Revista Brasileira de Climatologia
Brazilian Journal of Climatology

OPEN ACCESS

EFFECTS OF CLIMATE ON BANK DEFAULT

Efeitos do clima na inadimplência bancária

Efectos del clima sobre la incumplimiento bancario

Guilherme Resende Oliveira
Instituto Mauro Borges de Estatísticas e Estudos Socioeconômicos, Governo de Goiás
resendego@gmail.com

Abstract: Developing countries are more vulnerable to the consequences of climate change. The access to credit has been highlighted as crucial to the investment in adaptation strategies and to build resilient economies, but bank lending behavior in response to climatic shocks is still not well understood. The demand for credit is expected to increase in periods of extreme climate events, but loan delinquency rates would likely go up as well. In recent decades, Brazil has already experienced unusual climate variability with severe droughts in the Northeastern 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 earmarking of funds for regional development in the Constitution of 1988. This study examines the impact of climatic shocks on the BNB's credit operations and delinquency rates when several climatic events occurred over the period of 2002-2013. The econometric regressions method was used with fixed-effects panel data and its estimates indicate that deviations of temperature and precipitation from their annual mean increased default rates considerably. One of the factors that affects bank defaults may be the reduction in agricultural production, since default rates are higher in this sector, which suffers from the income reduction of producers whom are affected by these climate variations.

Keywords: Effects of climate. Bank default. Regional funds.

Resumo: Os países em desenvolvimento são mais vulneráveis às consequências das mudanças climáticas. O acesso ao crédito tem sido apontado como crucial para investir em estratégias de adaptação e construir economias resilientes, mas o comportamento dos empréstimos bancários em resposta a choques climáticos ainda não é bem compreendido. A demanda por crédito pode aumentar em épocas de eventos climáticos extremos, mas as taxas de inadimplência também podem subir. O Brasil já experimentou uma variabilidade climática incomum nas últimas décadas, com fortes secas na região Nordeste, a área semiárida mais populosa do mundo. O Banco do Nordeste (BNB), um banco público que tem sido usado para implementar políticas de desenvolvimento local, já emprestou mais de US$ 20 bilhões desde a Constituição de 1988 destinou recursos para o desenvolvimento regional. Este estudo examina o impacto dos choques climáticos sobre as operações de crédito do BNB e as taxas de inadimplência ao longo do período 2002-2013, quando vários eventos climáticos ocorreram. Foi utilizado o método de regressão econométrica com dados em painel de efeitos fixos, os quais indicam que os desvios de temperatura e precipitação em relação à média anual aumentam consideravelmente as taxas de inadimplência. Um dos fatores que afeta a inadimplência bancária pode ser a redução da produção agrícola, uma vez que as taxas de inadimplência são maiores neste setor, que sofre com a queda de receita dos produtores atingidos por variações climáticas.

Palavras-chave: Efeitos do clima. Inadimplência bancária. Fundos regionais.

Resumen: Los países en desarrollo son más vulnerables a las consecuencias del cambio climático. Se ha señalado que el acceso al crédito es fundamental para invertir en estrategias de adaptación y construir economías resilientes, pero aún no se comprende bien el comportamiento de los préstamos bancarios en respuesta a las crisis climáticas. La demanda de crédito puede aumentar en épocas de eventos climáticos extremos, pero las tasas de morosidad de los préstamos también pueden aumentar. Brasil ya ha experimentado una variabilidad climática inusual en las últimas décadas, con severas sequías en la región noreste, la zona semiárida más poblada del mundo. El Banco del Noreste (BNB), banco público que se ha utilizado para implementar políticas de desarrollo local, ha prestado más de 20 mil millones de dólares desde la Constitución de 1988 con fondos destinados al desarrollo regional. Este estudio examina el impacto de los choques climáticos en las operaciones crediticias del BNB y las tasas de morosidad durante el período 2002-2013, cuando ocurrieron varios eventos climáticos. Se utilizó el método de regresión econométrica com datos de panel de efectos fijos, que indican que las desviaciones de las temperaturas y la precipitación de su media anual aumentan considerablemente las tasas de incumplimiento. Uno de los factores que incide en la morosidad bancaria puede ser la reducción de la producción agrícola, ya que las tasas de incumplimiento bancario son más altas en este sector, que sufre con la disminución de ingresos de los productores afectados por las variaciones climáticas.

