 and S4 banks as controls, and their credit allocation to sectors with high and low environmental risks.

Results for the triple difference-in-differences methodology are displayed in Table 3, columns 1 to 4. Columns 1 and 3 present the estimates for total lending volume and the share of short-term credit for the full sample. Total lending from treated banks to exposed firms decline by 2.7% after the ICAAP (column 1). The credit contraction is more pronounced in long-term credit, and in turn, the share of short-term credit from treated banks to firms in these sectors increase after the ICAAP policy (by 0.7% according to column 3). We also confirm that the contraction of credit is most pronounced for small firms operating within sectors characterized by high socio-environmental risks (columns 2 and 4). Total credit volume from treated banks to small borrowers in exposed sectors drops by 4.1% after the ICAAP. Additionally, the share of short-term credit increases by 1% following the policy. In robustness exercises, we replicate the triple differences-in-differences analysis but include the partially treated banks in the sample ($TB_q = 1$ for this

group). The findings are generally consistent, showing a decrease in the volume of credit to firms in exposed sectors and shorter loan maturities, although the magnitudes of these changes are relatively smaller (see Appendix Table C3)

The analysis documents the relative decline in credit from treated banks to firms with high socio-environmental risks. The credit contraction is measured relative to the lending for firms with low socio-environmental risks and relative to the change in credit by control banks across exposed and non-exposed sectors. A remaining question is whether control banks, those in groups S3 and S4, adjust their lending around the capital assessment policy. To study the behavior of control banks, we replicate the triple differences-in-differences methodology but exclude time fixed effects (and their interactions). In this setting, coefficient α_1 in Equation (2) captures the change in credit before and after the ICAAP from control banks to non-exposed sectors, $\alpha_1 + \alpha_6$ represent the change for exposed firms, and α_6 is the relative change between exposed and non-exposed sectors. Results are presented in columns 5-8 of Table 3.

After the policy, control banks increase their total lending volume to firms in exposed and non-exposed sectors, by 9.6% and 8.5% respectively (column 5). While it appears that credit to exposed sectors from control banks is growing at a faster rate, the difference between sectors is indistinguishable from zero ($\alpha_6 = 0.011$ with standard error equal to 0.009). In other words, banks not subject to the ICAAP are expanding their credit in both high and low environmentally risky firms at similar rates after September 2017. The credit expansion is more pronounced among smaller firms (column 6) and is similar between short-term and long-term credit: the share of short-term credit remains constant after the policy (columns 7 and 8). The results further confirm the visual findings in Figure 3-Panel B –the relative lending behavior of control banks in exposed and non-exposed sectors does not change with the introduction of the ICAAP. During the months following the policy, control banks grow their credit to all sectors, and to smaller borrowers.

4. Real Effects

The results indicate that the ICAAP leads to a reallocation of credit, shifting the supply away from small firms operating in sectors with high socio-environmental risks and this contraction is particularly pronounced among long-term loans.

We now examine if the documented credit shock has any effects on real economic activity. To explore this idea, we argue that the credit contraction would have a stronger impact among firms headquartered in regions where S1 banks have a higher presence. So far, because our lending data at the *sector-borrower size-maturity-bank group* quadruplet is only available at the federal level, we have used 27 states as our geographical unit. However, since aggregate lending data is available for the 5,565 municipalities in the country (the smallest administrative unit), we can identify specific locations where treated banks are more active. The objective is to use the heterogeneity in the geographical presence of banks subject to the ICAAP to measure potential cross-sectional variations in real outcomes for firms operating in different locations, both before and the policy implementation.

In the remaining of the section, we introduce the data for an exercise that evaluates the impact of the supply credit shock on economic activity, discuss our empirical strategy, and present the results.

4.1 Data

Our first dataset consists of information on greenhouse gas emissions, which is collected on a yearly basis since 2011 for a subsample of sectors at the municipality level: The Greenhouse Gas Emission and Removal Estimating System (SEEG). Our second dataset corresponds to the census of the Brazilian formal labor market "Relação Anual de Informações Sociais" (RAIS). This dataset provides yearly information on the universe of formal firms, including the firm's sector (reported at the 5-digit level), number of workers, and size classification (i.e., if the firm is micro, small, medium, or large). Finally, we add the yearly GDP and population size for each municipality in the country from the Brazilian Institute of Geography and Statistics. We aggregate this dataset at the *municipality-year-sector* level. More concretely, we calculate the total number of workers and of firms that operate in each *municipality-year-sector*. In addition, we calculate the average firm size (measured by the number of workers of the average firm) as well as the share of micro firms and of workers employed in micro firms for each *municipality-year-sector* triplet.

We merge the SEEG and RAIS data with two additional data sources:(i) The 2014 FEBRABAN taxonomy described in Section 2 and (ii) the yearly number of commercial bank branches and total lending volume across municipalities. Our final dataset consists of the universe of formal firms operating in the 332 sectors identified as having high socio-environmental risk, for the years 2012 to 2019.

