IPECE

Textos para Discussão

Nº 122 – outubro / 2017

Natural Disasters and Economic Growth in the Northeastern Brazil: Evidence from Municipal Economies of the State of Ceará

Victor Hugo de Oliveira

IPECE INSTITUTO DE PESQUISA E ESTRATÉGIA ECONÔMICA DO CEARÁ

GOVERNO DO ESTADO DO CEARÁ
Secretaria do Planejamento e Gestão

IPECE | Textos para Discussão

Ano 13 - nº 122 – outubro de 2017

Autor: Victor Hugo de Oliveira

O **Instituto de Pesquisa e Estratégia Econômica do Ceará (IPECE)** é uma autarquia vinculada à Secretaria do Planejamento e Gestão do Estado do Ceará. Fundado em 14 de abril de 2003, o IPECE é o órgão do Governo responsável pela geração de estudos, pesquisas e informações socioeconômicas e geográficas que permitem a avaliação de programas e a elaboração de estratégias e políticas públicas para o desenvolvimento do Estado do Ceará.

Missão: Propor políticas públicas para o desenvolvimento sustentável do Ceará por meio da geração de conhecimento, informações geossocioeconômicas e da assessoria ao Governo do Estado em suas decisões estratégicas.
Valores: Ética e transparência; Rigor científico; Competência profissional; Cooperação interinstitucional e Compromisso com a sociedade.
Visão: Ser uma Instituição de pesquisa capaz de influenciar de modo mais efetivo, até 2025, a formulação de políticas públicas estruturadoras do desenvolvimento sustentável do estado do Ceará.

Instituto de Pesquisa e Estratégia Econômica do Ceará (IPECE) - Av. Gal. Afonso Albuquerque Lima, s/n | Edifício SEPLAG | Térreo - Cambeba | Cep: 60.822-325 | Fortaleza, Ceará, Brasil | Telefone: (85) 3101-3521
http://www.ipece.ce.gov.br/

Sobre o **Textos para Discussão**

A Série Textos para Discussão do Instituto de Pesquisa e Estratégia Econômica do Ceará (IPECE) tem como objetivo a divulgação de estudos elaborados ou coordenados por servidores do órgão, que possam contribuir para a discussão de temas de interesse do Estado. As conclusões, metodologia aplicada ou propostas contidas nos textos são de inteira responsabilidade do(s) autor(es) e não exprimem, necessariamente, o ponto de vista ou o endosso do Instituto de Pesquisa e Estratégia Econômica do Ceará - IPECE, da Secretaria de Planejamento e Gestão ou do Governo do Estado do Ceará.

Nesta Edição

Usando um conjunto de dados inexplorados sobre desastres naturais no Brasil, o presente estudo mostra que os eventos climáticos extremos reduzem a taxa de crescimento do PIB por capital das economias municipais cearenses entre 2002 e 2011. Esses efeitos são particularmente causados por secas, especialmente em casos de danos aos recursos hídricos dos municípios. Além disso, os danos que causam grandes perdas per capita nos setores de agricultura e serviços contribuem para diminuir o crescimento econômico. Por último, mas não menos importante, o crescimento da produção do setor de serviços é sensível a inundações que causam prejuízos dispendiosos ao setor industrial, sugerindo um potencial efeito “spillover” de desastres naturais entre esses dois setores econômicos. Os resultados neste estudo não só contribuem para entender os efeitos do desastre natural sobre o crescimento econômico no Brasil, mas também adicionam novas evidências a uma literatura crescente que tem sido principalmente focada em estudos para países.

Natural Disasters and Economic Growth in the Northeastern Brazil: Evidence from Municipal Economies of the State of Ceará

Victor Hugo de Oliveira

Instituto de Pesquisa e Estratégia Econômica do Ceará. IPECE

Laboratório de Econometria e Otimização, LECO/UFC

Abstract

Using an unexplored data set on hazardous events in Brazil, the current study shows that extreme climatic events reduce the growth rate of per capital GDP of municipal economies in the state of Ceará between 2002 and 2011. These effects are particularly driven by droughts, especially in cases of damages to water sources in the municipalities. Not only costly droughts in the agriculture sector can reduce the GDP per capita growth rate, but also costly floods in the services sector can slow output growth. Negative spillover effects between services and industrial sector due to flood damages are also reported in this study. The results contribute to understand the effects of natural disaster on economic growth in the Northeastern Brazil, as well as add new evidence to an increasing literature that have been mainly focused on cross-country studies.

Key-words: Economic growth, natural disasters, Ceará, Brazil.

Resumo

Usando um conjunto de dados inexplorados sobre desastres naturais no Brasil, o presente estudo mostra que os eventos climáticos extremos reduzem a taxa de crescimento do PIB por capital das economias municipais cearenses entre 2002 e 2011. Esses efeitos são particularmente causados por secas, especialmente em casos de danos aos recursos hídricos dos municípios. Além disso, os danos que causam grandes perdas per capita nos setores de agricultura e serviços contribuem para diminuir o crescimento econômico. Por último, mas não menos importante, o crescimento da produção do setor de serviços é sensível a inundações que causam prejuízos dispendiosos ao setor industrial, sugerindo um potencial efeito "spillover" de desastres naturais entre esses dois setores econômicos. Os resultados neste estudo não só contribuem para entender os efeitos do desastre natural sobre o crescimento econômico no Brasil, mas também adicionam novas evidências a uma literatura crescente que tem sido principalmente focada em estudos para países.

Palavras-chave: Crescimento econômico, desastres naturais, Ceará, Brasil.

1. Introduction

Natural disasters have devastating impacts on human and economic development. For two decades (1992-2012), these hazardous events affected 4.4 billion people worldwide, claimed 1.3 million lives and caused US$ 2 trillion in economic losses (UNISDR, 2012). Natural disasters may cause population mobility in poor (Gray and Mueller, 2012; Drabo and Mbaye, 2014) and rich countries (Strobl, 2011; duPont IV et al., 2015), as well as changes in household income/expenditure (Aurori et al., 2014; Lohmann and Lechtenfeld, 2015), and affects the local labor market (Halliday, 2012; Coffman and Noy, 2012). Natural hazards may also trap vulnerable population into poverty condition (Carter et al., 2006; Jakobsen, 2012; Rodriguez-Oreggia et al., 2012). Moreover, countries with higher income, higher educational attainment, greater openness, more complete financial systems and smaller government are more likely to experience fewer losses (Toya and Skidmore, 2007).

Nonetheless, natural disasters can either have positive, negative, or even none effect on economic growth (Cavallo and Noy, 2011; Cavallo et al., 2013; Shabnam, 2014). Some studies have shown that natural hazards boost economic growth (Albala-Bertrand, 1993; Skidmore and Toya, 2002; Noy and Vu, 2010; Fomby et al, 2011; Loayza et al., 2012), while others provide evidence of the negative effect in the short-run (Rasmussen, 2004; Noy, 2009; Strobl 2011; 2012; Felbermayr and Gröschl, 2014), medium-run (McDermott et al., 2014) and long-run (Raddatz, 2009; Hsiang and Jina, 2014).

In this literature, four hypotheses related to the impact of natural disasters on economic growth in the long-run have been tested (Hsiang and Jina, 2014). Firstly, disasters may transitorily stimulate the economy because of the increasing demand for goods and services and the inflow of international aid and innovation, leading to a creative destruction hypothesis (Skidmore and Toya, 2002). Secondly, the economic growth may slow down initially due to human and physical capital losses, but the gradual replacement of lost assets with modern unities may produce net positive effects on economic growth in the long-rung, which is known as the "building back better" hypothesis (Hallegatte et al., 2007; Cuaresma et al., 2008; Hallegatte and Dumas, 2009). Thirdly, in the “recovery to trend” hypothesis, the destruction of human and physical capital may increase the marginal product of these two inputs, which stimulates individuals and wealth flow to a devastating area until output recovers its pre-disaster trend (Yang, 2008; Strobl, 2011). Fourthly, a natural disaster may destroy capital and/or durable goods (e.g. homes) and reduce consumption, so that productive investment has no priority in the economy. In the "no recovery hypothesis", an economy may have a growing path in the long-run, but permanently below the pre-disaster path (Anttila-Hughes and Hsiang, 2013; Field et al., 2012).

Notwithstanding, McDermott et al. (2014) argue that economic growth in developed economies is unlikely to be affected by extreme natural events because the access to credit allows these economies to recover their pre-disaster path in the long-run, even if it experiences output fall in the short-run. According to the authors, it is not the case in low-income economies, once a disaster occurrence will not be fully compensated by increased investment due to the low access to credit. Their predictions show that a disaster occurring in a relatively poor country will not only reduce output in the short-term, but will, *ceteris paribus*, reduce the economy growth rate in the medium to long term.

