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Climate Change Regulations

Bank Lending and Real Effects

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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.

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Climate Change Regulations: Bank Lending and Real Effects[1]

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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.[5,6] 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 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 policy makers 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.

The Brazilian setting helps shed light on the impact on bank lending from climate-related prudential measures for several reasons. First, in 2014, the National Monetary Council (CMN)[7]

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[5] 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.

[6] 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).

[7] The CMN is the institution in charge of formulating monetary and credit policies.

published a guidance directive for financial institutions implementing social and environmental responsibility policies.[8] In response to CMN directives, the Brazilian Federation of Banks (FEBRABAN) developed a taxonomy identifying economic activities with potentially large environmental impacts, and banks voluntary began to report the credit allocation to these sectors.[9] When the regulator formally included social and environmental risks in the *2017 ICAAP* regulation,[10] banks had a reasonable understanding of the type of firms and sectors that were exposed to such risks. Second, while all banks in Brazil are expected to assess their capital needs according to the risks they incur, only the largest institutions were required to perform the ICAAP exercise (e.g., for banks with size greater than 10% of Brazil's GDP). In other words, although smaller banks were not exempt from capital management and capital allocation that is consistent with their business risks, by explicitly using the ICAAP tool for systemic institutions, the regulator was signaling its intention to closely monitor larger banks. In turn, we are able to use the cross-sectional variation among banks to identify the effects from the policy.[11] Moreover, since the capital assessment policy addressed social and environmental risks, we can also use the within-bank variation in credit to firms in exposed and non-exposed sectors before and after the policy for identification. Third, even though the 2017 regulation did not explicitly refer to climate-related 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, when the taxonomy was updated in 2020 to deal with climate change risks, there was an extensive overlap between sectors first classified as having high environmental risk and sectors with climate change exposure (more details in Section 3). Therefore, we interpret our finding more broadly in the context of prudential measures that are aimed to address climate change risks.

We first combine monthly bank lending data at the five-digit sector level with the 2014 FEBRABAN taxonomy of environmentally exposed sectors to evaluate the incidence of the 2017 regulation. We find that the introduction of the new 2017 ICAAP led to a lending reallocation by large banks away from exposed sectors. The change in credit to exposed sectors by large banks

[8] Social and Environmental Responsibility Policy (PRSA). In this context, "social and environmental risk means the possibility of loss of the institution arising from social and environmental damage." More details in Section 2.
[9] FEBRABAN (2021).
[10] Circular 3846, September 2017, CMN.
[11] It is well-established in the finance literature that the threat of enhanced oversight and closer monitoring affects banks' behavior (Ivanov and Wang, 2019; Bonfim et al, 2022).

was also in the form of shorter loan maturity, as the ratio of short-term loans to such sectors increased substantially after the reform. In contrast, small banks, which were exempt from the ICAAP exercise, increased their total credit volume and loan maturity to firms in exposed sectors after the regulation. In fact, we find that at the aggregate level, the lending expansion by smaller banks to firms in exposed sectors makes up for the contraction of credit by larger banks.

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 × month fixed effects in all our specifications. By doing so, we compare the lending obtained by the same 5-digit sector in a given period between large and small banks. With this strategy, we measure the impact of the regulation by the relative difference in lending to a given sector between large and small 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 × 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 smaller banks compensate for the credit contraction by large banks to exposed sectors, 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 data set 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 large banks (treatment group). We compare firms in these municipalities to firms in municipalities with a smaller presence of large banks (control) and estimate the changes before and after the ICAAP 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 to only those 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 firms[12] within exposed sectors decline after the policy in municipalities with more incidence of large banks. Overall, the evidence suggests that the contraction in credit to environmentally exposed firms by large banks is largely offset by the increase in supply from small banks. The negative effects from the contraction in credit appears to concentrate in smaller firms, those that are less able to substitute borrowing across banks.

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 to exposed sectors, 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-

[12] Firms with less than 2.4 million reais of yearly revenue.

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.

We also add to a growing literature that studies how climate risks affect the financial sector.[13] 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 is 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.[14] Whether it is by giving preferential capital treatment to clean loans –the Green Supporting Factor[15]– or by requiring financial institutions to hold more capital for high-carbon assets, the Dirty Penalizing Factor (DPF).[16] 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.

[13] See Giglio, et al., (2021) for a review of this literature.
[14] See Monasterolo et al., (2022) for a comprehensive review of financial sector initiatives to support the low-carbon transmission.
[15] Oehmke & Opp, (2022) introduce a theoretical framework to evaluate this idea.
[16] 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.

The rest of the paper is organized as follows. Section 2 discusses the Brazilian institutional background. 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 of firms. In section 5, we discuss the main limitations of our analysis and potential extensions. Finally, 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 was 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.[17] Since 2015, banks have been using the taxonomy to track and report their lending to exposed sectors.

In February 2017, the CMN introduced a new risk management framework.[18] The directive required, for the first time, the explicit identification, monitoring and mitigation of socio-environmental 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 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). While the regulation does not explicitly restrict banks from lending to exposed sectors, to the extent that capital is costly, it might discourage the supply of credit to firms with high social and environmental risks. Moreover, even if a bank is not capital constrained, expanding its loan portfolio to exposed firms might enhace the regulatory oversight,

[17] 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).
[18] CMN Resolution 4,557, February 23, 2017.

through increased supervisory scrutiny. For example, 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 even in the requirement of additional capital allocations on top of the bank's self-imposed capital (Bonfim et al, 2022; Ivanov and Wang, 2019).[19]

Following principles of proportionality, the implementation of the new ICAAP was mandatory for larger banks –with assets greater than 10% of GDP (S1 group per BCB rule). A simplified ICAAP would apply to banks with assets between 1% and 10% of GDP (S2) and the regulation excluded smaller banks (groups S3 and S4).[20]

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 (e.g., the ICAAP was adjusted to reflect these changes in 2021, see Appendix Figure 1). 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.

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 data set 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),

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[19] 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)."

[20] While the February Resolution 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.

funding source (earmarked vs. non-earmarked credit), tenor, and lender size. One limitation with this data set 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 restrict the data to outstanding volumes funded in the non-earmarked credit market, as government-sponsored loans tend to be subject to especial rules and are typically restricted to specific 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 socio-environmental risk. 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 data set.[21] 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.

The summary statistics for the pre-regulation period of our main outcomes of interest for all bank groups, as well as for the groups of small (i.e., S2, S3 and S4 banks) and large banks (i.e., S1 banks) are displayed in Table 1.[22] Our first measure is the share of corporate lending that each bank group channels to exposed sectors every month. As shown in the table, exposed sectors obtain on average 0.13 percent of the lending of banks prior to the reform (column 2),[23] with this share being statistically identical between small and large bank groups (columns 4 and 6). In Panel A of Figure 1, we illustrate graphically the monthly share of total lending channeled by bank size to the 332 exposed sectors. As shown in the figure, this share followed a similar path for both bank groups prior to the regulation, with large and small banks channeling approximately 46 percent and 43 percent of their corporate lending to firms in these sectors. In the months following the regulation, the lending share to exposed sectors declines for both bank groups, with a sharper decline for large banks. The next outcome is the bank lending volume issued to exposed sectors,

[21] For example, extraction sectors, such as coal, oil, and natural gas were classified as exposed to socio-environmental risk and to climate-change risks.
[22] The group of large banks only considers S1 banks as the 2017 regulation targeted banks with size greater than 10% of Brazil's GDP (i.e., S1 banks). While S2 banks tend to be medium to large-sized banks, they are included in the group of "small" banks for the analysis. Given that S2 banks were subjected to a simplified ICAAP, we confirm that our results hold when dropping these banks from the sample.
[23] The median exposed sector obtains 0.03 percent of the lending of banks.

reported in logs of thousand reais. This variable indicates that the average outstanding lending to these sectors by banks in the S1 group is 3.7 times larger than the combined lending channeled to these sectors by banks in the S2, S3 and S4 categories. A similar pattern is observed in the lending to sectors with low socio-environmental risk, where banks in the S1 group extend 3.9 times more credit than banks in the remaining groups. Figure 2 illustrates graphically the monthly lending volumes (in logs) by large and small banks to firms in exposed and non-exposed sectors.

