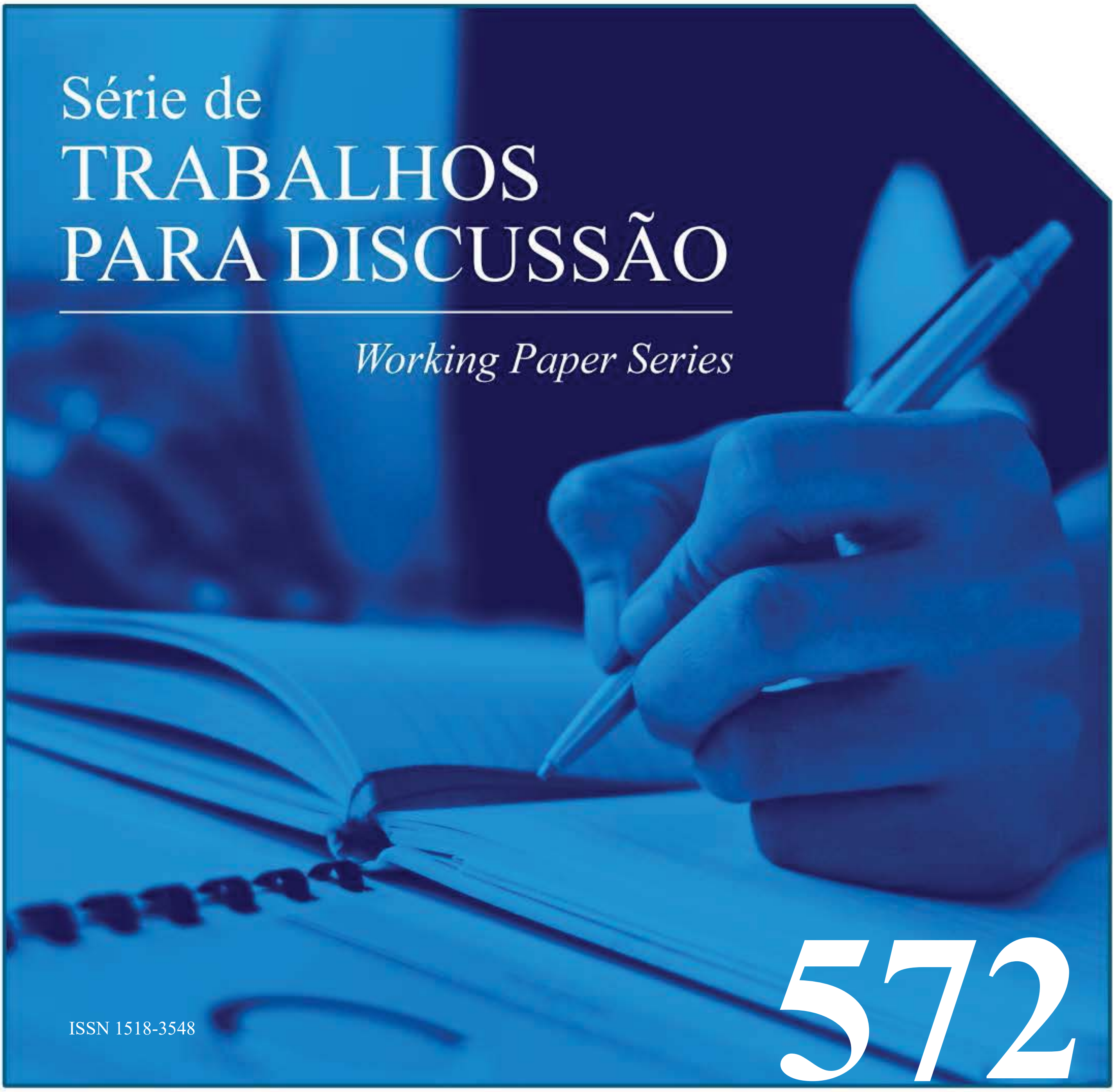

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Another Boiling Frog: the impact of climate-related events on financial outcomes in Brazil

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Non-technical Summary

Climate change is attracting a lot of attention in the recent years. Although the scientific consensus about the sizable effects in the long-run, as the boiling frog fable describes, the consequential effects of greenhouse gases build up slowly. Indeed, a large body of evidence shows how businesses and people adapt to gradual climate-related changes, while another branch of the literature suggests climate change can have sizeable economic impacts.

The evidence on how climate-related events affect financial markets still needs to be explored. This paper fills this knowledge gap by examining detailed data from the Brazilian banking sector. Brazil is an interesting case study for a few reasons: (i) as the fifth largest territory in the world, Brazil depicts a large variety of climate conditions, an essential feature for evaluating the consequences of climate-related episodes; (ii) being a developing country, it provides lessons that may apply to a large set of vulnerable regions; and (iii) the availability of detailed information on financial flows makes it is possible to characterize the impact of climate-related events on different aspects of the banking sector.

There are important lessons to be learned from our analysis of physical risks. Although short-run weather fluctuation or extreme events (droughts and floods) still have limited impacts on financial outcomes, offering no immediate risks to the banking system, climate change can have sizeable consequences to deposits and credit. We also document important adaptation mechanisms in place – banks foresee some areas more vulnerable to climate-related events and reduce credit exposure to control non-performing loans.

In addition to evaluating the physical risks of climate-related events on financial outcomes, we also assess the transition risks related to the political, technological, and institutional implications of climate change in a transition towards a low-carbon economy.

We analyze the evolution of banks' exposure to two groups of activities from 2004 to 2017: sectors associated with sustainable practices (**green sectors**) and sectors with the potential to cause socio-environmental impacts (**high-impact sectors**). The relative importance of green credit concerning high-impact sectors has a U-shape, decreasing in the 2004-2010 period and growing after 2011.

Resumo não técnico

A crise climática tem atraído muita atenção nos anos recentes. Apesar do consenso científico sobre seus efeitos substanciais no longo prazo, como ilustrado pela fábula do sapo na água fervente, as consequências das emissões de gases de efeito estufa se compõem lentamente. De fato, há uma vasta literatura mostrando como as empresas e as pessoas estão se adaptando às mudanças graduais dos eventos relacionados ao clima, enquanto outra vertente da literatura sugere que as mudanças climáticas podem ter impactos econômicos consideráveis.

Evidências de como os eventos relacionados ao clima afetam os mercados financeiros, no entanto, ainda são escassas. Este artigo contribui para preencher essa lacuna de conhecimento, examinando dados detalhados do setor bancário brasileiro. O Brasil é um estudo de caso interessante pelos seguintes motivos: (i) como o quinto maior território do mundo, o Brasil apresenta uma grande variedade de condições climáticas, característica essencial para avaliar as consequências de episódios relacionados ao clima; (ii) sendo um país em desenvolvimento, oferece lições que podem ser aplicadas a um grande conjunto de regiões vulneráveis; e (iii) pela disponibilidade de informação detalhada sobre os fluxos financeiros, é possível caracterizar o impacto dos eventos climáticos em diferentes aspectos do setor bancário.

Há lições importantes a serem extraídas da análise de riscos físicos. Embora a flutuação climática de curto prazo ou eventos extremos (secas e inundações) ainda tenham impacto limitado sobre os resultados financeiros, não oferecendo riscos imediatos para o sistema bancário, as mudanças climáticas podem ter consequências consideráveis para depósitos e crédito. Também são identificados importantes mecanismos de adaptação em vigor – os bancos avaliam que algumas áreas são mais vulneráveis a eventos relacionados ao clima e reduzem a exposição de crédito como meio de controlar a inadimplência.

Além da avaliação dos riscos físicos, também fornecemos uma avaliação preliminar dos riscos de transição, os quais estão relacionados às implicações políticas, tecnológicas e institucionais das mudanças climáticas em uma transição para uma economia de baixo carbono. Analisamos a evolução da exposição dos bancos a dois grupos de atividades: setores associados a práticas sustentáveis (setores verdes) e setores com potencial de causar impactos socioambientais (setores de alto impacto). A importância relativa do crédito verde em relação aos setores de alto impacto tem formato de U, diminuindo no período 2004-2010 e crescendo após 2011.

Another Boiling Frog: the impact of climate-related events on financial outcomes in Brazil[1]

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Abstract

We evaluate the impact of climate-related events on the Brazilian banking sector. The analysis of physical risks reveals that, although short-run weather fluctuations and extreme events (droughts and floods) have limited impact on financial outcomes, climate change projections are expected to generate sizeable consequences to deposits and credit. We also document relevant geographical heterogeneity in the results and the importance of bank adaptation responses, avoiding areas with more considerable climate risks. The analysis of transition risks shows that the exposure of banks to green sectors concerning high impact sectors has a U-shape, growing since 2011.

Keywords: climate change, extreme events, credit, banking
JEL Classification: E50, G21, Q54

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1. Introduction

Climate change is real and is no longer a problem of the future. But, as usually described by the boiling frog fable, the consequential effects of greenhouse gases build up slowly. A large body of evidence, as emphasized by Barreca et al (2016) and Burke and Emerick (2016), shows how businesses and people are adapting to the gradual changes in climate-related events. In another branch of the literature, simulation exercises suggest climate change can have sizeable economic impacts (e.g., Mendelsohn, Nordhaus and Shaw, 1994; Stern, 2006; Deschenes and Greenstone, 2011; Dell, Jones and Olken, 2012; 2014; Wood and Mendelsohn, 2015; Assunção and Chein, 2016), as well as financial implications for markets and institutions (Batten et al., 2016; NGFS, 2018). Climate physical risks derive from direct impacts of extreme events and of slow and chronic changes; their main risks are related to agricultural productivity, food security and human health, as clarified by Deschenes and Moretti (2009); and Deschenes and Greenstone (2011). Climate transition risks relate to the impacts from transitioning towards a low carbon economy that could become abrupt if not prepared and could be due to policy changes, technology changes and market behavior (NGFS, 2018).

The impacts of climate change are stronger in developing countries, due to the expected higher temperature changes in tropical and semi-tropical latitudes and the importance of rural activities in the gross domestic product, as well as due to higher macroeconomic vulnerability (ND-GAIN, 2020). Moreover, as pointed by Lybbert and Summer (2012) and Huang et al. (2011), developing countries face difficulties to adapt to climate change as they are far from the technological frontier.

The evidence on how climate-related events affect financial markets is increasing, but there’s not sufficient quantitative evidence of how such risks impact the ability of financial institutions to lend to potentially vulnerable actors, while remaining financially solid (Batten, Sowerbutts and Tanaka (2015); Christophers (2017); Paddam and Mackenzie (2016); Frisari et al. (2019); Kling et al. (2018)). This paper contributes to fill this knowledge gap, examining detailed data from the Brazilian banking sector. Climate change poses risks that are distinctly financial. As new climate scenarios emerge, the global economy and governments must be ready to act to mitigate and adapt, designing a new generation of policies. A failure to adequately price the additional risks associated with climate change in the current financial operations could substantially affect the performance of financial institutions and therefore create economic consequences through an additional channel. In fact, there is an increasing concern about the relationship between climate-related risks and financial systems in developed as well as emerging markets.

Brazil is an interesting case study for a few reasons: (i) as the fifth largest territory in the world, Brazil depicts a large variety of climate conditions, an essential feature for evaluating the consequences of climate-related episodes; (ii) being a developing country, it provides lessons that may apply to a large set of vulnerable regions; (iii) given the availability of detailed information on financial flows, it is possible to characterize the impact of climate-related events on different aspects of the banking sector. We conduct quantitative regression analysis to characterize the importance of physical risks to the financial sector, examining the impact of weather fluctuations, droughts, floods and climate change on deposits and credit volume on a municipality-level dataset covering the 2004-2017 period. In addition, we assess how exposed banks are to specific sectors that climate transitions and new policies may most impact.

There are important lessons to be learned from our analysis of physical risks. Although short-run weather fluctuation or extreme events (droughts and floods) still have a limited impact on financial outcomes, offering no immediate risks to the banking system, climate change is shown to have sizeable consequences to deposits and credit. We also document important adaptation mechanisms in place – banks anticipate that some areas are more vulnerable to climate-related events and reduce credit exposure as a means of controlling non-performing loans; similarly, the economic activity seems to avoid these areas, determining the reduction in deposits or demand for loans. Consequently, the indicators about deposits and credit amounts are more sensitive to climate-related events than the indicator of non-performing loans.

The analysis of physical risks is presented in three steps. First, we examine the impact of short-run weather fluctuations. Although the temperature and rainfall are significant determinants of all financial outcomes considered in the analysis, short-run fluctuation in weather does not generate relevant impacts on deposits or credit in Brazil. Despite regional heterogeneity in the results, the quantitative figures are still limited. Another interesting pattern is that the credit amount is more sensitive than non-performing loans, suggesting banks may anticipate weather fluctuations by reducing the number of loans and being more selective in the credit concessions.

Second, droughts and floods are considered possible extreme events affecting financial outcomes. In the case of droughts, we study the impact of these extreme events in two alternative scenarios, with and without adaptation mechanisms. Facing unfavorable conditions, economic agents (people, businesses, banks, …) adapt their behavior, reducing the impact of extreme events on welfare and production. As a consequence, the population and the economic activities in regions with a higher likelihood of droughts are already adapted to recurrent adverse shocks. Over time, these adaptation mechanisms build up to cross-section differences in the production structure, population, and financial exposure across municipalities. Droughts are shown to impact local municipalities in the scenario without adaptation dramatically. They induce relevant deposits and credit volume reductions when hitting a municipality. However, in the adaptation scenario, incorporating the behavioral responses of banks and the economy to the exposure of such risks, the occurrence of droughts is associated with almost no impact on deposits and a slight increase in the credit portfolio – delinquency is not affected. These two pieces of evidence suggest that if climate change increases the occurrence of droughts, it can reduce the overall scope of the banking business due to the adaptation of the system to the new risk profile. In counterfactual exercises, we find no evidence that the recent occurrence of droughts creates a substantial aggregate risk to the Brazilian banking system.

In the case of floods, due to an additional econometric challenge, we can only consider the scenario with adaptation. Floods are usually a combination of solid rainfalls with conditions for water accumulation, such as urbanization. Thus, we cannot disentangle the natural conditions driving floods from urban infrastructure and other determinants of floods, which compromises the possibility of investigating the scenario without adaptation in our methodology. We can focus only on the impact of floods on municipalities over time, allowing municipalities to adapt to the ex-ante probability of flooding. The results reinforce the message obtained in the analysis of droughts, in which the occurrence of such events has a relatively small impact on financial outcomes.

