EFFECTS OF CLIMATE ON FINANCE DEFAULT

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Abstract: Developing countries are more vulnerable to the consequences of climate change. Access to credit has been pointed out as crucial to invest in adaptation strategies and to build resilient economies, but bank lending behavior in response to climatic shocks is still not well understood. Demand for credit might increase in times of extreme climate events, but loan delinquency rates might go up as well. Brazil has already experienced unusual climate variability in recent decades, with severe droughts in the Northeast region, the most populous semiarid area in the world. The Bank of the Northeast (BNB), a public bank that has been used to implement local development policies, has lent over US$ 20 billion since the Constitution of 1988 earmarked funds for regional development. This study examines the impact of climatic shocks on BNB's credit operations and delinquency rates over the period 2002-2013, when several climatic events occurred. Fixed-effects panel data estimates indicate that deviations of temperatures and precipitation from their annual mean increase default rates considerably. The main mechanism may be reductions in agriculture output, as delinquency rates are higher in the agricultural sector.

Keywords: effects of climate; finance default; regional funds.
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1. INTRODUCTION

The effects of climate change will not be uniformly distributed across the globe. Developing countries are more likely to disproportionately experience the negative effects of global warming (Adger 2006; Mendelsohn, Dinar, and Williams 2006; Dell, Jones, and Olken 2009, 2012; Fussel 2010; Tol 2018). They have naturally warmer climates than those in the developed world, rely more heavily on climate sensitive sectors such as agriculture, forestry, and tourism, and tend to have a limited adaptive capacity (Tol 2018). Under the Paris Agreement, developed countries will continue to provide climate finance to help the poorest and most vulnerable countries adapt to climate change and build low-carbon economies. It is assumed that most adaptation will occur through normal market reactions, with public spending needed only to provide and strengthen public goods, and to facilitate private sector adjustment (IMF 2008; UNEP-FI 2016). In that context, financial institutions would provide credit to households in times of climatic shocks to offset the effect of the shocks and enhance resilience to the impacts of climate variability. It is not clear, however, that bank lending behavior would be countercyclical with respect to climatic shocks. Demand for credit might increase in the aftermath of extreme climate events, but loan delinquency rates might go up as well. Combined with the well-known credit market imperfections in developing countries (Banerjee 2003), households may find it difficult to get a loan to face the shocks and engage in adaptive behavior.[5] Hence, a systematic empirical investigation in the field is warranted.

In this study, we examine the impact of climatic shocks on bank lending behavior in the most populous semiarid area in the world, in the Northeast region in Brazil. We focus on the effects on the number of credit operations, volume of credit, and delinquency rates over the period 2002-2013, which includes a number of extreme weather conditions. The Brazilian Constitution of 1988 instituted Regional Funds to reduce economic inequality across regions, and public banks have been used to implement those regional policies. The Fund of the Northeast (FNE), in particular, has financed over US$ 20 billion in loan contracts since its inception in 1989. Because public banks might obtain additional resources from the federal government in the aftermath of climate events, this setting may provide the best case scenario of how banks respond to climatic shocks.

In order to estimate the effect of climatic variables on credit operations and default rate, we build a database at the municipality level, and use a fixed-effect panel data approach from 2002 to 2013. The database used in this study was provided by the Ministry of National Integration, the Brazilian federal agency responsible for the FNE. The data on the credit market were from the Central Bank of Brazil (BCB), and the climatic data came from the National Institute of Space Research (INPE), which uses meteorological stations to measure parameters municipalized.

Our core results suggest that the main factors affecting the default rate are the deviation of temperatures around the annual mean, the deviation of rainfall around the annual mean and the municipality's GDP. These estimates reveal an important role for climate in explaining loan delinquency rates. Our results also show that drought shocks are associated

[5] In fact, several case and descriptive studies have suggested that (lack of) access to credit is a key factor associated with (lack of) private adaptation to climate change in the developing world (Deressa et al. 2009; Deressa, Hassan, and Ringler 2011; Below et al. 2012; Ogalleh et al. 2012; Sahua and Mishra 2013; Islam et al. 2014; Abid et al. 2015; Komba and Muchapondwa 2015; Muzamhindo et al. 2015; Abraham and Fonta 2018; Fagariba, Song, and Baoro 2018). The ability of the government to facilitate private adaptive adjustment in developing economies has also been undermined by the increase in the average cost of public debt due to climate vulnerability. It has been estimated that developing countries have paid USD 40 billion in additional interests over the past 10 years on government debt alone (Buhr et al. 2018).

with a decline in agriculture production and that the delinquency rate is higher in the agricultural sector.

There are several studies in the Brazilian economic literature that evaluate the impact of the FNE fund on employment and income, but the literature has paid little attention to the factors associated with FNE's delinquency rates. To the best of our knowledge, we are the first to examine the effects of climate on banking delinquency rates.