4.2 Methodology

To evaluate the impact of the ICAAP regulation on the real outcomes across sectors, we follow a difference-in-difference approach. With this methodology, we compare the outcomes of exposed sectors in municipalities more and less dependent on treated bank lending before and after the policy. We measure the strength of bank presence in each municipality as the ratio of treated bank branches to the municipality' population size in 2016 (one year prior to the regulation). As an alternative measure, we use the share of lending by volume and present the full set of results in the Appendix. Since S1 banks were the only financial institutions required to fully comply with the ICAAP, we conjecture that firms operating in municipalities with a higher ratio of S1 bank branches or where S1 bank credit represents a larger share of total lending are more dependent on these banks to obtain commercial credit. In turn, firms in exposed sectors would be more likely to be affected by the introduction of the regulation. We estimate the following equation:

$$y_{s,l,t} = \alpha_s + \alpha_l + \alpha_t + \gamma Treatment_l * Post_t + \varepsilon_{s,l,t}$$
(3)

where $y_{s,l,t}$ is an outcome of interest for sector *s*, location *l* (at the municipality level), and year *t*. The terms α_s , α_l and α_t correspond to fixed effects at the sector, municipality, and year level. $\varepsilon_{s,l,t}$ is an error term, clustered at the municipality level. The coefficient γ represents the treatment effect of the regulation on outcome $y_{s,l,t}$. The indicator variable *Treatment* equals one for municipalities in the treated group and zero otherwise. As a first approach, we classify treated locations as the 2,783 municipalities where S1 banks incidence is above the median. That is, those for which the S1 bank branches ratio to population is above the median, or municipalities where the share of total lending by S1 banks is above the median at the end of 2016. The remaining 2,782 municipalities below the median represent the control group.

Panel A of Table 4 compares the mean outcomes prior to the regulation between treatment and control groups using the ratio of S1 branches as the measure of S1 banks' presence. Overall, sectors in municipalities with a greater ratio of large banks have statistically lower CO₂ emissions and tend to be larger in terms of their number of workers, number of firms and average firm size. Moreover, compared to control municipalities, sectors in treated municipalities have a lower share of workers employed in micro firms (77% vs 66%), and a lower share of firms classified as micro (83% vs 74%). This finding is consistent with large banks operating in larger and wealthier municipalities and suggests that the set of all municipalities below the median ratio of large bank branches to population is not a good comparison group for municipalities above this ratio. We also find similar results when we classify treatment and control municipalities by the share of total lending from S1 banks.

To define a more comparable set of control and treated municipalities, we use propensity score matching techniques. More specifically, for each 5-digit sector, we estimate the propensity score by running a probit regression at the municipality level, where the dependent variable is an indicator variable that equals one if the municipality is treated and zero otherwise.¹⁵ The first five independent variables of the probit regression capture the total number of workers employed in the sector at each municipality during the pre-regulation years, from 2012 to 2016, measured in logs. Extending the observation period beyond a short window prior to the ICAAP policy is beneficial as it enables us to enhance the matching process. This means we can identify municipalities with similar characteristics over time. The next four variables correspond to each municipality's 2012-2016 log average number of firms operating in the sector, firm size of the sector (measured by number of workers), population and GDP. Including these variables in the propensity score helps us identify a set of control and treated municipalities that would have similar GDP and population levels as well as similar levels and trends in each sector's real outcomes. Moreover, previous research finds that past values of an outcome of interest are the ones that are most strongly correlated with future outcomes (Bruhn & McKenzie, 2009). We then use the propensity score to select the single nearest neighbor for each treated municipality within the common support. After this exercise, our sample of municipalities is refined to 922 (524 in the control group and 398 in the treated group).

Panel B of Table 4 shows the mean outcomes prior to the regulation between these two matched treatment and control groups. Across all outcomes, sectors in treated and control matched municipalities are more similar. We show that matched treatment and control municipalities followed a parallel trend in the pre-2017 years (Appendix B).

4.3 Results

¹⁵ The average sector in the census operates in 638 municipalities, sectors in the 10th percentile distribution operate in 77 municipalities.

Table 5-Panel A displays the estimates of Equation (3) on our six outcomes of interest for the restricted sample of municipalities. Across all outcomes, we find no statistically significant evidence that after the reform, sectors classified as with high socio-environmental risk were affected differently in treated vs control municipalities.¹⁶ Graphical evidence is illustrated in Figure 4. Overall, outcomes of our matched treated and control municipalities follow parallel paths before the regulation, with no substantial change afterwards. It seems that firms in exposed sectors fully offset the credit shock, by substituting the slowdown in lending by S1 banks with credit from non-S1 banks or by obtaining other forms of financing.

We use alternative cutoffs for our definition of treatment group. For example, we define treated municipalities as those with a 2016 ratio of S1 bank branches to population above the 75th percentile. To the extent that in those locations S1 banks represent an even larger share of the lending market, it is possible that the credit substitution channel is attenuated, as firms in exposed sectors are unable to obtain credit from non-S1 banks. We estimate Equation (3) on our six outcomes of interest for this alternative definition of treatment group (Table 5-Panel B). While sectors in treated municipalities do not experience significant changes in their emissions and total employment, we find evidence suggestive of a redistribution of workers towards larger firms. After the regulation, the fraction of workers employed in micro firms in exposed sectors declines in 0.4 percent after the reform in treated municipalities. Similarly, the share of firms that are micro also drops by 0.5 percent.

We interact the treatment municipality variable (*Treatment*_l) with year dummies to estimate the yearly evolution for each of the six outcome variables and define treatment as municipalities with the ratio of S1 branches above the 75th percentile. Figure 5 displays the coefficient plots of these interactions with the associated confidence intervals. The figure displays graphical evidence of the relative dynamics of treated and control municipalities. While outcomes of our matched treated and control municipalities follow close trends over time, both the share of workers employed in micro firms and the share of firms that are consider micro begin decreasing in treated municipalities in the post-reform years. These findings suggest that for some small firms in exposed sectors, the substitution of credit is only partial. Overall, in credit markets where large

¹⁶Results are also similar if we use the share of total lending from S1 banks to define the treatment and control groups (Appendix Table C4).

banks dominate the lending activity, the smallest firms seem to be less able to smooth the credit shock.

