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. Moreover, damages that cause large per capita losses in the agriculture and services sectors contribute to slow down the economic growth. Last but not least, the output growth of the services sector is sensitive to floods that cause costly damages to industrial sector, suggesting a potential spillover effect of natural disasters between these two economic sectors. The results in this study not only contribute to understand the effects of natural disaster on economic growth in Brazil, but also 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 atual 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 derramamento 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 de cross-country.

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

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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). Natural disasters also cause indirect costs related with population mobility in poor (Gray and Mueller, 2012; Drabo and Mbaye, 2015) and rich countries (Strobl, 2011; duPont IV et al., 2015), affects household income and expenditure (Aurori et al., 2014; Lohmann and Lechtenfeld, 2015), and local labor market (Coffman and Noy, 2012; Halliday, 2012) as well. Natural hazards can also trap vulnerable population in poverty condition (Carter et al., 2006; Jakobsen, 2012; Rodriguez-Oreggia et al., 2012), as well as perpetuate armed conflicts in conflict-prone and developing countries (Ghimire and Ferreira, 2016). However, countries with higher income, higher educational attainment, greater openness, more complete financial systems and smaller government experience fewer losses and fatalities (Toya and Skidmore, 2007), which opens space for public policy of adaptation and mitigation.

Nonetheless, natural disasters can either have positive or negative affect economic growth (Cavallo and Noy, 2011; Shabnam, 2014). Some studies have shown that natural hazards boosts 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). First, disasters may transitorily stimulate the economy because the increasing demand for goods and services, inflow of international aid and innovation, leading to a "creative destruction" hypothesis (Skidmore and Toya, 2002). Second, 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 effect 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). Third, 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 recover its pre-disaster trend (Yang, 2008; Strobl, 2011). Fourth, a natural disaster may destroy capital and/or durable goods may (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 experience 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 because 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 growth rate of the economy 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 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 policy in Brazil still lacks capacity of resilience and preparedness for this type of extreme events (Gutiérrez et al., 2014). Simulation studies have shown that climate change will substantially affect the Northeastern Brazil, specially the agriculture sector (Ferreira Filho and Moraes, 2014; Assunção and Chen, 2016).

The current investigation aims to provide evidence of the impact of climatic disasters caused by droughts and floods in the state of Ceará, Brazil, which is one of the most affected states 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 of the country and exhibits a high social vulnerability to natural disasters (Hummell et al., 2016).

Furthermore, this investigation rely on an unexplored data source on disasters in Brazil is used. The information on extreme events come from the Damage Assessment Report (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, are measured by annual per capita losses, and their impact on economic growth is estimated through dynamic panel models. Empirical evidence shows that the economic growth of Ceará state is negatively affected by droughts, and persistent in the short-run. The agriculture sector is the most affected sector by droughts, in which the losses of crops/livestock and destruction of water resources are the main mechanism driving the negative effect. Municipalities of the semiarid region are the most vulnerable economies to climatic disasters. On the other hand, losses of infrastructure either caused by droughts or floods did not have any effect on economic growth. Floods slow down growth in the service sector, only when such extreme weather events cause losses for the industrial sector, suggesting the existence of a spillover effect.

This study is a first attempt to understand the effects of natural disaster on economic growth in Brazil. Although this study is restricted to one out of 27 federal unities of the country, its results could be representative for the semiarid region that covers 89,5% of the territory of the Northeast region and part of the territory of Minas Gerais. 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 drop 5,13% in the industrial production. Haddad and Teixeira (2015) find that floods contributed to reduce city growth and residents' welfare, as well as hampering local competitiveness in both domestic and international markets.

The remainder of this study is structures as follows: Section 2 contains a review of the literature regarding the macroeconomic impacts of natural disasters. Section 3 describes the data sources. Section 4 brings the methodology, while Section 5 discusses 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 increase in deficit in 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 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 disaster. Noy and Vu (2010) show that more lethal disasters result in lower output growth, but more costly disaster actually appear 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 hurricane, 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 strike caused output 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 impact of natural disasters on economic growth. They estimate dynamic panel models based on system of GMM using a 1961-2005 cross-country panel data, and analyze the effects of natural disasters on economic growth. The author find 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 than on developed countries, and not all natural disasters are alike in terms of growth response they induce, and some can even have positive effects on economic growth. Moreover, the timing of the growth response varies with both the type of natural disaster and the sector of economic activity.