Several studies have shown adverse effects of natural disasters on economic growth of low-income and developing countries in the short-run (Noy, 2009; Strobl, 2012; Loayza et al., 2012; Felbermayr and Gröschl, 2014). Particularly, Latin America is vulnerable to a variety of natural disasters such as earthquakes in Mexico and Chile, volcanic eruption in Colombia, hurricanes in Haiti, droughts and floods in Brazil (Stillwell, 1992). These natural disasters not only produce destruction of physical capital in this part of world, but also generate negative consequences for human capital accumulation in the long-run (Caruso, 2017), which can jeopardize economic growth.

Extreme climate events are the most common natural hazards in Brazil, and the ongoing climate change may contribute to intensify such kind of disasters in the near future (Reyer, 2017). For instance, the Northeast region of Brazil is one of the places in the world that will experience intensification of droughts due to reduced precipitation and/or increased evaporation caused by global warming during the 21st century (IPCC, 2012). Between 1995 and 2014, almost half of the total losses due to climatic disasters occurred in this particular region of the country (CEPED, 2016), and the current drought (2010-2016) in the Northeast region (Marengo et al., 2017) has demonstrated that public policies in Brazil still lack the capacity of resilience and preparedness for this type of extreme event (Gutiérrez et al., 2014). Simulation studies have shown that climate change will substantially affect the Northeast of Brazil, specially the agriculture sector (Ferreira Filho and Moraes, 2014; Assunção and Chen, 2016).

The current investigation aims to provide evidence on the impact of climatic disasters caused by droughts and floods Ceará, Brazil, which is one of the states that are mostly affected by climatic hazards in the country (CEPED, 2016). In this Brazilian state, about 87% of the territory is within the great semiarid region with annual precipitation below 800mm, dryness index of 0.5 or below, and risk of drought of at least 60%. It is also one of the poorest states in the country and it exhibits a high social vulnerability to natural disasters (Hummell et al., 2016).

Furthermore, this investigation relies on an unexplored data source on disasters in Brazil. The information on extreme events come from the Damage Assessment Report of the Civil Defense (Relatório de Avaliação de Danos da Defesa Civil), which is used to gather information of affected population and losses caused by all types of disasters at municipal level in the country. Information on climate disasters is combined with GDP and other economic information for all 184 municipalities of Ceará between 2002 and 2011. The intensity of droughts and floods, the most common natural hazards in this region of the country, is measured by annual per capita losses, and their impact on economic growth is estimated through dynamic panel model based on system GMM. Empirical evidence shows that the economic growth in Ceará is negatively affected by droughts, especially in the agriculture sector. Damages to water supply appear as the main channel of the effect of natural disasters on the growth rate of agriculture. Not only costly droughts in the agriculture sector can reduce the GDP per capita growth rate, but also costly floods in the services sector can slow output growth. Negative spillover effects of flood damages between services and industrial sector are also reported in this study.

The results in this paper contribute not only to public policies focused to understand the effects of natural disasters to economic growth in Brazil, but also add new evidence to an increasing literature that has been mainly focused on cross-country studies (Skidmore and Toya, 2002; Noy, 2009; Strobl, 2012; Loayza et al., 2012; Cavallo et al., 2013; Felbermayr and Gröschl, 2014; Hsiang and Jina, 2014). Particularly, it is a first attempt to understand the effects of natural disasters on economic growth at subnational level in Brazil. Other studies try to measure the economic impacts of natural hazards in other regions of the country. For instance, Ribeiro et al. (2014) use the synthetic control approach to measure the economic impact of the 2008 floods in Santa Catarina, and find a decrease of 5,13% in the industrial production. Haddad and Teixeira (2015) find that floods contributed to reduce city growth and residents' welfare in São Paulo, as well as hampering local competitiveness in both domestic and international markets.

The remainder of this study is structured as follows: section 2 describes the data sources; section 3 presents the methodology; and section 4 analyzes the results. Finally, section 5 concludes the study.

2. Data

2.1 Information about Natural Disasters

The data used in this study is restricted to the 184 municipalities in the state of Ceará, Brazil. In particular, the interval of years is constrained by the availability of data about natural disasters, which comes from the Damage Assessment Report that was carried out by the Civil Defense in each disaster occurrence in the national territory between 2002 and 2011. This report is required for any municipality that aims to declare state of emergency or calamity after a disaster occurrence. In 2012, a new system of disaster records was employed by the Ministry of National Integration (Ministério da Integração Nacional), in which the electronic version of AVADAN replaced the paper form.[1]

Table 1 brings the main descriptive statistics about reported natural disasters in the State of Ceará. The records show that there are two main types of natural disaster in this part of the country, which are: droughts (76% of the reports) and floods (22.9% of the reports). In particular, reports about droughts are more than three times the number of reports regarding floods.[2] Other natural disasters involve storms, marine erosion, landslides, and forest fires, which accounts for less than 1% of recorded damages. It is also important to highlight that not all episodes of disasters have a Damage Assessment Report, but the Civil Defense reported the damages for 76% of the total episodes of disaster (ABDN, 2013).

[1] All Damage Assessment Reports can be found in the following link: https://s2id-search.labtrans.ufsc.br/.
[2] Droughts in the state of Ceará can be influenced by El Niño, and produces negative consequences for corn market (Chimeli et al., 2008).

The intensity of the natural disasters in municipalities is measured by per capita losses. Since material damages caused by natural disasters are well discriminated by AVADAN, it allows for a better analysis of the mechanism. The measure of disaster intensity is given by

$$D_{i,t} = \log \sum_{j} \frac{Losses_{i,j,t}}{Population_{i,t}}$$

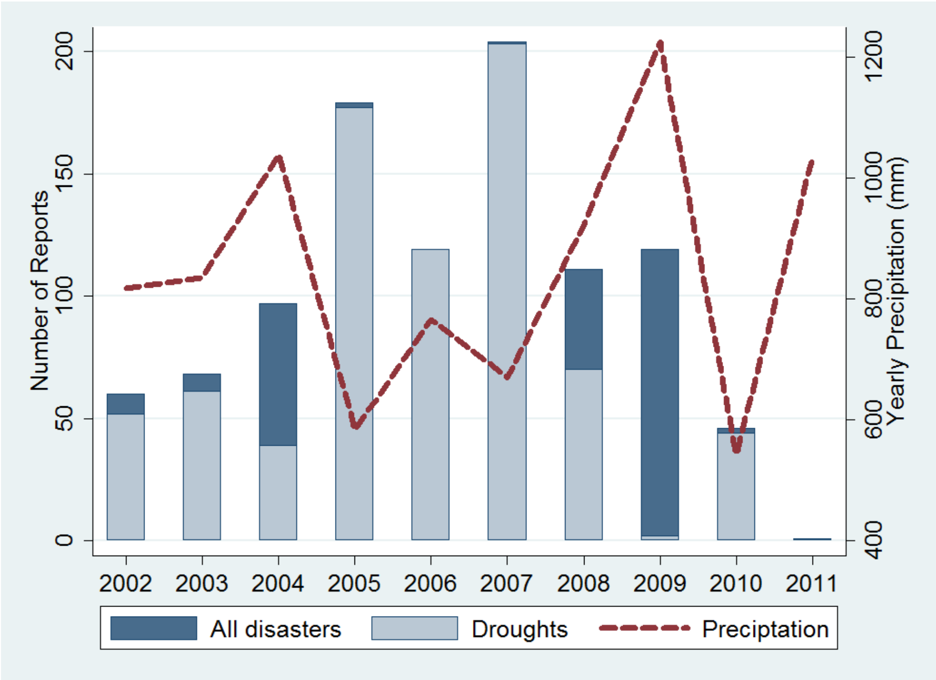
where i is the index of municipalities, j indicates the type of disaster, and t is the year of the disaster.

In Table 1, droughts are the most frequent natural disaster in the state of Ceará., corresponding to more than three times the number of episodes of floods. The annual average losses per municipality is near R$ 4.4 million. Besides, the average per capita losses are slightly larger to droughts in comparison to floods, but floods tend to occur in richer municipalities as judged by differences in GDP per capita.