5. Limitations, alternative channels, and future work

We document a credit contraction in lending to exposed sectors from banks subject to the ICAAP framework. Throughout our analysis, we examine credit and economic activity at the sector level. However, banks' response to the policy might differ across borrowers within the same exposed sector. The heterogeneity in firms' characteristics could be useful to uncover the channels through which banks respond to climate-related prudential rules. For instance, if banks have to cut credit, they might be less likely to cut it from firms that that represent a higher share of their revenue (Imbierowicz, et al., 2018). Alternatively, banks might shield firms with longer relationship from the shock relative to new borrowers (De Marco, et al., 2021). Other important margins are the pricing of new loans to exposed sectors and the collateral required to these firms. Unfortunately, due to data limitations, such analysis is outside the scope of this paper and left for future work. Ideally, access to loan-level data would allow us to disentangle the prevalence of each transmission channel.

Our evidence suggests that the impact from the bank lending contraction is partly mitigated by substitution of credit. Accordingly, we find that on aggregate, the real effects from the policy are only moderate. The fact that the labor share and the number of formal micro firms is declining, precisely in exposed sectors and in municipalities where treated banks have a stronger presence, suggests the policy affects most strongly firms that are less able to substitute credit. An interesting avenue for future research would be to examine the predominance of this substitution channel. For example, for firms headquartered in less competitive lending markets, replacing credit sources might be prohibitive or too costly. In these local markets, the effect from the policy might be more pronounced for firms in exposed sectors. Also, it would be interesting to study the composition effect. Are exposed firms with existing relation with smaller banks obtaining more credit at longer maturity, or these banks are attracting new corporate clients following the credit decline from large banks? The current findings suggest that control banks are willing to expand their credit and maturity to sectors with high environmental risks, precisely for type of exposure that the regulator is requesting additional capital for stability reasons. How precisely is the substitution working through the banking sector is still an open question. Overall, the unintended consequences of climate-related capital requirements on economic activity may be small, but as we document, these effects are present under some circumstances. An ambitious research agenda would be to study the impact of climate-related capital in a multi-country setting. Since 2020, both the Bank of England and the European Central Bank have introduced guidelines to climate-related and environmental risk management. It could be interesting to explore whether country specific features are an additional source of heterogeneity (alongside bank and firm characteristics) in the impact of climate-related capital requirements on credit supply.

Finally, our assumption that the inclusion of social and environmental risks in the ICAAP is a good proxy for more recent regulation explicitly addressing climate-change has an important caveat. To the extent that GHG reduction is a fundamental objective of climate policy, banks might require firms to meet specific targets of GHG emission in order to supply credit. In this case, financial policies addressing climate-change risks might generate GHG reduction through the banks' commitment to comply with the policy.

6. Conclusions

Climate change poses a major challenge for world economies. The use of prudential tools to protect the financial system from climate-related risks has become widespread, but the impact of such policies remains largely unexplored. In this paper, we exploit the introduction of a capital assessment rule that includes environmental risks as a quasi-natural experiment to study the effect of climate-related prudential measures on bank lending, and the transmission of this effect to the real economy and GHG emissions. Our findings are relevant from a policy perspective as they illustrate the tradeoffs from using capital requirements to promote bank resilience to climate-change exposure.

We provide first evidence that large banks, subject to the policy, reallocate their lending, reducing their exposure to economic activities with high environmental risks while also shortening the maturity of loans to these firms. In contrast, smaller banks, exempt from the capital assessment rule, expand their credit supply to exposed sectors. The growth in lending from small banks appear to compensate the contraction in the supply of large banks, mitigating the shock, but at the cost of increased exposure from smaller banks to environmentally exposed sectors. The shift in exposure

of environmental risks from large to small banks in our setting, highlights the importance to safeguard the entire financial system when implementing climate-related prudential measures.

In line with the substitution of credit, we show that the transmission of the capital adequacy rule to the real economy is only moderate, but there are some important effects under the right circumstances. For example, in municipalities where treated banks have the strongest presence (making up for the most branches and the largest share of total credit), we find that there is a redistribution of workers towards larger firms. The heterogenous effects suggest that while many firms are insulated from the supply shock, adjustment of bank portfolios in response to climate-related capital requirements may disproportionally affect borrowers that typically have limited access to credit.

A major overall challenge for financial authorities is how to define and monitor climaterelated risks. Policies that rely on taxonomies based on industry classifications, rather than on project outcomes, can divert capital away from sectors requiring external funding for essential green innovations. The key tradeoff for policymakers is integrating prudential measures to protect banks from climate risk exposure without affecting credit supply, especially for firms that may already face limited access to credit and have projects with the most substantial social and environmental impact.

References

Atanasova, C. & Schwartz, E., 2019. Stranded fossil fuel reserves and firm value. *National Bureau of Economic Research Working Paper Series,* Issue 26497.

Austin, P., 2011. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behavioral Research*, 46(3), pp. 399-424.

Austin, P., 2014. The use of propensity score methods with survival or time-to-event outcomes: reporting measures of effect similar to those used in randomized experiments. *Statistics in Medicine*, 33(7), pp. 1242-1258.

Bank of England, 2019. *Enhancing banks' and insurers' approaches to manage the financial risks from climate change*, London: Bank of England.