The remainder of this paper is organized as follows. Section 2 presents a background on the Brazilian credit market and reviews the literature on the determinants of banking delinquency rates. Section 3 describes the database, and outline the empirical strategy used to examine the impact of several variables, specially the climatic ones, on delinquency rates. Section 4 reports the results, including descriptive analysis of the Northeast's municipalities. Lastly, Section 5 provides some concluding remarks.

2. BACKGROUND

The Brazilian credit market

Brazil has the world's most populated semiarid area with 23 million people, which represents approximately 15% of the Brazilian population. More than half of these people have income below the poverty line and live in rural areas. Climate and, consequentially, places matter for economic and social development. The Brazilian Regional Funds aim to decrease the economic inequality between regions. In case of Northeast region, the Constitutional Financing Fund of the Northeast (FNE) lent only in 2018 almost US$ 4 billion to producers, totalizing more than US$ 20 billion in loan contracts since 1989. At least half of these resources must be allocated to producers in the semiarid region. The FNE fund is managed by the "Banco do Nordeste" (Northeast Bank), a development public bank.

The Brazilian credit market has grown significantly in recent years. According to Toledo (2013), the volume of credit increased from 25% to 50% of GDP in the period between 2002 and 2012. The Constitutional Funds accompanied this trend. Resende et al. (2014) shows that in 1995 the Funds disbursed US$ 800 million, and in 2012 R$ 7 billion (2010 values) were invested. Moreover, between 2015 and 2025 are projected more than US$ 100 billion in financing.

Despite the increase in financing by the Brazilian Regional Funds over the last decades, there is an ambiguous effect on the incentive of banks to lend. On the one hand, given the regional development goal of the constitutional funds, there is a strong motivation to lend. On the other hand, the legislation also encourages loan quality. In particular, the regional banks receive a management fee proportional to the net worth of the funds administered by them, inducing the incentive to loan quality to be considered, otherwise, a delay in payment would directly affect bank earnings. Therefore, there is an ambiguous effect on bank lending behavior.

The importance of the financial system for economic growth has been widely debated in the economic literature (Levine, 1997). Regarding the role of the government over the control of public enterprises, including public banks and their impacts on economic activity, two opposing views have emerged. On the one hand, Atkinson and Stiglitz (1980) argue that public companies are created with the aim of correcting market failures. Shleifer and Vishny (1994) argue that public enterprises are created to achieve political objectives. Banerjee (1997) argues that public banks are supposed to correct market failures, but that does not rule out the possibility of pursuing other objectives.

International empirical studies on financial institutions show a differentiated behavior of public banks vis-à-vis private banks. Public banks may contribute to the promotion of banking competition but, conversely, generate a crowding-out effect in private banking. In the Brazilian case, Coleman and Feler (2014) show that regions with greater presence of public banks had lower losses after the crisis of 2008. Those regions experienced lower rates of payments with more than 90 days of delay and charge offs.

In Brazil, public banks are used to implement regional development policies. More specifically, to make credit operations and manage resources of the Constitutional Finance Funds, which were created by the Federal Constitution of 1988 and regulated by the Law 7,827 of 1989 with the purpose of generating economic and social development.

Determinants of delinquency rates

The international literature points out several factors affecting non-performing loans (bad lending), highlighting the role of macroeconomic variables (systematic) and microeconomic variables (idiosyncratic). From the macroeconomic point of view, the hypothesis is that bank crises are preceded by countries' debt solvency crises (Reinhart; Rogoff, 2010). From the microeconomic point of view, the hypotheses of Berger and De Young (1997) can be summarized as: i) poor management increases default; ii) banks that devote less resources securing quality loans and monitoring them have greater delinquency; iii) poorly capitalized banks tend to lend to worse borrowers, thereby increasing default; iv) diversification reduces delinquency; v) large banks tend to have greater delinquency.

The national literature has followed the international literature in examining the role of micro and macroeconomic factors in explaining default. Linardi and Ferreira (2008) show that the delinquency of Brazilian financial institutions between 2000 and 2007 was sensitive to shocks in the output gap, the variation in the average worker income, and the nominal interest rate. In other words, it was affected by business cycles. Silva et al. (2014) analyze the effect of macroeconomic variables during the period 2001 to 2012 and find that the main explanatory variable of default in Brazil is the economic performance. More specifically, the greater the economic growth, the lower the default and the credit risk.

The literature shows that both macro and microeconomic variables have influence over default. All these factors help to explain the current situation of the Funds, in addition to other variables, which also interfere in the distribution of resources and, consequently, the default rates of constitutional financing.

Another strand of literature relates climate and economic variables. Mendelsohn et al. (1994) provides evidence of the impacts of climate change on farmland value and rural income, and estimate the impacts of variables such as temperature and precipitation. The effects of the climate are non-linear and vary with the seasons. Schlenker et al. (2006) analyses the relationship between climate and socioeconomic variables of North American counties, including land value. They show that the relationship between climate and agricultural production and the price of land is non-linear.