To examine changes in the maturity composition of credit, we next display the share of lending to sectors with high socio-environmental risk that is short term (i.e., with a maturity of a year or less). In the months prior to the regulation, 74 percent of the credit issued to exposed sectors was in the form of short-term lending, with large banks offering loans of lengthier maturity. In Panel B of Figure 1, we aggregate the lending of the 332 exposed sectors for each bank group and month, and display the share of short-term credit by large and small banks. While prior to the regulation, small and large banks followed similar trends in their maturity structure to exposed firms, the maturity composition of loans by large banks begins to shorten following the introduction of the new capital assessment process. The adjustments in lending maturity to exposed sectors by large banks after the regulation are also shown in Figure 3, where we compare the share of short-term lending to exposed and non-exposed sectors for large (Panel A) and small (Panel B) banks. In Appendix Figures 2 to 4, we show that the credit outcomes over time by small and large banks remain similar when we drop from the group of small banks those banks classified as S2, which due to the principles of proportionality were only subject to a simplified ICAAP.

3.2 Methodology

To evaluate the impact of the ICAAP on bank lending, we follow a difference-in-difference methodology where we compare the lending of large vis-à-vis small banks before and after the policy. The baseline specification is given by equation (1):

$$y_{g,s,m} = \alpha_0 + \alpha_1 Post_m + \alpha_2 LargeBank_g + \alpha_3 LargeBank_g * Post_m + \gamma_g + \gamma_s + \gamma_m + \varepsilon_{g,s,m} \quad (1)$$

where $y_{g,s,m}$ is the outcome variable of bank group g to sector s at month m. Our first two outcomes are the lending volume (in logs) and the lending share (in percentage) of bank group g to sector s, where we restrict the sample to exposed sectors. The third outcome of interest is the share of short-term lending of bank group g to sector s. $Post_m$ is an indicator variable that equals one from September 2017 onwards and zero otherwise. The indicator variable $LargeBank_g$ is equal to one for banks classified as S1 and zero otherwise. The coefficient α_3 represents the effect of the ICAAP regulation on sector *s*. We include a series of fixed effects at the bank group (γ_g), sector (γ_s) and month γ_m level to control for time unvarying characteristics of bank groups and sectors, as well as for time varying factors (e.g., the business cycle) affecting bank lending patterns. The last term in equation (1), $\varepsilon_{g,s,m}$, is an error term clustered at the date level.

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 banks regardless of their size. While this assumption cannot be tested, we use equation (2) to test if the outcomes of large and small bank groups followed a parallel trend in the pre-regulation period.

$$y_{g,s,m} = \beta_0 + \beta_1 Trend_m + \beta_2 LargeBank_g + \beta_3 LargeBank_g * Trend_m + \varepsilon_{g,s,m} \qquad (2)$$

In equation (2), 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* of large and small bank groups followed a parallel trend in the pre-regulation months. The results of this test are displayed in Table 2. We find no statistically significant differences in the trends of our outcomes across large and small banks in the period prior to the regulation, lending credibility to our identification strategy.

3.3 Results

Table 3 displays the results of Equation (1) on our outcomes of interest. Estimates in the first two columns suggest that the lending volume to exposed sectors from large banks decreases after the regulation, between 13.7 and 14.4 percent. This result is robust to controlling for time-unvarying characteristics in the credit demand (column 1) as well as time-varying changes in the demand for credit (column 2).[24] We should caution about the interpretation of these magnitudes. In this empirical exercise, the decline from S1 banks' lending is estimated relative to changes in

[24] Since S2 banks were subject to a simplified ICAAP rule, in an alternative exercise we exclude them from our sample and find similar results (results available upon request).

the credit supply from other banks. In particular, after September 2017, small banks' lending volume to exposed sectors increased by 13 percent from their pre-policy trend, while large banks decreased their total lending to these sectors by 0.12 percent in the same period. The policy seems to simultaneously deter large banks from lending to exposed sectors, while allowing smaller banks not subject to the capital rules to aggressively expand their portfolio in this market.[25] Overall, small banks seem to attenuate the supply shock at the sector level. Due to data limitations, we are not able to determine whether there is credit substitution at the firm level. For example, if firms in exposed sectors substitute credit of large banks with that of small banks, or if instead, the additional lending by non-S1 banks is channeled to new firms.

The next outcome is the share of lending allocated to exposed sectors (columns 3 and 4 of Table 3). Our evidence indicates that after the capital adequacy policy, large banks reallocate their lending portfolios towards non-exposed sectors. More specifically, compared to small banks, large banks reduce their lending shares to exposed sectors by 0.3 percent after the regulation, which implies a post-regulation contraction in the fraction of credit of about 10 percent for the median exposed sector.

Finally, the last two columns display our evidence on the impact of the regulation on the maturity composition of loans to environmentally exposed sectors. We find that after the reform, large banks issue loans of shorter maturity to high-risk sectors. Relative to small banks, the share of short-term lending by large banks to these sectors increases in 2.8 percent after the regulation.

As a robustness check, we compare the impact of the regulation on the share of short-term lending by large and small banks to sectors with low and high socio-environmental risk. Table 4 summarizes our findings. We find that after the regulation, high-risk sectors obtain loans of lengthier maturity from small banks, as indicated by the negative coefficient of the interaction Exposed*Post. In contrast, the coefficient of the triple interaction indicates that large banks reduce substantially the maturity of such loans. It appears that small banks are not only compensating for the credit slowdown from large banks, but they are also taking on longer maturity loans. In line

[25] Overall, our results find that while prior to the regulation, the lending to exposed sectors by small and large banks was statistically similar, their lending begins diverging afterwards, with small banks channeling more credit to exposed sectors. Consistent with our results, a recent study by the BCB finds that by 2021, smaller banks have gained market share as a whole and have considerably increased their exposure to climate-related risks (Banco Central do Brasil, 2022).

with our previous findings, it seems that by being unconstrained by the policy, these lenders can take on more risk by expanding their portfolio and maturity of exposed sectors.

4. Real effects

So far, our results suggest that following the ICAAP regulation, sectors with high socio-environmental risk experience a contraction in the supply of credit by large banks, in the form of reduced lending volumes and shorter loan maturity. In this section, we present the data, methodology and results of an exercise that evaluates the impact of the supply of credit shock on economic activity.

4.1 Data

Our first data set 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 data set corresponds to the census of the Brazilian formal labor market "Relação Anual de Informações Sociais" (RAIS). This data set 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 of the 5,565 municipalities in the country from the Brazilian Institute of Geography and Statistics. We aggregate this data set 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. The first one corresponds to the 2014 FEBRABAN taxonomy described in Section 3. The second one consists of the yearly number of commercial bank branches across municipalities. Our final data set 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 S1 bank lending before and after the policy. While we do not observe the outstanding lending volumes of banks across municipalities, we use the presence of S1 bank branches to proxy for the dependence of a municipality on the lending of S1 banks. More concretely, for each municipality, we calculate the ratio of S1 bank branches to its population size in 2016 (one year prior to the regulation). 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 are more dependent on the lending of these banks, and as such, are likely more affected by the introduction of the regulation. The estimating equation is:

$$y_{s,m,y} = \alpha_s + \alpha_m + \alpha_y + \gamma Treatment_m * Post_y + \varepsilon_{s,m,y} \quad (3)$$

where $y_{s,m,y}$ is an outcome of interest for sector *s* of municipality *m* in year *y*. The terms α_s, α_m and α_y correspond to fixed effects at the sector, municipality and year level. ε_{smy} is an error term, clustered at the municipality level. The coefficient γ represents the treatment effect of the regulation on outcome $y_{s,m,y}$. The indicator variable $Treatment_m$ equals one for municipalities in the treated group and zero otherwise. As a first approach, we classify treated municipalities as the 2,783 municipalities with 2016 ratios of S1 bank branches to population above the median, and control municipalities as the 2,782 municipalities below the median S1 bank branches to population ratio in 2016.

Panel A of Table 5 compares the mean outcomes prior to the regulation between these two groups. Overall, sectors in municipalities with a greater ratio of large banks have statistically lower CO_2 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.

