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

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**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.

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## 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). Particularly, developed countries are more likely to experience fewer losses than poor and developing countries (Toya and Skidmore, 2007).

The literature has documented a remarkable diversity of economic consequences of natural disasters. For instance, these extreme events may cause population mobility in poor (Gray and Mueller, 2012; Drabo and Mbaye, 2015) and rich countries (Strobl, 2011; duPont IV et al., 2015), affect household income and expenditure (Arouri et al., 2014; Lohmann and Lechtenfeld, 2015), as well as the local labor market (Halliday, 2012; Coffman and Noy, 2012). Natural hazards may also contribute to the maintenance of armed conflicts (Ghimire and Ferreira, 2015), trap vulnerable population into poverty (Carter et al., 2006; Jakobsen, 2012; Rodriguez-Oreggia et al., 2012), besides threatening human capital formation still in the womb (Torche, 2011; Simeonova, 2011; Currie and Rossin-Slater, 2013; Liu et al., 2015; Rosales-Rueda, 2016; Oliveira and Quintana-Domeque, 2016).

Nonetheless, natural disasters can either have positive or negative effect on economic growth (Cavallo and Noy, 2011; 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; Cunado and Ferreira, 2014), 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). Cavallo et al. (2013) found that the negative impact of large disasters on economic growth vanishes after accounting for political instability following the extreme event.

In this specific 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 becomes less preferable in the economy than consumption. In this "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). Notably, Latin America is vulnerable to a variety of natural disasters (Stillwell, 1992). These extreme events 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). The predictions of the International Panel of Climate Change show intensification of droughts in the Northeastern Brazil throughout the 21st Century due to global warming (Field et al., 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 recent 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 agriculture sector in the Northeast of Brazil (Ferreira Filho and de Moraes, 2014; Assunção and Chein, 2016).

The current investigation aims to provide evidence on the impact of climatic disasters caused by droughts and floods on the economic growth of municipalities of the state of 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 disasters 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 is negatively affected by droughts, especially in the agriculture sector. Damages to water supply appear as the main channel of the effect of droughts on the growth rate of agriculture. Not only costly droughts in the agriculture sector can reduce the growth rate of per capita GDP, 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 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 brings a review of empirical studies in the literature; section 3 describes the data sources; section 4 presents the methodology; and section 5 analyzes the results. Finally, section 6 concludes the study.

## 2. Literature Review

The study of the macroeconomic impacts of natural disasters has increased substantially in the recent years, but Albala-Bertrand (1993) analyzes the macroeconomic effects of natural disasters across countries from 1960-1979. Using a before-after approach, the study shows that the disaster lead to an increase in capital formation, agriculture and construction output, as well as an increase in the deficit of the current account balance and in the government budget balance. Thus, the author documented that disasters lead to a positive short-run impact on GDP of about 0.4%, and conclude that they are not necessarily a problem for development. In the same line of reasoning, Skidmore and Toya (2002) find that a one-standard-deviation increase in climate disasters, measured by the total number of significant events occurring in a country over the 1960-90 period, results in a 22.4% increase in the average annual rate of economic growth. The authors show that the disasters increase the total factor productivity, suggesting that natural hazards provide opportunities to update the capital stock and adopt new technologies.

However, Rasmussen (2004) shows that large natural disasters in Eastern Caribbean countries cause a reduction of 2.2% in real GDP growth in the short-run, as well as a large decline in agriculture production and an offsetting increase in investment. Raddatz (2009), using a Panel-VAR to analyze the impacts of mass-disasters (geological, climatic and other type of disasters) on the growth of real GDP per capita since 1900, show that climate-related disasters reduce real GDP per capita in at least 0.6%. The larger impacts come from droughts that cause cumulative losses of 1% of GDP per capita.