Bosello and Roson (2006) report that global warming may have harmful health-related effects, such as respiratory and cardiovascular problems. In addition to the indirect effects, through changes in food production, water distribution, migration and economic development. One of the effects on health and the economy is verified through hours worked (stock of labor) and spending on health services.

Fankhauser and Tol (2005) make a series of simulations of climate change in the economy, verifying the effects in several economic models. They find that these changes reduce production and, consequently, investment. Developing countries are more vulnerable to climate change. The relationship between environmental variables and agriculture is more direct, because temperature and water are inputs of the biological process. The general findings are that higher temperatures have negative effects on agricultural production. Although uncertain, the effects on manufacturing and services are in the same direction, especially in poor or developing countries, more vulnerable to climatic shocks.

Fishman (2012) examines the potential effect of irrigation as a mechanism for mitigating climate change in the Indian context. Irrigation minimizes impacts from a higher temperature. On the other hand, long-term effects are difficult to estimate due to adaptation, such as the development of new technologies, public policies, among others, can mitigate the effects of climate change. The study also states that migration may be a form of adaptation to climatic shocks. In general, studies have found that increasing the temperature by 1°C reduces the per capita income between 1% and 2%.

Dell et al. (2014) review the literature on climate and economics, presenting several empirical models used in a multifaceted range of studies. They cite Hsiang and Jina (2014), that find negative effects of extreme events (such as storms) on countries' growth rates. Barrios et al. (2010) find that higher precipitation in sub-Saharan Africa is related to higher growth rates. All these pieces of evidences corroborate the effects of climate on economics factors and, consequently, the possibility to affect default.

3. EMPIRICAL STRATEGY

The database used in this study was provided by the Ministry of National Integration, the Brazilian federal agency responsible for the FNE. The data on the credit market were from the Central Bank of Brazil (BCB), specifically from the Monthly Banking Statistics base by municipality (Estban), which includes the monthly position of the balances of the main balance sheets of commercial banks and multiple banks with commercial portfolio. The climatic data came from the National Institute of Space Research (INPE), which uses meteorological stations to measure various meteorological parameters, among which temperature and precipitation were used in this study, municipalized for this study. To obtain different variables on the default rate of the fund while preserving the confidentiality of the data, it was necessary to build the database at the municipal level. The final dataset is a panel with annual information from 2002 to 2013.

To uncover the impact of climatic shocks on bank lending behavior, we use a fixed-effect panel data analysis. The estimating equation is:

$$y_{it} = \alpha + C_{it}\beta + Z_{it}\gamma + \eta_i + \delta_t + \lambda_s f(t) + u_{it} \quad (1)$$

where *i* refers to each of the municipalities analyzed, *t* refers to years, y_{it} is number/volume of credit operations or the default rate,[6] C_{it} represents climatic variables, and Z_{it} represents control variables. The term η_i denotes a set of municipal fixed effects, and δ_t denotes a set of year fixed effects. Lastly, u_{it} is an error term that is allowed to have arbitrary correlation over time and space in the covariance matrix by clustering at the municipality level.

Noting that *C* varies plausibly randomly over time – i.e., "weather" draws from the county "climate" distribution – this approach resembles an experimental design and, therefore, β identifies the causal effect of climatic shocks on bank lending behavior. The fixed effects for municipality, η_i, absorb fixed spatial characteristics, whether observed or unobserved, disentangling the shock from many possible sources of omitted variable bias, such as geographic features (e.g., elevation and ruggedness) and municipality baseline economic characteristics (e.g., GDP, population, employment) that are likely to be correlated

[6] The default rate refers to the total value of installments with more than 90 days late divided by the amount of loans.

to climatic variables. Year-fixed effects, δ_t, further neutralize any common trends and thus help ensure that the relationships of interest are identified from idiosyncratic local shocks. State-specific time trends $\lambda_s f(t)$ are added to allow for differential trends in subsamples of the data, controlling for a number of observed and unobserved factors affecting the outcome of interest that vary over time at the state level such as banking regulations, and state public awareness regarding the impacts of climate change. In our preferred specification of equation (1) *f(t)* is a quadratic function of time, that is, it includes state-specific quadratic time trends, as will be explained in more details in the Results section.

An important methodological decision to make when implementing panel regression models regards the inclusion of other time-varying observables, Z_{it}. Including Z_{it} may absorb residual variation, hence producing more precise estimates. However, adding more controls will not necessarily produce an estimate of β that is closer to the true β. If the Z's are themselves an outcome of C, which may well be the case for controls such as GDP, institutional measures, and population, including them will induce an "over-controlling problem" (Dell, Jones, and Olken 2014). For example, suppose that poorer municipalities in Brazil tend to both be hot and have low-quality institutions. If hot climates were to cause low-quality institutions, which in turn cause low income, then controlling for institutions in equation (1) can have the effect of partially eliminating the explanatory power of climate, even if climate is the underlying fundamental cause. Therefore, if loan delinquency rate is the outcome of interest, for example, then controlling for changes in local employment or infrastructure would be problematic if the climatic variables influence those changes, directly or indirectly. Our preferred specification of equation (1) includes only a few time-varying explanatory variables, to reflect patterns of development across the Northeast region.