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.[26] The first five independent variables of the probit regression capture the total number of workers employed in the sector in each municipality during the pre-regulation years (from 2012 to 2016, measured in logs). 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 5 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 similar. To test the validity of our empirical approach more formally, we run a regression outlined in equation 2 to 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:

$$y_{s,m,y} = \alpha_s + \alpha_m + \alpha_y + \gamma Treatment_m * Trend_y + \varepsilon_{s,m,y} \qquad (4)$$

where $Trend_y$ is a linear time trend and $Treatment_m$ 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. $\varepsilon_{s,m,y}$ is an error term, clustered at the municipality level. If the coefficient γ is not statistically different from zero, we can conclude that outcome $y_{s,m,y}$ followed a parallel trend for treatment and control group municipalities in the pre-regulation years. We summarize the results of this test in Table 6. Overall, we find no statistically significant differences in the trends of our six outcomes

[26] The average sector in the census operates in 638 municipalities, sectors in the 10th percentile of the distribution operate in 77 municipalities.

of interest between the matched treated and control municipalities in the period prior to the regulation.

4.3 Results

Table 7 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.[27] 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 substituted the slowdown in lending by large banks with credit from smaller banks.

We use alternative cutoffs for our definition of the 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 small banks. Appendix Table 2 shows the pre-regulation mean outcomes between treated and control municipalities using our alternative definition of treatment. Panel A presents the statistics for the full sample of municipalities. Panel B displays the statistics for the refined sample using propensity score matching. As in the previous exercise, sectors in the refined sample of treated and control matched municipalities are much similar across all outcomes prior to the regulation. We again use equation 2 to test if the matched treated and control municipalities follow parallel trends in our outcomes of interest during the pre-regulation years.[28]

Using this alternative definition, we run equation 3 on our six outcomes of interest. The results of this exercise are summarized in Appendix Table 4. 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

[27] As Appendix Table 1 shows, these results remain robust to exhaustively controlling for time-varying changes in the credit demand of a 5-digit sector.

[28] As we show in Appendix Table 3, we find no statistically significant differences in the trends of our six outcomes of interest between the alternative matched treated and control municipalities prior to the regulation.

the reform in treated municipalities. Similarly, the share of firms that are micro also drops by 0.5 percent. In Figure 5, we display graphical evidence of the 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 considered 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 banks dominate the lending activity, the smallest firms seem to be less able to smooth the credit shock. These findings are robust to the inclusion of fixed effects at the sector*year level, as shown in Appendix Table 5.

5. Limitations, alternative channels, and future work

We document a credit contraction in lending to exposed sectors from large banks. 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 pay a higher interest rate to protect their earning potential (Imbierowicz, et al., 2018). Alternatively, banks might shield firms with a 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 from 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 are declining, precisely in exposed sectors and in municipalities where larger 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 of 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 relationships with smaller banks obtaining more credit at longer maturity, or are these banks attracting new corporate clients following the credit decline from large banks? The current findings suggest that small banks are willing to expand their credit and maturity to sectors with high environmental risks, precisely for the type of exposure that the regulator is requesting additional capital for stability reasons. How precisely the substitution is 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 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 trade-offs from using capital requirements to promote bank resilience to climate-change exposure.

We provide the 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 and the maturity of loans to exposed sectors. The growth in lending from small banks compensates 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 of safeguarding 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 large banks have the strongest presence (making up the most branches), 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.

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Table 1. Pre-reform summary statistics of banks

	(1)	(2)	(3)	(4)	(5)	(6)
	All Bank Groups		Large Bank Groups		Small Bank Group	
	N	Mean/SE	N	Mean/SE	N	Mean/SE
Share of lending to sectors with high socio-environmental risk (%)	5,291	0.134	2,656	0.138	2,635	0.13
		(0.004)		(0.009)		(0.006)
Lending volume to sectors with high socio-environmental risk (logs)	5,284	16.725	2,656	18.713	2,628	17.403
		(0.027)		(0.039)		(0.044)***
Lending volume to sectors with low socio-environmental risk (logs)	5,047	16.677	2,571	18.66	2,476	17.304
		(0.030)		(0.051)		(0.051)***
Share of short-term lending to sectors with high socio-environmental risk	5,284	0.740	2,656	0.687	2,628	0.752
		(0.002)		(0.004)		(0.004)***
Share of short-term lending to sectors with low socio-environmental risk	5,047	0.687	2,571	0.655	2,476	0.693
		(0.002)		(0.003)		(0.003)***

Notes: Observations are at the bank group-sector-month level, where banks are grouped into 4 categories depending on their size (S1, S2, S3 and S4), and sectors are disaggregated at the 5-digit level. The first two columns display summary statistics of all banks. The next two columns display the summary statistics of small banks (banks classified by regulators as S2, S3 and S4). The last two columns display summary statistics of large banks (banks classified by regulators as S1). The definition of sectors with high socio-environmental risk follows the 2015 Febraban taxonomy. Data covers all months from January 2017 to August 2017. ***, **, and * indicate that the mean difference between small and large banks is different at the 1, 5, and 10 percent significance level.

Table 2. Pre-reform trends in bank lending to sectors with high socio-environmental risk

	(1)	(2)	(3)	(4)	(5)	(6)
	Lending Volume		Lending Share		Share of Short-Term Lending	
$Trend_m$	-0.003		-0.000		-0.000	
	(0.547)		(0.169)		(0.517)	
$LargeBank_g$	2.745***	2.745***	0.004***	0.004***	-0.063***	-0.063***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
$LargeBank_g$ * $Trend_m$	-0.011	-0.010	0.000	0.000	-0.002***	-0.002***
	(0.171)	(0.174)	(0.643)	(0.644)	(0.000)	(0.000)
Constant	16.029***	16.015***	0.134***	0.133***	0.760***	0.759***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	10,085	10,085	10,110	10,110	10,085	10,085
R-squared	0.196	0.196	0.000	0.000	0.023	0.023
Date FE	No	Yes	No	Yes	No	Yes

Notes: Observations are at the bank group-sector-month level, where banks are grouped into 4 categories depending on their size (S1, S2, S3 and S4), and sectors are disaggregated at the 5-digit level. The table reports the coefficients of equation 1, where $Trend_m$ is a linear time trend for the pre-reform months (January 2017-August 2017). $LargeBank_g$ is equal to 1 for banks classified as S1 and 0 otherwise. For each bank group *g* and month *m*, y_{gm} corresponds to the lending volumes (in logs) to firms in high socio-environmental risk sectors; the share of total lending channeled to high socio-environmental risk sectors; and the share of lending to high socio-environmental sectors that has a maturity of less than a year. $\varepsilon_{g,s,m}$ is an error term clustered at the month level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Table 3. Impact of regulation on bank lending to sectors with high socio-environmental risk

	(1)	(2)	(3)	(4)	(5)	(6)
	Lending Volume		Lending Share		Share of Short-Term Lending	
$LargeBank_g$ * $Post_m$	-0.144***	-0.137***	-0.003***	-0.003***	0.028***	0.028***
	(0.000)	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)
Constant	16.828***	16.836***	0.131***	0.131***	0.724***	0.724***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	45,568	45,456	45,625	45,521	45,568	45,456
R-squared	0.910	0.940	0.914	0.946	0.647	0.751
Date FE	Yes	-	Yes	-	Yes	-
Bank Group*Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector*Date FE	No	Yes	No	Yes	No	Yes

Notes: Observations are at the bank group-sector-month level, where banks are grouped into 4 categories depending on their size (S1, S2, S3 and S4) and sectors are disaggregated at the 5-digit level. The sample period covers all months from January 2017 to December 2019. $Post_m$ is an indicator variable that equals one from September 2017 onwards and zero otherwise. $LargeBank_g$ is an indicator variable that equals one for bank group S1 and zero otherwise. The table reports the difference-in-difference impact estimates of the reform on the lending volumes (in logs) to firms in high socio-environmental risk sectors (columns 1 and 2); the share of total lending channeled to high socio-environmental risk sectors (columns 3 and 4); and the share of lending to high socio-environmental sectors with a maturity of less than a year (columns 5 and 6). Residuals are clustered at the month level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Table 4. Impact of regulation on the share of short-term lending to all sectors by small and large banks