Using the synthetic control approach, Cavallo et al (2013) find that natural disasters do not have any significant effect on subsequent economic growth, and political instability followed the disaster is the main driven factor in two cases where natural disaster caused reduction in economic growth. Nonetheless, Felbermayr and Gröschl (2014) find 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 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) use meteorological data to construct a measure of country's exposure to tropical cyclones during the period 1950-2008. They exploit random within-country 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 following migrations or transfers of wealth. Indeed, the results show that countries that are frequently or persistently exposed to cyclones exhibit annual average growth rates to be 1-7.5 percentage points lower than simulations of “cyclone-free” counterfactuals.

The current study not only provides the estimate the short-term effect of natural disasters on economic growth of the municipal economies of the state of Ceará, but also verifies which economic sector is most sensitive to extreme events (Loayza et al., 2012). The study also try to shed light in the potential mechanism by analyzing whether damages cause by natural disasters to a specific economic sector produce effects to the growth rate of the other economic sectors, and whether damages to water resources and infrastructure drives 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 of 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 (Relatório de Avaliação de Danos - AVADAN) 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 emergency or calamity state after a disaster occurrence. In 2012, a new system of disaster records was employed by the Ministry of National Integration (Ministério da Integração National), in which the electronic version of the 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 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.[3] 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).

[2] Damage Assessment Reports can be found in the following link: 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 intensity of the natural disasters in municipalities is measured by per capita losses. Since material damages caused by natural disasters is well discriminated by the AVADAN, it allows for a better analysis of the mechanism. The disaster measure is given by

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

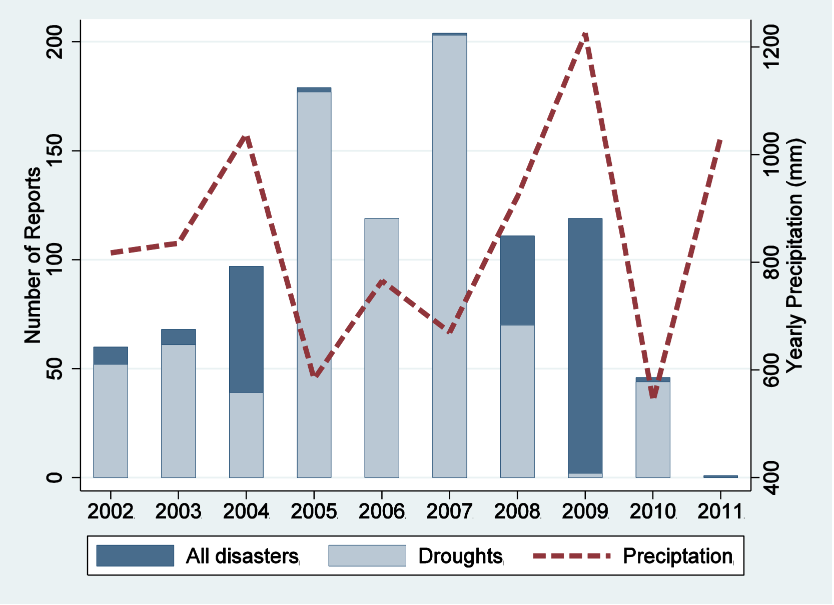
where i is the index of municipalities, j indicates the type of disaster, and t is the year of the disaster.

In Table 1, droughts are the most frequent natural disaster in the state of Ceará, 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 is slightly larger to droughts in comparison to floods, but floods tend to occur in richer municipalities as judged by differences in per capita GDP.

[INSERT TABLE 1 ABOUT 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 year in which the yearly precipitation is below 800mm, except in 2010 due to the high precipitation in 2009 that 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 increases 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 into account only these two types of natural events. Moreover, the current analysis incorporates other important variables for determination of

GDP growth 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.

3.2 Additional Control Variables

Control variables used in this study come from different source of information, but they are public available in the Anuário Estatatístico do Ceará.[4] The first variable in Table 2 is the per capita consumption of electricity (MWh/population), which is provided by the Companhia Energética do Ceará (COELCE). This variable is largely used in studies about economic growth in Brazil, because the absence of an appropriate measure for physical capital at municipality level (Firme and Filho, 2014). Per capita consumption of electricity is larger in rural sector probably because the impossibility of distinguishing between residential and productive consumption. Another variable included in the vector of covariates is the size of the formal sector, which comes from the Relação Anual de Informações Sociais (RAIS). La Porta and Shleifer (2014) discuss about the relationship between economic development and (in)formal economy (firms and workers). The authors argue that informal sector is predominant in developing economies and are very unproductive, but it is the formal sector the 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 high-school relative to the total population in the municipality, which is provided by the Secretaria Estadual de Educação do Ceará. Loayza et al. (2012) use the ratio of the number of students enrolled in secondary school to the number of persons of the corresponding school age.[5] Moreover, Government spending is also included as explanatory variable (Barro, 1990; Loayza ey al., 2012), which can be obtained in the Secretaria do Tesouro Nacional . Finally, the ratio of hospital beds relative to total population of municipalities is included in the analysis as a proxy for preparedness of municipality to health response to the disasters (WHO, 2013). Information on hospital beds comes from the Secretaria de Saúde do Ceará. These control variables are also important in accounting for potential difference in resilience of municipalities to natural disasters.