Palabras clave: efectos del clima. Incumplimiento bancario. Fondos regionales.

Submetido em: 30/04/2021

Aceito para publicação em: 20/01/2022

Publicado em: 18/02/2022

1. INTRODUCTION

The effects of climate change will not be uniformly distributed across the globe. Developing countries are far 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 most of 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 emission based 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 this context, financial institutions would provide credit to households in times of climatic shocks to offset the effect of these 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 then increase as well. Combined with the well-known credit market imperfections in developing countries (Banerjee 2003), households may find it difficult in the future to get a loan in order to face these shocks and thus engage in adaptive behavior.[1] 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 Northeastern region in Brazil. We focus on the effects of the number of credit operations, volume of credit, and delinquency rates over the period of 2002-2013, a period which included a number of extreme weather

[1] 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).

CC BY NC SA

conditions. The Brazilian Constitution of 1988 instituted Regional Funds to reduce economic inequality across regions, and public banks have been used to implement these regional policies. In particular, the Fund of the Northeast (FNE) has financed over US$ 20 billion in loan contracts since its inception in 1989. Since 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 built a database at the municipality level, and used a fixed-effect panel data approach for the period of 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 was obtained 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 by municipality.

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 each municipality's Gross Domestic Product (GDP). These estimates reveal the important role of climate in explaining loan delinquency rates. Our results also show that drought shocks are associated with a decline in agricultural production and that the delinquency rate is higher in the agricultural sector.

There are several studies in Brazilian economic literature that evaluate the impact of the FNE on employment and income, but this 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 materials and methods, the database, and outlines the empirical strategy used to examine the impact of several variables, especially the climatic ones, on delinquency rates. Section 4 reports the results and elaborates discussion, including descriptive analysis of the Northeastern municipalities. Lastly, Section 5 provides some conclusions regarding our findings.

2. BACKGROUND

2.1. The Brazilian credit market

Brazil has the world's most populated semiarid area with over 23 million people in the Northeast, 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, consequently, location both matter when it comes to economic and social development. The Brazilian Regional Funds aim to decrease the economic inequality between regions. In the case of the Northeast, the Constitutional Financing Fund of the Northeast (FNE) lent almost US$ 4 billion to producers in 2018 alone, with a total of over 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 is managed by the *Banco do Nordeste* (Northeast Bank), a public development 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 the GDP in the period between 2002 and 2012 and The Constitutional Funds accompanied this trend. Resende et al. (2014) shows that the funds disbursed US$ 800 million in 1995 and R$ 7 billion in 2012 (2010 values) for investment. Moreover, between 2015 and 2025 over US$ 100 billion in financing has been projected.

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 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, leading to loan quality strongly being considered, otherwise a delay in repayment would directly affect the bank's 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 economic literature (Levine, 1997). Two opposing views have emerged regarding the role of the government over the control of public enterprises, including public banks and their impacts on economic activity. Atkinson and Stiglitz (1980) argue that public companies are created with the aim of correcting market failures, while Shleifer and Vishny (1994) argue that public enterprises are created to achieve political objectives. Banerjee (1997) also argues that public banks are supposed to correct market failures, but he does not rule out the possibility of them pursuing other objectives as well.

International empirical studies on financial institutions show divergent 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 a greater presence of public banks had lower losses after the financial crisis of 2008. Those regions experienced lower rates of late repayments over 90 days and charge-offs.

In Brazil, public banks are used to implement regional development policies. More specifically, they are used 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.