	(1)	(2)	(3)	(4)
$LargeBank_g$ * $Post_m$	0.005	0.005	0.003	0.006
	(0.178)	(0.179)	(0.482)	(0.151)
$Exposed_s$*$Post_m$	-0.012***	-0.012***	-0.012***	
	(0.000)	(0.000)	(0.000)	
$LargeBank_g$ * $Exposed_s$	-0.018***	-0.019***		
	(0.000)	(0.000)		
$Exposed_s$*$Post_m$*$LargeBank_g$	0.025***	0.025***	0.026***	0.022***
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.724***	0.709***	0.707***	0.701***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	89,227	89,227	89,207	88,685
R-squared	0.364	0.364	0.669	0.768
Date FE	Yes	Yes	Yes	-
Sector FE	Yes	Yes	-	-
Bank Group FE	No	Yes	-	-
Bank Group*Sector FE	No	No	Yes	Yes
Date*Sector FE	No	No	No	Yes

Notes: Observations are at the bank group-sector-month level, where banks are grouped into 4 categories depending on their size (S1, S2, S3 and S4) and sectors are disaggregated at the 5-digit level. The sample period covers all months from January 2017 to December 2019. $Post_m$ is an indicator variable that equals one from September 2017 onwards and zero otherwise. $LargeBank_g$ is an indicator variable that equals one for bank group S1 and zero otherwise. $Exposed_s$ is an indicator that equals one for sectors classified as with high socio-environmental risk and zero otherwise. The table reports the difference-in-difference impact estimates of the reform on the lending volumes (in logs) to firms in high socio-environmental risk sectors (columns 1 and 2); the share of total lending channeled to high socio-environmental risk sectors (columns 3 and 4); and the share of lending to high socio-environmental sectors with a maturity of less than a year (columns 5 and 6). Residuals are clustered at the month level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Table 5. Pre-reform summary statistics for firms with high socio-environmental risk in treated and control

	Firms in treated		Firms in control municipalities	
	N	Mean/SE	N	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)***

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

Table 6. Pre-reform trends in 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
$Treatment_m$ * $Trend_y$	-0.000	-0.000	-0.001	0.002	0.001	0.000
	[0.004]	[0.002]	[0.001]	[0.002]	[0.001]	[0.001]
Constant	5.573***	0.878**	0.476***	0.758**	0.762***	0.786***
	[0.653]	[0.369]	[0.132]	[0.341]	[0.192]	[0.176]
Observations	74,650	463,628	463,628	463,628	304,806	304,806
R-squared	0.799	0.253	0.317	0.197	0.239	0.235
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes

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 3, where α corresponds to a constant term; $Trend_y$ 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 large bank 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). ε_{my} is an error term clustered at the municipality level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Table 7. 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
$Treatment_m$ * $Post_y$	-0.010	0.001	-0.001	0.002	0.001	-0.001
	[0.015]	[0.006]	[0.003]	[0.005]	[0.002]	[0.002]
Constant	4.014***	0.556**	0.296***	0.492**	0.668***	0.683***
	[0.528]	[0.258]	[0.100]	[0.229]	[0.093]	[0.085]
Observations	119,437	741,806	741,806	741,806	490,013	490,013
R-squared	0.794	0.242	0.310	0.185	0.230	0.227
Municipality 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 socio-environmental risk. All specifications include fixed effects at the municipality, 5-digit sector and year levels. The table reports the difference-in-difference impact estimates of the reform on the aggregate CO_2 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). $Treatment_m$ is equal to 1 for treated municipalities (above the median ratio of large bank branches to population in 2012) and 0 otherwise. $Post_y$ is an indicator variable that equals 1 from 2017 onwards. The residuals are clustered at the municipality level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Appendix Table 1. Impact of regulation on real outcomes of firms with high socio-environmental risk (matched municipalities, including fixed effect at the sector*year level)

	(1)	(2)	(3)	(4)	(5)	(6)
	CO2 emissions	Employment	Number of firms	Firm Size	Employment Share Micro	Share Micro Firms
$Treatment_m$ * $Post_y$	-0.010	0.001	-0.001	0.002	0.000	-0.001
	[0.014]	[0.006]	[0.003]	[0.005]	[0.002]	[0.002]
Constant	3.568***	0.552**	0.311***	0.494**	0.728***	0.750***
	[0.497]	[0.242]	[0.096]	[0.217]	[0.090]	[0.082]
Observations	119,429	741,806	741,806	741,806	489,966	489,966
R-squared	0.797	0.246	0.313	0.190	0.233	0.230
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector*Year 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 socio-environmental risk. All specifications include fixed effects at the municipality level, as well as at the 5-digit sector*year level. The table reports the difference-in-difference impact estimates of the reform on the aggregate CO_2 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). $Treatment_m$ is equal to 1 for treated municipalities (above the median ratio of large bank branches to population in 2012) and 0 otherwise. $Post_y$ is an indicator variable that equals 1 from 2017 onwards. The residuals are clustered at the municipality level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Appendix Table 2. Pre-reform summary statistics for firms with high socio-environmental risk in treated and control municipalities (alternative treatment definition)

	Firms in treated municipalities		Firms in control municipalities	
	N	Mean/SE	N	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	1.45
		(0.002)		(0.003)***
Number of firms (logs)	746875	0.83	311742	0.66
		(0.001)		(0.001)***
Firm size (logs)	746875	1.41	311742	1.16
		(0.002)		(0.002)***
Share of workers in micro firms	528801	0.66	196012	0.71
		(0.001)		(0.001)***
Share of micro firms	528801	0.74	196012	0.77
		(0.001)		(0.001)***
Panel B. Matched municipalities				
CO_2 emissions (logs)	43564	6.91	43674	6.90
		0.017		(0.017)
Number of workers (logs)	278080	1.73	278080	1.78
		(0.003)		(0.003)***
Number of firms (logs)	278080	0.81	278080	0.81
		(0.002)		(0.001)
Firm size (logs)	278080	1.31	278080	1.35
		(0.002)		(0.002)***
Share of workers in micro firms	195015	0.70	194020	0.67
		(0.001)		(0.001)***

Share of micro firms	195015	0.77	194020	0.75
		(0.001)		(0.001)***

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 75th percentile ratio of large bank branches to population in 2012. The last two columns display summary statistics of firms in control municipalities (municipalities below the 75th percentile 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.

Appendix Table 3. Pre-reform trends in real outcomes of firms with high socio-environmental risk (matched municipalities using alternative treatment definition)

	(1) CO2 emissions	(2) Employment	(3) Number of firms	(4) Firm Size	(5) Employment Share Micro	(6) Share Micro Firms
$Treatment_m$ * $Trend_y$	0.001	0.001	-0.001	0.003*	0.001	-0.000
	[0.004]	[0.002]	[0.001]	[0.002]	[0.001]	[0.001]
Constant	6.079***	1.750***	0.672***	1.582***	0.294**	0.427***
	[0.705]	[0.344]	[0.146]	[0.300]	[0.126]	[0.119]
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

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 3, 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 large bank 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). ε_{my} is an error term clustered at the municipality level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Appendix Table 4. Impact of regulation on real outcomes of firms with high socio-environmental risk (matched municipalities using alternative treatment definition)

	(1)	(2)	(3)	(4)	(5)	(6)
	CO2 emissions	Employment	Number of firms	Firm Size	Employment Share Micro	Share Micro Firms
$Treatment_m$ * $Post_y$	0.015	0.002	-0.004	0.008	-0.004**	-0.005***
	[0.011]	[0.007]	[0.003]	[0.005]	[0.002]	[0.002]
Constant	4.073***	0.723***	0.368***	0.651***	0.641***	0.684***
	[0.463]	[0.259]	[0.108]	[0.213]	[0.074]	[0.068]
Observations	139,575	889,833	889,833	889,833	622,690	622,690
R-squared	0.800	0.271	0.352	0.203	0.234	0.228
Municipality 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 socio-environmental risk. All specifications include fixed effects at the municipality, 5-digit sector and year levels. The table reports the difference-in-difference 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). $Treatment_m$ is equal to 1 for treated municipalities (above the median ratio of large bank branches to population in 2012) and 0 otherwise. $Post_y$ is an indicator variable that equals 1 from 2017 onwards. The residuals are clustered at the municipality level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