Bolton, P. & Kacperczyk, M., 2021. Do investors care about carbon risk. *Journal of Financial Economics*, 142(2), pp. 517-549.

Borghesi, R., Houston, J. & Naranjo, A., 2014. Corporate socially responsible investments: CEO altruism, reputation, and shareholder interests. *Journal of Corporate Finance*, Volume 26, pp. 164-181.

Bruhn, M. & McKenzie, D., 2009. In pursuit of balance: Randomization in practice in development field experiments. *American Economic Journal: Applied Economics*, 1(4), pp. 200-232.

De Jonghe, O., Dewachter, H. & Ongena, S., 2020. Bank capital (requirements) and credit supply: Evidence from pillar 2 decisions. *Journal of Corporate Finance,* Volume 60, p. 101518.

De Marco, F., Kneer, C. & Wieladek, T., 2021. The real effects of capital requirements and monetary policy: Evidence from the United Kingdom. *Journal of Banking and Finance*, Volume 133, p. 106237.

Dehejia, R. & Wahba, S., 2002. Propensity Score-Matching Methods For Nonexperimental Causal Studies. *The Review of Economic and Statistics*, 84(1), pp. 151-161.

Delis, M., De Greiff, K. & Ongena, S., 2019. Being stranded with fossil fuel reserves? Climate policy risk and the pricing of bank loans. *Swiss Finance Institute Research Paper Series*.

Demirguc-Kunt, A., Pedraza, A., Pulga, F. & Ruiz-Ortega, C., 2023. Global banks lending under climate policy. *IMF Economic Review Forthcoming*.

Dunz, N. et al., 2021. Compounding Covid-19 and climate risks: The interplay of banks' lending and government's policy in the shock recovery. *Journal of Banking and Finance*, Volume https://doi.org/10.1016/j.jbankfin.2021.106306.

ECB, 2020. *Guide on climate-related and environmental risks, s.l.:* European Central Bank.

FEBRABAN, 2021. *Explanatory guide to FEBRABAN's green taxonomy*, s.l.: Brazilian Federation of Banks.

Fraisse, H., Le, M. & Thesmar, D., 2020. The real effects of bank capital requirements. *Management Science*, 66(1), pp. 5-23.

Giglio, S., Kelly, B. & Stroebel, J., 2021. Climate finance. *Annual REview of Financial Economics*, Volume 13, pp. 15-36.

Gropp, R., Mosk, T. & Ongena, S., 2019. Banks response to higher capital requirements: Evidence from a quati-natural experiment. *Review of Financial Studies*, 21(1), pp. 266-299.

Imbierowicz, B., Kragh, J. & Rangvid, J., 2018. Time-varying capital requirements and disclosure rules: Effects on capitalization and lending decisions. *Journal of Money, Credit and Banking*, 50(4), pp. 573-602.

Jimenez, G., Ongena, S., Peydro, J.-L. & Saurina, J., 2017. Macroprudential policy, countercyclical bank capital buffers, and credit supply: Evidence from the spanish dynamic provisioning experiments. *Journal of Political Economy*, 125(6), pp. 2126-2177.

Kacperczyk, M. & Peydró, J., 2022. Carbon emissions and the bank-lending channel. https://ssrn.com/abstract=3915486 or http://dx.doi.org/10.2139/ssrn.3915486.

Konietschke, P., Ongena, S. & Ponte Marques, A., 2022. Stress tests and capital requirement disclosures: Do they impact banks' lending and risk-taking decisions?. *Swiss Finance Institute Research Paper*, Volume 60.

Monasterolo, I. et al., 2022. The role of green financial sector initiatives in the low-carbon transition. *Wold Bank Policy Research Working Paper*, Issue 10181.

Oehmke, M. & Opp, M., 2022. Green capital requirements. Working Paper.

Oustry, A., Erkan, B. & Svartzman, R., 2020. Climate-related risks and central banks' collateral policy: A methodological experiment. *Banque de France Working Paper Series*.



Figure 1. Lending to exposed and not exposed sectors by treated bank groups

Panel A. Lending volume to exposed and not exposed sectors

Panel B. Share of short-term lending to exposed and not exposed sectors

Notes: Panel A displays the monthly aggregate corporate lending of treated banks channeled to all 5-digit sectors classified as exposed and not exposed. Panel B displays the share of lending of treated banks that has maturity of one year or less to all 5-digit sectors classified as exposed and not exposed. Treated banks correspond to S1 banks.











Notes: The top panels display the sectoral distribution of lending of treated and control banks for exposed (left) and not exposed (right) sectors. The bottom panels display the distribution of lending of treated and control banks across small, medium and large corporate borrowers for exposed (left) and not exposed (right) sectors. Treated (control) banks correspond to S1 (non-S1) banks.





Notes: The figure displays the monthly coefficients of the effect of the ICAAP regulation on credit outcomes of exposed sectors by treated banks (Panel A) and control banks (Panel B). The monthly coefficients α_m are obtained from regressions comparing the lending over time to exposed vs. not exposed sectors, which are summarized by the equation $y_{s,m,l,f} = \alpha_0 + \sum_m \alpha_m Exp_s \cdot Month_m + \delta_{s,l,f} + \delta_{l,f,m} + \varepsilon_{tm}$, where Exp_s is an indicator variable equal to one for 5-digit sectors classified as with high environmental risk exposure, and zero otherwise. The indicator variable $Month_m$ equals one in month *m* and zero otherwise. Fixed effects at the sector-location-firm size and location-firm size-month levels are included in all regressions. Treated (control) banks correspond to S1 (non-S1) banks.