2.2. Determinants of delinquency rates

The international literature points out several factors affecting non-performing loans (bad lending), highlighting the role of both macroeconomic variables (systematic) and microeconomic variables (idiosyncratic). From the macroeconomic point of view, the hypothesis is that bank crises are preceded by a country's 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; and (v) large banks tend to have greater delinquency. National literature has similarly examined, just as international literature, 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) analyzed the effect of macroeconomic variables during the period of 2001 to 2012 and found that the main explanatory variable of default in Brazil is economic performance. More specifically, the greater the economic growth, the lower the default and the credit risk.

The literature illustrates that both macro and microeconomic variables have influence over default. All of 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 climatic and economic variables. Mendelsohn et al. (1994) provides evidence of the impacts of climate change on both farmland value and rural income, and estimated the impacts of variables such as temperature and precipitation. According to their findings, 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, 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 health service costs.

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 and the relationship between environmental variables and agriculture is more direct in them, because temperature and water are inputs of the biological processes. The general findings are that higher temperatures have negative effects on agricultural production. Although uncertain, the effects on manufacturing and services trend in the same direction, especially in poor or developing countries which are more vulnerable to climatic shocks.

Fishman (2012) examines the potential effect of irrigation as a mechanism for mitigating climate change in the Indian context, since irrigation minimizes the impacts of higher temperatures. However, long-term effects are difficult to estimate due to adaptation, such as the development of new technologies, public policies, and others, that 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 1ºC reduces 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) impact a country's growth rates. While Barrios et al. (2010) find that higher precipitation in sub-Saharan Africa is related to higher growth rates. All of this evidences corroborates the effects of climate changes on economic factors and therefore, the possibility of affecting defaults.

3. MATERIAL AND METHODS

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 was from the Central Bank of Brazil (BCB), specifically from the Monthly Banking Statistics database by municipality (Estban), which includes the monthly position of the balances of the main balance sheets of commercial banks and multiple banks with commercial portfolios. 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, according to municipality. To obtain different variables on the default rate of the funds 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 used 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,[2] C_{it} represents climatic variables, as deviation at precipitation and temperature, and Z_{it} represents

[2] The default rate refers to the total value of installments over 90 days late divided by the amount of loans.

control variables. The term α_i denotes the constant or intercept, 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. Thus, the explanatory variables used in the regressions are: (i) average rainfall in millimeters; (ii) deviation from the average rainfall; (iii) average temperature in Celsius degrees; (iv) deviation from the average temperature; (v) logarithm of municipal GDP, to measure local wealth; (vi) total value financed by each type of risk (FNE, PROCERA, bank or shared), classified by bank in different lines; (vii) total loans granted in the municipality; and (viii) dummy equal to 1 if the municipality has any BNB agency.

Noting that *C* varies plausibly, randomly over time – i.e., "weather" draws from the country "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 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 various 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 the 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, either directly or indirectly. Our preferred specification of equation (1) includes only a few time-varying explanatory variables to reflect patterns of development across the Northeastern region.