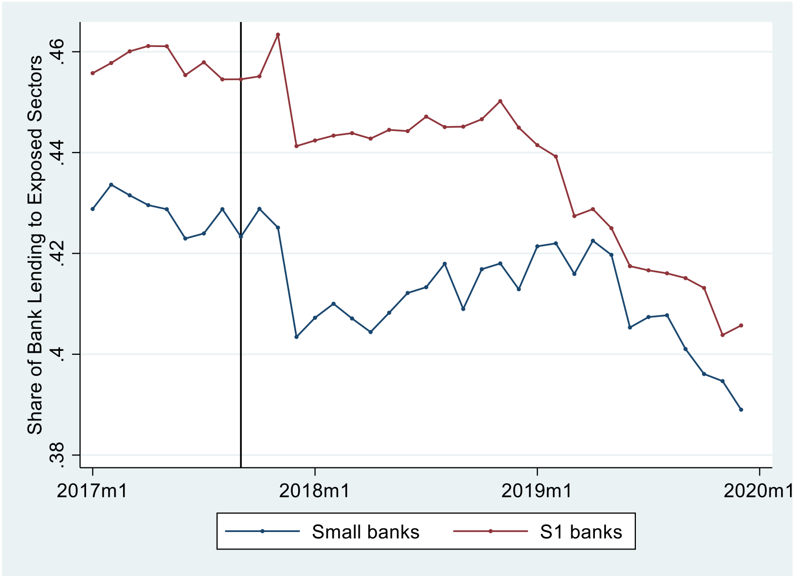
Appendix Table 5. Impact of regulation on real outcomes of firms with high socio-environmental risk (matched municipalities, including fixed effect at the sector*year level and using alternative treatment definition)

	(1)	(2)	(3)	(4)	(5)	(6)
	CO2 emissions	Employment	Number of firms	Firm Size	Employment Share Micro	Share Micro Firms
$Treatment_m$ * $Post_y$	0.014	0.002	-0.004	0.008	-0.004**	-0.005***
	[0.011]	[0.006]	[0.003]	[0.005]	[0.002]	[0.002]
Constant	4.082***	0.743***	0.429***	0.660***	0.706***	0.753***
	[0.446]	[0.260]	[0.110]	[0.213]	[0.073]	[0.066]
Observations	139,567	889,833	889,833	889,833	622,671	622,671
R-squared	0.802	0.275	0.355	0.207	0.237	0.231
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector*Year FE	Yes	Yes	Yes	Yes	Yes	Yes

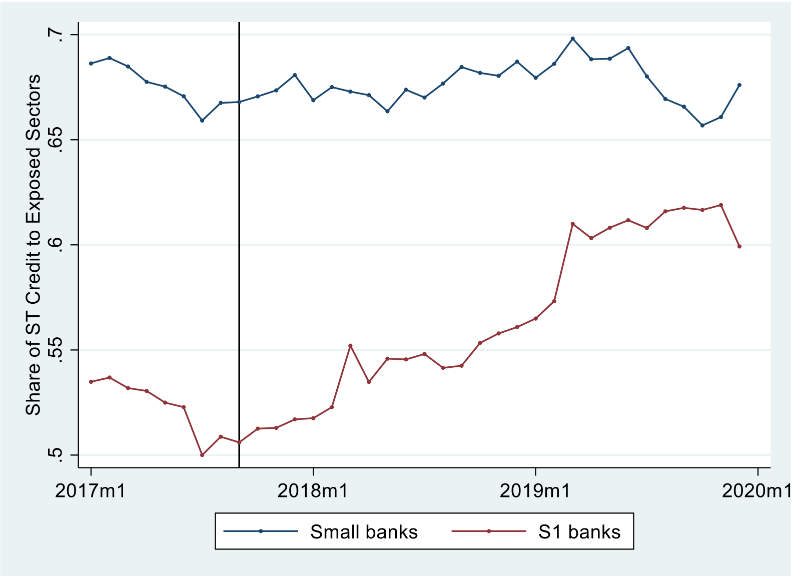
Notes: Data covers the years 2012-2019. The sample is restricted to firms in matched municipalities that operate in sectors with high socio-environmental risk. All specifications include fixed effects at the municipality level, as well as at the 5-digit sector*year level. The table reports the difference-in-difference 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). $Treatment_m$ is equal to 1 for treated municipalities (above the median ratio of large bank branches to population in 2012) and 0 otherwise. $Post_y$ is an indicator variable that equals 1 from 2017 onwards. The residuals are clustered at the municipality level. ***, **, and * indicate significance levels at the 1, 5, and 10 percent.

Figure 1. Lending outcomes of small and large bank groups

Panel A. Share of lending to exposed sectors by small and large banks



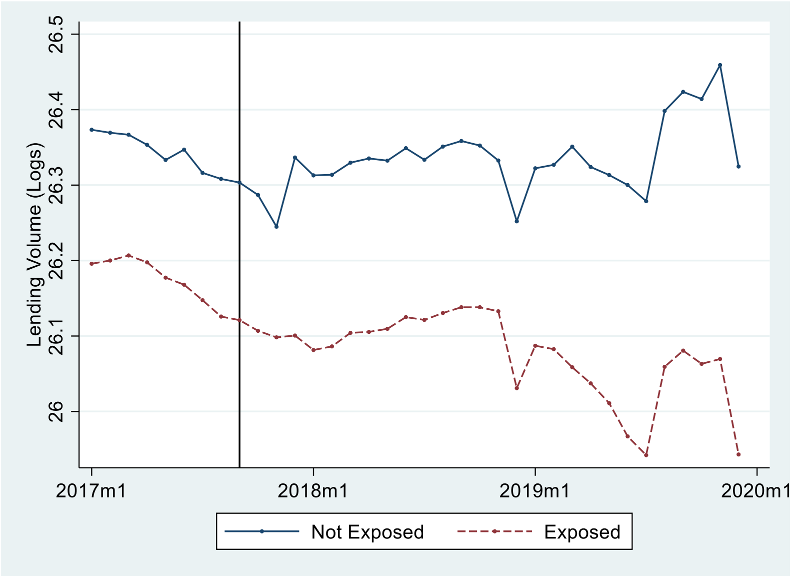
Panel B. Share of short-term lending to exposed sectors by small and large banks



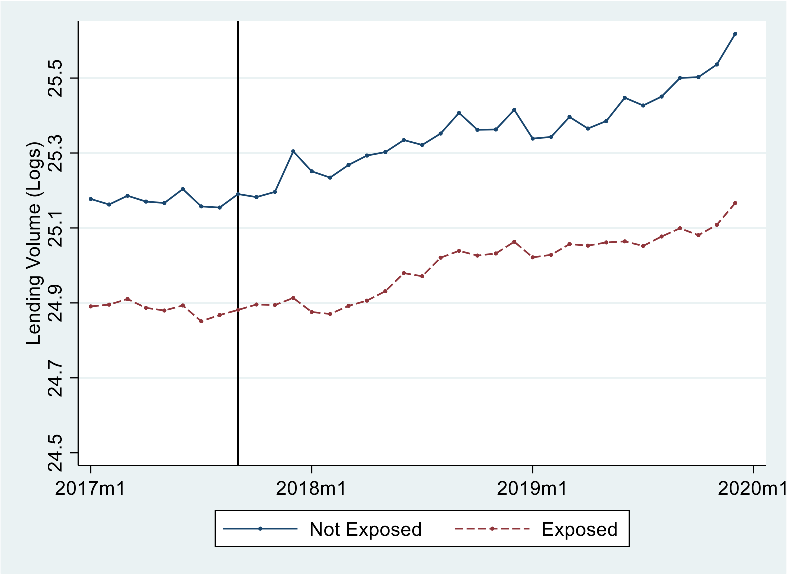
Notes: Panel A displays the monthly aggregate share of corporate lending of small and large banks channeled to the 332 5-digit sectors classified as exposed. Panel B displays the share of lending to exposed sectors by small and large banks that has maturity of one year or less.