Third, we investigate the impact of climate change on the Brazilian banking system. In this exercise, we first run models on the long-run impact of temperature and rainfall on financial outcomes. Then, we simulate the impact of a moderate business-as-usual climate change scenario of the Intergovernmental Panel on Climate Change (IPCC) on those financial outcomes[6]. Different from the other impacts mentioned above, a structural change in temperature and rainfall is expected to create substantial impacts on the banking system. Under the IPCC scenario, deposits are expected to fall, in the aggregate figures, from 3% to 22%. Credit is expected to reduce by about 23%, and delinquency rates are expected to rise by 12%. Thus, a climate change scenario with sustained and long-term changes, different from the others, is the one in which climate variation can matter the most for the banking sector.

Thus, the analysis of physical risks combines the lack of short-run impacts of climate-related events with expected high implications for the long-run climate change scenario. This combination, on the one hand, explains a fair part of the political difficulties for implementing a well-structured climate agenda in financial markets but, on the other hand, illustrates how important it is to get climate change under control and to prepare the financial sector to operate in a climate change scenario. The results also reveal important adaptation mechanisms in place.

In addition to physical risks, climate change could also have transition risks. Transition risks stem from the political, technological, and institutional implications of climate change in a transition toward a low-carbon economy. Transition risks are typically higher for economic sectors with high environmental impact, mainly due to the emission of greenhouse gases (GHG), which could be affected by the abrupt policy, technological, and consumer changes in favor of low-carbon solutions.

As for transition risk drivers, Christophers (2017) provides a proper classification, consistent with the work of The Task Force on Climate-Related Financial Disclosures (TCFD): (i) policy and legal risks, comprising international, national and subnational targets, mandates, legislation and regulations to address climate change; (ii) technology risk, referring to investments to support the low-carbon economy or reduce the carbon emissions; (iii) market/economic risk, refers to change in consumer preferences; and (iv)

[6]We consider the scenario A1B of the Fourth Assessment Report (AR4) in which the assumptions of rapid economic growth, peaked world population in 2050, and a balanced emphasis on all energy sources. This scenario points to projections in between the most favorable and most dramatic ones.

reputation risks, related to the probability of losses following business's activities seen as harmful by the public.

However, characterizing transition risks empirically is still challenging. For this sake, we have followed the directions of the TCFD, relying on a project developed by the Brazilian Federation of Banks (Febraban, 2017). Febraban aims to characterize exposure of the banking system to sectors associated with sustainable practices (**green sectors**) and sectors with the potential to cause socio-environmental impacts (high-impact **sectors**). Although the classification of economic activities into these two categories involves subjective assessments and imprecision due to data limitations, it is the best proxy for characterizing transition risk in Brazil.

We analyze the evolution of the exposure of banks to these two groups of activities in the period from 2004 to 2017. This is a period of expansion of the credit market in Brazil, except 2016-2017, when an economic crisis hit the country. Loans to both green and high-impact sectors grew consistently until 2015, although with differential trends. The relative importance of green credit concerning high impact sectors has a U-shape, decreasing in the 2004-2010 period and growing after 2011. Thus, although the share of the portfolio allocated to green sectors is smaller than the share allocated to high-impact sectors, this figure has been changing continuously since 2011.

The paper is organized as follows. Section 2 presents the climate-related events considered in the analysis and a statistical summary of the related data. Section 3 describes the data set. Section 4 describes the methodology, including the empirical strategy of the estimation and the counter-factual exercises, for each of the analyses of short-run weather fluctuations, extreme events, and climate change. Section 5 analyzes the estimated impacts and counterfactuals. Section 6 shows the analysis of transition risks. Concluding remarks are made in Section 7. The detailed data description and robustness exercises are in the appendices.

2. Climate-related events in Brazil

With the fifth largest territory in the world, Brazil is exposed to a variety of climate-related events[7]. The region covers six terrestrial biomes, in which soils,

[7] See Appendix A for detaileid information about climate events in Brazil.

vegetation, altitude, and latitude are associated with substantial climate variation. In this sense, Brazil is an interesting case study to assess the impact of climate-related events on financial outcomes.

In the case of extreme climate events, it is worth noting that droughts in Brazil are widespread in the semi-arid climate region, comprising 1,133 municipalities, which is equivalent to approximately 20% of the total number of Brazilian municipalities. The semi-arid region in Brazil is located in the Northeast region and the northern region of the state of Minas Gerais, covering 11% of the Brazilian population. Although the semi-arid region is more exposed to droughts, there are relevant episodes in the other areas and substantial variation in the occurrence across time and space. Floods, on the other hand, show a different pattern, less concentrated than the observed pattern for droughts. There is substantial time-series variation in the occurrence of these events. These differences in the patterns of droughts and floods will help us better characterize their relative importance to financial flows and risk.

It is also possible to observe a clear pattern in Brazilian territory related to weather conditions. This pattern suggests that the variation that will prevail in the estimation is mainly associated with more minor deviations in temperature and rainfall over time.

3. Data sets and indicators

The data on savings and deposits reported in this section come from ESTBAN (Banking Statistics), which comprises financial statements at the branch level for all commercial banks operating in the country. The data on credit, on the other hand, was obtained through the SCR (Credit Information System of the Central Bank of Brazil).

Figure 1 presents Brazil's aggregate trends and growth dynamics of savings accounts and deposits (demand deposits and term deposits). It is possible to observe that each category has a specific time trend and growth dynamics. The geographical dynamics of term deposits are reported in **Figure 2.** There is a high concentration of term deposits in the southern part of the country. A similar pattern (not reported here for the sake of brevity) can be found for demand deposits and savings. Deposits are concentrated in more populous areas.

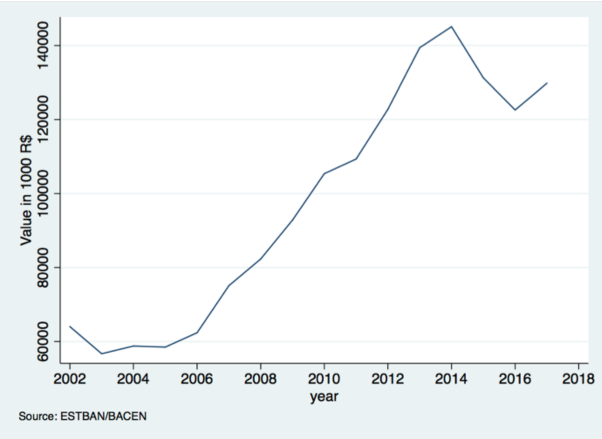
Figure 3 presents the evolution of crucial aggregated credit indicators. In the 2004-2017 period, there was a sharp increase in the credit portfolio. Surprisingly, the trend in the rate of non-performing loans[8] is quite different without a clear upward or downward trend in the period. Finally, **Figure 4** and **Figure 5** depict the geographical distribution of the financial variables in the whole period. There is an apparent heterogeneity in the financial outcomes across the Brazilian territory.

[8] Percentage of total loan balance overdue for more than 90 days on total loan balance.

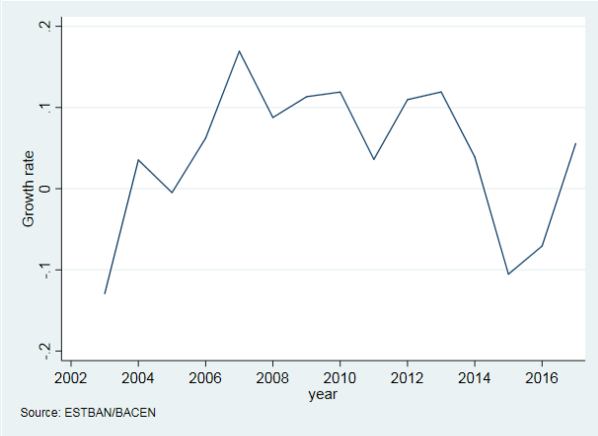
Figure 1 *- Evolution and Growth Dynamics of Savings and Deposits*

(a) Savings Account

a.1) Evolution

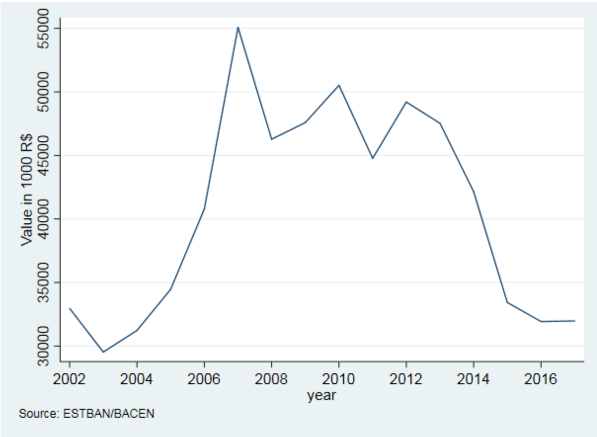


a.2) Growth Dynamics

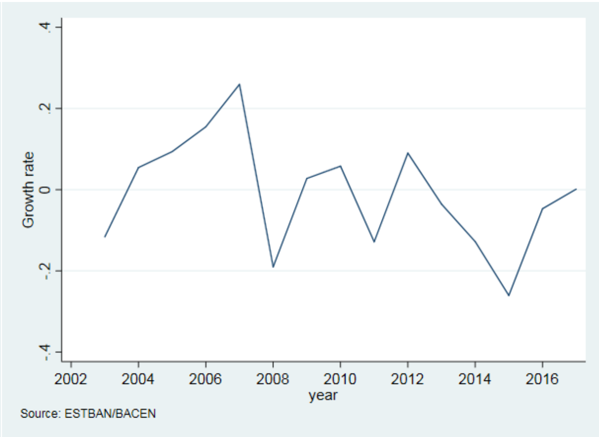


(b) Demand Deposits

b.1) Evolution

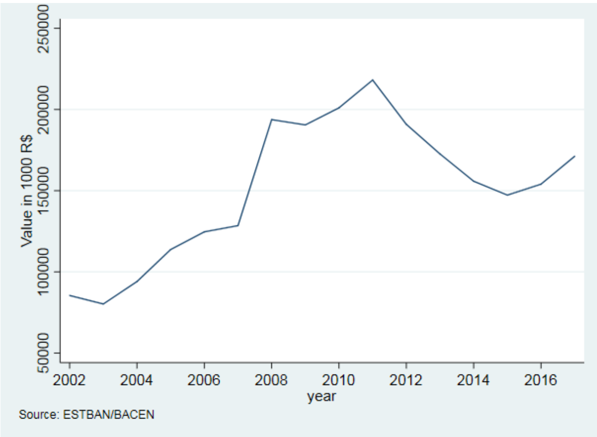


b.2) Growth Dynamics

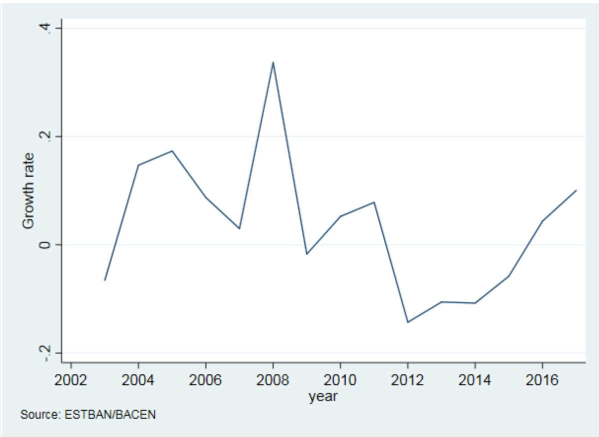


(c) Evolution of Term Deposits

c.1) Evolution

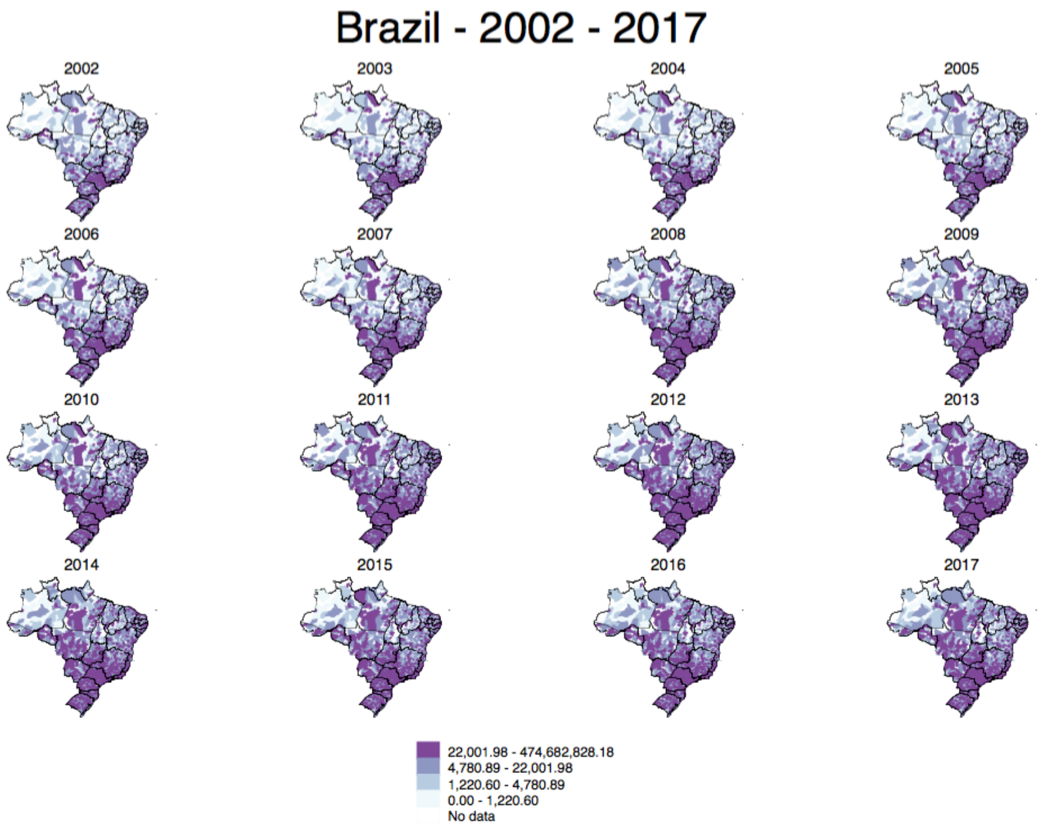


c.2) Growth Dynamics



Source: ESTBAN/BACEN

Figure 2 *- Distribution of Term Deposits in Brazil*

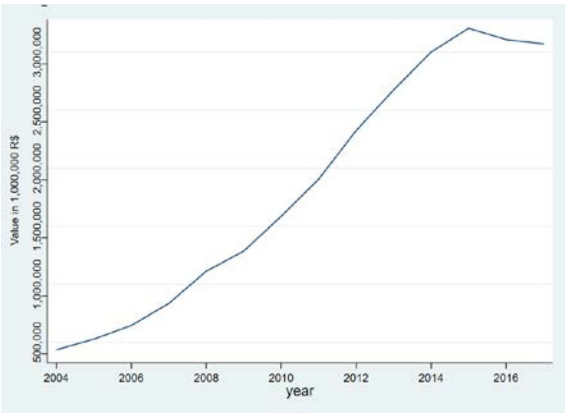


Source: ESTBAN/BACEN

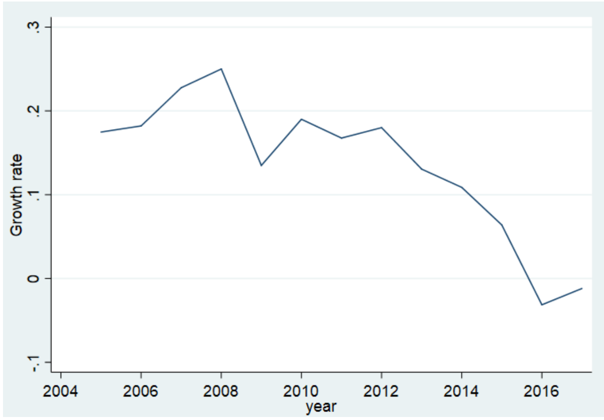
Figure 3 *- Evolution of key credit indicators*