4. RESULTS AND DISCUSSION

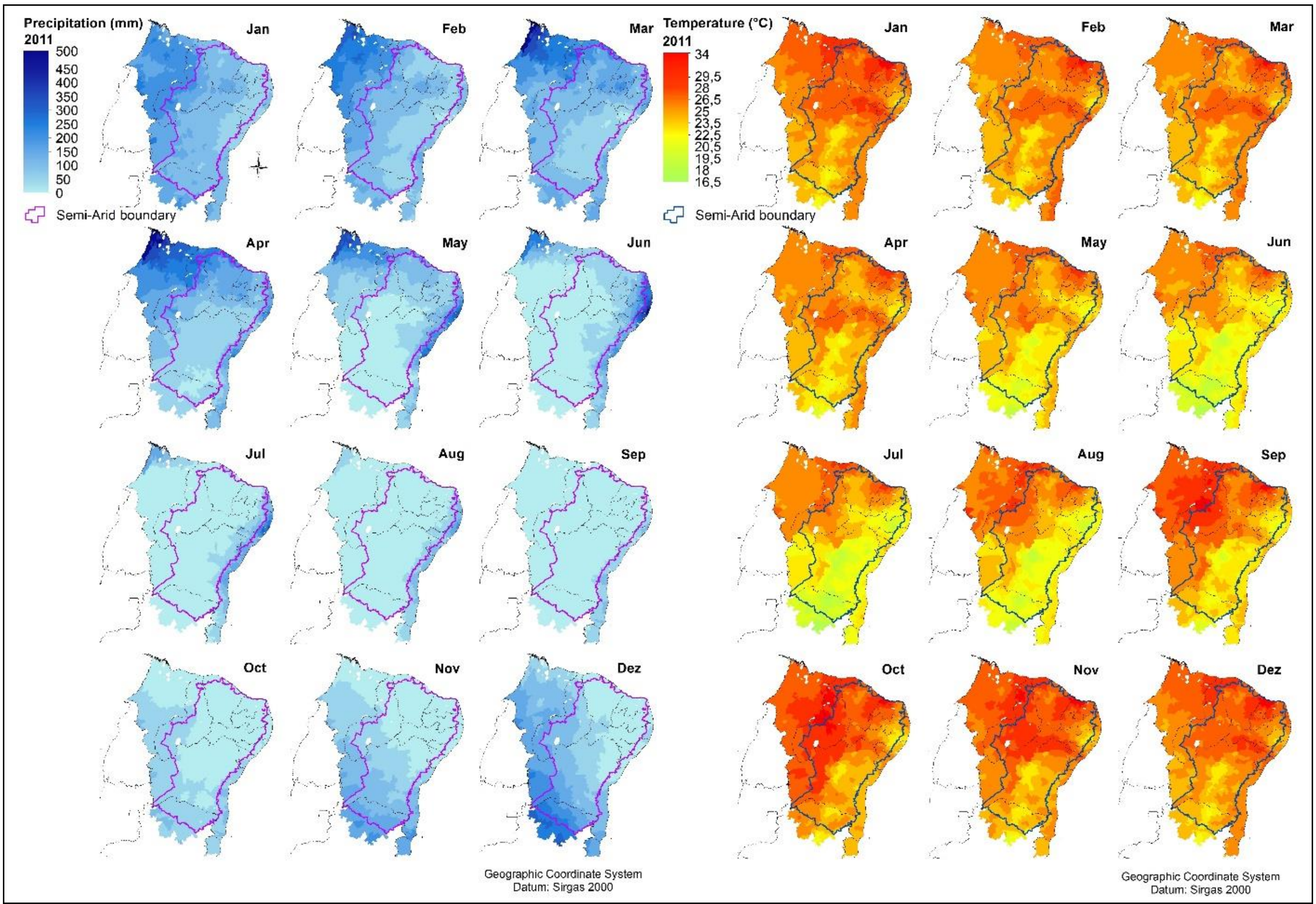
4.1. Descriptive Analysis

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

The region is divided into nine states or 1,990 municipalities, with more than 62% of its area belonging to a semiarid climate (equal to 1,135 municipalities), highlighted by the purple line on the map below. The FNE borders the north of the Southeastern region, a semiarid area as poor as the Northeast, which is also managed by the Northeast Development Superintendence (SUDENE).