Figure 4. Real outcomes of sectors with high socio-environmental risks in treated and control municipalities

Notes: The figure displays monthly means of the outcomes of interest of exposed sectors for the set of matched treated and control municipalities, where treatment consists of municipalities with a 2016 ratio of treated banks to population above the median. Treated banks correspond to S1 banks. The vertical line shows the year of the introduction of the ICAAP.



Figure 5. Evolution of activity by sectors with high socio-environmental risks in treated and control municipalities

Notes: The figure displays the yearly coefficients of the effect of the ICAAP regulation on the outcomes of interest of exposed sectors for the set of matched treated and control municipalities. The plotted coefficients are obtained from regressions outlined in Equation (3).Treatment (control) municipalities are those with a 2016 ratio of treated banks to population above (below) the median. Treated (control) banks correspond to S1 (non-S1) banks. The vertical line shows the year of the introduction of the ICAAP.

Table 1. Summary statistics (pre-reform period)								
				Mean/SD		Mean/SD		
	Ν	Mean/SD	N Not-Exposed	Not-Exposed	N Exposed	Exposed		
Treated Banks- Total lending volume (logs)	111,313	14.8	40,510	14.9	70,803	14.7		
		2.8		2.4		2.3		
Treated Banks- Share of short-term lending	111,313	0.7	40,510	0.7	70,803	0.7		
		0.2		0.2		0.2		
Control Banks- Total lending volume (logs)	124,688	12.2	43,230	12.4	81,458	12.1		
		2.8		2.7		2.6		
Control Banks- Share of short-term lending	124,688	0.7	43,230	0.7	81,458	0.7		
	-	0.2		0.3	-	0.3		
Treated Banks- Share of credit to North/North-								
East/Center	111,313	0.19	40,510	0.18	70,803	0.19		
		0.07		0.09		0.03		
Treated Banks- Share of credit to South/South-								
East	111,313	0.81	40,510	0.82	70,803	0.81		
		0.23		0.25		0.16		
Treated Banks- Share of credit to North/North-								
East/Center	124,688	0.23	43,230	0.21	81,458	0.23		
		0.07		0.11		0.06		
Control Banks- Share of credit to South/South-								
East	124,688	0.77	43,230	0.79	81,458	0.77		
	·	0.23	·	0.296	·	0.22		

Notes: Observations are at the bank group-5-digit sector-federative unit-borrower size-month level for all months from January 2017 to August 2017. The first two columns display the summary statistics for credit indicators of all sectors. The next two columns display the summary statistics for credit indicators of sectors with low socio-environmental risk. The last two columns display summary statistics for credit indicators of sectors with high socio-environmental risk. The definition of sectors with high socio-environmental risk follows the 2015 Febraban taxonomy. Treated (control) banks correspond to S1 (non-S1) banks.

Table 2. Impact of ICAAP regulation on credit outcomes of treated banks to exposed vs not exposed sectors								
	(1)	(2)	(3)	(4)				
	Total Lendin	ng Volume (logs)	Share Short-	Ferm Lending				
Exp _s * Post _m	-0.015* (0.008)		0.005*** (0.001)					
Exp _s * Post _m * Small _f		-0.031** (0.014)		0.005*** (0.002)				
Observations	221,756	221,426	221,756	221,426				
R-squared	0.906	0.912	0.752	0.766				
Sector*UF*Borrower Size FE	Yes	Yes	Yes	Yes				
UF*Borrower Size*Time FE	Yes	Yes	Yes	Yes				
Sector*Time FE	No	Yes	No	Yes				

Notes: Observations are at the 5-digit sector-federative unit-borrower size-month level for treated banks in all months from January 2017 to April 2018. The table reports the coefficients of equation 1, where $Post_m$ is an indicator variable equal to one from September 2017 onwards, and zero otherwise. Exp_s is an indicator variable equal to 1 for 5-digit sectors classified as with high environmental risk exposure, and 0 otherwise. Small_f is an indicator variable equal to one for borrowers classified as small, and zero otherwise. The dependent variables correspond to the log total lending volume and the share of short-term lending channeled by bank group S1 (treated banks) to borrower firms of size *f* in federative unit *UF* and sector *s* at month *m*. Constant terms not reported in the table. Standard errors are clustered at the sector*time level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Table 3. Impact of ICAAP regulation on credit outcomes of treated banks to exposed vs not exposed sectors (relative to control banks)									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
	Total Lendir	ng Volume (logs)	Share Short	-Term Lending	Total Lending	g Volume (logs)	Share Short-	Term Lending	
	All firms	Small firms	All firms	Small firms	All firms	Small firms	All firms	Small firms	
Post _m					0.085***	0.120***	0.000	0.001	
					(0.006)	(0.006)	(0.001)	(0.001)	
Post _m * TB _g					-0.201***	-0.238***	0.003***	0.006***	
					(0.007)	(0.007)	(0.001)	(0.001)	
Exps * Postm					0.011	0.010	-0.002*	-0.002	
					(0.009)	(0.011)	(0.001)	(0.002)	
Exps * Post _m * TB _g	-0.027**	-0.041***	0.007***	0.010***	-0.013	-0.033**	0.005***	0.008***	
	(0.012)	(0.013)	(0.002)	(0.002)	(0.012)	(0.014)	(0.002)	(0.002)	
Observations	473,779	228,297	473,779	228,297	474,006	228,703	474,006	228,703	
R-squared	0.780	0.840	0.483	0.465	0.777	0.835	0.474	0.450	
Sector*Bank Group FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Sector*UF*Size FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
UF*Size*Time FE	Yes	Yes	Yes	Yes	No	No	No	No	
Sector*Time FE	Yes	Yes	Yes	Yes	No	No	No	No	
Exp sectors by control banks					0.096	0.130	-0.002	0.000	
P-value					0.000	0.000	0.050	0.830	
Exp sectors by treated banks					-0.118	-0.141	0.006	0.014	
P-value					0.000	0.000	0.000	0.000	