In the next section, I describe the econometric approach use to measure the impact of the natural disasters on economic growth of municipalities in the State of Ceará.

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. The empirical model is given by

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

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. The vector $X_{i,t}$ includes growth determinants that vary across time and geographical unities. 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.

[4] For further details, access the following link: 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).

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,

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

where $D_{i,t}$ is the measure of natural disaster, which has been proxied by 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 is the per capita losses caused by natural disasters as presented in Table 1.

However, the equation (2) is a typical lagged-dependent-variable model, and the standard within-group or first-difference estimation method of dealing with fixed effects is inappropriate because a transformed term involving $\log y_{i,t-1}$ is correlated with transformed errors. Moreover, some explanatory variables may be jointly determined with economic growth, which is another source of endogenous bias in the model. A widely-used approach is to differentiate equation (2) 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 (3) expresses the first difference transformation of equation (2).

$$\Delta\log y_{i,t} = (1+\beta)\,\Delta\log y_{i,t-1} + \rho\Delta\log D_{i,t} + \Delta\log X_{i,t}\,\theta + \Delta\mu_t + \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right) \qquad (3)$$

Following Loayza and Oliberría (2012), GMM estimators developed for dynamic models of panel data are used to control for 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[6], and that the explanatory variables are not correlated with its future realizations, the required moment conditions are:

$$E\left[\log y_{i,t-s}\cdot\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0,\ for\ s \geq 2; t = 3, \dots, T \qquad (4)$$
$$E\left[\log X_{i,t-s}\cdot\left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0,\ for\ s \geq 2; t = 3, \dots, T \qquad (5)$$

Nonetheless, difference estimator based on moment conditions (4) and (5) 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 the equation (3). 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 (2) and the regression in differences (3) 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

$$E\left[\left(\log y_{i,t-1} - \log y_{i,t-2}\right) \cdot \left(\lambda_i + \varepsilon_{i,t}\right)\right] = 0,\ for\ s \geq 2; t = 3, \dots, T \quad (6)$$
$$E\left[\left(\log X_{i,t-1} - \log X_{i,t-2}\right) \cdot \left(\lambda_i + \varepsilon_{i,t}\right)\right] = 0,\ for\ s \geq 2; t = 3, \dots, T \quad (7)$$

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 (4)-(7) are the required moment conditions to obtain consistent and efficient estimates of the impact of natural disasters on economic growth of the municipalities of Ceará state.

Nonetheless, Loayza et al. (2012) avoid over-fitting bias (Roodman, 2009a) by using a small set of moment conditions. In this case, we use at most six lags for each endogenous explanatory variables and a common variance-covariance of moments across periods. This last procedure allows them to use only one instrument for each endogenous variable and lag distance (rather than one instrument for each time period, variable, and lag distance).[7] For small samples, such procedure can avoid the bias that arises as the number of instruments climbs toward the number of observations, but it reduces efficiency in large samples (Roodman, 2009b). Thus, we also use two-step estimation in order to improve efficiency, but reported two-step standard errors tend to be severely downward biased (Arellano and Bond 1991; Blundell and Bond 1998). In this case, we have to adopt the finite-sample correction to the two-step covariance matrix derived by Windmeijer (2005). It makes two-step standard errors more efficient than one-step procedure, especially for system GMM.[8]

The validation of the instruments is obtained from the Hansen test for overidentifying restrictions, in which model's identification is the null hypothesis. Moreover, we test the serial correlation of the residuals from differenced equation. If a significant AR(2) statistic is encountered, the second lags of endogenous variables will not be appropriate instruments for their current values.

Loayza et al. (2012) highlighted that while disasters are independent from GDP, disaster losses may not be. For 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 for initial conditions. As a robustness analysis, the model includes per capita losses as an endogenous variable, assuming that the disaster measure is currently determined by per capita GDP and estimated through the GMM procedure. However, this modification is costly because it entails losing part of the information provided by the contemporaneous observation of the natural disaster variables, and a reduction in statistical significance should be expected (Loayza et al., 2012).