The Northeastern region is located in the Earth's intertropical zone. Hence, the incidence of solar irradiance implies high temperatures throughout the year and severe droughts, especially in the countryside. The figure 1 below shows a map of precipitation and average temperature by month in 2011. The rains are not well distributed spatially nor temporally during the year. In some periods the average monthly temperature reaches 32ºC and 16ºC simultaneously in different locations. Regarding precipitation, it has a high amplitude from 240mm to 2100mm per year. This climate surely influences economic activities, specifically 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 Northeastern 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 1,990 northeastern municipalities, highlighting the large amplitude between socioeconomics and climate variables. In general, the municipalities are medium size, poor, with low-medium HDI, and the value of the FNE represents very little in the local economy (less than 3% of GDP). But in some cases, the value of the FNE was 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)

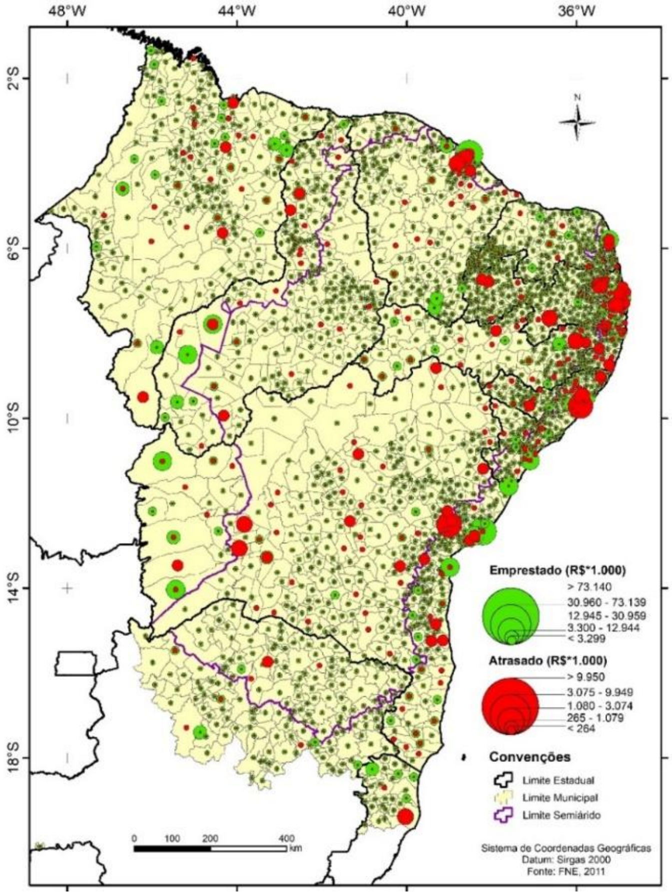
Variable	Mean	Std. Dev.	Min	Max
FNE				
Value of financing	54,570	286,007	0	4,969,533
Number of operations	201	213	0	1,763
Socioeconomics				
Population	28,321	103,779	1,247	2,650,633
HDI Municipality	0.594	0.045	0.443	0.788
Life expectancy	70.5	1.9	65.3	77.1
Years of study	8.9	0.8	5.8	11.0
Income per 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 (°C)	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.

CC BY NC SA

Table 2 – Credit operations of FNE by year [3]

	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, deflated by IPCA (Brazilian index of inflation, measured by IBGE).

Source: Ministry of National Integration.

4.2. Regressions

This subsection reports the results of the estimation of equation (1) considering the deviations of rainfall and temperature with respect to the historical average as the main explanatory variables. The results show that the greater the deviations of temperature and rainfall from the historical average are, the higher the default rates. Since the deviations in reaction to temperature are much higher in relation than 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 the table below show the economic fragility of each bank's operating region, showing that adverse weather events strongly determine bank defaults in the FNE.

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

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

In addition, there is evidence that rainfall and temperature levels correlate with loan repayment, which deserves further investigation with analyses 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 price-paid in relation to the price-received ratio for agriculture affects the default rate, due to a loss of repayment capacity of borrowers. As climate factors determine prices, especially agricultural prices due to the direct relationship with productivity and supply, it is possible that this is a mechanism through which delinquency is affected, corroborating 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, there is variation in the coefficients between the equations since the months are included in analysis, considering the deviations of rainfall from normal seasons.