(a) Total loan portfolio

a.1) Evolution

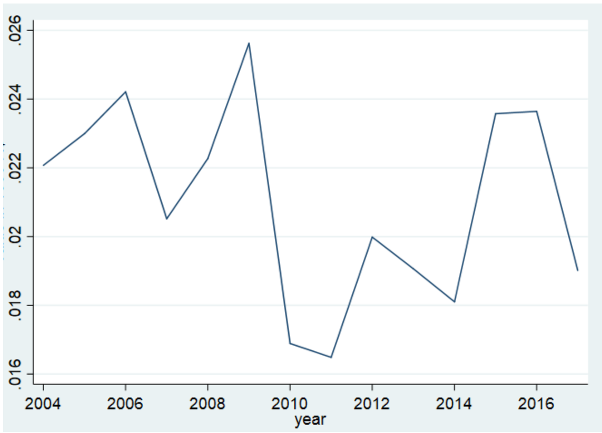


a.2) Growth Dynamics

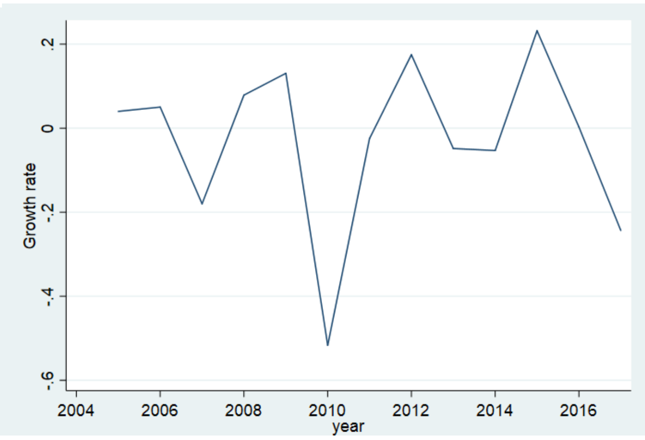


(b) Rate of non-performing loans

b.1) Evolution

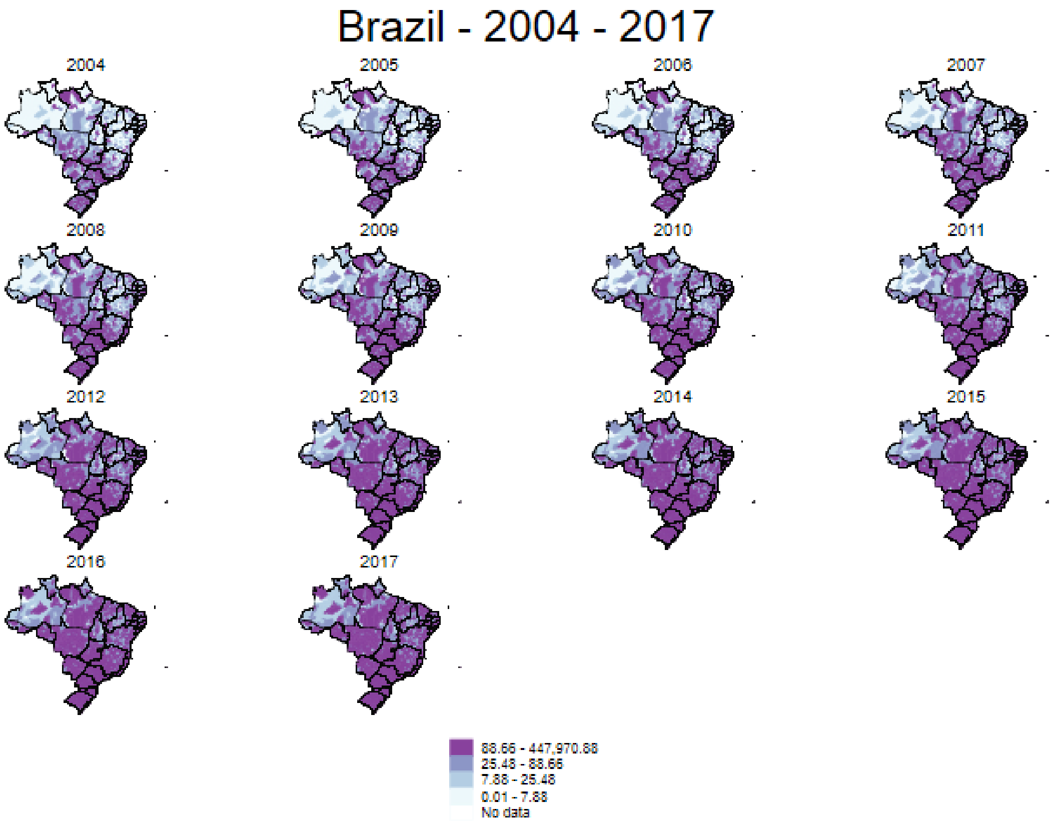


b.2) Growth Dynamics



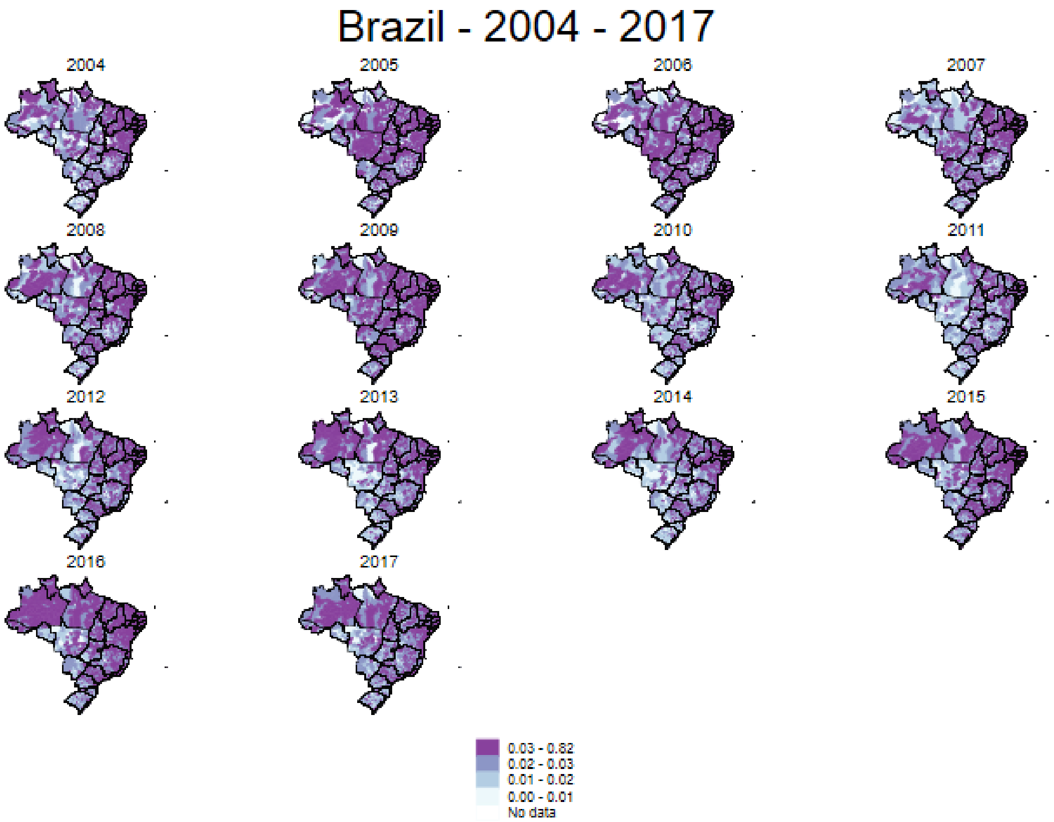
Source: SCR/BACEN

Figure 4 *- Distribution of Total Loan Portfolio in Brazil*



Source: SCR/BACEN

Figure 5 - Distribution of Rate of Non-Performing Loans in Brazil



Source: SCR/BACEN

4. Methodology

We follow three different approaches to estimate and analyze the impact of climate-related events on financial outcomes. Each approach is especially designed to incorporate specific characteristics of the analysis of the short-run weather fluctuations, the occurrence of extreme events (droughts and floods), or climate change. In all cases, results are primarily driven by regression analysis of municipalities in Brazil, as in the recent literature (Deschenes and Greenstone (2011); Dell, Jones and Olken (2012); Hornbeck and Keskin (2014) and Assunção and Chein (2016)). We focus on two financial outcomes: deposits (demand deposits, term deposits and savings) and credit (outstanding loans and non-performing loans). Robustness exercises at aggregate micro-regions are presented in Appendix B.

4.1. Impact of short-run weather fluctuation

To estimate the impact of short-run fluctuation of temperature and rainfall, we estimate fixed effect panel models as in Deschenes and Greenstone (2011), using financial outcomes as dependent variables. The basic specification is:

$$Y_{it} = \alpha_t + \beta W_{it} + \theta X_{it} + \gamma_i + \epsilon_{it}, \quad (1)$$

where Y_{it} is a financial outcome, α_t is the time fixed effect, W_{it} is the vector of observed weather variables (temperature and rainfall), X_{it} is a vector of time-varying municipality characteristics (GDP and population), and γ_i is the municipality fixed effects. The parameter vector β is our main focus for the estimation and counterfactual analysis.

Equation (1) is estimated in three versions[9] for each one of the outcome variables, considering yearly averaged temperature, squared yearly average temperature, annually averaged rainfall, and squared yearly average rainfall, as in Mendelsohn, Nordhaus and Shaw (1994) and Assunção and Chein (2016). The first one corresponds to estimated models with $\alpha_t = \gamma_i = \theta = 0$. In this version, our parameter of interest β is estimated considering common trend variation, cross-section variation across municipalities as well as variation in the economic activity or in any other municipal characteristic. Thus, the estimated parameter β in this version captures, for example, the differences in the financial outcome between municipalities in the Northeast (dry and hot) and municipalities in the South (rainy and cool). In the second version, we eliminate the common time trends and cross-section variation from the estimation of the parameter β by including time and municipality fixed effect in the regression. The estimated results reflect how each municipality's financial outcomes change with temperature and rainfall over time, assuming that these variables are not correlated with other time-varying characteristics that also affect the financial results and were not included in the model. Finally, in the third version, we shut down any channel associated with variation in GDP or population from the estimation of β.

The previous analysis shows temperature and rainfall as statistically significant determinants of financial outcomes. To better assess the quantitative relevance of weather fluctuations on credit and deposits, we run a counter-factual exercise. In this analysis, we eliminate the weather fluctuation from the analysis, simulating the financial trajectories

[9] Appendix B brings the regression results considering the three different versions of equation (1).

assuming constant values for temperature and rainfall based on the estimated equation (1). In the counter-factual analysis we focus on the results for the second specification, with time and municipality fixed-effects:

$$E(Y_{it}|W_{it} = \overline{W}_i) = \hat{\alpha}_t + \hat{\beta}\overline{W}_i + \hat{\gamma}_i, \quad (2)$$

where $\overline{W}_i$ is the averaged (and constant) weather conditions for each municipality. The average impact of weather fluctuation is given by the average difference between the preditcted Y_{it} estimated by equation (1) and the counter-factual, $E(Y_{it}|W_{it} = \overline{W}_i)$. As Equation (2) can be computed for each municipality at time t, the average impact is estimated at municipality level and can also be aggregated by state.

4.2. Impact of Extreme Events on Deposits and Credit

To estimate the impact of extreme events on financial outcomes, we use an anticipation effects framework presented in Malani and Reif (2015). This specification allows us to account for different assumptions regarding how the outcome variables can react to the expected impact of the extreme events. More specifically, we consider equations such as:

$$Y_{it} = \beta D_{it} + \sum_{j=1}^{\infty} \lambda_j E[D_{i,t+j}] + \theta X_{it} + \epsilon_{it}, \quad (3)$$

Where Y_{it} is a financial outcome indicator, D_{it} is an indicator that equals one if the unit is exposed to an extreme climate event in period t and zero otherwise. The vector X_{it}comprises characteristics of a municipality that vary over the years (population and GDP). Notice that, in this case, the parameter β represents the average impact of the extreme event on the affected municipalities, conditional on the expectations of future occurrence of those events.