Figure 2. Total lending volume of small and large bank groups

Panel A. Lending volume of large banks to exposed and not exposed sectors



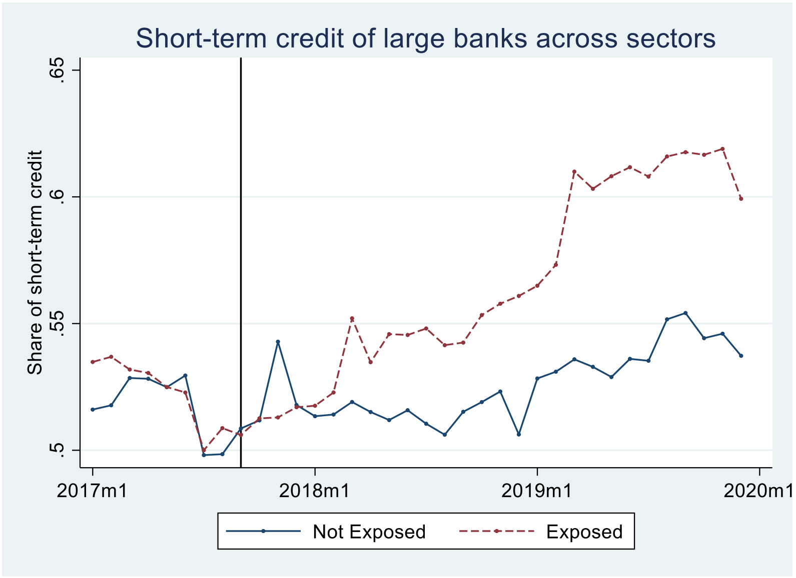
Panel B. Lending volume of small banks to exposed and not exposed sectors



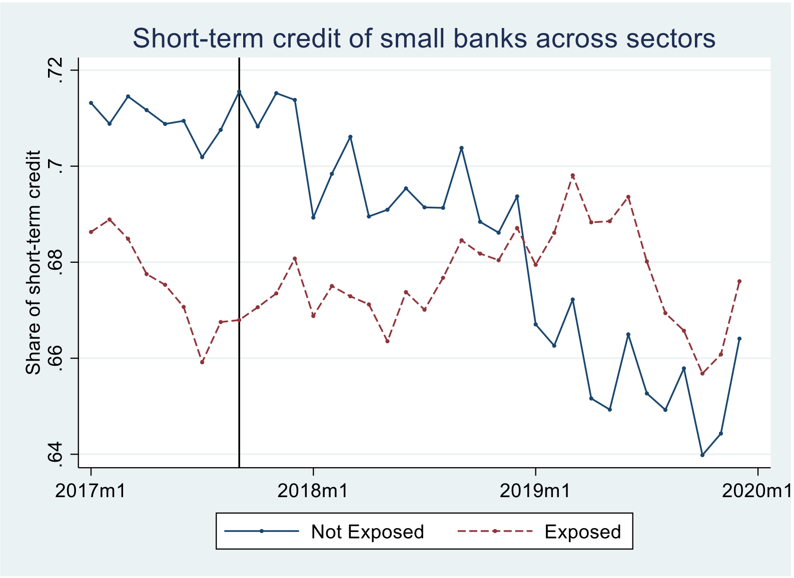
Notes: Panel A displays the monthly aggregate corporate lending volume (in logs) of large banks channeled to sectors classified as exposed and not exposed. Panel B displays the monthly aggregate corporate lending volume (in logs) of small banks channeled to sectors classified as exposed and not exposed.

Figure 3. Share of short-term credit to sectors with low and high socio-environmental risk