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

CC BY NC SA

specifications, and the results are higher but qualitatively similar to the previous two analyses.

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 greater (columns 2-4). Perhaps because defaults do not seem to increase in this temperature range. With regard to precipitation intervals, intermediate levels in default do not seem to increase and credit seems to expand. This is consistent with maximizing profits for banks. More interesting is the fact that defaults and credit seem to increase when annual precipitation is high. This is consistent with when public banks rescue struggling citizens.

5. CONCLUSIONS

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

The literature emphasizes that both macroeconomic and microeconomic variables have influence over default. These factors help explain the current situation of the FNE, in addition to other variables which also interfere in the distribution of resources, and 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 key results, we can now highlight the influence of temperature and average rainfall, temperature deviation and average rainfall, GDP, presence of BNB agencies in the municipalities, and whether the type of risk is 100% the FNE's 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. This could work well in the case of some sectors, such as those that need to 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 repayment of its loans. 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 impoverished scenario verified in several municipalities in the region.

One of the limitations of this paper was that we did not examine the factors correlated with default at the individual level,[4] that is, to investigate characteristics of both the contractor and the borrower, as analyzed by 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 correlation. That is, the higher that the temperature disparity is in relation to the average, the lower the default rate is. It is possible that the temperature deviations positively affect the productivity of a region's primary products and, thus, increases the payment capacity of producers.

REFERENCES

ABID, M., J. SCHEFFRAN, U. A. SCHNEIDER, AND M. ASHFAQ. Farmers' Perceptions of and Adaptation Strategies to Climate Change and Their Determinants: The Case of Punjab Province, Pakistan, **Earth System Dynamics,** v. 6, p. 225-243, 2015.

ABRAHAM, TERFA W., AND WILLIAM M. FONTA. Climate Change and Financing Adaptation by Farmers in Northern Nigeria, **Financial Innovation,** v. 4, p. 11, 2018.

[4] In this case, because of the database's confidentiality restriction.

ADGER, W. N. Vulnerability, **Global Environmental Change,** v. 16(3): p. 268-81, 2006.

ALTMAN, E. Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. **Journal of Finance,** v. 23 (4), p. 589–611, 1968.

ATKINSON, A. B.; STIGLITZ, J.E. **Lectures on Public Economics.** McGraw-Hill: Maidenhead (UK), 1980.

BARRIOS, S.; BERTINELLI, L.; STROBL, E. Trends in Rainfall and Economic Growth in Africa: A Neglected Cause of the African Growth Tragedy. **Review of Economics and Statistics,** v. 92 (2): p. 350–66, 2010.

BANERJEE, A. A theory of misgovernance. **Quarterly Journal of Economics,** v. 112, p. 1289–1332, 1997.

BANERJEE, ABHIJIT V. Contracting Constraints, Credit Markets, and Economic Development. In: Dewatripont, Mathias, Lars Peter Hansen, and Stephen J. Turnovsky (eds.) **Advances in Economics and Econometrics,** v. 3, p. 1-46, 2003.

BARRECA, A.; CLAY, K.; DESCHENES, O.; GREENSTONE, M. SHAPIRO, J. Adapting to Climate Change: The Remarkable Decline in the US Temperature-Mortality Relationship over the Twentieth Century. **Journal of Political Economy,** v. 124, n. 1, 2016.

BELOW, TILL B., KHAMALDIN D. MUTABAZI, DIETER KIRSCHKE, CHRISTIAN FRANKE, STEFAN SIEBER, ROSEMARIE SIEBERT, AND KAREN TSCHERNING. Can Farmers' Adaptation to Climate Change Be Explained by Socio-economic Household-level Variables? **Global Environmental Change** v. 22(1): p. 223-235, 2012.

BERGER, A.; DE YOUNG, R. Problem Loans and Cost Efficiency in Commercial Banks. **Journal of Banking and Finance,** v. 21, 1997.