Notes: Observations are at the bank group-5-digit sector-federative unit-borrower size-month level for all months from January 2017 to April 2018. The table reports the coefficients of equation 3, where $Post_m$ is an indicator variable equal to one from September 2017 onwards, and zero otherwise. Exp_s is an indicator variable equal to 1 for 5-digit sectors classified as with high environmental risk exposure, and 0 otherwise. TB_g is an indicator equal to one for treated banks (banks in group S1) and zero otherwise. Estimates in columns 2, 4, 6 and 8 restrict the sample to borrowers classified as small. The dependent variables correspond to the log total lending volume and the share of short-term lending channeled by bank group *b* to borrower firms of size *f* in federative unit *UF* and sector *s* at month *m*. Constant terms not reported in the table. Standard errors are clustered at the sector*time level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

	Firms in tre	ated municipalities	Firms in control municipalities		
	Ν	Mean/SE	Ν	Mean/SE	
Panel A. All municipalities					
CO ₂ emissions (logs)	93639	6.80	52906	6.91	
		0.012		(0.015)***	
Number of workers (logs)	746875	1.85	311742	1.42	
		(0.002)		(0.003)***	
Number of firms (logs)	746875	0.83	311742	0.69	
		(0.001)		(0.001)***	
Firm size (logs)	746875	1.41	311742	1.10	
		(0.002)		(0.002)***	
Share of workers in micro	528801	0.66	196012	0.77	
		(0.001)		(0.001)***	
Share of micro firms	528801	0.74	196012	0.83	
		(0.001)		(0.001)***	
Panel B. Matched					
CO ₂ emissions (logs)	37346	6.81	37305	6.92	
		0.018		(0.018)***	
Number of workers (logs)	231815	1.50	231815	1.55	
		(0.003)		(0.003)***	
Number of firms (logs)	231815	0.71	231815	0.71	
		(0.001)		(0.002)	
Firm size (logs)	231815	1.18	231815	1.21	
		(0.002)		(0.003)***	
Share of workers in micro	154007	0.73	150855	0.70	
		(0.001)		(0.001)***	
Share of micro firms	154007	0.79	150855	0.77	
		(0.001)		(0.001)***	

Table 4. Pre-reform summary statistics for firms with high socio-environmental risk in treated and control municipalities

Notes: Sample restricted to firms operating in sectors classified as with high socio-environmental risk in the 2015 taxonomy. The first two columns display summary statistics of firms in treated municipalities (municipalities above the median ratio of large bank branches to population in 2012). The last two columns display summary statistics of firms in control municipalities (municipalities below the median ratio of large bank branches to population in 2012). Data is for the years 2012-2016. ***, **, and * indicate that the mean difference between control and treated groups is different at the 1, 5, and 10 percent significance level.

Table 5. Impact of regulation on real outcomes of firms with high socio-environmental risk (matched municipalities)								
	(1)	(2)	(3)	(4)	(5)	(6)		
	CO2 emissions	Employment	Number of firms	Firm Size	Employment Share Micro	Share Micro Firms		
Panel A. Treatment defined as municipalities above the median ratio of S1 bank branches to population in 2012								
Treatment _l * Post _t	-0.01	0.001	-0.001	0.002	0.001	-0.001		
	[0.015]	[0.006]	[0.003]	[0.005]	[0.002]	[0.002]		
Observations	119,437	741,806	741,806	741,806	490,013	490,013		
R-squared	0.794	0.242	0.31	0.185	0.23	0.227		
Panel B. Treatment def	fined as municipalitie	es above the 75th pe	ercentile ratio of S1 ba	nk branches to p	population in 2012			
Treatment _l * Post _t	0.015	0.002	-0.004	0.008	-0.004**	-0.005***		
	[0.011]	[0.007]	[0.003]	[0.005]	[0.002]	[0.002]		
Observations	139,575	889,833	889,833	889,833	622,690	622,690		
R-squared	0.8	0.271	0.352	0.203	0.234	0.228		
Mun FE	Yes	Yes	Yes	Yes	Yes	Yes		
Year FE	Yes	Yes	Yes	Yes	Yes	Yes		
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes		

Notes: Data covers the years 2012-2019. The sample is restricted to firms in matched municipalities that operate in sectors with high socioenvironmental risk. All specifications include fixed effects at the municipality, 5-digit sector and year levels. The table reports the difference-indifference impact estimates of the reform on the aggregate CO2 emissions (in logs) of firms; the number of workers (column 2); the number of firms (column 3); the average firm size (column 4); the share of workers employed in micro firms (column 5); and the share of firms classified as micro (column 6). Treatment₁ is equal to 1 for treated municipalities (above the median ratio of S1 bank branches to population in 2012) and 0 otherwise. Post_t is an indicator variable that equals 1 from 2017 onwards. Constant terms not reported in the table. The residuals are clustered at the municipality level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Appendix A. Parallel trends in lending