Panel A. Large Banks

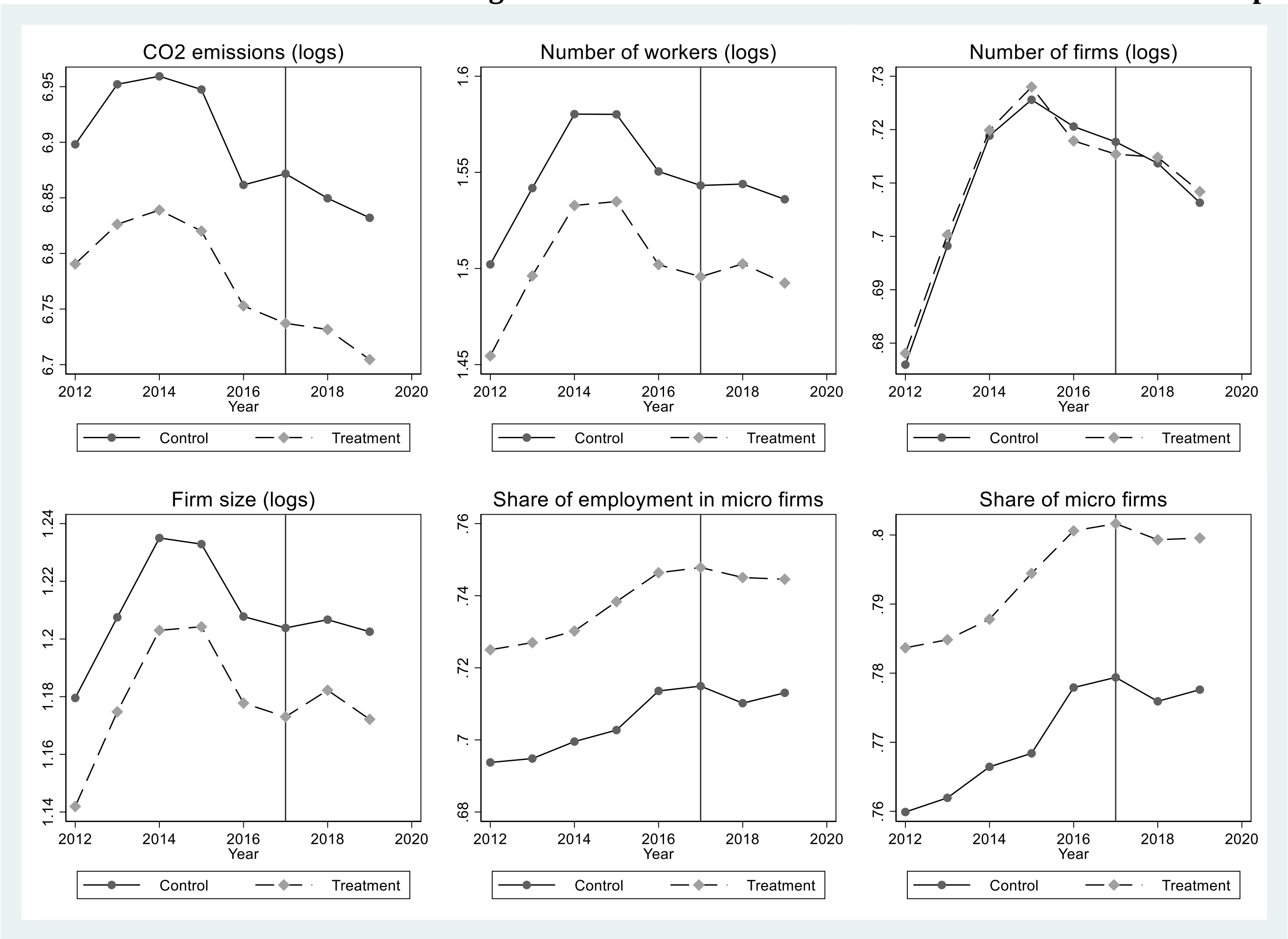


Panel B. Small Banks



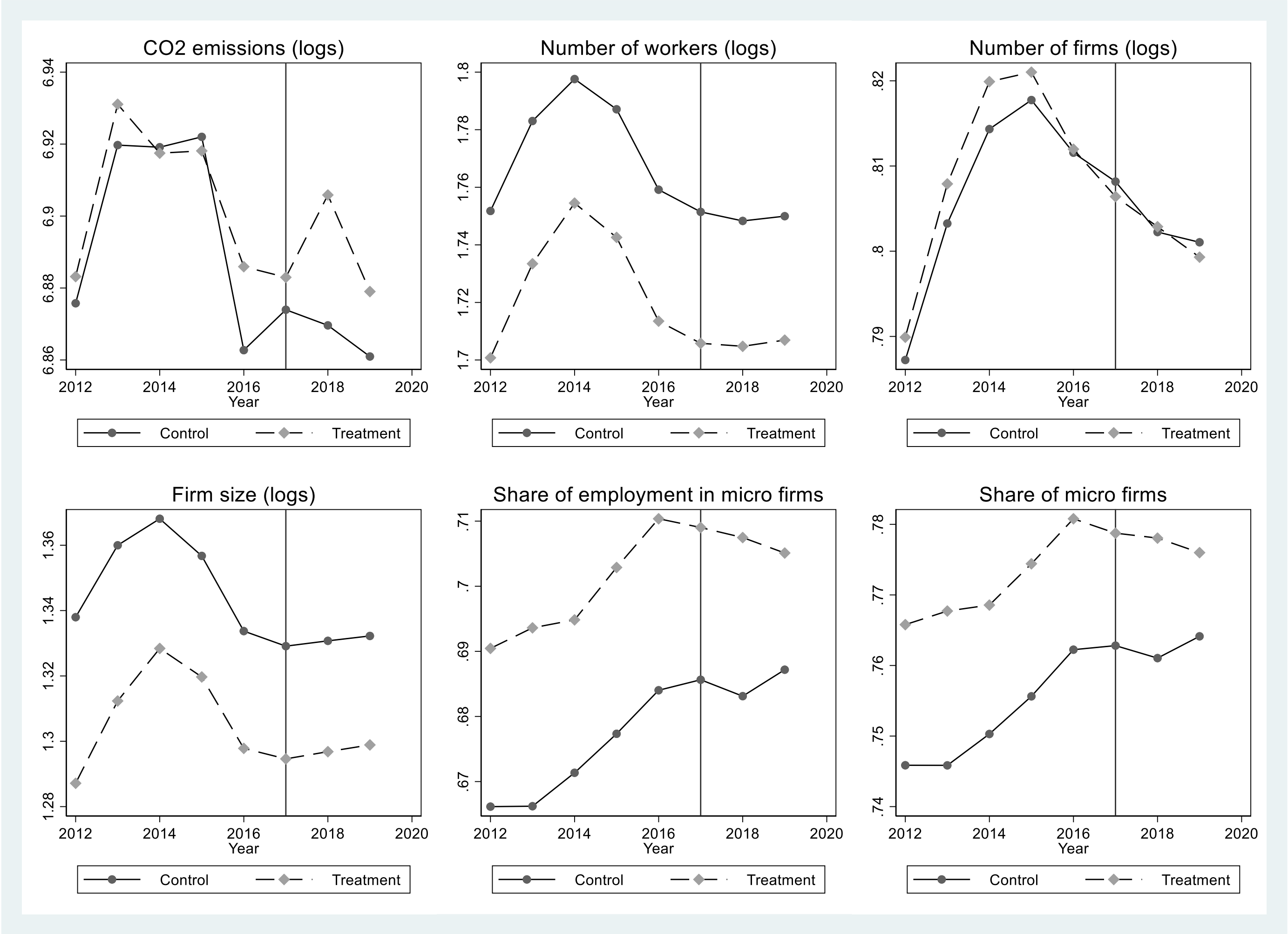
Notes: The figure displays the monthly share of lending to exposed and non-exposed sectors by large (Panel A) and small (Panel B) banks that has maturity of one year or less.

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 S1 banks to population above the median. The vertical line shows the year of the introduction of the ICAAP.

Figure 5. Real outcomes of sectors with high socio-environmental risks in treated and control municipalities (alternative treatment definition)



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 S1 banks to population above the 75th percentile. The vertical line shows the year of the introduction of the ICAAP.

Appendix Figure 1. Timetable of Green Financial Sector Initiatives

2014

Social and Environmental Responsibility Policy (PRSA)

- **Resolution 4327, April:** CMN guidance for the establishment of a PRSA by supervised entities based on relevance and proportionality.
- **SARB Directive N0. 14, August**: FEBRABAN introduced a self-regulatory standard to establish common principles for implementation of E&S governance. Socio and Environmental exposed sector taxonomy.

2017

Integrated risk management approach

- **Resolution 4553, January:** Segmentation by bank size for proportional implementation of prudential regulation. Five bank segments, S1 through S5.
- **Resolution 4557, February:** Replaced previous requirements on operational risk, market risk, interest rate risk in the banking book, credit risk and liquidity risk, while also incorporating the monitoring, reporting and mitigation of socio-environmental risk as defined in 2014.
- **Circular 3846, September:** Central bank established procedures and parameters for the ICAAP, including the requirement of capital to cover for socio-environmental risks.

2020

Agenda BC# - Sustainability dimension

- The Sustainability dimension of the Agenda BC# was launched with three main objectives: (i) promoting sustainable finance within the SFN; (ii) improving the social, environmental and climate risk management rules applicable to FIs; and (iii) incorporating variables associated with sustainability in the work and decision making processes in the BCB.

2021

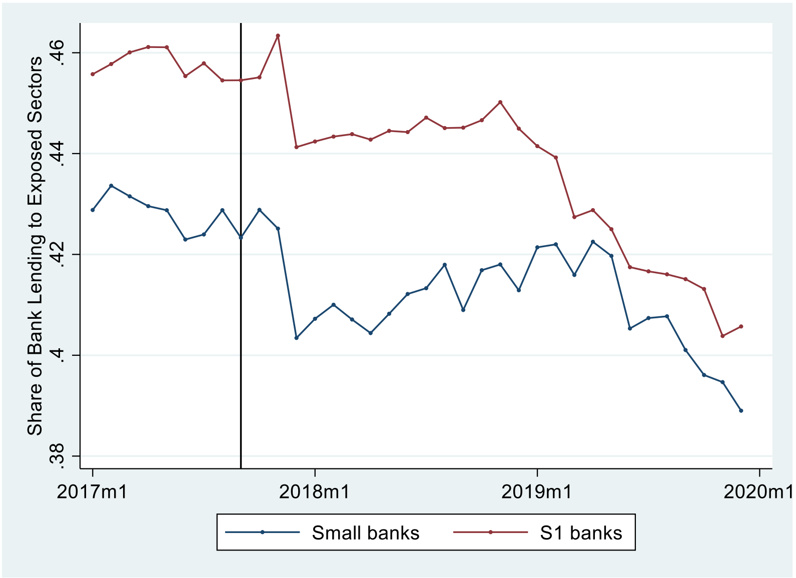
New regulations on social, environmental, and climate-related risks and opportunities for the financial sector

- **Resolution 4943, September:** The definition of climate-related risk was included in the risk management framework.
- **BCB Resolution 139, September:** Disclosure of information in the Report on Social, Environmental and Climate-related Risks and Opportunities (GRSAC Report)

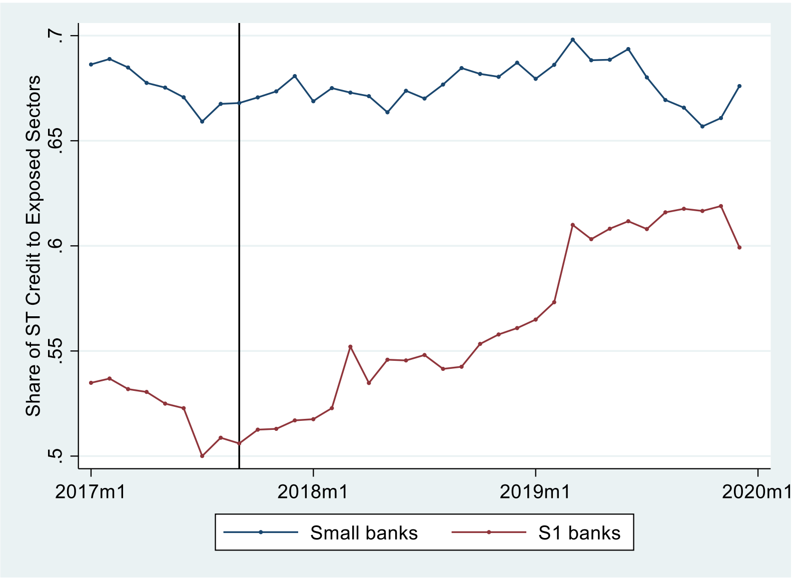
Source: Banco Central do Brasil and FSAP (WB/IMF).