[INSERT TABLE 1 HERE]

Figure 1 provides support to the evidence in Table 1 by showing that notifications of natural disasters are correlated with yearly precipitation in the state of Ceará. For instance, notifications of droughts are larger in years when the yearly precipitation is below 800mm, except in 2010 due to the high precipitation in 2009, which increased the volume of water in the reservoirs. Moreover, we also observe a low number of notifications of droughts in years of large precipitation, but notifications about floods increased in those years (2004, 2008 and 2009). In 2011, no droughts were reported by municipalities in the state of Ceará, which is aligned with the increase in yearly precipitation.

Figure 1: Damage Assessment Reports and Yearly Precipitation



Source: AVADAN/Defesa Civil and Fundação Cearense de Meteorologia e Recursos Hídricos - FUNCEME.

Because natural disasters in the state of Ceará are mainly caused by droughts and floods, disaggregated effects take only these two types of natural events into account. Moreover, the current analysis incorporates other important variables to determine GDPgrowth rate of the municipalities in the State of Ceará. The source of data and some descriptive statistics of additional control variables are reported in the next subsection.

2.2 Additional Control Variables

Control variables used in this study come from different sources of information, but they are publicly available in the Statistical Yearbook of Ceará (Anuário Estatístico do Ceará).[3] The first variable in Table 2 is the per capita consumption of electricity (MWh/population), which is provided by the Energy Company of Ceará (Companhia Energética do Ceará - COELCE). This variable is largely used in studies about economic

[3] For further details, access the following link: http://www.ipece.ce.gov.br/index.php/anuario-estatistico-do-ceara.

growth in Brazil due to the absence of an appropriate measure for physical capital at municipality level (Firme and Filho, 2014). Per capita consumption of electricity is larger in the rural sector probably because of the impossibility of distinguishing residential and productive consumption. Another variable included in the vector of covariates is the size of the formal sector, which comes from the Annual Report on Social Information (Relação Anual de Informações Sociais - RAIS). La Porta and Shleifer (2014) discuss the relationship between economic development and (in)formal economy (firms and workers). The authors argue that the informal sector is predominant in developing economies and are very unproductive, but the formal sector is the one responsible for economic growth. In Table 2, the average proportion of formal workers relative to the total population is higher in service/commerce, and smaller in agriculture.

[INSERT TABLE 2 ABOUT HERE]

A proxy for human capital is the proportion of enrollment in secondary school concerning the total population in the municipality, which is provided by the State Secretariat of Education in Ceará (Secretaria Estadual de Educação do Ceará - SEDUC). Loayza et al. (2012) use the ratio of the number of students enrolled in secondary school to the number of people at the corresponding school age.[4] Moreover, government spending is also included as an explanatory variable (Barro, 1990; Loayza ey al., 2012), which can be obtained in the National Treasury Secretariat (Secretaria do Tesouro Nacional). Finally, the ratio of hospital beds relative to the total population of municipalities is included in the analysis as a proxy for the municipality's preparedness concerning health response to the disasters (WHO, 2013). Information on hospital beds comes from the Secretariat of Health in Ceará (Secretaria de Saúde do Ceará - SESA). These control variables are also important in accounting for potential differences in the resilience of municipalities to natural disasters.

[4] School enrollment has been used as a proxy for human capital by Barro (1991).

3. Empirical Approach

The empirical strategy of this study is based on the standard empirical growth equation (Durlauf et al., 2005) proposed by Islam (1995) in the analysis of the convergence hypothesis across countries. Several studies have extended the growth equation to incorporate the intensity of natural disasters, assuming a multiplicative risk formulation (Noy, 2009; Loayza et al., 2012; Felbermayr and Gröschl, 2014). That is,

$$\log y_{i,t} = (1+\beta)\log y_{i,t-1} + \rho D_{i,t} + \theta X_{i,t} + \mu_t + \lambda_i + \varepsilon_{i,t} \qquad (1)$$

where $y_{i,t}$ is the output per capita of geographical unit i in year t, and $y_{i,t-1}$ is the initial output. Vector $X_{i,t}$ includes growth determinants that vary across time and geographical units. The formulation also includes the time-specific effect, μ_t, that captures the potential productivity growth and common shocks over time, and the unit-specific fixed effect, λ_i. The term $D_{i,t}$ is the measure of natural disaster, which has been proxied by the costs of the disaster (Noy, 2009), affected population (Loayza et al., 2012), or number of disasters (Skidmore and Toya, 2002). In this paper, the variable of interest, $D_{i,t}$, corresponds to the per capita losses caused by natural disasters as presented in Table 1.

Because equation (1) is a typical lagged-dependent-variable model, a widely-used approach is to differentiate it to eliminate the fixed effects, and then use Two-Stage Least Square (2SLS) or Generalized Method of Moments (GMM) to address the correlation between the differenced lagged-dependent-variable and the induced MA(1) error term (Durlauf et al, 2005). Equation (2) expresses the first difference transformation of equation (1).

$$\Delta\log y_{i,t} = (1+\beta)\,\Delta\log y_{i,t-1} + \rho\Delta\log D_{i,t} + \Delta\log X_{i,t}\,\theta + \Delta\mu_t + \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right) \qquad (2)$$

Following Loayza and Oliberría (2012), GMM estimators developed for dynamic models of panel data are used as control of unit-specific effects and joint endogeneity (Holtz-

Eakin et al., 1988; Arellano and Bond, 1991; and Arellano and Bover, 1995). The GMM approach is typically based on using lagged levels of the series as instruments for lagged first differences. If the error terms in the levels equation (ε_{it}) are serially correlated then $\Delta \log y_{i,t-1}$ can be instrumented using $\log y_{i,t-2}$ and earlier lagged levels. This requires a set of moment conditions in order to estimate the first-differenced equation by GMM. Under the assumptions that the error term, ε, is not serially correlated[5], and that the explanatory variables are not correlated with its future realizations, the required moment conditions are:

$$E\left[\log y_{i,t-s} \cdot \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0,\ for\ s \geq 2; t = 3, \dots, T \qquad (3)$$

$$E\left[\log X_{i,t-s} \cdot \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0,\ for\ s \geq 2; t = 3, \dots, T \qquad (4)$$

Nonetheless, difference estimators based on moment conditions (3) and (4) can be severely biased in shot panels if explanatory variables are persistent over time. In this case, lagged levels of these variables are weak instruments for equation (2). In this case, the asymptotic and small-sample performance of the difference estimator are influenced by instrument weakness, leading to inefficient and biased estimators (Blundell and Bond, 1998; Alonso-Borrego and Arellano, 1999). In order to overcome such statistical shortcomings, we rely on the Generalized Method of Moments (Arrellano and Bover, 1995; Blundell and Bond, 1998). The approach combines the regression in levels (1) and the regression in differences (2) into one system. Whereas the instruments of the equation in differences are lagged levels of the explanatory variables, the instruments for the equation in levels are the lagged differences of the explanatory variables. Thus, the moment conditions for the equation in levels are given by

$$E\left[\left(\log y_{i,t-1} - \log y_{i,t-2}\right) \cdot \left(\lambda_i + \varepsilon_{i,t}\right)\right] = 0,\ for\ s \geq 2; t = 3, \dots, T \qquad (5)$$

$$E\left[\left(\log X_{i,t-1} - \log X_{i,t-2}\right) \cdot \left(\lambda_i + \varepsilon_{i,t}\right)\right] = 0,\ for\ s \geq 2; t = 3, \dots, T \qquad (6)$$

[5] This assumption can be tested using the methods developed in Arellano and Bond (1991), and can also be relaxed by an appropriate choice of instruments.

assuming that there are appropriate instruments under the assumption that the correlation between explanatory variables and municipality-specific effect is the same for all time period, and that the future growth shocks are exogenous. Thus, expressions (3)-(6) are the required moment conditions to obtain consistent and efficient estimates of the impact of natural disasters on the municipalities' economic growth in the state of Ceará.

The estimation procedure uses a small set of moment conditions in order to avoid over-fitting bias (Roodman, 2009), considering at most six lags for each endogenous explanatory variable.[6] The two-step procedure with finite-sample correction is also adopted in order to improve efficiency (Windmeijer, 2005), once two-step standard errors more efficient than one-step procedure for system GMM.[7] Besides, the validation of the instruments is obtained from the Hansen test for overidentifying restrictions, in which model's identification is the null hypothesis. Moreover, serial correlation of the residuals from a differenced equation is also tested, in which the second lags of endogenous variables will not be appropriate instruments for their current values in case of AR(2).

Loayza et al. (2012) highlighted that while disasters are independent from GDP, disaster losses may not be. Given the intensity of natural hazards, human and economic losses are likely to depend on the development level. In this case, per capita losses due to disasters are assumed to be predetermined in the model, once past GDP values can influence the intensity of the disaster in the current period. The model also accounts for initial GDP, which controls initial conditions.