An exciting feature of specification (3) is the possibility of accounting for alternative adaptation scenarios. For instance, in the case the extreme events are assumed to be idiosyncratic and independently distributed across municipalities, we would have $E\left[D_{i,t+j}\right] = c$ and the specification (3) would be equivalent to estimating:

$$Y_{it} = \alpha + \beta D_{it} + \theta X_{it} + \epsilon_{it}. \quad (4)$$

Alternatively, extreme events might be independently distributed across periods in a given municipality, but each municipality can have a specific probability of being hit by an event. In this case, we would have $E[D_{i,t+j}] = c_i$ and specification (3) would be equivalent to estimating:

$$Y_{it} = \alpha + c_i + \beta D_{it} + \theta X_{it} + \epsilon_{it}, \quad (5)$$

where c_i is a municipality fixed-effect. Equation (5) represents the impact of extreme events on financial outcomes conditional on any municipal-level characteristic that is constant in the sample period. In particular, the term c_i also accounts for the possibility that each municipality has a specific exposure to the events. Adaptation measures coming from behavioral adjustments of the population and local business, as well as optimal responses of the banks to the long-run local conditions, are absorbed by the parameters c_i, being eliminated from the estimation of β. Thus, while the parameter β represents the impact of extreme events on the financial outcomes in equation (4), the parameter β estimated with fixed effects in equation (5) accounts for the impact of extreme events on the financial outcomes, considering all possible adaptations to the specific characteristics of each municipality. Since banks and the local economy might be adjusting their choices in anticipation of the occurrence of such events, we expect to observe substantial differences between the estimated impacts from equations (4) and (5). The equations above are estimated for two sets of financial outcomes (deposits and credit).

The previous analysis focuses on the impact of extreme events on the financial outcomes of the affected municipalities when they face such episodes. However, to evaluate possible macroeconomic consequences for Brazil, we need to run counterfactual exercises to compute the average impact for each municipality. Based on the estimation of equation (3), the effect of the climate event of the respective outcome in municipality i can be obtained through:

$$Average\ Impact_i = \frac{1}{T}\sum_t E(Y_{it} - E(Y_{it}|D_{it} = 0)). \quad (6)$$

As in the analysis of short-run weather fluctuation, we focus on the version of the econometric specification for equation (5), considering only fixed effects.

4.3. Impact of Climate Change

The analysis of temperature and rainfall, aiming at studying the impact of climate change, focuses on the cross-section variation rather than the within variation as in

Mendelsohn, Nordhaus and Shaw (1994) and Assunção and Chein (2016). Our baseline specifications take the form of:

$$Y_{it} = \alpha_t + \beta C_i + \theta X_{it} + \epsilon_{it}, \qquad (7)$$

where Y_{it} is the same financial outcome indicator used in equation (1), α_t is the time fixed effect, C_i is the vector of observed climate variables – temperature or rainfall (see detailed description in Appendix A). The vector X_{it} comprises characteristics of a municipality that vary over the years (population and GDP).

Based on equation (5), we use the projection of IPCC for changes in temperature and rainfall in Celsius degree for the period from 2030 to 2049 to build a different climate vector for each municipality, $\widehat{C_\iota}$. As mentioned before, we consider a mild business-as-usual scenario to quantify the potential impacts of climate change on the financial outcome. The expected financial indicator in each municipality under the new climate scenario, based on the IPCC forecasts, is given by:

$$E(Y_{it}) = \hat{\alpha}_t + \hat{\beta}\widehat{C_\iota}. \qquad (8)$$

We depict the counterfactuals without control variables, so we allow for broader adaptation channels.

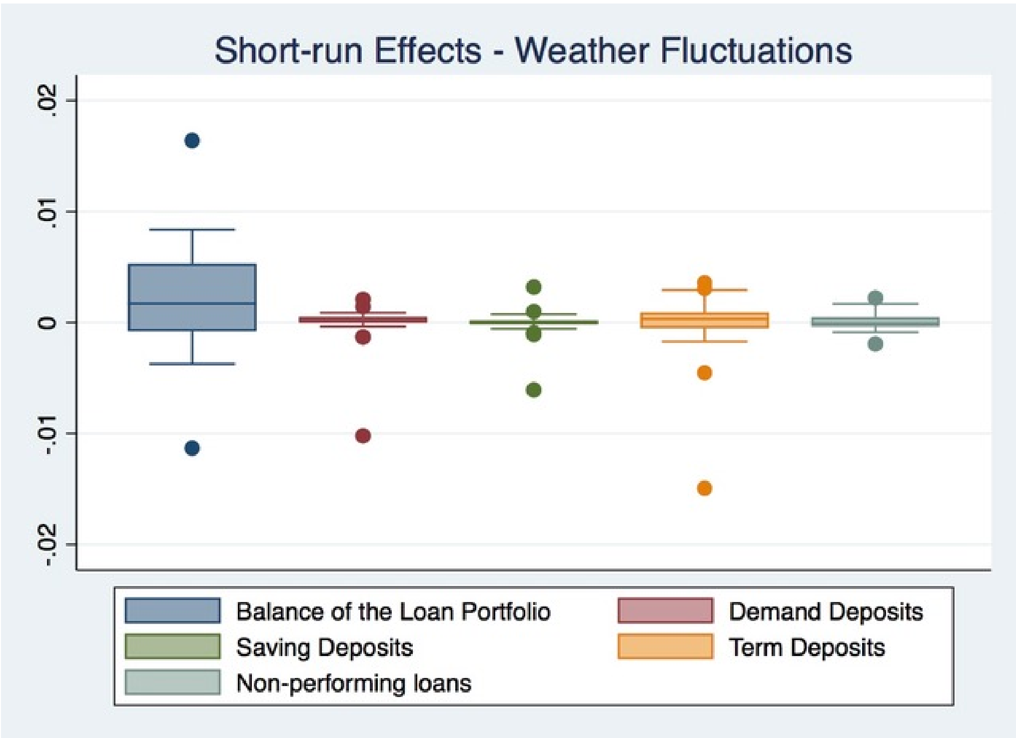
5. Results

5.1. Impact of Short-Run Weather Fluctuation on Financial Outcomes

We first investigate the impact of weather fluctuation on financial outcomes. Yearly changes in temperature and rainfall affect the economy and might have consequences for the financial system. Based on a fixed-effect panel model as in Deschenes and Greenstone (2011), we quantify the impact of weather fluctuation on two sets of outcome variables: deposits (demand deposits, term deposits and savings) and credit (outstanding loans and non-performing loans). For each outcome variable, we estimate fixed effects regressions considering (average) annual temperature, squared annual temperature, (average) annual rainfall, and squared rainfall as the key independent variables. Then, based on a counterfactual scenario in which the fluctuation in temperature and rainfall is eliminated, we estimate what would be the trajectory of each financial outcome and thus the impact of the weather fluctuation, as depicted by equation (8).

The main results of weather fluctuation impacts are summarized in **Figure 6**[10]. Although the temperature and rainfall are significant determinants of all financial outcomes considered in the analysis, short-run fluctuation in weather does not generate a relevant impact on deposits, savings, or credit in Brazil. Despite regional heterogeneity in the results, figures are still limited – almost all effects are below 1%. Another interesting pattern is that the volume of credit is more sensitive than non-performing loans, suggesting that banks can anticipate climate fluctuations by reducing the value of credit, being more selective in concessions, or producers anticipating adverse weather conditions may decide not to produce, reducing demand for credit.

Figure 6 - Counterfactual analysis



Note: The figure depicts the distribution of the state-level counterfactual variation in financial outcomes under the scenario with no weather fluctuation. The box plots present outliers values (dots), upper and lower adjacent values (whiskers), and a box with the 75th percentile (upper hinge), median (central line), and 25th percentile (lower hinge).

[10] The detailed results of the regressions are presented in Appendix B.

5.2. Impact of Extreme Events on Financial Outcomes

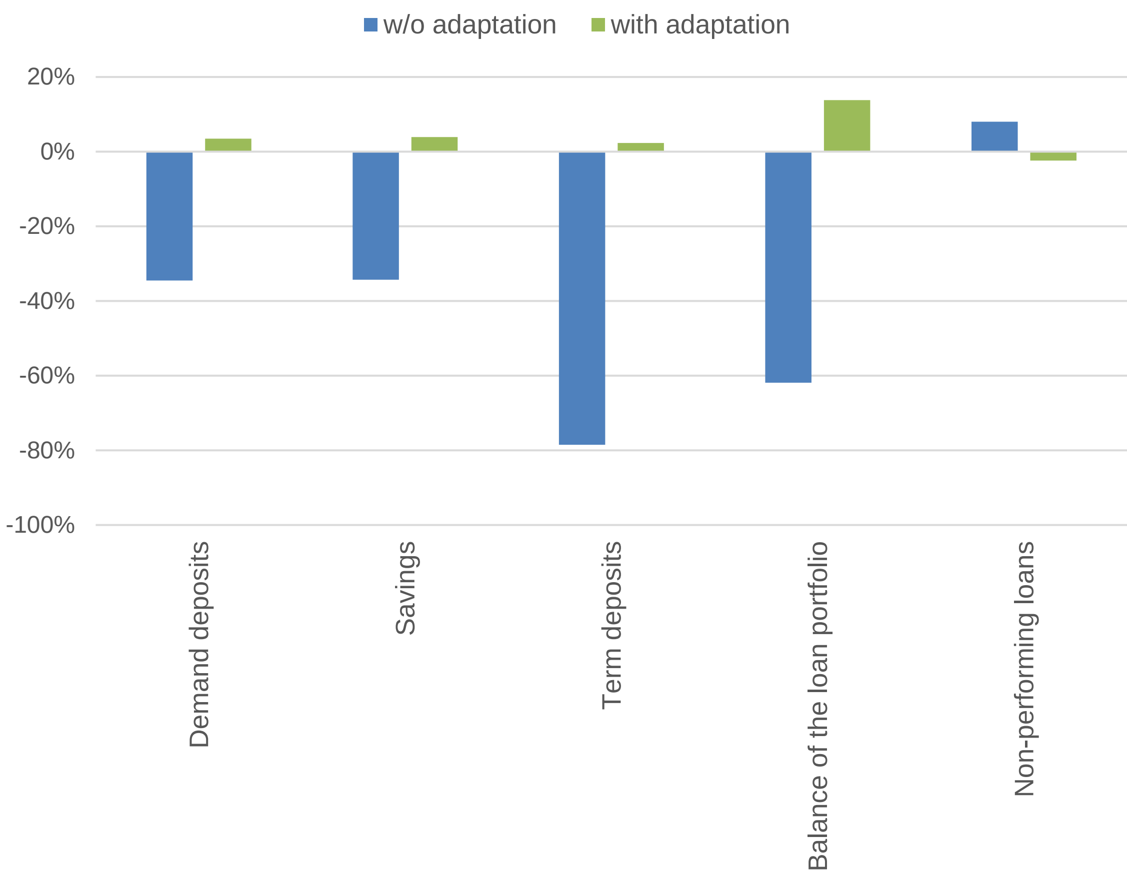
The impact of droughts and floods on financial outcomes is estimated through regression analysis, comparing each variable of interest during the event and outside the event in municipalities affected and non-affected by the event. We also consider alternative specifications to account for possible adaptation of the economy and the financial system, as described in Section 4.

Droughts

Droughts have a dramatic impact on local municipalities when we do not take into account possible adaptations. The impact on deposits ranges from a reduction of 34% (for demand deposits and savings accounts) to a reduction of 78% (for term deposits). Credit is also substantially affected when we do not account for adaptation. There is a reduction in the balance of the loan portfolio of 62% and an increase in non-performing loans of 8% (Figure 7)[11].

[11] The detailed results of the regressions are presented in the Appendix.

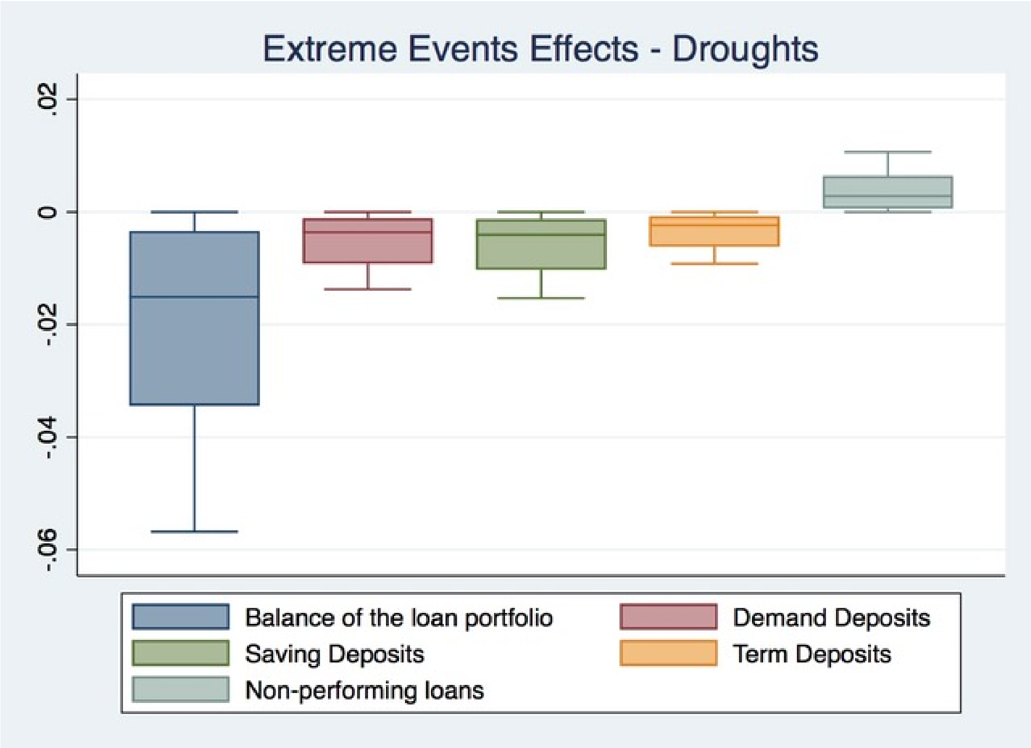
Figure 7 *– Local Impacts of Droughts on Financial Outcomes (scenarios with and without adaptation)*



However, the figures change significantly when we consider the possibility of local adaptation (Figure 7). Instead of observing a sharp reduction in the amounts of deposits and credit, we estimate slight positive impacts of droughts on both deposits and credit. It seems that decision-makers in general, and banks in particular, foresee some municipalities are more exposed to drought risks and adapt their decisions. Anticipating the potential impact of extreme events, firms and individuals reduce deposits while banks reduce their exposure through credit rationing. This is what explains the differences across the estimates with and without adaptation in Figure 7. However, when the droughts hit these municipalities, individuals and firms reduce consumption and investments, increasing the observed deposits, and banks slightly increase credit to support them to manage their immediate needs better as suggested by the estimates with adaptation. It is essential to clarify that, in Brazil, historically, droughts are concentrated in a very well-defined region and, not by chance, a region characterized by high levels of poverty.