Another robustness analysis is to test whether the effects of the natural disasters on the growth rate of per capita GDP are persistent or not. In this case, the lagged values of per capita losses are included in the model. Besides, episodes of natural disaster are used as exogenous measure of natural disasters in the robustness analysis. In order to understand the effect of natural hazards on growth rate of per capita GDP, the study provides estimates of potential spillover effects across economic sectors. Since the AVADAN reports the type of the disaster and the amount of losses by economic sectors (i.e. industry, service/commerce,

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

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, losses due to damage to private and public infrastructure (e.g. roads, paved streets, public buildings, schools, health facilities, etc.) are also recorded by the AVADAN, which allows us to test whether infrastructure losses due to natural disaster affects the growth rate of the GDP. It is also investigated whether damages to water supply (e.g. water treatment plant, network distribution and water source) caused by natural hazards affect the growth rate of per capita GDP. Thus, the next sections present the results, as well as the sensitive analyzes of the proposed empirical approach.

5. Results

5.1 Baseline Estimations

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

[INSERT TABLE 3 ABOUT HERE]

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

Analyzing the effect of natural disasters for each economic sector, the agricultural sector appears as the economic sector 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 the per capita added value of the agriculture sector in 0.14%. This effect is especially influenced by droughts, which exhibits the same magnitude of the 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 sector in 0.07% and 0.02%, but these estimates are significantly only at the level of 10%. Loayza et al. (2012) using the fraction of affected population as the intensity measure of the disaster find that droughts only affects the growth rate of agriculture sector, whereas floods increase the growth rate of both agriculture and services sectors.

5.2 Sensitive analysis

Endogenous natural disasters

Table 4 displays the estimates assuming that the measure of natural disaster is endogenously determined with per capita GDP. Although the overall effect of natural disaster on growth rate of per capita GDP remains negative and larger than the estimate of the Table 3, it is not statistically significant due to the larger standard error. The estimates are also insignificant for disaggregated effects of natural disaster on growth rate of per capita GDP.

[INSERT TABLE 4 ABOUT HERE]

However, the agriculture sector remains as the most sensitive economic sector to climatic disasters in the state of Ceará as shown by columns (3) and (4) of Table 4. An increase of 10% in the per capita losses due to natural disasters reduces the growth rate of per capita added value of agriculture in approximately 0.3%. The same variation caused by droughts causes a reduction of about 0.4%. Floods appears positively associated to growth rates in agriculture and services, but the estimates are insignificant.

Moreover, natural disasters have a positive effect on the growth rate of per capita added value of the industrial sector. A variation of 10% in the per capita losses due to natural disasters increases the growth rate of per capita added value of the industrial in approximately 0.18%. Nonetheless, this estimate is significant only at the level of 10%. This positive impact is driven by monetary losses caused by droughts. Such result is aligned with the "creative destruction" hypothesis as suggested by Skidmore and Toya (2002). For instance, the scarcity of water may induce industrial firms to invest in new technologies to reduce their dependence on such natural resource, which may increase productivity and the growth rate in the short-run.

Persistent effects

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

[INSERT TABLE 5 ABOUT HERE]

The estimated coefficients for contemporaneous effects of natural disasters remain negative and significant in column (1) of Table 5, despite the effect for droughts is significant only at the level of 10% in column (2). No significance is observed for coefficients for lagged variables in columns (1) and (2). On the other hand, disasters exhibit contemporaneous and lagged effects on the growth rate of added value 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 one year lag, but the estimate is negative and significant with two years lag (-0.007, p-value<0.05). In the industrial sector, droughts have positive and significant impact with two years lag (0.006, p-value<0.05), while floods have negative and marginally significant effect with two years 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) find the reverse: floods with 5 years 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 6 ABOUT HERE]

In column (1) of Table 6, each natural disaster reduces the growth rate of the GDP in 0.012%. Results confirm that droughts are the most harmful natural hazards for municipal economies in Ceará state, in which an additional drought relative to the average can reduces the growth rate of the GDP 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 the growth rate of per capita GDP, 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 flood can reduces the growth rate in 0.043%. The economic sectors of industry and services remain not sensitive to the natural disasters. Loayza et al. (2012) find 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%.

Semiarid municipalities

In this sensitive analysis, the sample is restricted to municipalities that belong to the semiarid region of Brazil. These municipalities are especially vulnerable to droughts, and it is important to check whether they drive the results in Table 3.

[INSERT TABLE 7 ABOUT HERE]

Results in Table 7 suggest that the impact of natural disasters on economic growth of the municipalities in the Ceará state is driven by those municipalities in the semiarid region. The estimates are pretty similar to those presented in Table 3. It is worth noting that the impact of per capita losses due to floods and droughts on the growth rate of per capita GDP is the same, -0.004. However, the impact of droughts is still higher than the impact of floods when considering the agriculture sector. No significant effects are found for the sector of industry, or services.