BOSELLO, F.; ROSON, R.; TOL, R. Economy-wide estimates of the implications of climate change: Human health. **Ecological Economics,** v. 58, p. 579– 591, 2006.

BOUDRIGA, A.; TAKTAK, N.; JELOULLI, S. Banking Supervision and nonperforming loans: a cross country analysis. **Journal of Financial Economic Policy.** v. 1, N. 4, p. 286-318, 2009.

BUHR, B.; DONOVAN, C.; KLING, G.; LO, Y.; MURINDE, V.; PULLIN, N.; VOLZ, U. **Climate Change and the Cost of Capital in Developing Countries: Assessing the Impact of Climate Risks on Sovereign Borrowing Costs.** Report prepared by the Imperial College Business School and SOAS University of London, by the United Nations (Environment), 2018.

COLEMAN, N.; FELER, L. Bank Ownership, lending, and local economic performance during the 2008-2009 financial crisis. **Journal of Monetary Economics.** Article in Press, 2014.

DESCHÊNES, OLIVER; GREENSTONE, MICHAEL. Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in Weather in the US. **American Economic Journal: Applied Economics.** v. 3, no. 4, p. 152-85, October, 2011.

DELL, M.; JONES, B.; OLKEN, B. Temperature and Income: Reconciling New Cross-Sectional and Panel Estimates, **American Economic Review: Papers & Proceedings**, v. 99(2): p. 198-204, 2009.

DELL, M.; JONES, B.; OLKEN, B. Temperature Shocks and Economic Growth: Evidence from the Last Half Century, **American Economic Journal: Macroeconomics,** v. 4 (3): p. 66-95, 2012.

DELL, M.; B. JONES, B. OLKEN. What Do We Learn from the Weather? The New Climate-Economy Literature. **Journal of Economic Literature,** v. 52(3), p. 740–798, 2014.

DERESSA, T.; HASSAN, R.; RINGLER, C.; ALEMU, T.; YESUF, M. Determinants of Farmers' Choice of Adaptation Methods to Climate Change in the Nile Basin of Ethiopia, **Global Environmental Change**, v. 19(2): p. 248-255, 2009.

DERESSA, T.; HASSAN, R.; RINGLER, C. Perception of and Adaptation to Climate Change by Farmers in the Nile Basin of Ethiopia, **Journal of Agricultural Science**, v. 149(1): p. 23-31, 2011.

FAGARIBA, C.; SONG, S.; BAORO, S. Climate Change Adaptation Strategies and Constraints in Northern Ghana: Evidence of Farmers in Sissala West District, **Sustainability**, v. 10(5): p. 1-18, 2018.

FANKHAUSER, S.; TOL, R. On climate change and economic growth. **Resource and Energy Economics,** n. 27, pgs. 1–17, 2005.

FISHMAN, R. Climate Change, Rainfall Variability, and Adaptation through Irrigation: Evidence from Indian Agriculture. **Working Paper,** Columbia University, New York, 2012.

FUSSEL, HANS-MARTIN. How Inequitable is the Global Distribution of Responsibility, Capability, and Vulnerability to Climate Change: A Comprehensive Indicator-based Assessment, **Global Environmental Change**, v. 20(4): p. 597-611, 2010.

HSIANG, S; JINA, A. The causal effect of environmental catastrophe on long-run economic growth: evidence from 6,700 cyclones. **Working Paper 20352**, National Bureau of Economic Research, Cambridge, July, 2014.

INTERNATIONAL MONETARY FUND - IMF. **The Fiscal Implications of Climate Change.** Fiscal Affairs Department, 2008.

ISLAM, MD. MONIRUL, SUSANNAH SALLU, KLAUS HUBACEK, JOUNI PAAVOLA. Limits and Barriers to Adaptation to Climate Variability and Change in Bangladeshi Coastal Fishing Communities, **Marine Policy**, v. 43: p. 208-216, 2014.