Noy (2009), based on the dynamic growth model, finds that the amount of property damage incurred during the disaster is a negative determinant of GDP growth performance, in which the impact is mostly driven by developing countries. The author argues that destruction of capital stock and infrastructure is the potential mechanism underlying the negative effect of natural disasters. Noy and Vu (2010) show that more lethal disasters result in lower output growth, but more costly disasters actually seem to boost the Vietnam's economy in the short-run. The authors argue that this result is aligned with the creative destruction hypothesis, once regions with higher access to reconstruction funds from the private and public sectors (i.e. richer and less remote regions) exhibit faster growth following the disaster.

Strobl (2011) investigates the impact of hurricanes on the economic growth of coastal counties in the US from 1970 to 2005 and demonstrates that growth rate falls, on average, 0.45 percentage points in counties struck by hurricanes, in which such effect is partially driven by relatively richer people moving away from affected counties in response to the hurricane. Using a similar approach, Strobl (2012) analyzes the effects of the hurricanes in the economies of the Central American and Caribbean regions, and show that hurricane strikes caused outputs to fall by at least 0.83 percentage points in the region.

Loayza et al. (2012) try to reconcile this previous literature that has reported both positive and negative impacts of natural disasters on economic growth. They estimate dynamic panel models based on the system GMM using a 1961-2005 cross-country panel data, and analyze the effects of natural disasters on economic growth. The authors found that: i) disasters do affect economic growth, but not always negatively, with effects that differ across types of disasters and economic sectors; ii) although moderate disasters (such as moderate floods) can have a positive growth effect in some sectors, severe disasters do not;

and iii) growth in developing countries is more sensitive to natural disasters than in developed ones, with more sectors affected and the effects larger and economically meaningful. These results are aligned with Fomby et al (2011) who use VAR models applied to a panel of cross-country and time series data. They show that natural disasters are stronger on developing countries than on developed ones, and not all of the natural disasters are alike in terms of the growth response they induce, and some can even have positive effects on economic growth. Moreover, the timing of the growth response varies for both types of natural disaster and the sector of economic activity.

Using the synthetic control approach, Cavallo et al (2013) found that natural disasters do not have any significant effects on subsequent economic growth, and the political instability following the disaster is the main driven factor in both cases in which natural disasters caused reduction in economic growth. Nonetheless, Felbermayr and Gröschl (2014) found a substantial negative and robust impact of disasters on economic growth across countries. The worst 5% disaster years come with a growth damage of at least 0.46 percentage points. In this study, the authors argue that the average effect is driven mainly by very large earthquakes and some meteorological disasters, and that poor countries are more strongly affected by geophysical disasters while rich countries are more affected by meteorological events.

Hsiang and Jina (2014) used meteorological data to construct a measure of country's exposure to tropical cyclones during the period of 1950-2008. They exploited random within-country and year-to-year variation in cyclone strikes to identify the causal effect of environmental disasters on long-run growth, and reject the hypothesis that disasters stimulate growth or that short-run losses disappear after migrations or transfers of wealth. Indeed, the results show that countries which are frequently or persistently exposed to cyclones exhibit annual average growth rates of 1-7.5 percentage points lower than simulations of their cyclone-free counterfactuals.

Recently, Cunado and Ferreira (2016) use panel vector autoregression models to trace the dynamic response of output growth to flood shocks based on new data on large flood events in 135 countries between 1985 and 2008. In this study, flood shocks tend to have a positive and significant average impact on per capita GDP growth. However, this effect is limited to developing countries and to moderate floods. The positive impact of floods is larger and more significant in the agricultural sector. While floods seem to have a direct effect on agricultural growth rates in developing countries, their effect on nonagricultural growth rates is mainly indirect.

The current study not only provides the estimate of the short-term effect of natural disasters on economic growth of the municipal economies in the state of Ceará, but it also verifies which economic sector is most sensitive to extreme events (Loayza et al., 2012). The study also tries to shed light into the potential mechanism by analyzing if damages to a specific economic sector produce effects on the growth rate of the other economic sectors, and whether damages to water resources and infrastructure drive the effect of natural disasters in the short-run.