As robustness analysis, it is tested whether the effects of the natural disasters on the growth rate of GDP per capita are persistent or not. In this case, the lagged values of per capita losses are included in the model. Besides, episodes of natural disasters are used as an exogenous measure in the robustness analysis. In order to understand the effect of natural

[6] It corresponds to the use of the option "collapse" of STATA's statistical package "XTABOND2".
[7] It corresponds to the joint use of the options "two-step" and "robust" of STATA's statistical package "XTABOND2".

hazards on growth rate of GDP per capita, the study provides estimates of potential spillover effects across economic sectors. Since the AVADAN reports, the type of disaster and the amount of losses by economic sectors (i.e. industry, service/commerce, and agriculture), it is possible to test whether the per capita losses of an economic sector affect not only its own growth rate of the per capita added value, but also the economic growth of other economic sectors.

In addition, damages to private/public infrastructure (e.g. roads, paved streets, public buildings, schools, health facilities, etc.) and to water supply (e.g. water treatment plant, network distribution and water source) are also recorded by AVADAN, which allows for testing whether disruption in the infrastructure and/or water supply mediates the effect of natural disasters on economic growth. The next section presents the results, as well as the sensitive and mechanism analyses.

4. Results

4.1 Baseline Estimations

Table 3 displays the estimates of the effects of natural disasters on growth rate of per capita GDP of municipal economies in the state of Ceará, as well as the estimates considering the effect of the main types of natural disasters on the per capita added value's growth rate for each economic sector.

[INSERT TABLE 3 ABOUT HERE]

Column 1 shows that per capita losses due to natural disasters negatively impact the GDP per capita growth rate of the municipalities in Ceará in the short-run. Estimates suggest that an increasing of 10% in per capita losses reduces the growth rate in 0.04%. This impact is particularly driven by the effects of droughts, which exhibit the same elasticity than the overall effect. Although floods have a negative effect on GDP per capita growth rate, the estimate is not statistically significant.

Analyzing the effect of natural disasters for each economic sector, the agricultural sector appears as the one most penalized by natural disasters in the state of Ceará. An increase of 10% in the per capita losses due to natural disasters reduces the growth rate of per capita added value in the agriculture sector in 0.14%. This effect is especially influenced by droughts, which exhibit the same magnitude of impact. Floods negatively affect both agriculture and services. An increase in 10% in the average per capita losses due to floods reduces the growth rate of the agriculture and services sectors in 0.07% and 0.02%, but these estimates are only significant at the level of 10%. Loayza et al. (2012), by using the fraction of affected population as the intensity measure of the disaster, found that droughts only affect the growth rate of the agriculture sector, whereas floods increase both agriculture and services sectors'.

4.2 Sensitive analysis

Persistent effects

Now, the analysis is related to the existence of persistent effects of natural disasters on GDP per capita growth rate for municipal economies in Ceará. In this case, the system GMM is estimated including the lagged values of per capita losses.

[INSERT TABLE 4 ABOUT HERE]

The estimated coefficients for contemporaneous effects of natural disasters remain negative and significant in column (1) at Table 4, despite the effect for droughts is significant only at the level of 10% in column (2). No significance is observed in coefficients for lagged variables in columns (1) and (2). On the other hand, disasters exhibit contemporaneous and lagged effects on the added value growth rate of the agriculture sector, especially in case of droughts. Contemporaneous estimates are slightly larger than the estimated coefficients of Table 3. In the agriculture sector, a 10% increase in per capita losses caused by droughts reduces the growth rate of added value in 0.18%, and drops 0.1% in case of floods. Besides, the economic growth in the agriculture sector is not sensitive to droughts with a one-year lag, but the estimate is negative and significant with a two-year lag (-0.007, p-value<0.05). In the industrial sector, droughts have positive and significant impacts with a two-year lag (0.006, p-value<0.05), while floods have negative and marginally significant effects with a two- year lag (-0.007, p-value<0.10). In other words, whereas droughts boost industrial growth in the short-run, floods cause destruction that decelerates industrial growth. Loayza et al. (2012) found the reverse: floods with a five-year lag boost economic growth, while droughts reduce economic growth of the industrial sector across countries.

Number of natural disasters

Instead of measuring the effects of per capita losses, this subsection shows the results using the number of natural disasters as the variable of interest.

[INSERT TABLE 5 ABOUT HERE]

In column (1) at Table 5, each natural disaster reduces the GDP growth rate in 0.012%. Results confirm that droughts are the most harmful natural hazards for municipal economies in Ceará, in which an additional drought relative to the average can reduce the GDP growth rate in 0.013%. Although the estimate of floods is negative in column (2), no significance for this estimate is obtained. However, in the agriculture sector, both droughts and floods have impact on per capita growth rate, which is reduced in approximately 0.04% as a result of the occurrence of one of these two events. Specifically, a drought reduces the growth rate of per capita added value in 0.034%, whereas floods can reduce the growth rate in 0.043%. The economic sectors of industry and services remain not sensitive to the natural disasters. Loayza et al. (2012) found that an increase of a unit in the average number of droughts reduces economic growth across countries in 2.1%, whereas the same variation in the average number of floods increases the growth rate in approximately 1.5%.

4.3 Mechanism Analysis

Spillover effects

Before analyzing the existence of spillover effects in damages caused by natural disasters across economic sectors, it is relevant to know which damaged economic sector contributes to the fall in GDP per capita growth rate. The results of such analysis are displayed in columns (1) and (2) of Table 8. The estimates in column (1) suggest that per capita losses in the sectors of agriculture (-0.004, p-value<0.05) and services (-0.016, p-value<0.05) negatively affect the per capita growth rate. These effects are driven by damages in the agriculture sector caused by droughts (-0.004, p-value<0.05), and by damages in the services sector caused by floods (-0.019, p-value<0.05). Damages caused by floods in the industrial sector is also negative, but significant only at the level of 10%. It is worth noting that the growth rate of GDP per capita is more sensitive to a natural shock that causes damages in the services sector.

[INSERT TABLE 6 ABOUT HERE]

In the agriculture sector, growth rate is reduced when natural hazards cause damages to the sector itself as shown in column (3). This effect is basically driven by damages caused by droughts (-0.016, p-value<0.01). Damages caused by floods in the industrial sector negatively affect the growth rate of agriculture as well, but the estimate is significant only at the level of 10%. In the services sector, the growth rate is lowered by damages caused by floods in the industrial sector (-0.006, p-value<0.05). However, the growth rate in the industrial sector is not sensitive to damages in the sector itself, but it is sensitive to damages caused by floods in the services sector with marginal significance (-0.046, p-value<0.10). Thus, the evidence in Table 6 shows that floods may generate spillover effects between industrial and services sectors.

Damages to water supply and to infrastructure

In this part of the study, the hypothesis to be tested is whether damages to water supply and to infrastructure imply a lower GDP per capita growth rate. Losses related to water supply are basically determined by the complete exhaustion of water resources, while losses related to public/private infrastructure include damages to homes, roads, paved streets, schools, health facilities, public/private buildings, etc.

[INSERT TABLE 7 ABOUT HERE]

Panel A of Table 7 shows that an increase of 10% in the per capita losses related to water supply reduces the GDP per capita growth rate in 0.09%, being particularly affected by droughts (-0.011, p-value<0.05) as show in column (2). For the agriculture sector, the same variation in the per capita losses reduces the growth rate of the per capita added value in 0.12% (p-value<0.10), but the effect is even larger when it is caused by droughts (-0.020, p-value<0.05). Nevertheless, losses related to public/private infrastructure did not exhibit effects on GDP per capita growth rate as shown by Panel B in Table 7.

5. Conclusion

The current study aimed to analyze the effects of natural hazards on the economic growth of municipal economies in the state of Ceará, Brazil. Using an unexplored data set on disasters, several results were obtained from dynamic panel model based on a system GMM. First of all, losses from damages caused by droughts reduced GDP per capita growth rate of municipal economies in Ceará between 2002 and 2011. The agriculture sector appeared as the most sensitive economic sector to such natural hazard. This result provides support to studies that have shown the sensibility of the agriculture sector in the Northeast region to climate changes, once droughts tend to intensify in this part of the country with global warming (Ferreira Filho and Moraes, 2014; Assunção and Chen, 2016).