Appendix Figure 2. Lending outcomes of small and large bank groups (excluding S2 banks)

Panel A. Share of lending to exposed sectors by small and large banks



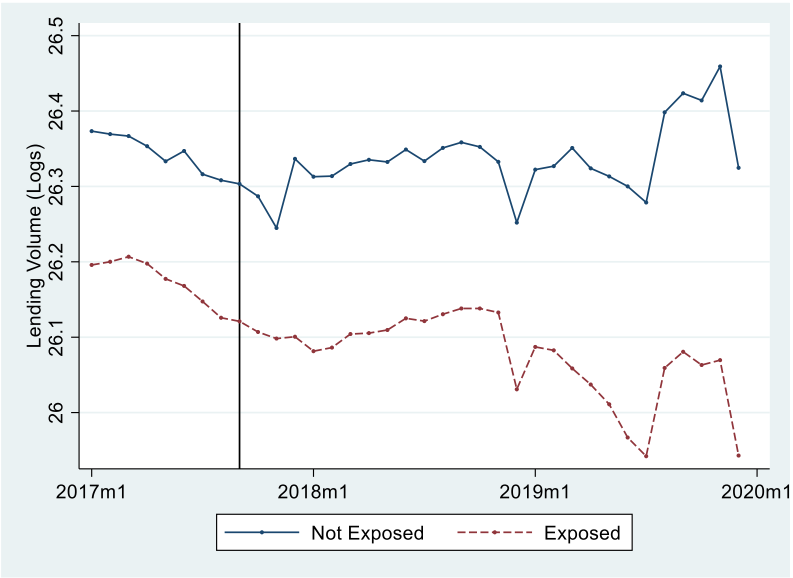
Panel B. Share of short-term lending to exposed sectors by small and large banks



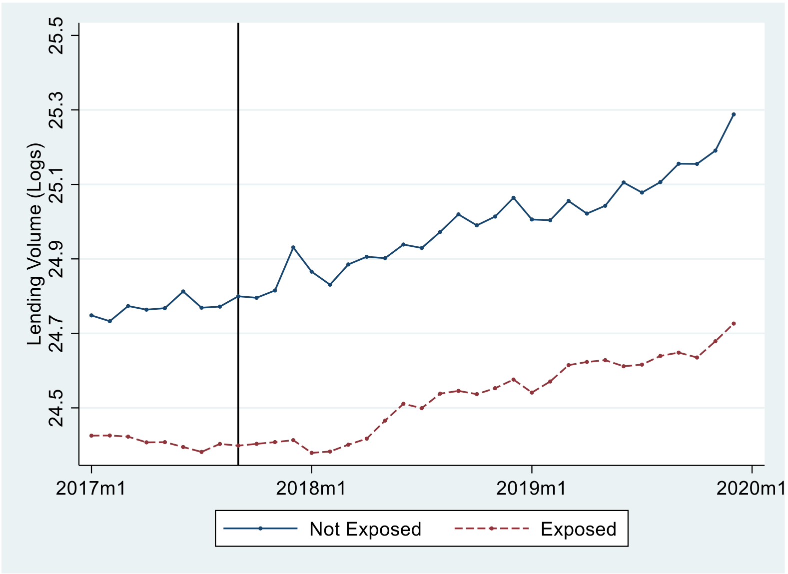
Notes: Large banks are banks classified as S1. Small banks are those banks classified as S3 and S4, with S2 banks excluded from the sample. Panel A displays the monthly aggregate share of corporate lending of small and large banks channeled to the 332 5-digit sectors classified as exposed. Panel B displays the share of lending to exposed sectors by small and large banks that has maturity of one year or less.

Appendix Figure 3. Total lending volume of small and large bank groups (excluding S2 banks)

Panel A. Lending volume of large banks to exposed and not exposed sectors



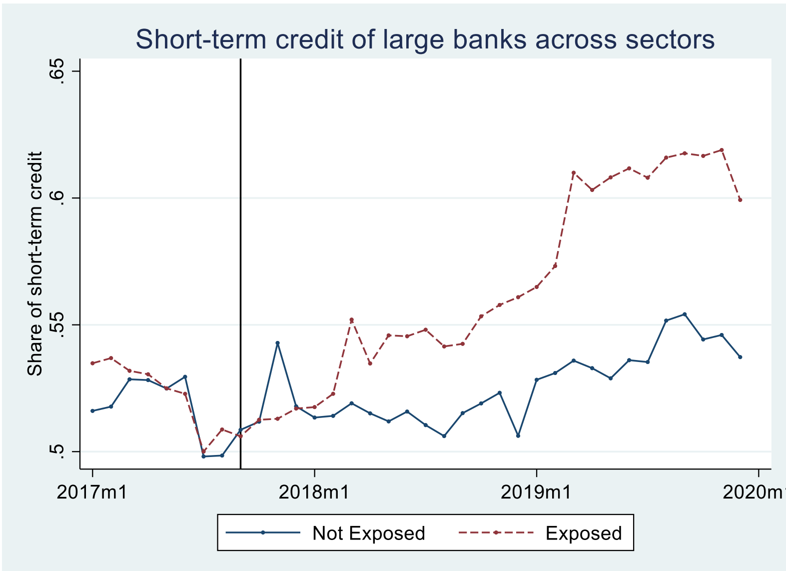
Panel B. Lending volume of small banks to exposed and not exposed sectors



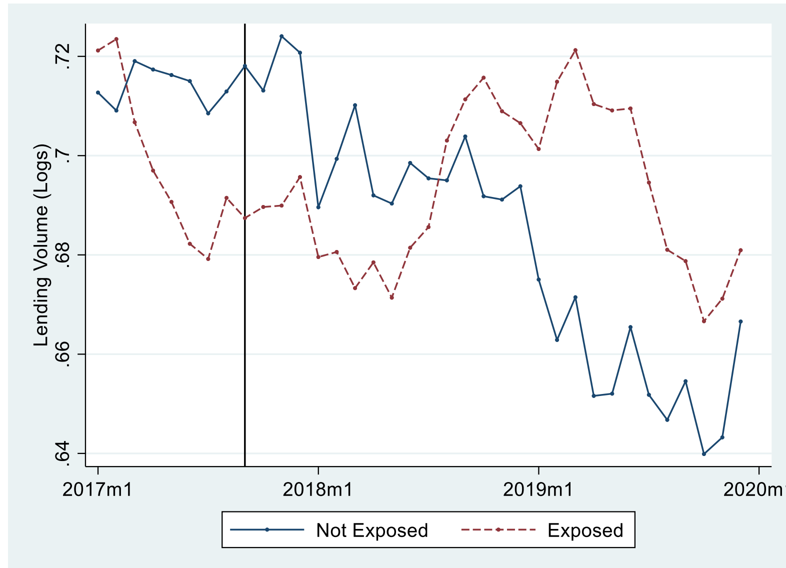
Notes: Large banks are banks classified as S1. Small banks are those banks classified as S3 and S4, with S2 banks excluded from the sample. Panel A displays the monthly aggregate corporate lending volume (in logs) of large banks channeled to sectors classified as exposed and not exposed. Panel B displays the monthly aggregate corporate lending volume (in logs) of small banks channeled to sectors classified as exposed and not exposed.

Appendix Figure 4. Share of short-term credit to sectors with low and high socio-environmental risk (excluding S2 banks)

Panel A. Large Banks



Panel B. Small Banks



Notes: Large banks are banks classified as S1. Small banks are those banks classified as S3 and S4, with S2 banks excluded from the sample. The figure displays the monthly share of lending to exposed and non-exposed sectors by large (Panel A) and small (Panel B) banks that has maturity of one year or less.