KOMBA, C.; MUCHAPONDWA, E. Adaptation to Climate Change by Smallholder Farmers in Tanzania, **Environment for Development Discussion Paper Series** p. 15-12, 2015.

LEVINE, R. Financial Development and Economic Growth: Views and Agenda. **Journal of Economic Literature.** v. XXXV, p. 688–726, jun., 1997.

LINARDI, F.; FERREIRA, M. Avaliação dos Determinantes Macroeconômicos da Inadimplência Bancária no Brasil, **Anais do XXXVI Encontro Nacional de Economia (Anpec)**, 2008.

MELO, L.; RESENDE FILHO, M. Determinantes do Risco de Crédito Rural no Brasil: Uma Crítica às Renegociações da Dívida Rural. **Revista Brasileira de Economia,** Rio de Janeiro v. 71 n. 1, p. 67–91, Jan-Mar, 2017.

MENDELSOHN, R.; NORDHAUS, W.; SHAW, D. The Impact of Global Warming on Agriculture: A Ricardian Analysis. **The American Economic Review,** v. 84, No. 4, p. 753-771, Sep., 1994.

MENDELSOHN, ROBERT, ARIEL DINAR, AND LARRY WILLIAMS. The Distributional Impact of Climate Change on Rich and Poor Countries, **Environment and Development Economics,** v. 11(2), p. 159-178, 2006.

MUZAMHINDO, NOLYN, SHINGIRAI MTABHENI, OBERT JIRI, EMMANUEL MWAKIWA, AND BENJAMINE HANYANI-MLAMBO. Factors Influencing Smallholder Farmers' Adaptation to Climate Change and Variability in Chiredzi District of Zimbabwe, **Journal of Economics and Sustainable Development,** v. 6(9): p. 1-8, 2015.

OGALLEH, SARAH AYERI, CHRISTIAN R. VOGL, JOSEF EITZINGER, AND MICHAEL HAUSER. Local Perceptions and Responses to Climate Change and Variability: The Case of Laikipia District, Kenya, **Sustainability,** v. 4(12): p. 3302-3325, 2012.

REINHART, C.; ROGOFF. K. Growth in a Time of Debt. **American Economic Review**, v. 100 (2), p. 573-578. 2010.

RESENDE, G. Measuring micro-and macro-impacts of regional development policies: the case of the FNE industrial loans in Brazil, 2000-2006. **Regional Studies,** v. 48, n. 4, p. 646-664, 2014.

SAHUA, NARESH CHANDRA, AND DIPTIMAYEE MISHRA. Analysis of Perception and Adaptability Strategies of the Farmers to Climate Change in Odisha, India, **APCBEE Procedia** v. 5: p. 123-127, 2013.

SCHLENKER, W.; HANEMANN, M.; FISHER, A. The Impact of Global Warming on U.S. Agriculture: An Econometric Analysis of Optimal. Growing Conditions. **The Review of Economics and Statistics,** v. 88, n. 1, p. 113-125, Feb., 2006.

SHLEIFER, A.; VISHNY, R.W. Politicians and firms. **Quarterly Journal of Economics,** v. 109, p. 995–1025, 1994.

SILVA, M, L.; VIEIRA, K, M.; CERTTA, P, S.; CORONEL, D, A. Risco do crédito bancário brasileiro: uma análise multifatores. **Revista Brasileira de Administração Científica.** v. 5, n. 3, 2014.

TOL, RICHARD S. J. The Economic Impacts of Climate Change, **Review of Environmental Economics and Policy,** v. 12(1): p. 4-25, 2018.

UNITED NATIONS DEVELOPMENT PROGRAMME – UNDP. **Human Development Report 2013**, New York, USA, 2013.

UNITED NATIONS ENVIRONMENT PROGRAMME – FINANCE INITIATIVE (UNEP-FI). **Demystifying Adaptation Finance for the Private Sector**, 2016.