Finally, the counterfactual exercises, depicted in Figure 8, suggest the occurrence of droughts does not create a substantial prudential risk to the Brazilian banking system as the impacts on non-performing loans are usually no higher than 1%. The figure depicts the state-level distribution of effects estimated. The financial outcome most sensitive to the occurrence of droughts is the credit portfolio, for which the median impact is a reduction of about 1.5 percentage points, with a range from 0 to almost -6 percentage points. We can see this by the size of the blue polygon in Figure 8.

Figure 8 - Counterfactual analysis



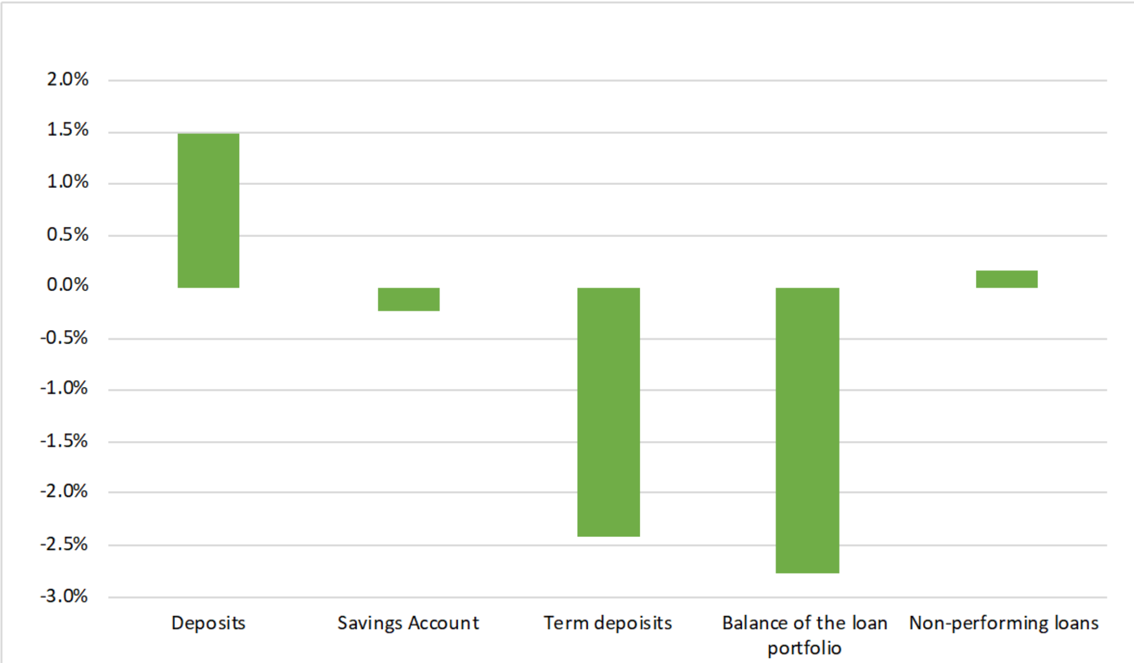
Note: The figure depicts the distribution of the state-level counterfactual variation in financial outcomes under the scenario with no weather fluctuation. The box plots present outside values (dots), upper and lower adjacent values (whiskers), and a box with the 75th percentile (upper hinge), median (central line), and 25th percentile (lower hinge).

Thus, the impact of droughts on the banking system operates primarily through an anticipation mechanism that structurally reduces the scope of the financial activity. The occurrence of the event by itself has a limited impact on the system, with no relevant prudential risk. In part, this reflects the fact that Brazil is a large country with many agroclimatic zones, which dilutes and smoothens the relevance of the negative shocks – while droughts hit some regions, others are not, providing a cushion for the financial system to manage the adverse shocks.

Floods

The impact of floods is trickier to measure than the impact of droughts since floods are the combination of intense rainfall with conditions for water accumulation, such as urbanization. This fact makes it hard to distinguish the assessment of the impact of floods in a scenario without adaptation (without fixed effects) from a situation where financial outcomes are different due to variations in features like urbanization. Thus, for the case of floods, we focus only on the impact of floods in municipalities over time, allowing municipalities to adapt to the *ex ante* probability of flooding.

Figure 9 - Local Impacts of Floods on Financial Outcomes (scenario with adaptation)

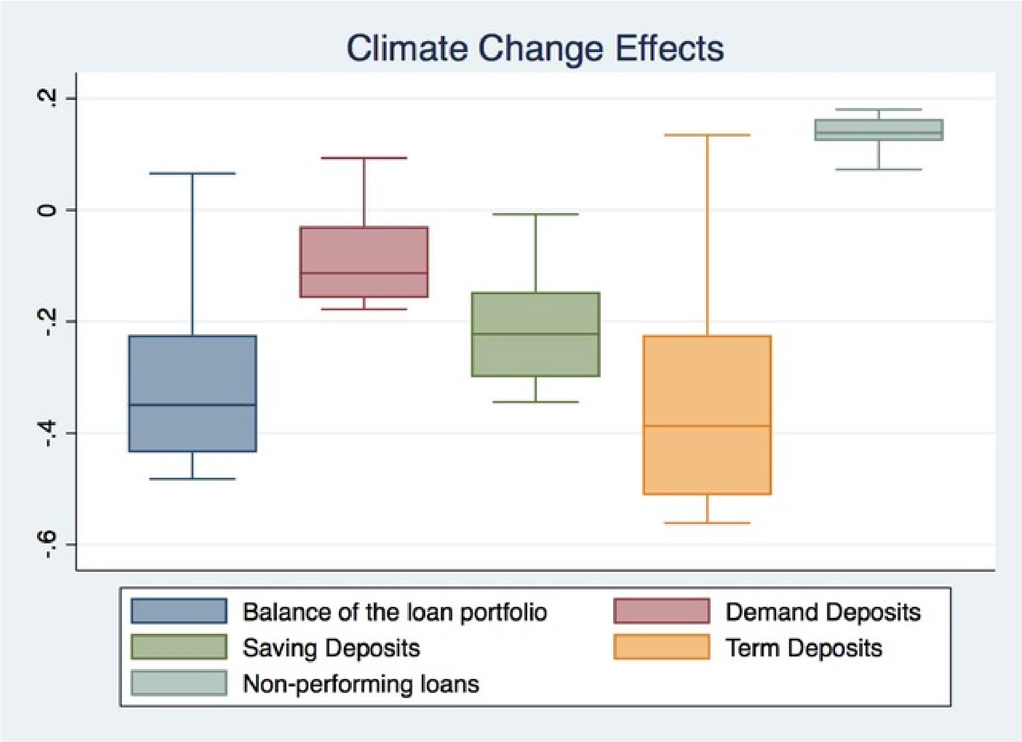


The results, once we control for the endogeneity and adaptation through the inclusion of municipalities' fixed effects, reinforce the message of the analysis of droughts, showing floods do not seem to represent substantial prudential risk at an aggregate level (see Figure 9). In most cases, the point estimate is quite close to zero, and the coefficients are not significant in most cases. In particular, floods do not have a material impact on non-performing loans. Floods are not expected to be a source of concern for the risk management of the banking system.

5.3. The Impact of Climate Change on Deposits and Credit

Finally, we investigate the long-term climate change impacts (temperature and rainfall changes) on deposits and credit. First, we run cross-section regressions of financial outcomes on the cross-section variation in temperature and rainfall. These regressions are used to build a counterfactual based on a mild business-as-usual IPCC climate change scenario.

***Figure 10** - Counterfactual analysis*



Note: The figure depicts the distribution of the state-level counterfactual variation in financial outcomes under the scenario with no weather fluctuation. The box plots present outside values (dots), upper and lower adjacent values (whiskers), and a box with the 75th percentile (upper hinge), median (central line), and 25th percentile (lower hinge).

Different from the other impacts estimated so far, a structural change in temperature and rainfall is expected to create a substantial impact on financial outcomes, with considerable state-level variation (Figure 10). Under the IPCC scenario, deposits are expected to fall, with higher impacts for term deposits in the aggregate figures. Credit amount is likely to contract over time while delinquency rates are expected to rise. Thus, the impact of long-term climate change, different from short-lived albeit more acute events, does matter more for prudential concerns of the financial sector, and it could also have profound consequences for the banking industry. Increased non-performing loans suggest the lending activity tends to become riskier, while reductions in deposits and credit volume point to a shrinkage in the bank business.

6. Discussion: Vulnerability to Climate Transitions

In addition to physical risks, climate change could also have transition risks. Transition risks are related to the political, technological, and institutional implications of climate change in a transition toward a low carbon economy. Transition risks are typically higher for economic sectors with high environmental impact, mainly due to the emission of greenhouse gases (GHG), which could be affected by the abrupt policy, technological, and consumer changes in favor of low-carbon solutions.

As for transition risk drivers, Christophers (2017) provides a proper classification, consistent with the work of The Task Force on Climate-Related Financial Disclosures (TCFD): (i) policy and legal risks, comprising international, national and subnational targets, mandates, legislation and regulations to address climate change; (ii) technology risk, referring to investments to support the low-carbon economy or reduce the carbon emissions; (iii) market/economic risk, referring to change in consumer preferences; and (iv) reputation risks, related to the probability of losses following business's activities seen as harmful by the public.

We rely on a project developed at the Brazilian Federation of Banks (Febraban) that classifies selected sectors into two groups: sectors associated with sustainable practices (**green sectors**) and sectors with the potential to cause socio-environmental impacts (**high impact sectors**). The classification criteria are based on definitions established by the United Nations Environment Program (UNEP) and by the National Council of Environment (CONAMA). Based on these concepts, Febraban identifies sectoral codes from the National Classification of Economic Activities (CNAE) for defining the green sectors and the high-impact sectors. Although the classification of economic activities into these two categories involves subjective assessments and imprecision due to data limitations, it is the best proxy for characterizing transition risk in Brazil.

The green sector comprises sectors with a potential impact for improving human welfare and social equity while at the same time low environmental risk and efficient use of natural resources. The green sector comprises activities like sustainable energy, sustainable tourism, water, fishing, forestry, sustainable agriculture, and waste treatment, as well as specific activities of the agribusiness and some social sectors such as education, health, productive inclusion and local and regional development.

The high environmental impact sector is defined based on activities that have a potential socio-environmental impact, where risk management is fundamental, either to mitigate adverse effects or to enhance positive ones. As emphasized by Febraban (2017), these sectors are presented by the provisions of Resolution 237/1997 of the National Environmental Council (CONAMA). The high-impact sector includes activities like extraction and treatment of minerals, manufacture of non-metallic mineral products, metallurgical industry, mechanical engineering, electrical, electronic, and communications equipment industry, transport industry and wood industry, paper, and cellulose industry, rubber industry, leather and skins industry, chemical industry, manufacture of plastics products, textile, apparel, footwear and fabrics industry, food and beverage industry and smoke industry, civil works, utility services, transportation, terminals and warehouses, tourism, agricultural activities and use of natural resources.

Table 3 – Composition of the Banking Credit Portfolio

year	Total loans (BRL millions)	Green sectors (BRL millions)	% total	High impact sectors (BRL millions)	% total	Ratio Green/ High impact (%)
2004	434,833	61,084	14.1	142,255	32.7	42.9
2005	527,014	70,218	13.3	162,413	30.8	43.2
2006	644,346	77,433	12.0	190,953	29.6	40.6
2007	834,283	94,051	11.3	244,778	29.3	38.4
2008	1,112,398	129,377	11.6	346,316	31.1	37.4
2009	1,285,728	157,690	12.3	396,683	30.9	39.8
2010	1,585,854	177,208	11.2	463,296	29.2	38.2
2011	1,905,667	206,401	10.8	549,134	28.8	37.6
2012	2,324,522	235,783	10.1	626,889	27.0	37.6
2013	2,675,019	269,687	10.1	710,611	26.6	38.0
2014	3,001,459	302,465	10.1	773,876	25.8	39.1
2015	3,206,279	331,108	10.3	838,764	26.2	39.5
2016	3,108,858	310,938	10.0	754,257	24.3	41.2
2017	3,072,252	306,773	10.0	695,326	22.6	44.1

Based on this classification, we analyze the composition of the banking loans to assess the evolution of banks exposure to green sectors and high-impact sectors in the period of 2004-2017 (Table 3 and Figure 11). This is a period of rapid expansion of the credit market due to a combination of favorable macroeconomic conditions, both internally and externally, and to a set of institutional reforms implemented in the early 2000s, especially for consumer credit.

In 2004, the two groups accounted for almost 47% of the total credit portfolio of banks. In 2017, on the other hand, the allocation of the two groups combined was reduced to approximately one-third of the portfolio. Although there is a reduction in the exposure of banks to both groups, the ratio between the green and high-impact sectors depicts a U-shape trend. In the second half of the period, there is an increased exposure of banks to green industries (Figure 12).