The explanatory variables used in the regressions are: i) average rainfall; ii) deviation from the average rainfall iii) average temperature; iv) deviation from the average temperature; v) logarithm of municipal GDP; vi) total value financed by each type of risk (FNE, PROCERA, bank or shared); vii) total loans granted in the municipality; and viii) dummy equal to 1 if the municipality has any BNB agency.

4. RESULTS

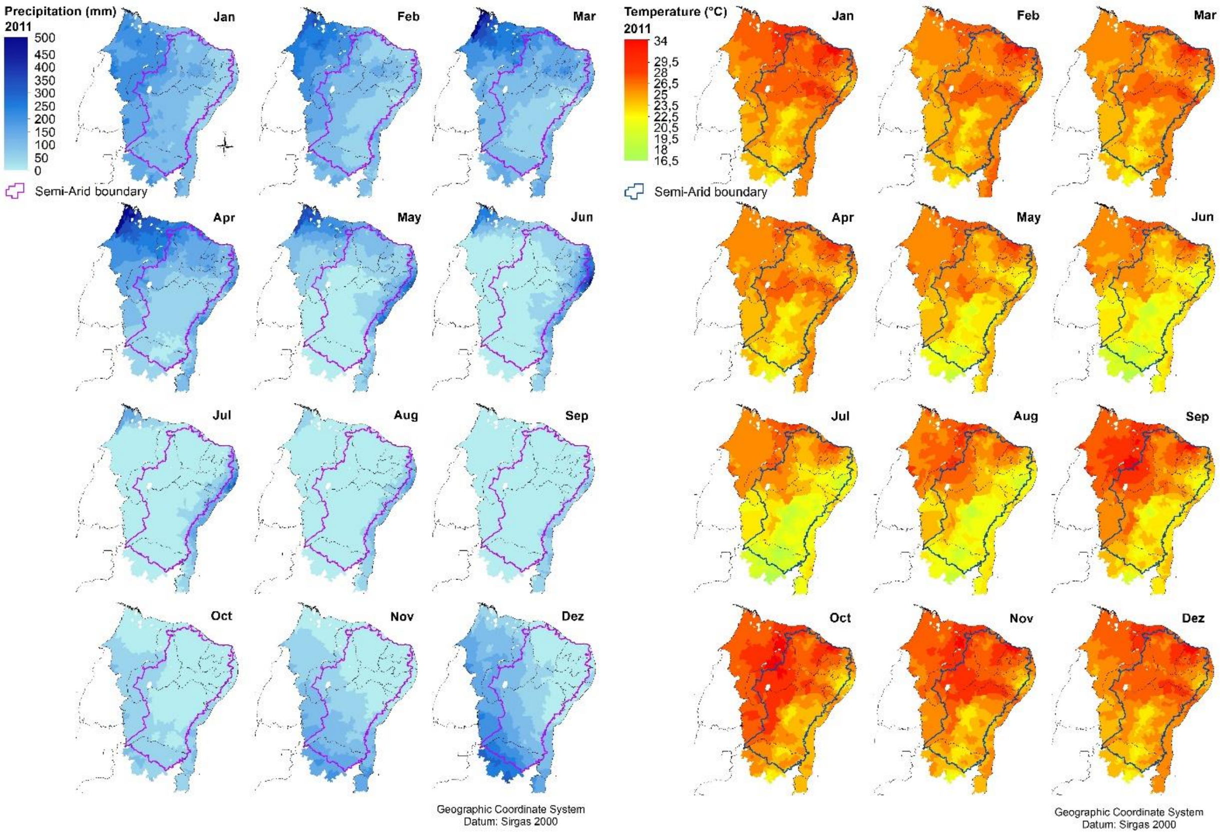
a. Descriptive Analysis

The Northeast is one of five macro regions of Brazil. It has a population of 56.5 million of habitants, equivalent to the Italian population, and an area of 1.5 million of squared kilometers, larger than France, Spain and Sweden together. Its average Human Development Index (HDI) was 0.659 in 2010, worse than all European countries in 2013 (UNDP, 2013).

The region is divided in nine states, 1990 municipalities, and more than 62% of its area belongs to the Semiarid (actually with 1135 municipalities), highlighted by the purple line on the map below. The FNE reaches the north of another region, Southeast, a semiarid area as poor as the Northeast, which is also managed by the Northeast Development Superintendence (SUDENE).