In an attempt to understand the mechanism underlying the sensibility of growth rate to natural hazards, the results show that losses caused by damages in the agriculture and services sector reduce municipal economic growth. Not only costly droughts in the agriculture sector can reduce the GDP per capita growth rate, but also costly floods in the services sector can slow output growth. Moreover, the output growth of the services sector is sensitive to floods that cause costly damages to industrial sector. The reverse situation is also observed, but with less robustness. Thus, natural hazards may generate negative spillover effects between the industrial and services sectors, although flood damages do not reduces their own growth rates.

Last but not the least, droughts that cause damages to water supply mediates the effect of such natural hazards in the economic growth of municipalities in the state of Ceará, despite its pioneering role of water resource management in Brazil (Gutiérrez et al., 2014). Reuse and desalinization of water in large scale appear as important alternatives to water-demanding economic activities (e.g. irrigation and manufacturing), but only in 2015 such strategies were included in the public policy agenda (Ceará, 2015). Therefore, future research shall verify whether improvements in water resource management will be well-succeed to mitigate the impacts of droughts in the economic growth.

References

ABDN (2013), 'Atlas brasileiro de desastre naturais', Universidade Federal de Santa Catarina, Florianópolis, Brazil. [Available at] http://www.ceped.ufsc.br/atlas-brasileiro-de-desastres-naturais-1991-a-2012/

Albala-Bertrand, J.M., (1993), *Political Economy of Large Natural Disasters*. Clarendon Press, Oxford.

Alonso-Borrego, C., and M. Arellano (1999), 'Symmetrically normalized instrumental-variable estimation using panel data', *Journal of Business and Economic Statistics* **17**(1): 36–49.

Anttila-Hughes, J. K. and S. M. Hsiang (2013), 'Destruction, Disinvestment, and Death: Economic and Human Losses Following Environmental Disaster,' Working paper, University of California Berkley, United States.

Arellano, M., and S. Bond (1991), 'Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations', *Review of Economic Studies* **58**(2): 277–297.

Arellano, M., and O. Bover, (1995), 'Another look at the instrumental variable estimation of error-components models', *Journal of Econometrics* **68**(1): 29–52.

Arouri, M., C. Nguyen and A. B. Youssef (2015), 'Natural disasters, household welfare, and resilience: Evidence from rural Vietnam', *World Development* **70**: 59–77.

Assunção, J., and F. Chein (2016), 'Climate change and agriculture productivity in Brazil: Future perspectives', *Environmental and Development Economics* **21**(5): 1-22.

Barro, R. J. (1990), 'Government spending in a simple model of endogenous growth', *Journal of Political Economy* **98**(5): S103-S125.

Barro, R. (1991), 'Economic growth in a cross section of countries', *The Quarterly Journal of Economics* **106**(425): 407-443.

Blundell, R., and S. Bond (1998), 'Initial conditions and moment restrictions in dynamic panel data models', *Journal of Econometrics* **87**(1): 115–143.

Carter, M. R., P. D. Little, T. Mogues, and W. Negatu (2006), ‘Poverty traps and natural disasters in Ethiopia and Honduras’, *World Development* **35**(5): 835–856.

Caruso, G. D. (2017), ‘The legacy of natural disasters: The intergenerational impact of 100 years of disasters in Latin America’, *Journal of Development Economics* **127**: 209–233.

Cavallo, E., and I. Noy (2011), ‘Natural disasters and the economy — A Survey’, *International Review of Environmental and Resource Economics* **5**: 63–102.

Cavallo, E., S. Galiani, I. Noy, and J. Pantano (2013), ‘Catastrophic natural disasters and economic growth’, *The Review of Economics and Statistics* **95**(5): 1549–1561.

Ceará (2015), ‘Plano estadual de convivência com a seca: Ações emergenciais e estruturantes’, Governo do Estado do Ceará, Brazil. [Available at] http://www.ipece.ce.gov.br/index.php/politicas-publicas

CEPED (2017), ‘Relatório dos danos materiais e prejuízos decorrentes de desastres naturais em Santa Catarina: 1995 – 2014’, Centro Universitário de Estudos e Pesquisas sobre Desastres, Universidade Federal de Santa Catarina, Brazil.

Chimeli, A. B., F. A. De Souza Filho, M. C. Holanda, and F. C. Petterini (2008), ‘Forecasting the impacts of climate variability: lessons from the rainfed corn market in Ceará, Brazil’, *Environment and Development Economics* **13**: 201-227.

Coffman, M., and I. Noy (2012), ‘Hurricane Iniki: measuring the long-term economic impact of a natural disaster using synthetic control’. *Environment and Development Economics* **17**(2): 187-205.

Cuaresma, J. C., J. Hlouskova and M. Obersteiner (2008), ‘Natural disasters as creative destruction? Evidence from developing countries’, *Economic Inquiry* **46**(2): 214–226.

Drabo, A., and L. M. Mbaye (2015), ‘Natural disasters, migration and education: an empirical analysis in developing countries’, *Environment and Development Economics* **20**(6): 767–796.

duPont IV, W., I. Noy, Y. Okuyama, and Y. Sawada (2015), ‘The long-run socio-economic consequences of a large disaster: The 1995 earthquake in Kobe’, *PLoS ONE* **10**(10): e0138714. doi:10.1371/journal.pone.0138714

Durlauf, S. N., P. A. Johnson, and J. R. W. Temple (2005), ‘Growth econometrics’, in P. Aghion and S. N. Durlauf (eds.), *Handbook of Economic Growth*, Vol. 1A, 555-677, Elservier. doi: 10.1016/S1574-0684(05)01008-7.

Firme, V. A. C. and J. S. Filho (2014), ‘Análise do crescimento econômico dos municípios de Minas Gerais via modelo MRW (1992) com capital humano, condições de saúde e fatores especiais’, *Economia Aplicada* 18(4): 679-716.

Felbermayr, G; and J. Gröschl (2014), ‘Naturally negative: The growth effects of natural disasters’, *Journal of Development Economics* **111**: 92–106.

Field, C. B., V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor, and P.M. Midgley (2012), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, Cambridge University Press.

Fomby, T., Y. Ikeda, and N. Loayza (2011), ‘The growth aftermath of natural disasters’, *Journal of Applied Econometrics*. doi: 10.1002/jae.1273

Gray, C. and V. Mueller (2012), ‘Drought and population mobility in rural Ethiopia’, *World Development* **40**(1): 134–145.

Gutiérrez A. P.; N. L. Engle; E. Nys, C. Molejón, E. S. Martins (2014), ‘Drought preparedness in Brazil’, *Weather and Climate Extremes* **3**: 95-106.

Haddad, E. A., and Teixeira E. (2015), 'Economic impacts of natural disasters in megacities: The case of floods in São Paulo, Brazil, *Habitat International* **45**: 106-113.

Hallegatte, S. and P. Dumas (2009), ‘Can natural disasters have positive consequences? Investigating the role of embodied technical change’, *Ecological Economics* 68 (3): 777–786.

Hallegatte, S., J.-C. Hourcadec and P. Dumas (2007), ‘Why economic dynamics matter in assessing climate change damages: Illustration on extreme events’, *Ecological Economics* **62**: 330-340.

Halliday, T. J. (2012), ‘Intra-household labor supply, migration, and subsistence constraints in a risky environment: Evidence from rural El Salvador’, *European Economic Review* **56**: 1001–1019.

Holtz-Eakin, D., W. Newey, and H. S. Rosen (1988), 'Estimating vector autoregressions with panel data', *Econometrica* **56**(6): 1371–1395.

Hsiang, S. M., and A. S. Jina (2014), 'The causal effect of environmental catastrophe on long-run economic growth: evidence from 6,700 cyclones', NBER Working Paper Series No. 20352, National Bureau of Economic Research, Cambridge, United States.

Hummell, B. M. L., S. L. Cutter, C. T. Emrich (2016), 'Social Vulnerability to Natural Hazards in Brazil', *International Journal of Disaster Risk Science*, doi: 10.1007/s13753-016-0090-9.

IPCC (2012), 'Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of working groups I and II of the intergovernmental panel on climate change,' [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 582 pp, 2012.

Islam, N. (1995), 'Growth empirics: A panel data approach', *Quarterly Journal of Economics* **110**(4): 1127–1170.

Jakobsen, K. T. (2012), 'In the eye of the storm — The welfare impacts of a hurricane', *World Development* **40**(12): 2578–2589.

La Porta, R., and Shleifer, A. (2014), 'Informality and Development', *Journal of Economic Perspectives* **28**(3): 109–126.

Lohmann S. and T. Lechtenfeld (2005), 'The effect of drought on health outcomes and health expenditures in rural Vietnam', *World Development* **72**: 432–448.