Figure 11 *- Evolution of the Banking Credit Portfolio (Green and High Impact Sectors)*

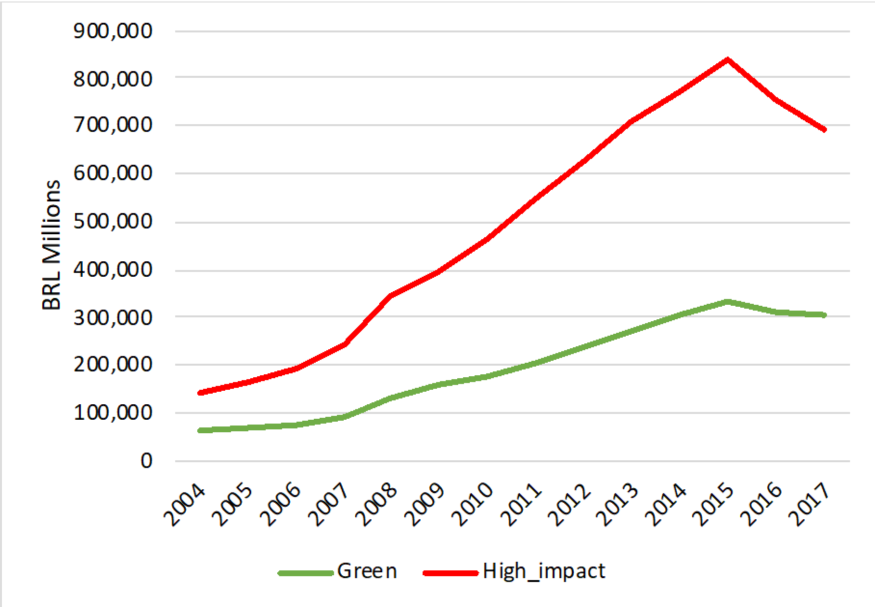
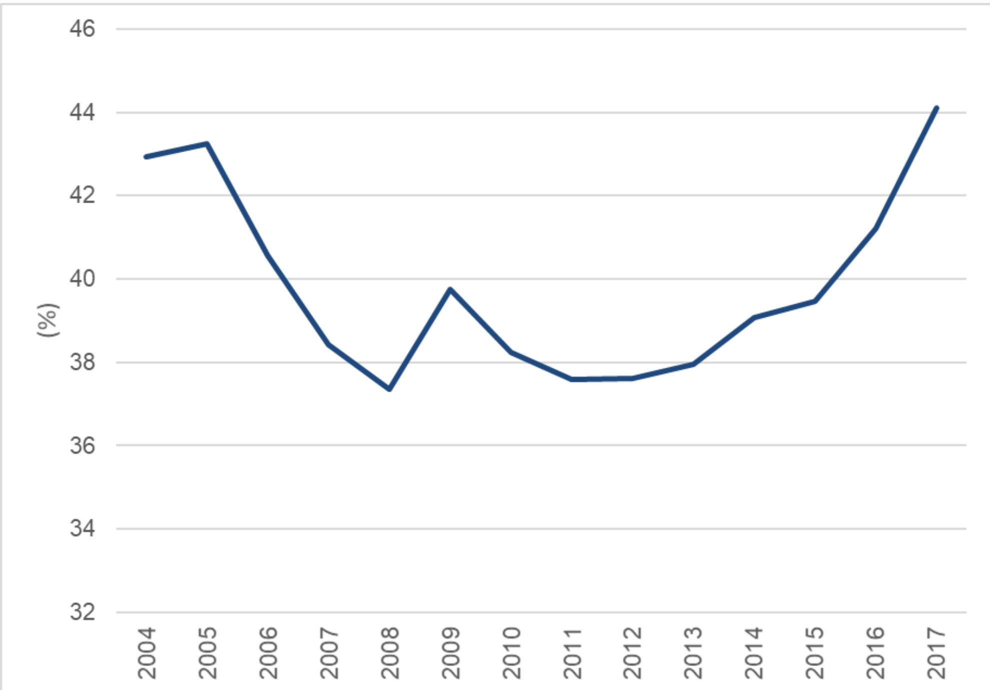


Figure 12 *- Evolution of the Share of Banking Exposure to Green and High-Impact Sectors*



7. Conclusion

We document the limited impacts of short-run weather fluctuation and extreme events on the banking system in Brazil. On the other hand, climate change impacts build up slowly and over time and could have a much more significant effect on both the ability to mobilize resources (deposits and savings) and the lending operations of banks in Brazil. It is worth noting that these impacts are heterogeneous across regions. Financial markets can also amplify the effects of climate change on the economy, reducing the scope of financial services for households and firms.

Climate adaptation is also an evolving effort with visible impacts, as documented more recently (Barreca et al. (2016); Burke and Emerick (2016)). Climate change poses distinctly financial risks. As a new climate scenario emerges, governments in the global economy must be ready to act to mitigate and adapt, designing a new generation of policies. A failure to adequately price the additional risks associated with climate change in the current financial operations could substantially affect the performance of financial institutions and create systemic risks.

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Appendix A – Data Sources

This paper combines data from different sources. The financial data comes from the Central Bank of Brazil (BCB). The National Secretariat of Civil Defense collects information about extreme weather events and natural disasters. Other climate information concerning temperature and rainfall comes from Climate Research Unit at the University of East Anglia (UEA) and IPCC (The Intergovernmental Panel on Climate Change), a scientific organization set up by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP).

The financial data comes from two sources inside the BCB – one dataset is collected at the branch level, and another one is comprised of contract-level information for firms and individuals. The branch-level data comes from ESTBAN (Monthly Banking Statistics). It is generated monthly with the information of the Monthly Banking Statistics, comprising financial statements at the branch level for all commercial banks operating in the country. It contains information on loans, deposits, and savings. Based on ESTBAN, we built a municipal-level panel from 2002 to 2017.

On the other hand, the contract-level data comes from the Credit Information System of the Central Bank of Brazil (SCR), a unique database. SCR is an instrument for recording and consulting information on credit operations, sureties, guarantees, and credit limits granted by financial institutions to individuals and legal entities in the country. It was created by the National Monetary Council and is administered by the BCB. The SCR is a confidential database of the BCB. Thus, exclusively the staff of the BCB conducted the collection and manipulation of individual loan-level data.

It is worth mentioning that, although we have data from the SCR system at the contract level, we are using data at the municipality level (and micro region level for robustness checks). The original contract-level information lets us observe our outcome variables per sectors. The contract-level data is aggregated per sector at the municipal level for analysis. This means that sector, municipality, and year index each cell of our database.

Following Garber et al. (2018), we exploit a unique feature of the SCR data that allows us to break down credit by the type of lending institution. Precisely, our analysis matches bank information from SCR to data on bank control sourced from the BCB database of financial institutions' characteristics (Unicad).

The data on extreme events (droughts and floods) is from the Integrated Information System on Natural Disasters (Sistema Integrado de Informações Sobre Desastres), collected by the Ministry of National Integration. Municipalities regularly report events that trigger action by the Civil Defense, according to the Brazilian Classification of Natural Disasters (COBRADE). Droughts and floods are the most relevant events accounting for more than 70% of the occurrences.

Data on temperature and rainfall comes from the National Center for Atmospheric Research Staff[12]. Based on the information grid of yearly averages, we build a municipality-level panel on temperature and rainfall by taking the average grid points in each municipality. Unfortunately, the data is available only for the 2002-2014 period.

Table A1 brings a detailed description of the main variables considered in our analysis and their respective sources.

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Table A1 – Data Description

Variable	Description	Source	Use of the variable
Climate Variables (Key explanatory variables)			
Droughts	Occurrence of one or more episodes of droughts in the year	National Secretariat of Civil Defense	One of the interest variables in the estimation of extreme climate event effect on financial outcomes
Floods	Occurrence of one or more episodes of floods in the year	National Secretariat of Civil Defense	One of the interest variables in the estimation of extreme climate event effect on financial outcomes
Average Rainfall	Estimates of the average quantity of water precipitation in each municipality for the period of 1961-1990, expressed in millimeters per month	(CRU-UEA)	Historical climate information used to estimate the effect of climate conditions on financial outcomes
Average Temperature	Estimates of the average temperature in each municipality for the period of 1961-1990, expressed in degrees Celsius	(CRU-UEA)	Historical climate information used to estimate the effect of climate conditions on financial outcomes
Average Annual Rainfall	Average annual rainfall across each of the Brazilian Municipalities, expressed in millimeters per year		Together with Average Annual Temperature represents weather conditions in the estimation of panel fixed effects model
Average Annual Monthly Temperature	Average annual temperature across each of the Brazilian Municipalities, expressed in degrees Celsius		Together with Average Annual Rainfall represents weather conditions in the estimation of panel fixed effects model
Average Change in Temperature	Forecast of temperature change for the period between 2030 – 2049, based on Atmospheric Ocean General degrees Celsiu	IPCC (WMO/UNEP)	This variable is added to the observed historical temperature to build the new climate variables $\widehat{C_i}$, used in equation 4

Variable	Description	Source	Use of the variable
Climate Variables (Key explanatory variables)			
Average Change in Rainfall	Forecast of average percent changes for the period between 2030 – 2049, in Rainfall based on Atmospheric Ocean Circulation Models	IPCC (WMO/UNEP)	This variable is added to the observed historical rainfall to build the new climate variables $\widehat{C}_{\iota}$, used in equation (4).
Financial Variables (Key dependent variables)			
Non-performing loans	The non-performing loans corresponds to the quotient of the total amount of credit with arrears of more than 90 days by the credit balance on the base date under analysis	SCR/BACEN	One of the financial outcomes variables used in the disaggregated estimation at sector-municipality level
Balance of the loan portfolio	Total of the "active portfolio", which includes the installments due and overdue (delayed) of credit operations, and excludes the operations assumed as losses. The active portfolio refers not only to the concessions made on the base date, but also to the credit stock at that date, regardless of the grant date	SCR/BACEN	One of the financial outcomes variables used in the disaggregated estimation at sector-municipality level
Demand Deposits	Total amount of demand deposits per municipality	ESTBAN/ BACEN	One of the financial outcomes variables used in the disaggregated estimation at sector-municipality level
Term Deposits	Total amount of term deposits per municipality	ESTBAN/ BACEN	One of the financial outcomes variables used in the disaggregated estimation at sector-municipality level
Savings	Total amount of savings per municipality	ESTBAN/ BACEN	One of the financial outcomes variables used in the disaggregated estimation at sector-municipality level

Source: Authors' Elaboration

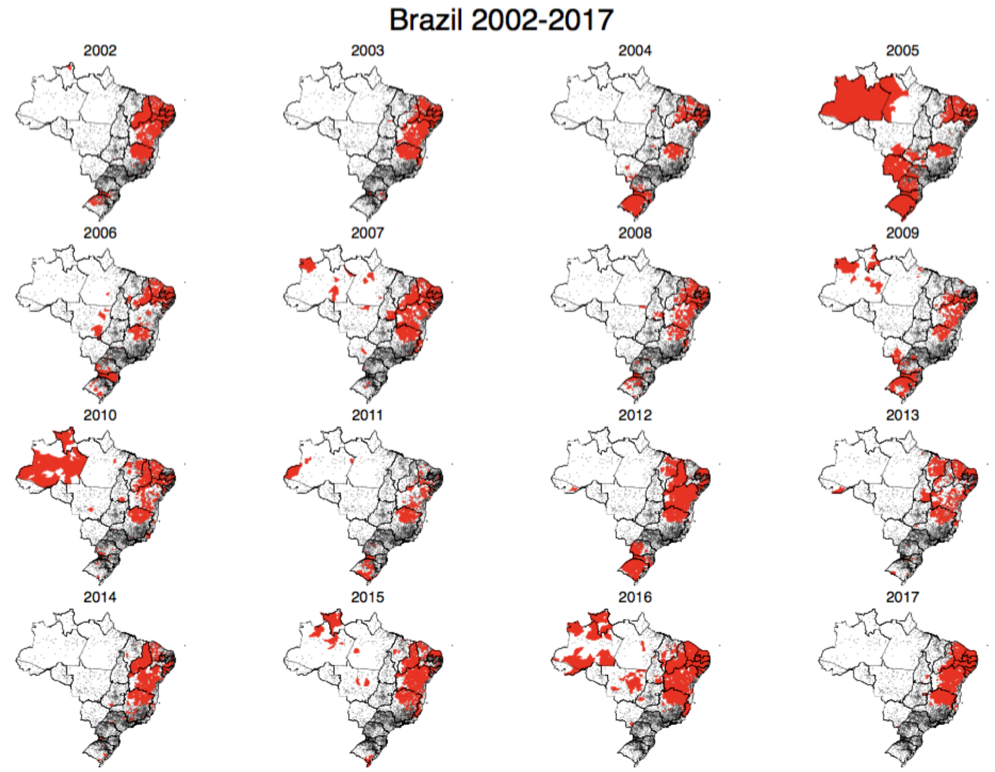
Table A2 : GCMs used in the analysis

Model ID, country, year	Atmosphere, resolution	Ocean, resolution	Temperature (annual and seasonal)	Precipitation (annual and seasonal)
BCCR-BCM2.0, Norway, 2005	T63 (~1.9°×1.9°) L31	0.5-1.5°×1.5°L35		X
CCSM3, USA, 2005	T85 (~1.4°×1.4°) L26	0.3-1°×1°L40		X
CGCM3.1(T47), Canada, 2005	T47 (~2.8°×2.8°) L31	1.9°×1.9°L29	X	X
CNRM-CM3, France, 2004	T63 (~1.9°×1.9°) L45	0.5-2°×2°L31		X
CSIRO-Mk3.0, Australia, 2001	T63 (~1.9°×1.9°) L18	0.8°×1.9°L31	X	X
ECHAM5/MPI-OM, Germany, 2005	T63 (~1.9°×1.9°) L31	1.5°×1.5°L40	X	X
ECHO-G, Germany/Korea, 1999	T30 (~3.9°×3.9°) L19	0.5-2.8°×2.8°L20		X
GFDL-CM2.0, USA, 2005	2.0°×2.5°L24	0.3-1.0°×1.0°L20	X	X
GFDL-CM2.1, USA, 2005	2.0°×2.5°L24	0.3-1.0°×1.0°L20		X
GISS-AOM, USA, 2004	3.0°×4.0°L12	3.0°×4.0°L16	X	X
GISS-EH, USA, 2004	4.0°×5.0°L20	2.0°×2.0°L16		X
GISS-ER, USA, 2004	4.0°×5.0°L20	4.0°×5.0°L13		X
INM-CM3.0, Russia, 2004	4°×5°L21	2°×2.5°L33		X
IPSL-CM4, France, 2004	2.5°×3.75°L19	1-2°×2°L31		X
MIROC3.2 (medres), Japan, 2004	T42 (~2.8°×2.8°) L20	0.5-1.4°×1.4°L44	X	X
MIROC3.2 (hirres), Japan, 2004	T106 (~1.1°×1.1°) L56	0.2-1.4°×0.3°L47	X	X
MRI-CGCM2.3.2, Japan, 2003	T42 (~2.8°×2.8°) L30	0.5-2.0°×2.5°L23		X
PCM, USA, 1998	T42 (~2.8°×2.8°) L26	0.5-0.7°×1.1°L40	X	X
UKMO-HadCM3, UK, 1997	2.5°×3.8°L19	1.5°×1.5°L20		X

Emission Scenario: A1B
Spatial Extent: Global
Present Time Period: 1980 - 1999
Future Time Period: 2030 - 2049

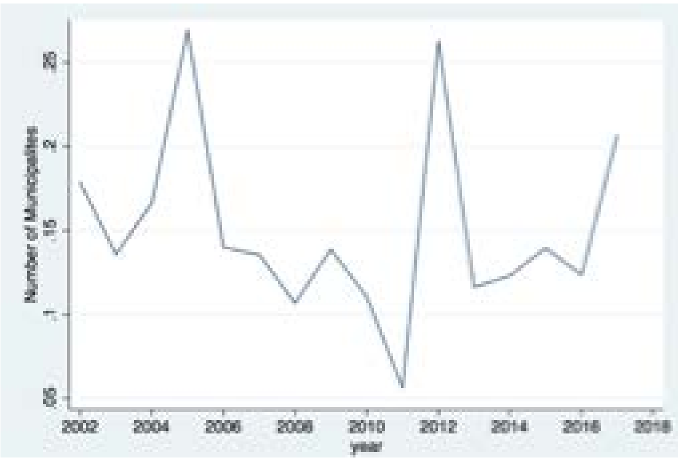
Methodology: All of the GCM outputs as netCDF files were brought into ArcGIS 9.2 as point coverages due to the spatially-variable grain cell sizes of many of the GCM outputs. The scripting language, Python 2.4.1, was used to select time ranges, calculate range means for each model and automate the subsequent process. The point coverages were converted to grids, with the resolutions specified above for each model, except that square grid cell resolutions were used. (The dimension was the minimum if the original answer was rectangular.). The grids were interpolated using kriging to fill in any missing values globally. All grids were resampled to a 2-degree resolution. The emblem means (temperature) and medians (precipitation) were then calculated.
Source: Assunção & Chein (2016)