## 3. Data

### 3.1 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.[2]

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). Reports about droughts are more than three times the number of reports regarding floods.[3] Other natural disasters involve storms, marine erosion, landslides, and forest fires, which accounts for less than 1% of recorded damages. It is worth noting that 76% of all episodes of disasters have a Damage Assessment Report (ABDN, 2013), in which the intensity of the natural disasters in municipalities is measured by per capita losses. 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 addition, the average of annual 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]

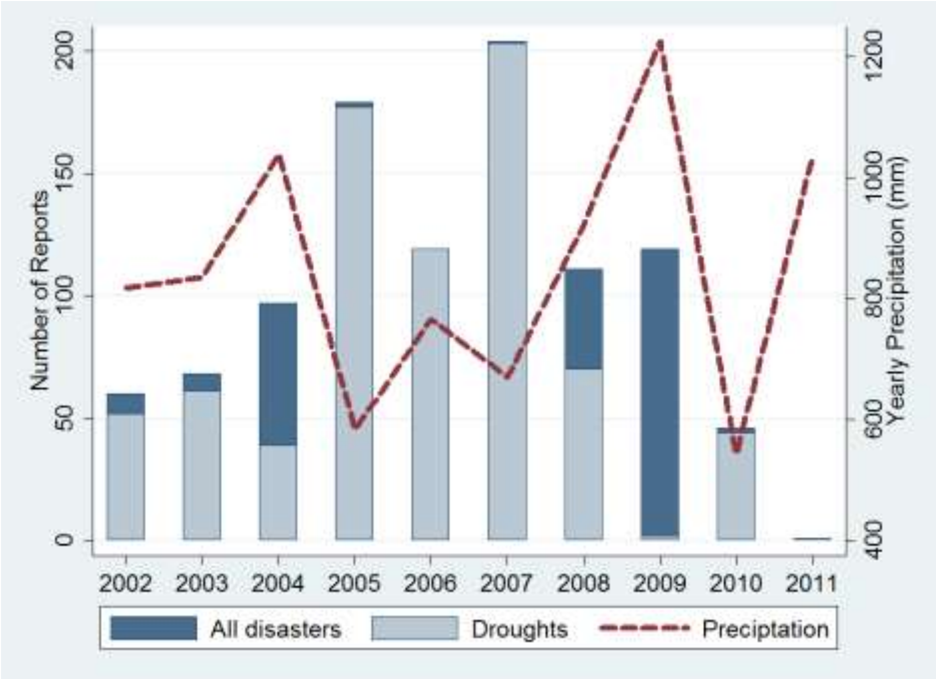
Figure 1 provides support to the evidence in Table 1 by showing that notifications of natural disasters are correlated with yearly precipitation in the state of Ceará. For instance, notifications of droughts are larger in years when the yearly precipitation is below 800mm, except in 2010 due to the high precipitation in 2009, which increased the volume of water in

[2] https://s2id-search.labtrans.ufsc.br/.

[3] Droughts in the state of Ceará can be influenced by El Niño, and produces negative consequences for corn market (Chimeli et al., 2008).

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 of natural disasters take only these two types of extreme events into account. Moreover, the current analysis incorporates other important variables to determine GDP growth rate of the municipalities in the State of Ceará, which are presented in the next subsection.

### 3.2 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).[4] 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 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.

[INSERT TABLE 2 ABOUT HERE]

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. The authors argue that the informal sector is predominant in developing economies and are very unproductive, whereas 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.

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.[5] 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

[4] http://www.ipece.ce.gov.br/index.php/anuario-estatistico-do-ceara.
[5] School enrollment has been used as a proxy for human capital by Barro (1991).

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. 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,

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

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, $\mu_t$, that captures the potential productivity growth and common shocks over time, and the unit-specific fixed effect, $\lambda_i$. 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 et al. (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 $(\varepsilon_{it})$ 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, $\varepsilon$, is not serially correlated[6], 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

[6] 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.

differences of the explanatory variables. Thus, the moment conditions for the equation in levels are given by

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

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

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.[7] 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.[8] 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

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

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 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.

## 5. Results

### 5.1 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'.

## 5.2 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%.

### 5.3 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.

## 6. 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.

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## 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.