Loayza, N., E. Olaberría, J. Rigolini, and L. Christiaensen (2012), 'Natural disasters and growth: Going beyond the averages', *World Development* **40**(7): 1317-1336.

Marengo, J. A., L. M. Alves, R. C. S. Alvala, A. P. Cunha, S. Brito, and O. L. L. Moraes (2017), 'Climatic characteristics of the 2010-2016 drought in the semiarid Northeast Brazil region,' Annals of the Brazilian Academy of Sciences, doi: 10.1590/0001-3765201720170206.

McDermott, T. K. J., F. Barryy, and R. S.J. Tol (2014), 'Disasters and development: natural disasters, credit constraints, and economic growth', Oxford Economic Papers **66**: 750–773.

Noy, I. (2009), ‘The macroeconomic consequences of disasters’, *Journal of Development Economics* **88**: 221–231.

Noy, I., and T. B. Vu (2010), ‘The economics of natural disasters in a developing country: The case of Vietnam’, *Journal of Asian Economics* **21**: 345–354.

Pereira Jr, J. S. (2007), ‘Nova delimitação do semiárido brasileiro’, Câmara dos Deputados, Brasilia, Distrito Federal, Brasil.

Raddatz, C. (2009), *The Wrath of God: Macroeconomic Costs of Natural Disasters*, Unpublished manuscript.

Rasmussen T. N. (2004), ‘Macroeconomic implications of natural disasters in the Caribbean’, IMF Working Paper No. 224, International Monetary Fund.

Reyer, P. O., S. Adams, T. Albrecht, F. Baarsch, A. Boit, N. C. Trujillo, M. Cartsburg, D. Coumou, A. Eden, E.Fernandes, F. Langerwisch, R. Marcus, M. Mengel, D. Mira-Salama, M. Perette, P. Pereznieto, A. Rammig, J. Reinhardt, A. Robinson, M. Rocha, B. Sakschewski, M. Schaeffer, C.-F. Schleussner, O. Serdeczny, and K. Thonicke (2017), ‘Climate change impacts in Latin America and the Caribbean and their implications for development’, *Regional Environmental Change* **17**: 1601–1621.

Ribeiro, F. G., G. Stein, A. Carraro, and P. L. Ramos (2014), ‘O impacto econômico dos desastres naturais: o caso das chuvas de 2008 em Santa Catarina’, *Planejamento e Políticas Públicas* **43**.

Rodriguez-Oreggia, E., A. de la Fuente, R. de la Torre, and H. A. M. Moreno (2012), ‘Natural disasters, human development and poverty at the municipal level in Mexico’, *Journal of Development Studies* **49**(3): 442-455.

Roodman, D. (2009), ‘A note on the theme of too many instruments’, *Oxford Bulletin of Economics and Statistics* **71**(1): 135–158.

Shabnam, N. (2014), ‘Natural disasters and economic growth: A review’, *International Journal of Disaster Risk Science* **5**: 157–163.

Skidmore, M., and H. Toya (2002), ‘Do natural disasters promote long-run growth?’, *Economic Enquiry* **40**(4): 664-687.

Stillwell, H. D. (1992), ‘Natural hazards and disasters in Latin America,’ *Natural Hazards* **6**(2):131-159.

Strobl, E. (2012), ‘The economic growth impact of natural disasters in developing countries: Evidence from hurricane strikes in the Central American and Caribbean regions’, *Journal of Development Economics* **97**: 130–141.

Strobl, E. (2011), ‘The economic growth impact of hurricanes: evidence from U.S. coastal counties’, *The Review of Economics and Statistics* **93**(2): 575–589.

Toya, H. and M. Skidmore (2007), ‘Economic development and the impacts of natural disasters,’ *Economic Letters* **94**: 20-25.

UNISDR (2012), ‘Impacts of disasters since the 1992 Rio de Janeiro Earth Summit’, The United Nations Office for Disaster Risk Reduction. [Available at] http://preventionweb.net/files/27162_infographic.pdf

Yang, D. (2008), ‘Coping with disaster: the impact of hurricanes on international financial flows, 1970-2002’, *Advances in Economic Analysis & Policy* **8**(1): 1903–1903.

Windmeijer, F. (2005), ‘A finite sample correction for the variance of linear efficient two-step GMM estimators’, *Journal of Econometrics* **126**: 25–51.

TABLES

Table 1. Mean and Standard Deviation of Disaster Measures

	Reports/Episodes	Losses (R$ Million)	Affected Population (per 1,000)	Per capita Losses (R$)	Per capita GDP (R$)
All disasters	1004/1328	4.38	8.42	185.04	5029.30
		(12.56)	(9.34)	(751.78)	(3102.78)
Droughts	767/1009	3.62	8.18	153.36	4549.06
		(12.74)	(7.53)	(678.08)	(1769.68)
Floods	230/311	2.92	7.89	128.32	5211.02
		(16.79)	(11.87)	(1106.01)	(2686.68)
Other	7/8	0.01	7.21	0.17	8460.71
		(0.24)	(6.59)	(4.34)	(3707.86)

Note. Standard deviations are in parentheses. All monetary values are in real terms regarding GDP deflator of 2012.

Table 2. Additional controls and descriptive statistics

Variable description	Source	Mean/SD
Per capita consumption of electricity	COELCE	0.272
		(0.705)
Industry	COELCE	0.108
		(0.551)
Service/commerce	COELCE	0.049
		(0.136)
Rural	COELCE	0.116
		(0.139)
% of formal workers relative to population	RAIS	0.297
		(0.269)
Industry	RAIS	0.048
		(0.072)
Service/commerce	RAIS	0.237
		(0.206)
Agriculture	RAIS	0.012
		(0.018)
% of enrollments in high schools relative to population	SEDUC	4.444
		(1.122)
Per capita public spending	STN	1089.257
		(534.723)
Per capita hospital beds	SESA	0.002
		(0.001)
Observations		1,840

Note. Standard deviations are in parentheses.

Table 3. Impact of Natural Disasters on Growth Rate of per capita GDP based on per capita Losses

	Growth Rate per capita GDP		Economic Sectors (Growth Rate of per capita Added Value)					
			Agriculture		Industry		Service	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All Natural Disasters	-0.004**		-0.014***		-0.000		-0.001	
	(0.002)		(0.004)		(0.003)		(0.001)	
Droughts		-0.004**		-0.014***		-0.001		-0.001
		(0.002)		(0.004)		(0.003)		(0.001)
Floods		-0.002		-0.007*		0.002		-0.002*
		(0.002)		(0.003)		(0.004)		(0.001)
Initial per capita GDP	-0.476***	-0.464***	-0.884***	-0.872***	-0.216***	-0.235***	-0.705***	-0.701***
	(0.093)	(0.092)	(0.122)	(0.126)	(0.054)	(0.055)	(0.087)	(0.088)
Specification tests (p-values)								
Hansen test of overidentification	0.246	0.141	0.175	0.199	0.478	0.250	0.238	0.295
Arellano-Bond test for AR(1) in 1st Diff.	0.000	0.000	0.001	0.001	0.000	0.000	0.029	0.028
Arellano-Bond test for AR(2) in 1st Diff.	0.841	0.773	0.192	0.271	0.800	0.694	0.145	0.142
Number of Instruments	44	49	51	57	51	57	51	57
Municipalities	184	184	184	184	184	184	184	184
Observations	1,656	1,656	1,656	1,656	1,656	1,656	1,656	1,656

Note. The vector of endogenous variables includes: lagged per capita GDP, per capita electricity consumption (MWh), proportion of formal workers relative to total population, and per capita government expenditures. The vector of predetermined variables includes: proportion of enrollments in high school relative to total population, high schools per inhabitants, and hospital beds per inhabitants. Robust standard errors are in parentheses. All variables are in log terms. ***p-value < 0.01, ** p-value < 0.05, and * p-value < 0.1.