Figure ~~A 13~~ – Brazilian Distribution of Droughts



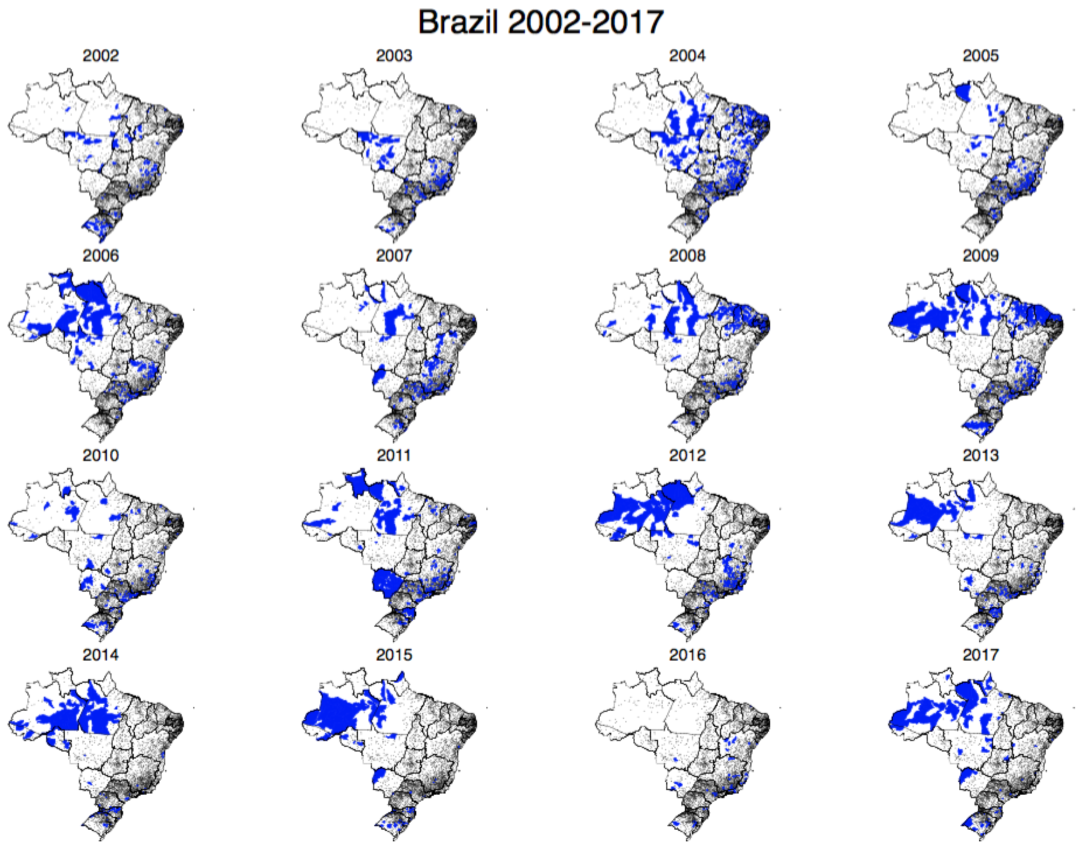
Source: Brazilian National Secretariat of Civil Defense

Figure ~~A 14~~ - Evolution of Droughts in Brazil



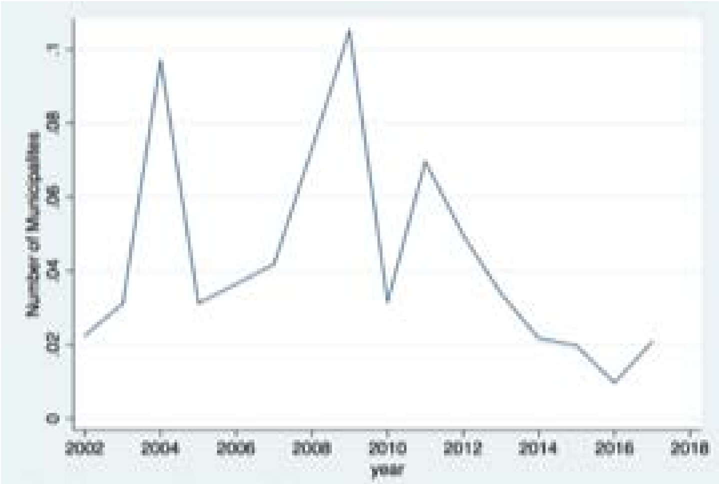
Source: Brazilian National Secretariat of Civil Defense

Figure ~~A 15~~ - Distribution of Floods in Brazil



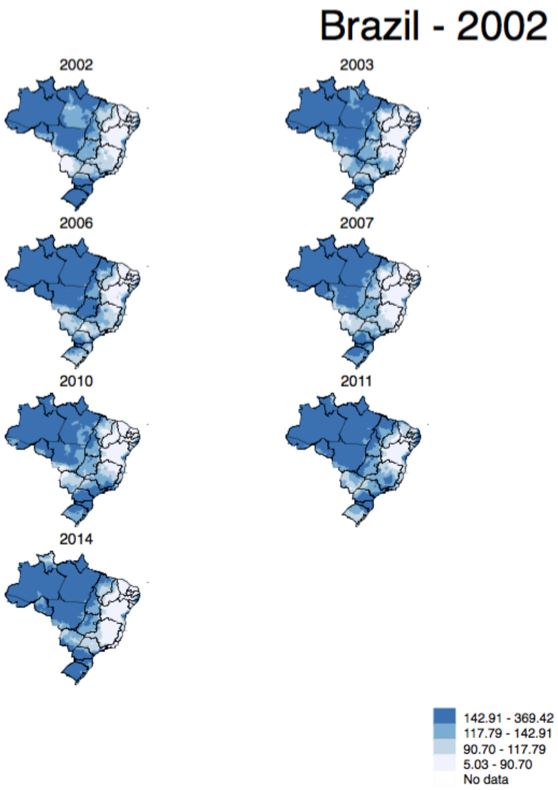
Source: Brazilian National Secretariat of Civil Defense

Figure ~~A 16~~ - Evolution of Floods in Brazil



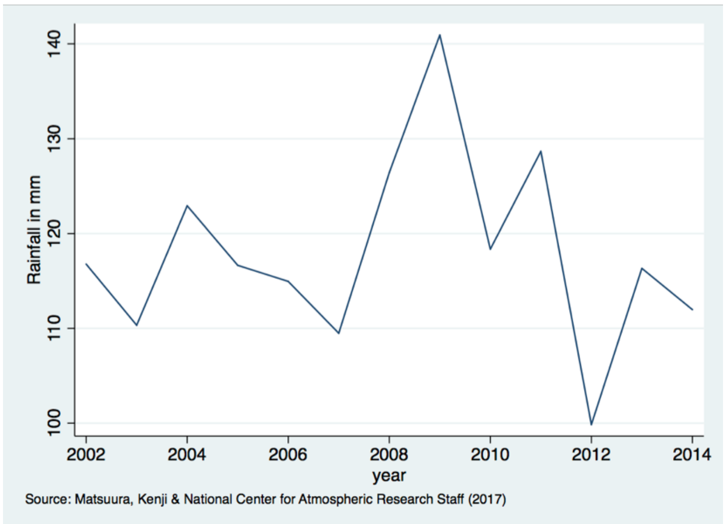
Source: Brazilian National Secretariat of Civil Defense

Figure A5 - Average Rainfall in Brazil



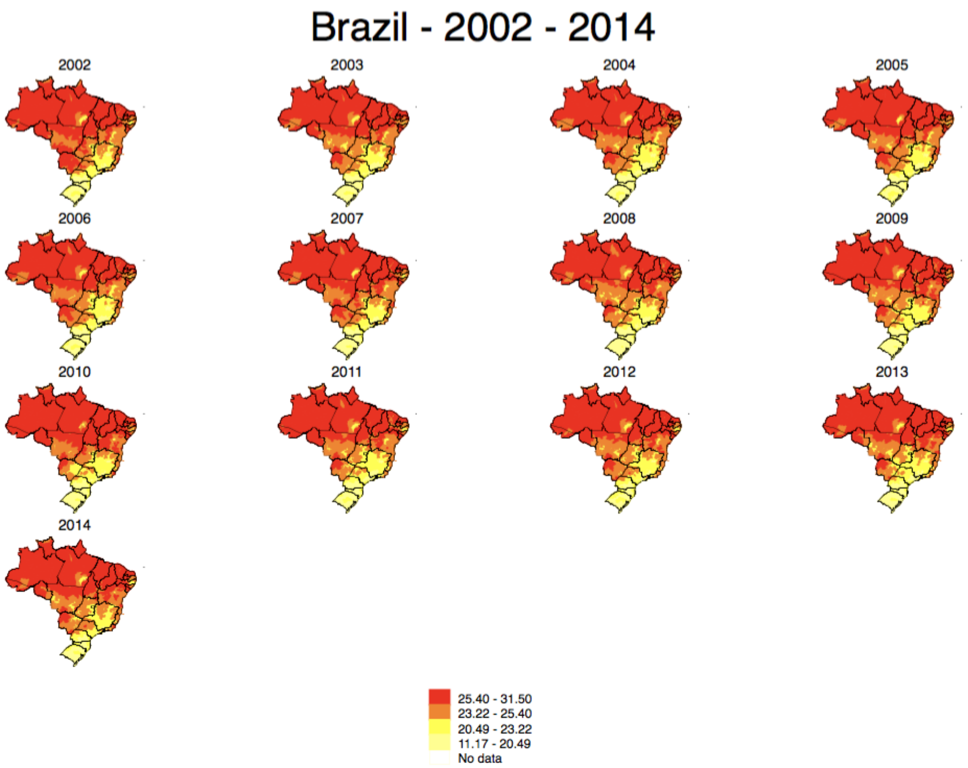
Source: Matsuura, Kenji & National Center for Atmospheric Research Staff (2017)

Figure A6 - Evolution of Rainfall in Brazil



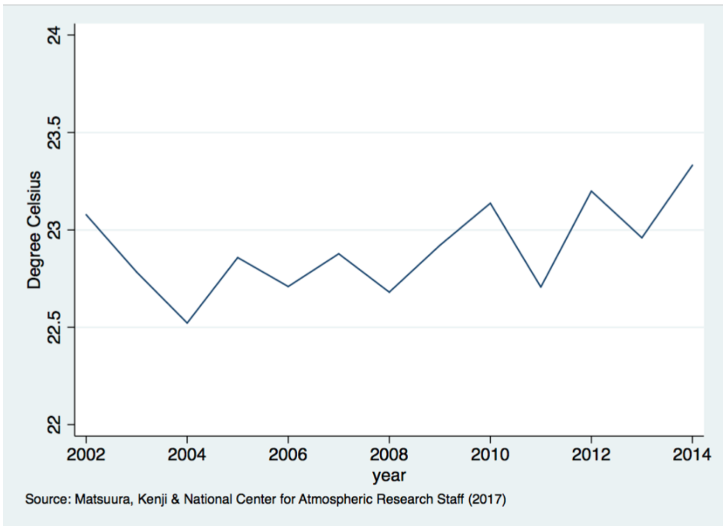
Source: Matsuura, Kenji & National Center for Atmospheric Research Staff (2017)

Figure A7 - Average Temperature in Brazil



Source: Matsuura, Kenji & National Center for Atmospheric Research Staff (2017)

Figure A8 *- Evolution of Temperature in Brazil*



Source: Matsuura, Kenji & National Center for Atmospheric Research Staff (2017)

Appendix B

B.1 Impact of Short-Run Weather Fluctuation

Deposits

Table B.1 - Demand deposits

	(1)	(2)	(3)
Average annual monthly temperature	0.310***	-0.344***	-0.321***
	(0.0337)	(0.0310)	(0.0308)
Average annual rainfall	0.00321***	-0.00105***	-0.00110***
	(0.000724)	(0.000349)	(0.000347)
Average annual monthly temperature squared	-0.00711***	0.00803***	0.00759***
	(0.000757)	(0.000697)	(0.000692)
Average annual rainfall squared	2.81e-06	2.88e-06**	3.01e-06**
	(2.64e-06)	(1.23e-06)	(1.22e-06)
Gdp			0.273***
			(0.0125)
Population			0.259***
			(0.0312)
Fixed-Effects	No	Yes	Yes
Observations	45,059	45,059	45,058
R-squared	0.011	0.171	0.184

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.2 - Savings account

	(1)	(2)	(3)
Average annual monthly temperature	0.392***	-0.198***	-0.180***
	(0.0352)	(0.0250)	(0.0249)
Average annual rainfall	-0.00473***	-0.00153***	-0.00159***
	(0.000739)	(0.000275)	(0.000273)
Average annual monthly temperature squared	-0.0111***	0.00454***	0.00422***
	(0.000791)	(0.000562)	(0.000557)
Average annual rainfall squared	1.94e-05***	4.49e-06***	4.67e-06***
	(2.69e-06)	(9.69e-07)	(9.61e-07)
Gdp			0.204***
			(0.00991)
Population			0.297***
			(0.0247)
Fixed-Effects	No	Yes	Yes
Observations	44,309	44,309	44,308
R-squared	0.034	0.648	0.654

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.3 - Term deposits

	(1)	(2)	(3)
Average annual monthly temperature	0.878***	-0.111	-0.0977
	(0.0528)	(0.0701)	(0.0700)
Average annual rainfall	0.00441***	-0.00157**	-0.00165**
	(0.00109)	(0.000755)	(0.000755)
Average annual monthly temperature squared	-0.0230***	0.00427***	0.00402**
	(0.00118)	(0.00157)	(0.00156)
Average annual rainfall squared	1.70e-06	6.12e-06**	6.34e-06**
	(3.95e-06)	(2.66e-06)	(2.66e-06)
Gdp			0.203***
			(0.0280)
Population			0.241***
			(0.0694)
Fixed-Effects	No	Yes	Yes
Observations	42,364	42,364	42,363
R-squared	0.050	0.475	0.476