One assumption behind the difference-in-difference approach is that in the absence of the regulation, the outcomes of interest would have followed parallel trends across borrowers regardless of their sector's exposure. While this assumption cannot be tested, we use Equation (A1) to test if the lending of S1 banks to exposed and non-exposed sectors followed a parallel trend in the pre-regulation period.

$$y_{s,m,l,f} = \beta_0 + \beta_1 Trend_m + \beta_2 Exp_s + \beta_3 Exp_s * Trend_m + \gamma_{s,l,f} + \delta_{m,l,f} + \varepsilon_{s,m,l,f}$$
(A1)

In equation (A1), the variable $Trend_m$ is a linear time trend for the months prior to the regulation (January 2017 to August 2017) and all other variables are defined as above. The coefficient β_3 tests if the outcome y for exposed and non-exposed sectors followed a parallel trend in the pre-regulation months. The results of this test are displayed in Appendix Table A1. We find no statistically significant differences in the trends of our outcome variables from S1 banks to exposed and non-exposed sectors in the period prior to the regulation, providing credibility to our identification strategy.

Appendix Table A1. Credit outcomes of treated banks to exposed vs not exposed sectors prior to reform								
	(1)	(2)	(3)	(4)				
	Total Lending	Volume (logs)	Share Short-T	erm Lending				
Exp _s * Trend _m	0.000 (0.002)	0.001 (0.002)	-0.000 (0.000)	-0.000 (0.000)				
Trend _m	-0.015*** (0.001)		-0.001*** (0.000)					
Observations	111,193	111,193	111,193	111,193				
R-squared	0.949	0.950	0.854	0.855				
Sector*UF*Borrower Size FE	Yes	Yes	Yes	Yes				
UF*Borrower Size*Time FE	No	Yes	No	Yes				

Notes: Observations are at the 5-digit sector-federative unit-borrower size-month level for treated banks in all months from January 2017 to August 2017. The table reports the coefficients of equation A1, where $Trend_m$ is a linear time trend for the pre-reform months. Exps is an indicator variable equal to 1 for 5-digit sectors classified as with high environmental risk exposure and 0 otherwise. The dependent variables correspond to the log total lending volume and the share of short-term lending channeled by bank group S1 to borrower firms of size f in federative unit UF and sector s at month m. Treated banks correspond to S1 banks. Constant terms not reported in the table. Standard errors are clustered at the sector*time level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Appendix B. Parallel trends in real outcomes across municipalities

To formally test the validity of our empirical approach, we examine whether the outcomes for matched treatment and control municipalities followed a parallel trend in the pre-2017 years. If this was the case, it is more plausible that the outcomes would have continued to follow a parallel trend in the post-regulation period:

$$y_{s,l,y} = \alpha_s + \alpha_l + \alpha_y + \gamma Treatment_l * Trend_y + \varepsilon_{s,l,y}$$
(B1)

where *Trendy* is a linear time trend and *Treatment*_l is equal to 1 for the 398 municipalities in the matched treatment group and is equal to 0 for the 524 municipalities in the matched control group. $\varepsilon_{s,l,y}$ is an error term, clustered at the municipality level. If the coefficient γ is not statistically different from zero, we can conclude that outcome $y_{s,l,y}$ followed a parallel trend for treatment and control group municipalities in the pre-regulation years. We summarize the results of this test in Appendix Table B1. Overall, we find no statistically significant differences in the trends of our six outcomes of interest between the matched treated and control municipalities in the period prior to the regulation.

	municipalities using alternative treatment definition)									
	(1)	(2)	(3)	(4)	(5)	(6)				
	CO2		Number of	Firm	Employment	Share Micro				
	Emissions	Employment	Firms	Size	Share Micro	Firms				
Treatment _m *										
Trendy	0.001	0.001	-0.001	0.003*	0.001	-0.000				
	[0.004]	[0.002]	[0.001]	[0.002]	[0.001]	[0.001]				
Observations	87,237	556,137	556,137	556,137	388,907	388,907				
R-squared	0.801	0.283	0.360	0.214	0.240	0.233				
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes				
Year FE	Yes	Yes	Yes	Yes	Yes	Yes				
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes				

Appendix Table B1. Pre-reform trends in real outcomes of firms with high socio-environmental risk (matched municipalities using alternative treatment definition)

Notes: The sample is restricted to firms in matched municipalities that operate in sectors with high socio-environmental risk. The table reports the coefficients of equation B1, where Trend_y is a linear time trend for the pre-reform years (2012-2016). X_{my} corresponds to the log GDP and log population size of municipality *m* in year *y*. Treatment_m is equal to 1 for treated municipalities (above the median ratio of treated bank (banks in S1 group) branches to population in 2012) and 0 otherwise. For each municipality *m* and year *y*, y_{my} corresponds to the aggregate CO2 emissions (in logs) of firms; number of workers (column 2); number of firms (column 3); average firm size (column 4); share of workers employed in micro firms (column 5); share of firms classified as micro (column 6). Constant terms not reported in the table. ε_{my} is an error term clustered at the municipality level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Appendix C

Appendix Figure C1. Timetable of green financial sector initiatives



Source: Banco Central do Brasil and FSAP (WB/IMF).