The Northeast region is located in the Earth's intertropical zone. Hence, the incidence of solar irradiance implies high temperatures during the whole year, and severe droughts especially in the countryside. The figure below shows a map of precipitation and average temperature per month in 2011. The rains are not well distributed spatially and temporally during the year. In some periods the average monthly temperature reaches 32^{o}C and 16^{o}C simultaneously in different locations. Regarding precipitation, it has a high amplitude from 240mm until 2100mm per year. This climate surely influences economic activities, especially agriculture. Indirectly, the agricultural impacts affect the industrial sector and even the services sector, generating multiplier effects in the economy. This helps understand the socioeconomic differences between the semiarid and the rest of Northeast region.

Figure 1 – Map of precipitation and average temperature per month in the FNE zone



Source: National Institute of Spatial Research – INPE.

Table 1 reveals the large differences across the 1990 northeastern municipalities, highlighting the large amplitude of the socioeconomics and climate variables. In general, the municipalities are medium size, poor, with low-medium HDI, and the value of the FNE represents little in the local economy (less than 3% of GDP). But in some cases, the value of FNE were high, considering the situation of the region, and the economic impacts were relevant, as showed by the literature (Resende, 2014).

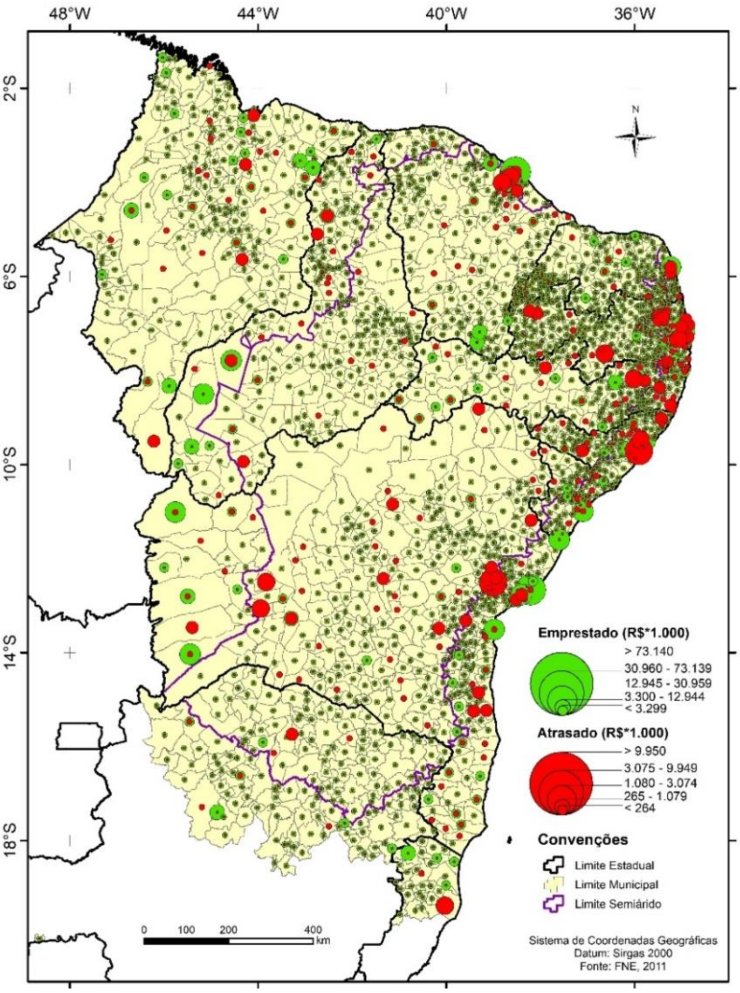
Table 1 – Summary statistics of municipalities (2010)

Variable	Mean	Std. Dev.	Min	Max
FNE				
Value of financing	54,570	286,007	0	4,969,533
Number of operations	201	213	0	1,763
Socioeconomics				
Population	28,321	103,779	1,247	2,650,633
HDI Municipality	0.594	0.045	0.443	0.788
Life expectancy	70.5	1.9	65.3	77.1
Years of study	8.9	0.8	5.8	11.0
Income per capita (R$ - month)	283.5	101.0	96.3	1,144.3
Percentage of poor	40.5	11.3	2.2	78.2
Percentage of sewage*	16.8	12.8	0	73.0
Climate				
Volume of rain (mm)	890.3	356.6	241.0	2,285.6
Average temperature per month (^oC)	25.6	1.9	19.5	30.9

* Percentage of people in households with inadequate water supply and sanitation
Source: IBGE, Ministry of National Integration, RAIS, IPEA/FJP/PNUD.

As discussed before, several studies suggest that climate influences economic activity and, consequently, loan repayment. Figure 2 maps municipalities according to loan volume and delinquent credit. High default values are shown in the richest and most populated municipalities, but high default rates (proportional to the total financed) not necessarily occurred in those locations. Although not evident in the figure, the literature provides evidence that more dynamic areas have received more FNE resources, but it is unclear whether these places, with high growth economic rates, have bigger default rates.