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Credit

Table B.4 - Balance of the loan portfolio

	(1)	(2)	(3)
Average annual monthly temperature	0.806***	-0.697***	-0.688***
	(0.0329)	(0.0198)	(0.0196)
Average annual rainfall	0.00485***	-0.00476***	-0.00477***
	(0.000662)	(0.000221)	(0.000219)
Average annual monthly temperature squared	-0.0215***	0.0148***	0.0146***
	(0.000730)	(0.000442)	(0.000439)
Average annual rainfall squared	2.78e-06	1.20e-05***	1.21e-05***
	(2.43e-06)	(7.77e-07)	(7.70e-07)
Gdp			0.276***
			(0.00858)
Population			-0.0418**
			(0.0188)
Fixed-Effects	No	Yes	Yes
Observations	61,170	61,170	61,165
R-squared	0.105	0.879	0.882

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.5 - Non-performing loans

	(1)	(2)	(3)
Average annual monthly temperature	0.236***	0.136***	0.137***
	(0.0166)	(0.0463)	(0.0462)
Average annual rainfall	-0.00703***	0.000732	0.000660
	(0.000335)	(0.000516)	(0.000515)
Average annual monthly temperature squared	-0.00324***	-0.00281***	-0.00286***
	(0.000369)	(0.00104)	(0.00103)
Average annual rainfall squared	2.26e-05***	-1.91e-06	-1.62e-06
	(1.23e-06)	(1.82e-06)	(1.81e-06)
Gdp			-0.329***
			(0.0202)
Population			0.277***
			(0.0447)
Fixed-Effects	No	Yes	Yes
Observations	60,809	60,809	60,806
R-squared	0.107	0.032	0.036

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

B.2 - Impact of Extreme Events on Deposits and Credit

Droughts and Deposits

Table B.6 - Demand deposits

	(1)	(2)	(3)
Drought	-0.345***	0.0349***	0.0190***
	(0.0204)	(0.00648)	(0.00674)
Gdp			0.279***
			(0.0118)
Population			0.237***
			(0.0295)
Fixed-Effects	No	Yes	Yes
Observations	55,593	55,593	48,649
R-squared	0.005	0.144	0.175

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.7 - Savings account

	(1)	(2)	(3)
Drought	-0.343***	0.0390***	0.0187***
	(0.0212)	(0.00530)	(0.00536)
Gdp			0.215***
			(0.00936)
Population			0.314***
			(0.0234)
Fixed-Effects	No	Yes	Yes
Observations	54,842	54,842	47,899
R-squared	0.005	0.641	0.665

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.8 - Term deposits

	(1)	(2)	(3)
Drought	-0.785***	0.0232*	-0.0150
	(0.0315)	(0.0137)	(0.0148)
Gdp			0.243***
			(0.0260)
Population			0.279***
			(0.0647)
Fixed-Effects	No	Yes	Yes
Observations	52,609	52,609	45,855
R-squared	0.012	0.439	0.465

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Droughts and Credit

Table B.9 - Balance of the loan portfolio

	(1)	(2)	(3)
Drought	-0.619***	0.138***	0.0940***
	(0.0189)	(0.00398)	(0.00423)
Gdp			0.289***
			(0.00823)
Population			-0.0325*
			(0.0183)
Fixed-Effects	No	Yes	Yes
Observations	77,965	77,951	66,759
R-squared	0.014	0.881	0.882

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.10 - Non-performing loans

	(1)	(2)	(3)
Drought	0.0801***	-0.0237***	-0.0267***
	(0.00928)	(0.00840)	(0.00951)
Gdp			-0.319***
			(0.0185)
Population			0.296***
			(0.0414)
Fixed-Effects	No	Yes	Yes
Observations	77,601	77,587	66,400
R-squared	0.001	0.050	0.048

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Floods and Deposits

Table B.11 - Demand deposits

	(1)	(2)	(3)
Flood	0.590***	0.0149*	0.00878
	(0.0318)	(0.00899)	(0.00895)
Gdp			0.278***
			(0.0118)
Population			0.238***
			(0.0295)
Fixed-Effects	No	Yes	Yes
Observations	55,593	55,593	48,649
R-squared	0.006	0.144	0.175

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.12- Savings account

	(1)	(2)	(3)
Flood	0.477***	-0.00238	-0.00499
	(0.0329)	(0.00729)	(0.00704)
Gdp			0.214***
			(0.00936)
Population			0.315***
			(0.0234)
Fixed-Effects	No	Yes	Yes
Observations	54,842	54,842	47,899
R-squared	0.004	0.640	0.665

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.13 - Term deposits

	(1)	(2)	(3)
Flood	0.674***	-0.0242	-0.0319
	(0.0488)	(0.0188)	(0.0194)
Gdp			0.244***
			(0.0260)
Population			0.280***
			(0.0647)
Fixed-Effects	No	Yes	Yes
Observations	52,609	52,609	45,855
R-squared	0.004	0.439	0.465

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Floods and Credit

Table B.14 - Balance of the loan portfolio

	(1)	(2)	(3)
Flood	0.109***	-0.0277***	-0.0292***
	(0.0332)	(0.00623)	(0.00620)
Gdp			0.286***
			(0.00826)
Population			-0.0248
			(0.0184)
Fixed-Effects	No	Yes	Yes
Observations	77,965	77,951	66,759
R-squared	0.000	0.879	0.881

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.15 - Non-performing loans

	(1)	(2)	(3)
Flood	0.0570***	0.00164	0.00802
	(0.0161)	(0.0130)	(0.0138)
Gdp			-0.318***
			(0.0185)
Population			0.294***
			(0.0414)
Fixed-Effects	No	Yes	Yes
Observations	77,601	77,587	66,400
R-squared	0.000	0.049	0.048

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

B.3 - Impact of Climate Change

Deposits

Table B.16 - Demand deposits

	(1)	(2)	(3)
Temperature	0.426***	0.431***	0.220***
	(0.0360)	(0.0358)	(0.0177)
Rainfall	0.00943***	0.00951***	0.00861***
	(0.000933)	(0.000928)	(0.000482)
Temperature squared	-0.00965***	-0.00977***	-0.00547***
	(0.000814)	(0.000810)	(0.000402)
Rainfall squared	-1.73e-05***	-1.75e-05***	-3.45e-05***
	(3.66e-06)	(3.64e-06)	(1.86e-06)
Gdp			0.672***
			(0.00587)
Population			0.509***
			(0.00709)
Fixed-Effects	No	Yes	Yes
Observations	54,474	54,474	47,709
R-squared	0.013	0.022	0.796

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.17 - Savings account

	(1)	(2)	(3)
Temperature	0.430***	0.475***	0.414***
	(0.0373)	(0.0362)	(0.0195)
Rainfall	0.00481***	0.00544***	0.00848***
	(0.000948)	(0.000922)	(0.000519)
Temperature squared	-0.0118***	-0.0128***	-0.0121***
	(0.000841)	(0.000818)	(0.000441)
Rainfall squared	-1.56e-05***	-1.85e-05***	-4.89e-05***
	(3.72e-06)	(3.62e-06)	(2.00e-06)
Gdp			0.502***
			(0.00633)
Population			0.685***
			(0.00768)
Fixed-Effects	No	Yes	Yes
Observations	53,735	53,735	46,970
R-squared	0.035	0.087	0.776

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.18 - Term deposits

	(1)	(2)	(3)
Temperature	1.211***	1.269***	0.901***
	(0.0546)	(0.0529)	(0.0342)
Rainfall	0.0252***	0.0256***	0.0176***
	(0.00137)	(0.00133)	(0.000899)
Temperature squared	-0.0300***	-0.0313***	-0.0228***
	(0.00123)	(0.00119)	(0.000774)
Rainfall squared	-6.75e-05***	-6.98e-05***	-7.51e-05***
	(5.38e-06)	(5.21e-06)	(3.48e-06)
Gdp			1.091***
			(0.0111)
Population			0.398***
			(0.0135)
Fixed-Effects	No	Yes	Yes
Observations	51,619	51,619	45,023
R-squared	0.059	0.118	0.692

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Credit

Table B.19 - Balance of the loan portfolio

	(1)	(2)	(3)
Temperature	0.878***	0.878***	0.200***
	(0.0355)	(0.0312)	(0.0140)
Rainfall	0.0270***	0.0270***	0.0171***
	(0.000858)	(0.000754)	(0.000353)
Temperature squared	-0.0225***	-0.0225***	-0.00616***
	(0.000795)	(0.000699)	(0.000315)
Rainfall squared	-7.21e-05***	-7.21e-05***	-6.27e-05***
	(3.41e-06)	(3.00e-06)	(1.38e-06)
Gdp			1.044***
			(0.00476)
Population			0.0285***
			(0.00571)
Fixed-Effects	No	Yes	Yes
Observations	69,608	69,608	59,663
R-squared	0.113	0.316	0.886

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' elaboration

Table B.20 - Non-performing loans

	(1)	(2)	(3)
Temperature	0.0367**	0.0371**	0.113***
	(0.0171)	(0.0169)	(0.0185)
Rainfall	-0.0114***	-0.0114***	-0.00439***
	(0.000414)	(0.000408)	(0.000467)
Temperature squared	0.000882**	0.000873**	-0.00132***
	(0.000384)	(0.000378)	(0.000417)
Rainfall squared	3.46e-05***	3.46e-05***	1.05e-05***
	(1.65e-06)	(1.62e-06)	(1.82e-06)
Gdp			-0.267***
			(0.00630)
Population			0.412***
			(0.00755)
Fixed-Effects	No	Yes	Yes
Observations	69,422	69,422	59,477
R-squared	0.111	0.139	0.179

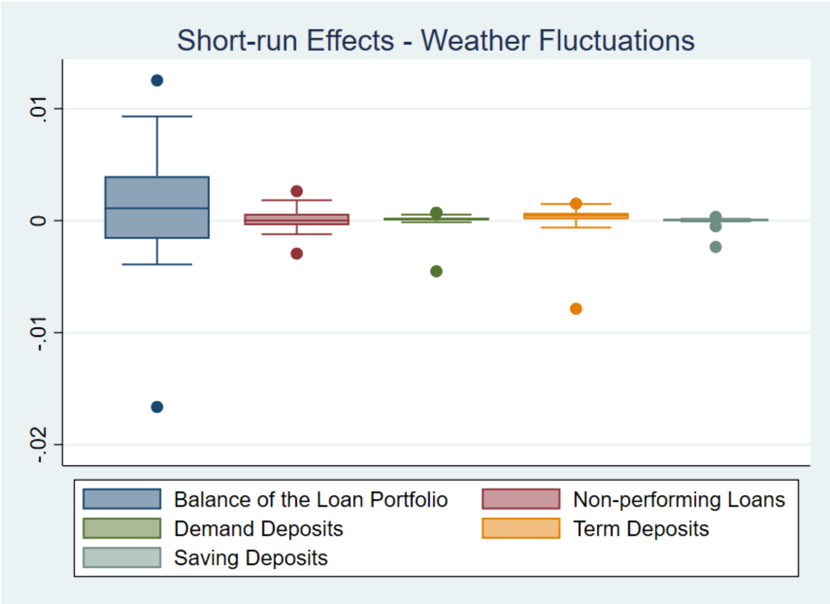
Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

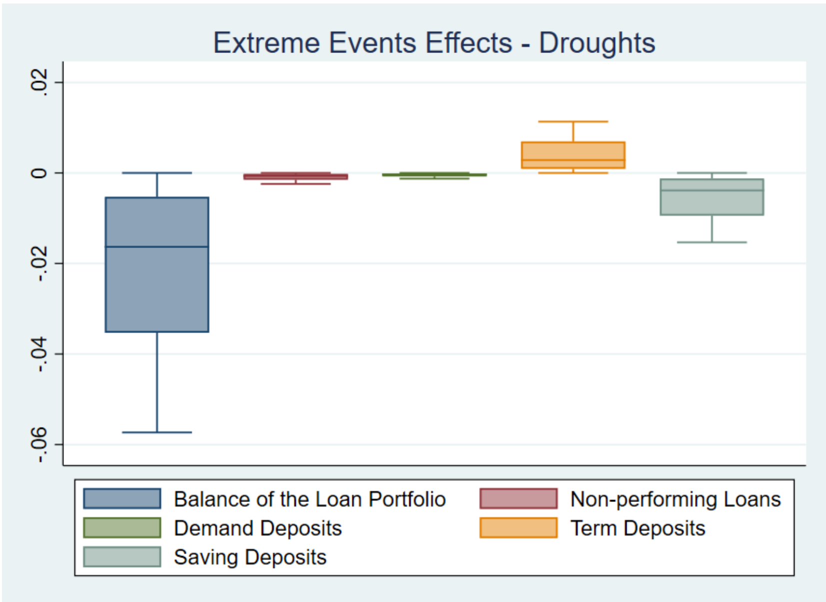
Source: Authors' elaboration

B.4 - Microregion-level estimation

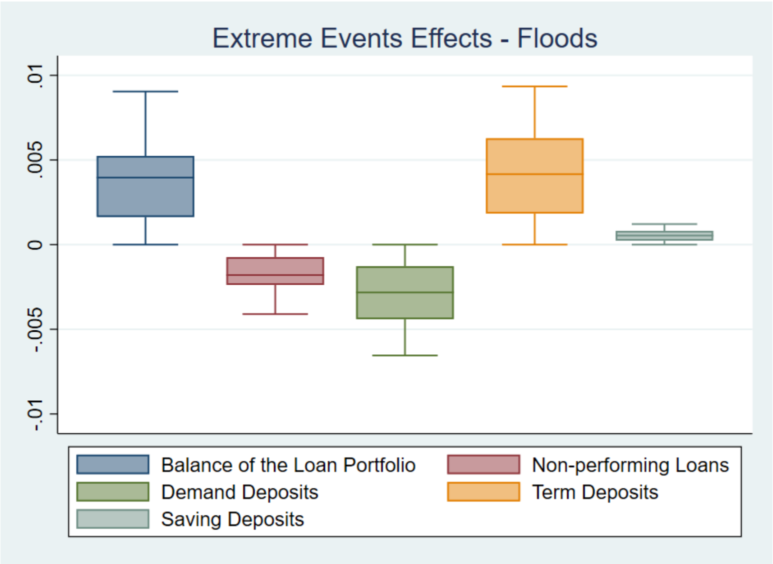
Impacts of Weather Fluctuation



Impacts of Droughts



Impacts of Floods



Impacts of Climate Change