Appendix Table C1. Balance sheet characteristics of treated vs control banks							
	Mean/SD All Banks	Mean/SD Treated Banks	Mean/SD Control Banks	Diff Treated vs Control (Mean/SE)			
Total assets (logs)	15.0	20.4	14.6	5.8***			
	(2.3)	(0.9)	(1.8)	(0.5)			
Total deposits (logs)	14.3	20.1	13.9	6.2***			
	(2.7)	(1.1)	(2.3)	(0.7)			
Regulatory capital ratio	30.8	16.9	31.9	-14.9			
	(34.0)	(1.9)	(35.0)	(10.1)			

Notes: Observations are at the bank level for the period prior to the reform (2017Q1 and 2017Q2). The first two columns display the mean and standard deviation of total assets (in logs), total deposits (in logs), and the regulatory capital ratio of all bank groups in the sample. The next four columns display the summary statistics for treated banks and for control banks. Treated (control) banks correspond to S1 (non-S1) banks. The last two columns display the mean difference of outcomes between treated and control banks and their corresponding standard errors. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Appendix Table C2. List of aggregated CNAE activities

- 1 Public administration, defense, and social security
- 2 Agriculture, livestock, forestry production, fishing, and aquaculture
- 3 Water supply, sewerage, waste management, and remediation activities
- 4 Accommodation and food services
- 5 Arts, culture, sports, and recreation
- 6 Administrative and support services
- 7 Financial and insurance activities
- 8 Real estate activities
- 9 Professional, scientific, and technical activities
- 10 Wholesale and retail trade; repair of motor vehicles and motorcycles
- 11 Construction
- 12 Education
- 13 Electricity, gas, steam, and air conditioning supply
- 14 Manufacturing industries
- 15 Extractive industries
- 16 Information and communication
- 17 International organizations and other extraterritorial institutions
- 18 Other service activities
- 19 Human health and social services
- 20 Domestic services
- 21 Transportation, storage, and courier activities

Notes: The list details the 21 sections in which the individual categories of CNAE-Subclasses in Brazil are organized at the most aggregated level.

	not exposed sectors (relation	ive to control danks		
	(1)	(2)	(3)	(4)
	Total Lendin	g Volume (logs)	Share Short	-Term Lending
	All firms	Small firms	All firms	Small firms
Exp _s * Post _m * TB _g	-0.034***	-0.017	0.006***	0.007***
	(0.010)	(0.011)	(0.001)	(0.002)
Observations	599,262	291,622	599,262	291,622
R-squared	0.742	0.797	0.428	0.405
Sector*Bank Group FE	Yes	Yes	Yes	Yes
Sector*UF*Size FE	Yes	Yes	Yes	Yes
UF*Size*Time FE	Yes	Yes	Yes	Yes
Sector*Time FE	Yes	Yes	Yes	Yes

Appendix Table C3. Impact of ICAAP regulation on credit outcomes of alternative group of treated banks to exposed vs not exposed sectors (relative to control banks)

Notes: Observations are at the bank group-5-digit sector-federative unit-borrower size-month level for all months from January 2017 to April 2018. The table reports the coefficients of equation 3, where $Post_m$ is an indicator variable equal to one from September 2017 onwards, and zero otherwise. Exp_s is an indicator variable equal to 1 for 5-digit sectors classified as with high environmental risk exposure, and 0 otherwise. TB_g is an indicator equal to one for treated banks (banks in groups S1 and S2) and zero otherwise. Estimates in columns 2 and 4 restrict the sample to borrowers classified as small. The dependent variables correspond to the log total lending volume and the share of short-term lending channeled by bank group *b* to borrower firms of size *f* in federative unit *UF* and sector *s* at month *m*. Constant terms not reported in the table. Standard errors are clustered at the sector*time level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

alternative definition of treatment)								
	(1)	(2)	(3)	(4)	(5)	(6)		
	CO2 Emissions	Employment	Number of	Firm Size	Employment Share	Share Micro		
Danal A Treatment de	finad as municipalitic	above the median	runis	ding volume to po	milation in 2012	1/11115		
Tunei A. Treatment de						0.000		
Treatment ₁ * Post _t	0.002	0.000	-0.001	0.002	-0.001	-0.002		
	[0.018]	[0.008]	[0.003]	[0.007]	[0.003]	[0.003]		
Observations	71,176	365,616	365,616	365,616	232,990	232,990		
R-squared	0.818	0.239	0.308	0.198	0.246	0.254		
Panel B. Treatment de	fined as municipalitie	es above the 75th per	centile ratio of S1 b	ank lending volun	ne to population in 2012			
Treatment _l * Post _t	0.022	0.005	0.000	0.003	-0.004*	-0.004**		
	[0.014]	[0.006]	[0.003]	[0.006]	[0.002]	[0.002]		
Observations	99,916	747,561	747,561	747,561	520,242	520,242		
R-squared	0.795	0.237	0.341	0.173	0.213	0.219		
Mun FE	Yes	Yes	Yes	Yes	Yes	Yes		
Year FE	Yes	Yes	Yes	Yes	Yes	Yes		
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes		

Appendix Table C4, Impact of regulation on real outcomes of firms with high socio-environmental risk (matched municipalities

Notes: Data covers the years 2012-2019. The sample is restricted to firms in matched municipalities that operate in sectors with high socioenvironmental risk. All specifications include fixed effects at the municipality, 5-digit sector and year levels. The table reports the difference-indifference impact estimates of the reform on the aggregate CO2 emissions (in logs) of firms; the number of workers (column 2); the number of firms (column 3); the average firm size (column 4); the share of workers employed in micro firms (column 5); and the share of firms classified as micro (column 6). Treatment₁ is equal to 1 for treated municipalities (above the median ratio of S1 bank lending volume to population in 2012) and 0 otherwise. Postt is an indicator variable that equals 1 from 2017 onwards. Constant terms not reported in the table. The residuals are clustered at the municipality level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.