Figure 2 – FNE Credit operations: current and default values by municipality (2010)



Source: Ministry of National Integration.

Table 2 reports the total amount financed and defaulted between 2006 and 2013. The values before 2006 had another methodology of measure, hence, was not showed. The Brazilian economy grew up considerably is this period such that the value of available resources of Constitutional Funds also increased, what explain that FNE real value almost doubling between 2006 and 2013. The same occurred with the average value of operation, that continued low, since the number of operations remained stable. Despite these facts, the default amount did not follow FNE trends, implying default rates even lower over time.

Table 2 – Credit operations of FNE by year [7]

	2006	2007	2008	2009	2010	2011	2012	2013
Total FNE (R$ million)	22,556	25,561	29,270	32,848	36,218	37,775	38,533	40,595
Number of operations (thousand)	1,534	1,490	1,401	1,533	1,579	1,484	1,572	1,481
Average value of operation (R$)	14,699	17,151	20,885	21,421	22,935	25,451	24,515	27,418
Total of default (R$ million)	1,129	1,363	1,368	1,196	1,341	1,250	1,356	1,356
Default rate	5.0%	5.3%	4.7%	3.6%	3.7%	3.3%	3.5%	3.3%

Note: 2013 Prices, which were deflated by IPCA (Brazilian index of inflation, measured by IBGE).
Source: Ministry of National Integration.

[7] For reference, the Real/USD and Real/Euro exchange rates in December 31, 2013, were R$ 2.34 and R$ 3.22, respectively.

b. Regressions

This subsection reports the results of the estimation of equation (1) considering as main explanatory variables the deviations of rainfall and temperature with respect to the historical average. The results show that the larger the deviations of temperature and rainfall from the historical average, the higher the default rates. Since the deviations in reaction temperature are much higher in relation to the deviation of rainfall.

Then, it is possible to observe the positive effect of the municipality having declared a state of emergency due to some type of climatic calamity on the rate of default. The results presented in table below show the economic fragility of the bank’s operating region, showing that adverse weather events strongly determine bank defaults in the FNE.

In Table 4 we present the results of the effect of the dummy variables of calamity for excess rainfall and calamity for little rainfall. As can be observed, the results suggest that if the municipality declare a state of emergency due to heavy rain, the effect is quite similar to the cases presented, increasing the default rate. The impact however is far superior than when all the calamity events were considered as a whole. This evidence suggests that shocks resulting from flooding and flooding-related situations greatly impair local economic activity, thereby reducing the borrower'' repayment capacity. However, unlike the previous cases, in situations of calamity declared by little rainfall there is no statistically significant evidence on FNE default.

Table 3 - Fixed Effects Model: Factors that affect the default rate

	Dependent Variable: Default Rate (%)						
	1	2	3	4	5	6	7
Deviation Rainfall	0.0789***	0.126***	0.122***	0.111***	0.0781***	0.0706***	0.0207***
	(0.00496)	(0.00514)	(0.00496)	(0.00488)	(0.00469)	(0.00455)	(0.00600)
Deviation Rainfall (t-1)	-11.25***	0.121***	0.124***	0.123***	0.107***	0.103***	0.0114*
	(0.575)	(0.00532)	(0.00514)	(0.00503)	(0.00478)	(0.00464)	(0.00592)
Temperature Deviation		-9.550***	-10.49***	-9.022***	-5.215***	-3.443***	3.697***
		(0.647)	(0.626)	(0.615)	(0.591)	(0.577)	(0.789)
Temperature Deviation (t-1)		-28.17***	-25.34***	-22.26***	-13.79***	-9.369***	0.690
		(0.654)	(0.643)	(0.642)	(0.645)	(0.652)	(0.673)
Risk FNE (%)			-0.101***	-0.0339***	0.157***	0.287***	0.180***
			(0.0372)	(0.0365)	(0.0349)	(0.0341)	(0.0369)
Risk Bank (%)			-1.397***	-1.293***	-0.250***	0.346***	0.259**
			(0.0834)	(0.0818)	(0.0818)	(0.0822)	(0.113)
Risk Shared (%)			-0.403***	-0.350***	-0.0816***	0.110***	0.0460
			(0.0370)	(0.0362)	(0.0350)	(0.0344)	(0.0375)
Operations number				-0.0138***	-0.0123***	-.0106***	-0.0101***
				(0.000559)	(0.0005)	(0.000)	(0.000696)
Agency BNB				-3.035	3.107	4.112	3.512
				(3.145)	(2.984)	(2.879)	(3.730)
Log GDP					-22.47***	-4.810***	-11.63***
					(0.568)	(0.818)	(1.005)
PNDR1*year						-4.263***	-3.125***
						(0.242)	(0.281)
PNDR2* year						-2.295***	-1.502***
						(0.0933)	(0.109)
PNDR3* year						-1.564***	-1.166***
						(0.0919)	(0.108)
PNDR4* year						-2.307***	-1.745***
						(0.0873)	(0.105)
Constant	22.15***	43.58***	66.47***	58.16***	268.9***	4,279***	3,173***
	(0.827)	(1.290)	(3.625)	(3.572)	(6.313)	(139.0)	(160.4)
Obs	17,722	15,734	15,734	15,734	15,734	15,734	
Municipalities	1,988	1,986	1,986	1,986	1,986	1,986	10,612
R2	0.033	0.162	0.221	0.254	0.330	0.378	1,984