Table 4. Persistency of the Impact of Natural Disasters on Growth Rate of per capita GDP based on per capita Losses

	Growth Rate per capita GDP		Economic Sectors (Growth Rate of per capita Added Value)					
			Agriculture		Industry		Service	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All Natural Disasters (t)	-0.005**		-0.020***		-0.001		-0.001	
	(0.002)		(0.005)		(0.004)		(0.001)	
All Natural Disasters (t-1)	-0.000		-0.001		-0.001		0.001	
	(0.002)		(0.004)		(0.003)		(0.001)	
All Natural Disasters (t-2)	-0.001		-0.007**		0.004		0.000	
	(0.001)		(0.003)		(0.003)		(0.001)	
Droughts (t)		-0.004*		-0.018***		-0.005		-0.000
		(0.002)		(0.006)		(0.004)		(0.001)
Droughts (t-1)		-0.000		-0.003		-0.005		0.001
		(0.002)		(0.005)		(0.003)		(0.001)
Droughts (t-2)		-0.001		-0.007**		0.006**		-0.000
		(0.002)		(0.004)		(0.003)		(0.001)
Floods (t)		-0.004		-0.010*		-0.004		-0.001
		(0.003)		(0.005)		(0.005)		(0.002)
Floods (t-1)		-0.002		0.001		-0.006		0.000
		(0.003)		(0.006)		(0.005)		(0.002)
Floods (t-2)		-0.003		-0.002		-0.007*		0.001
		(0.002)		(0.004)		(0.004)		(0.001)
Initial per capita GDP	-0.507***	-0.494***	-0.769***	-0.741***	-0.233***	-0.227***	-0.692***	-0.693***
	(0.118)	(0.116)	(0.101)	(0.106)	(0.071)	(0.070)	(0.108)	(0.109)
Specification tests								
Hansen test of overidentification	0.322	0.129	0.461	0.337	0.616	0.525	0.325	0.332
Arellano-Bond test for AR(1) in 1st Diff.	0.000	0.000	0.000	0.000	0.000	0.000	0.035	0.040
Arellano-Bond test for AR(2) in 1st Diff.	0.875	0.764	0.372	0.445	0.303	0.304	0.160	0.162
Number of Instruments	43	48	43	48	43	48	43	48
Municipalities	184	184	184	184	184	184	184	184
Observations	1,472	1,472	1,472	1,472	1,472	1,472	1,472	1,472

Note. See footnote of Table 3 regarding additional controls. Robust standard errors are in parentheses. ***p-value < 0.01, ** p-value < 0.05, and * p-value < 0.1.

Table 5. Impact of the Number of Disasters on Growth Rate of per capita GDP

	Growth Rate per capita GDP		Economic Sectors (Growth Rate of per capita Added Value)					
			Agriculture		Industry		Service	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All Natural Disasters	-0.012**		-0.037***		0.001		-0.005	
	(0.005)		(0.010)		(0.009)		(0.003)	
Droughts		-0.013***		-0.034***		-0.000		-0.005
		(0.005)		(0.011)		(0.009)		(0.003)
Floods		-0.007		-0.043**		0.003		-0.005
		(0.010)		(0.017)		(0.017)		(0.005)
Initial per capita GDP	-0.466***	-0.469***	-0.774***	-0.782***	-0.205***	-0.208***	-0.718***	-0.718***
	(0.090)	(0.089)	(0.119)	(0.119)	(0.054)	(0.055)	(0.091)	(0.090)
Specification tests (p-values)								
Hansen test of overidentification	0.281	0.282	0.366	0.371	0.477	0.471	0.152	0.151
Arellano-Bond test for AR(1) in 1st Diff.	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.029
Arellano-Bond test for AR(2) in 1st Diff.	0.841	0.833	0.475	0.420	0.771	0.765	0.150	0.150
Number of Instruments	40	41	46	47	46	47	46	47
Municipalities	184	184	184	184	184	184	184	184
Observations	1,656	1,656	1,656	1,656	1,656	1,656	1,656	1,656

Note. See footnote of Table 3 regarding additional controls. Robust standard errors are in parentheses. ***p-value < 0.01, ** p-value < 0.05, and * p-value < 0.1.

Table 6. Spillover (economic sectors) effect of natural disasters on growth rate of per capita GDP based on per capita losses

	Growth Rate per capita GDP		Economic Sectors (Growth Rate of per capita Added Value)					
			Agriculture		Industry		Service	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All natural disasters								
Agriculture	-0.004**		-0.013***		-0.000		-0.001	
	(0.002)		(0.004)		(0.003)		(0.001)	
Industry	-0.005		-0.002		0.001		-0.006**	
	(0.004)		(0.014)		(0.012)		(0.003)	
Service	-0.015**		-0.014		-0.032		-0.009*	
	(0.007)		(0.022)		(0.022)		(0.005)	
Droughts								
Agriculture		-0.004**		-0.016***		-0.001		-0.001
		(0.002)		(0.004)		(0.003)		(0.001)
Industry		-0.054		0.043		0.002		0.072
		(0.150)		(0.074)		(0.223)		(0.091)
Service		0.116		-0.054		-0.100		-0.044
		(0.348)		(0.090)		(0.486)		(0.163)
Floods								
Agriculture		-0.002		-0.006		-0.001		-0.001
		(0.002)		(0.006)		(0.004)		(0.002)
Industry		-0.007*		-0.019*		0.008		-0.006**
		(0.004)		(0.010)		(0.011)		(0.003)
Service		-0.019**		-0.019		-0.046*		-0.008
		(0.007)		(0.030)		(0.024)		(0.007)
Initial per capita GDP	-0.462***	-0.490***	-0.841***	-0.830***	-0.222***	-0.230***	-0.706***	-0.712***
	(0.083)	(0.078)	(0.114)	(0.114)	(0.054)	(0.052)	(0.091)	(0.088)
Specification tests								
Hansen test of overidentification	0.585	0.577	0.471	0.538	0.555	0.473	0.380	0.737
Arellano-Bond test for AR(1) in 1st Diff.	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.026
Arellano-Bond test for AR(2) in 1st Diff.	0.825	0.849	0.258	0.361	0.743	0.669	0.151	0.142
Number of Instruments	54	69	63	81	63	81	63	81
Municipalities	184	184	184	184	184	184	184	184
Observations	1840	1840	1840	1840	1840	1840	1840	1840

Note. See footnote of Table 3 regarding additional controls. Robust standard errors are in parentheses. ***p-value < 0.01, ** p-value < 0.05, and * p-value < 0.1.

Table 7: Impact of Natural Disasters related to Water Supply and Infrastructure on Growth Rate of per capita GDP

	Growth Rate per capita GDP		Economic Sectors (Growth Rate of per capita Added Value)					
			Agriculture		Industry		Service	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Water supply								
All Natural Disasters	-0.009***		-0.012*		-0.009		0.000	
	(0.004)		(0.007)		(0.006)		(0.002)	
Droughts		-0.011**		-0.020**		-0.013		0.001
		(0.005)		(0.008)		(0.008)		(0.003)
Floods		-0.003		-0.001		0.005		-0.001
		(0.003)		(0.008)		(0.006)		(0.002)
Initial per capita GDP	-0.494***	-0.507***	-0.791***	-0.764***	-0.207***	-0.231***	-0.732***	-0.727***
	(0.089)	(0.092)	(0.121)	(0.104)	(0.056)	(0.058)	(0.086)	(0.083)
Specification tests (p-values)								
Hansen test of overidentification	0.200	0.244	0.236	0.283	0.521	0.370	0.242	0.340
Arellano-Bond test for AR(1) in 1st Diff.	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.028
Arellano-Bond test for AR(2) in 1st Diff.	0.760	0.791	0.485	0.514	0.823	0.768	0.146	0.144
Panel B: Infrastructure								
All Natural Disasters	-0.001		-0.006		0.002		-0.002	
	(0.002)		(0.004)		(0.003)		(0.001)	
Droughts		-0.002		-0.009		-0.003		-0.001
		(0.004)		(0.019)		(0.005)		(0.002)
Floods		-0.001		-0.006		0.002		-0.002
		(0.002)		(0.004)		(0.004)		(0.001)
Initial per capita GDP	-0.445***	-0.442***	-0.790***	-0.763***	-0.207***	-0.213***	-0.728***	-0.727***
	(0.088)	(0.086)	(0.119)	(0.112)	(0.055)	(0.053)	(0.088)	(0.089)
Specification tests (p-values)								
Hansen test of overidentification	0.195	0.311	0.350	0.334	0.321	0.507	0.231	0.327
Arellano-Bond test for AR(1) in 1st Diff.	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.030
Arellano-Bond test for AR(2) in 1st Diff.	0.730	0.718	0.340	0.392	0.701	0.692	0.151	0.151
Number of Instruments	44	49	51	57	51	57	51	57
Municipalities	184	184	184	184	184	184	184	184
Observations	1,656	1,656	1,656	1,656	1,656	1,656	1,656	1,656

Note. See footnote of Table 3 regarding additional controls. Robust standard errors are in parentheses. ***p-value < 0.01, ** p-value < 0.05, and * p-value < 0.1.

Natural Disasters and Economic Growth in the Northeastern Brazil: Evidence from Municipal Economies of the State of Ceará

Victor Hugo de Oliveira

IPECE e LECO/UFC

O que diz a literatura sobre desastres naturais e crescimento econômico?