Notes: Standard errors in parentheses. * p<0.10; ** p<0.05; *** p<0.01. Data between the years 2002 and 2013 using 1988 municipalities in an unbalanced panel.

In addition, there is evidence that rainfall and temperature levels correlate with loan repayment, which deserves further investigation, with analyzes segmented by program or credit lines, since the rural program is likely to be even more influenced by climatic factors. One of the reasons for these results is related to the findings of Melo and Resende Filho (2017), who found evidence that the higher price-paid price ratio for agriculture increases the default rate. As climate factors determine prices, especially agricultural prices, it is possible that this is mechanism through which delinquency is affected, which corroborates the results found here.

In this sense, Mendelsohn, Nordhaus and Shaw (1994) examine the effects of climatic variables and show that farmers adapt crop production according to economic and environmental factors, including temperature and precipitation. Thus, the productive activities and, consequently, the profitability of the business are directly affected by the climate. They suggest that these effects tend to be non-linear and vary according to the seasons. Therefore, according to the results below, given the variation of the coefficients, including between the months.

Table 4 - Fixed Effects Model: Factors that affect the default rate

Dependent Variable: Default Rate (%)				
	1	2	3	4
Calamity for excess rainfall	1.591***	1.077***	2.002***	2.032***
	(0.286)	(0.299)	(0.296)	(0.296)
Calamity for excess rainfall (t-1)				1.640***
				(0.396)
Deviation Rainfall		0.0677***		
		(0.00440)		
Deviation Rainfall (t-1)		0.106***		
		(0.00431)		
Temperature Deviation		-3.288***	-2.124***	-1.933***
		(0.539)	(0.528)	(0.530)
Temperature Deviation (t-1)		-9.086***	-6.192***	-6.278***
		(0.612)	(0.614)	(0.614)
Risk FNE	0.162***	0.282***	0.324***	0.320***
	(0.0247)	(0.0324)	(0.0331)	(0.0331)
Risk Bank	0.302***	0.352***	0.581***	0.559***
	(0.0635)	(0.0772)	(0.0783)	(0.0784)
Risk Shared	0.0392	0.105***	0.145***	0.140***
	(0.0249)	(0.0327)	(0.0333)	(0.0333)
Operations number	-0.00962***	-0.0101***	-0.0105***	-0.0104***
	(0.000451)	(0.000472)	(0.000481)	(0.000481)
Dummy BNB	5.025***	3.960	4.906*	4.924*
	(1.934)	(2.795)	(2.855)	(2.853)
Log (GDP)	-11.41***	-4.789***	-5.630***	-5.602***
	(0.642)	(0.772)	(0.787)	(0.787)
PNDR(High)	-2.829***	-4.292***	-4.340***	-4.344***
	(0.176)	(0.236)	(0.241)	(0.241)
PNDR(Low)	-1.348***	-2.305***	-2.347***	-2.375***
	(0.0650)	(0.0881)	(0.0899)	(0.0901)
PNDR(Dinamic)	-0.893***	-1.552***	-1.788***	-1.809***
	(0.0609)	(0.0858)	(0.0870)	(0.0871)
PNDR(Stagnant)	-1.393***	-2.331***	-2.484***	-2.509***
	(0.0596)	(0.0826)	(0.0840)	(0.0842)
Constant	2,624***	4,265***	4,572***	4,620***
	(91.81)	(131.6)	(133.6)	(134.0)
Obs	21,502	17,482	17,482	17,482
Municipalities	1,987	1,986	1,986	1,986
R2	0.280	0.383	0.356	0.357

Notes: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

The next specifications used bins to filter temperature and precipitation, based on quartiles of the distribution. It offered non-parametric alternatives to linear and quadratic specifications, and the results are higher but qualitatively similar to the previous two.

As for the results of the non-parametric specifications, the default appears to increase when temperature and precipitation are high (column 1). Interestingly, volume and credit operations at lower temperatures appear larger (columns 2-4). Perhaps because default does not seem to increase in this temperature range. With regard to precipitation intervals, intermediate levels in default does not seem to increase, and credit seems to expand. This is consistent with maximizing profits by banks. More interesting is the fact that defaults and credit seem to increase when annual precipitation is high. This is consistent with public banks rescuing struggling citizens.

Table 5 - Fixed Effects Model: Factors that affect the default rate

Dependent Variable	**Default Rate (%)**	**ln(Credit Volume)**	**ln(#Credit Operations)**	**#Credit Operations**
	(1)	(2)	(3)	(4)
Avg Temp: Below 23C	0.5924	0.0832**	0.0557	24.3742
	(0.6935)	(0.0376)	(0.0413)	(18.1156)
Avg Temp: Above 27C	2.0134***	0.0110	0.0326	4.8876
	(0.6169)	(0.0261)	(0.0238)	(15.2130)
Reference - Avg Temp: 23-25C	0	0	0	0
Total Prcp: Below 500mm	0.2859	-0.0264	-0.0783***	-10.7500
	(0.5222)	(0.0221)	(0.0215)	(16.2557)
Total Prcp: 1000-1500mm	0.2513	0.0270*	0.0321**	18.4622**
	(0.3480)	(0.0158)	(0.0161)	(9.2113)
Total Prcp: Above 1500mm	1.8522***	0.0476	0.0484	39.4357**
	(0.6886)	(0.0337)	(0.0321)	(17.5892)
Reference - Total Prcp: 500-1000mm	0	0	0	0
Obs	17,722	17,722	17,722	17,722
R-squared	0.5937	0.9046	0.8743	0.8774
Mean Dependent Variable	13,52	14,88	5,73	592,75

Robust standard errors in parentheses

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

A fundamental issue in equation (1) regards the functional form of C. Inspired by Deschenes and Greenstone (2011) and Barreca et al. (2016) we use indicator variables for bins of annual average temperature and for bins of annual total precipitation. Thus, the only functional form restriction is that the impact of the annual average temperature on the default rate and credit is constant within those intervals. The choice of temperature bins represents an effort to allow the data, rather than parametric assumptions, to determine the credit-temperature relationship, while also obtaining estimates that are precise enough that they have empirical content. This degree of flexibility and freedom from parametric assumptions is only feasible because we are using 10 years of data from a large area of Brazil. Similarly, we use simple indicator variables for precipitation based on annual rainfall in municipality i in year t. Each indicator corresponds to roughly a 500mm bin, ranging from less than 500mm to more than 1500mm.

5. CONCLUDING REMARKS

The FNE is the main instrument of regional policy in the Northeast region of Brazil. This fund distributed more than US$ 20 billion in loan contracts since 1989. This study investigated the default of the FNE between 2002 and 2013, highlighting the link between economic and climate factors. Besides, the fall in the default rate in 2006 and the creation of the PNDR, which classified the regions according to typologies, gave relevant guidelines for the Constitutional Funds. In that period, another determining factor of the late loan payment was the creation of the bonus and the subsequent unification, in 2013.

The literature shows that both, macroeconomic and microeconomic variables, have influence over default. All these factors help to explain the current situation of the FNE, in addition to other variables, which also interfere in the distribution of resources and, consequently, the default rates of constitutional financing.

This article makes important contributions regarding FNE default rates, since it is the first to analyze the factors associated with FNE default. Among the main results, we can highlight the influence of temperature and average rainfall, temperature deviation and average rainfall, GDP, presence of BNB agency in the municipality, and whether the type of risk is 100% FNE or shared. From the results found, there are new opportunities for future research, especially regarding guarantees and risk sharing between the fund and BNB.

Among other suggestions not analyzed in the study is the use of fiduciary alienation in the Fund's contracts, which could work well in the case of some lines, such as those that finance certain types of machines and equipment. Although some financing requires collateral, instruments such as fiduciary alienation can minimize the bank's risk of not receiving its debts. This would ensure greater legal certainty for the lender by maintaining ownership of the property financed on its behalf. Mendonça (2013) states that, especially in the real estate market, the institution of this tool was essential to generate an environment favorable to its recent expansion. It is important to highlight the challenge of this tool in a rural poverty scenario verified in several municipalities in the region.

One of the limitations of the paper was not to examine the factors correlated with default at the individual level,[8] that is, investigate characteristics of both the contractor and the borrower, such analyzed Bouldriga, Taktak and Jellouli (2009). Another part that has not been studied, and therefore could be considered, is credit supply, more specifically banking, i.e. bank efficiency, spatial distribution, bank competition, agency characteristics, etc.

The main results of this study suggest that the main explanatory factors of FNE default are the deviation from the average temperature and the deviation from the average rainfall, the Gross Domestic Product of the municipality and the presence of a regional bank agency in the municipality. The effect of the mean rainfall deviation on the default rate is zero, as is the effect of average rainfall. On the other hand, the mean temperature deviation shows a negative signal. That is, the higher the temperature disparity in relation to the average, the lower the default rate.

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[8] In this case, because of the database confidentiality restriction.

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