Os desastres naturais possuem efeitos devastadores tanto para o desenvolvimento humano, quanto para o desenvolvimento econômico. Em duas décadas (1992-2012), esses eventos extremos afetaram 4,4 bilhões de pessoas em todo o mundo, levando 1,3 milhões de vidas e gerando uma perda de US$ 2 trilhões (UNISDR, 2012). Os desastres naturais podem causar migrações tanto em países pobres (Gray and Mueller, 2012; Drabo and Mbaye, 2014), quanto em países ricos (Strobl, 2011; duPont IV et al., 2015). Tais eventos também afetam a renda e os gastos domiciliares expenditure (Aurori et al., 2014; Lohmann and Lechtenfeld, 2015), bem como impactam no mercado trabalho local (Halliday, 2012; Coffman and Noy, 2012). Os desastres naturais podem inclusive mantem populações vulneráveis presas à armadilha da pobreza (Carter et al., 2006; Jakobsen, 2012; Rodriguez-Oreggia et al., 2012). No entanto, países com elevada renda e educação, aberto ao comércio exterior, sistema financeiro estruturado, e com governo economicamente menos intervencionista tendem a experimentar baixas perdas econômicas causadas pelos desastres naturais.

No entanto, os desastres naturais podem ter efeitos positivos, negativos, ou mesmo nenhum efeito sobre crescimento econômico dos países (Cavallo and Noy, 2011; Cavallo et al., 2013; Shabnam, 2014). Alguns estudos tem mostrado que os desastres naturais podem, na realidade, impulsionar o crescimento econômico (Albala-Bertrand, 1993; Skidmore and Toya, 2002; Noy and Vu, 2010; Fomby et al, 2011; Loayza et al., 2012). Outros estudos têm mostrado que tais eventos extremos podem reduzir o ritmo de crescimento econômico no curto (Rasmussen, 2004; Noy, 2009; Strobl 2011; 2012; Felbermayr and Gröschl, 2014), médio (McDermott et al., 2014), e longo-prazo (Raddatz, 2009; Hsiang and Jina, 2014). Cavallo et al. (2013) mostram que os efeitos negativos de desastres naturais sobre o crescimento econômico desaparecem após controlar os efeitos da instabilidade política pós-desastre.

Essa literatura tem focado quatro potenciais hipóteses de efeito dos desastres naturais no crescimento econômico de longo prazo (Hsiang and Jina, 2014). A primeira hipótese diz respeito à “creative destruction”, na qual um desastre pode estimular transitoriamente uma economia ao elevar a demanda por bens e serviços, além de elevar o fluxo de fundos interacionais e de inovação. A segunda hipótese está relacionada ao termo “building back better”, na qual um desastre pode até causar perdas de capital humano e físico, mas a gradual reposição destes dois fatores de produção de forma modernizada pode levar a um maior crescimento econômico no longo prazo (Hallegatte et al., 2007; Cuaresma et al., 2008;

Hallegatte and Dumas, 2009). Já a terceira hipótese associada ao termo “recovery to trend” nos diz que a destruição de capital humano e físico pode elevar o produto marginal desses dois fatores de produção, atraindo pessoas e investimentos para áreas atingidas até o ponto em que o produto interno bruto volta a sua trajetória pré-desastre (Yang, 2008; Strobl, 2011). Finalmente, a quarta hipótese conhecida como “no recovery” está associada o cenário em que desastres naturais causam importantes perdas de capital e bens duráveis (ex. habitações), e redução do consumo de tal modo que o investimento deixa de ser prioridade na economia. Neste cenário, a economia pode voltar a crescer, mas sem recuperar sua trajetória pré-desastre (Anttila-Hughes and Hsiang, 2013; Field et al., 2012).

Não obstante, McDermott et al. (2014) argumentam que o crescimento econômico em países desenvolvidos é menos propenso a sofrer os efeitos negativos dos eventos naturais extremos por causa do fácil acesso à crédito que permite estas economias recuperarem sua trajetória de crescimento pré-desastre no longo prazo. Os autores mostram que esse não é o caso em países pobres ou em vias de desenvolvimento, onde o baixo acesso a credito não permite uma recuperação adequada dessas economias aos desastres naturais.

Diversos estudos têm mostrado os efeitos de desastres naturais no crescimento econômico de países pobres ou em vias de desenvolvimento no curto-prazo (Noy, 2009; Strobl, 2012; Loayza et al., 2012; Felbermayr and Gröschl, 2014). Particularmente, a América Latina é vulnerável a uma variedade de desastres naturais tais como terremotos, erupções vulcânicas, furacões, secas e inundações (Stillwell, 1992). Esses eventos naturais extremos não somente produzem destruição de capital físico como geram consequências negativas para a formação de capital humano no longo prazo (Caruso, 2017), comprometendo o crescimento econômico dessa região do globo.

Motivação e Objetivo

Os eventos climáticos extremos provocam os mais frequentes desastres naturais no Brasil, onde as mudanças climáticas em curso podem intensificar tais tipos de desastres (Reyer, 2017). Por exemplo, o Nordeste do Brasil é uma das regiões do mundo que poderá experimentar uma intensificação das secas, como mostra as previsões do relatório International Panel of Climate Change de 2012. Entre 1995 e 2014, quase metade do total de perdas por eventos climáticos extremos ocorreram no Nordeste (CEPED, 2016), e a atual seca (2010-2016) na região (Marengo et al., 2017) tem demonstrado que o Brasil ainda sofre com a falta de políticas públicas que promovam uma maior resiliência e preparação para estes tipos de desastres. Estudos mostram que as mudanças climáticas reduziram substancialmente a produtividade agrícola no Nordeste (Ferreira Filho and Moraes, 2014; Assunção and Chen, 2016).

O presente estudo busca fornecer evidências do impacto dos desastres naturais causados por secas e inundações no crescimento econômico do Ceará, o qual é um dos estados mais afetados por eventos climáticos extremos no país (CEPED, 2016). Vale salientar que 87% do território do Ceará estão dentro do semiárido nordestino com precipitação anual abaixo de 800 mm, risco de aridez igual a 0,5 ou menor, e risco de seca de pelo menos 60%. Além disso, o Ceará é um dos estados mais pobres e que exibe uma alta vulnerabilidade social aos desastres naturais (Hummell et al., 2016).

Metodologia e Resultados

Ademais, a investigação usa uma base de dados sobre desastres naturais ainda inexplorada cientificamente no Brasil. As informações sobre desastres naturais provém dos Relatórios de Avaliação de Danos da Defesa Civil entre os anos de 2002 e 2011. Tais relatórios fornecem informações sobre população afetada e perdas causadas por todos os tipos de desastres em nível de município. Logo, o estudo combina dados sobre desastres climáticos e o PIB per capita dos 184 municípios do Ceará para um período de 10 anos. A intensidade das perdas causadas por secas e das inundações são mensuradas pelo valor anual real dos danos per capita. Usando modelo de painel de dados baseado em um sistema GMM, as evidências empíricas mostram que:

i. O crescimento econômico dos municípios é negativamente afetado pelos desastres naturais no Ceará, especialmente o setor agrícola;
    a. Um aumento de 10% nas perdas per capita causadas por desastres naturais podem reduzir a taxa de crescimento em até 0,04%;
    b. No setor agrícola, um aumento de 10% nas perdas per capita causadas por secas podem reduzir o crescimento do sector em 0,14%;
ii. Os danos causados aos recursos hídricos com a perda de mananciais aparecem como um potencial canal de efeito do efeito das secas sobre o crescimento econômico no setor agrícola;
iii. Não sobre as secas que causam danos ao setor agrícola, como também as inundações que causam perdas ao setor de serviços, contribuem para a redução do ritmo de crescimento das economias municipais;
iv. Além disso, as inundações quando causam perdas ao setor industriam afetam negativamente a taxa de crescimento do setor de serviços, mostrando a existência de efeito “spillover” ou transbordamento entre estes setores.

Os resultados neste estudo contribuem não somente para entender os efeitos dos desastres naturais sobre o crescimento econômico municipal, como também podem ajudar no delineamento de políticas públicas que possam atenuar os efeitos econômicos das secas e inundações no Ceará. Além disso, o estudo apresenta novas evidências para uma literatura que está restrita aos estudos para países (Skidmore and Toya, 2002; Noy, 2009; Strobl, 2012; Loayza et al., 2012; Cavallo et al., 2013; Felbermayr and Gröschl, 2014; Hsiang and Jina, 2014).