5.3 Mechanism Analysis

Spillover effects

Before analysis the existence of spillover effect of damages caused by natural disasters across economic sectors, it is relevant to know which damaged economic sector contributes to the fall in the per capita growth rate of the GDP. 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 growth rate of per capita GDP. 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 per capita GDP is more sensitive to a natural shock that causes damages in the services sector.

[INSERT TABLE 8 ABOUT HERE]

In the agriculture sector, growth rate is reduced when natural hazards cause damages to the own sector 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 the 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 own sector, 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 8 shows that floods may generate spillover effects between industrial and services sectors.

Damages to water supply versus infrastructure losses

In this part of the study, the hypothesis to be tested is whether damages to water supply and to infrastructure imply smaller growth rate of per capita GDP. 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 9 ABOUT HERE]

Panel A in Table 9 shows that an increase of 10% in the per capita losses related to water supply reduces the growth rate of per capita GDP 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 the growth rate of per capita GDP as shown in Panel B of Table 9.

6. Conclusion

The current study aimed to analyze the effects of natural hazards on economic growth of municipal economies in the state of Ceará, Brazil. Using an unexplored data set on disasters, several results are obtained from dynamic panel model based on a system of GMM. First of all, losses from damages caused by droughts reduce the growth rate of per capita GDP of municipal economies of Ceará between 2002 and 2011. The agriculture sector appear as the most sensitive economic sector to such natural hazard. This result is aligned to Loayza et al. (2012) who show that droughts largely reduce economic growth in the agriculture sector of developing countries. This result also provides support to studies that have shown the sensibility of the agriculture sector in the Northeast region to climate changes, once droughts will intensify in this part of Brazil with global warming (Ferreira Filho and Moraes, 2014; Assunção and Chen, 2016).

In an attempt to understanding the mechanism underlying the sensibility of growth rate to natural hazards, I 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 growth rate of per capita GDP, but also costly floods in the services sector can slow the 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 spillover effects between the industrial and services sectors, slowing their rate of economic growth. Last but not least, droughts that cause damages to water supply are the main driver factor of the effect of natural hazards in the agriculture sector.

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 have been mainly focused on cross-country study (Skidmore and Toya, 2002; Noy, 2009; Strobl, 2012; Loayza et al., 2012; Cavallo et al., 2013; Felbermayr and Gröschl, 2014; Hsiang and Jina, 2014). However, the study has some caveats. For instance, it would be important to analyze whether mitigation policies, financed by state and federal government, can reduce the impact of natural disasters on economic growth. If it is the case, the estimates obtained in this study may be a lower bound. Besides, the absence of private investment does not allows to check whether natural hazards can improve economic growth in the industrial sector, as suggested by the positive effect of droughts on the growth rate of its per capita added value.

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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: Impact of Endogenous 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	-0.006		-0.026**		0.017*		-0.003	
	(0.006)		(0.012)		(0.009)		(0.003)	
Droughts		-0.007		-0.037***		0.015*		-0.003
		(0.006)		(0.012)		(0.008)		(0.003)
Floods		0.005		0.017		-0.005		0.001
		(0.015)		(0.022)		(0.018)		(0.008)
Initial per capita GDP	-0.494***	-0.491***	-0.929***	-0.849***	-0.213***	-0.214***	-0.699***	-0.717***
	(0.098)	(0.097)	(0.128)	(0.129)	(0.054)	(0.055)	(0.093)	(0.102)
Specification tests (p-values)								
Hansen test of overidentification	0.165	0.113	0.217	0.459	0.704	0.424	0.236	0.316
Arellano-Bond test for AR(1) in 1st Diff.	0.000	0.000	0.001	0.001	0.000	0.000	0.029	0.026
Arellano-Bond test for AR(2) in 1st Diff.	0.895	0.695	0.135	0.984	0.828	0.670	0.158	0.162
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. All variables are in log terms. ***p-value < 0.01, ** p-value < 0.05, and * p-value < 0.1.

Table 5: 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. All variables are in log terms. ***p-value < 0.01, ** p-value < 0.05, and * p-value < 0.1.

Table 6: 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 7: Impact of Natural Disasters on Growth Rate of per capita GDP of the Semiarid Region

	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	-0.006***		-0.015***		-0.004		-0.002	
	(0.002)		(0.004)		(0.003)		(0.001)	
Droughts		-0.004**		-0.013***		-0.001		-0.001
		(0.002)		(0.005)		(0.003)		(0.001)
Floods		-0.004**		-0.009**		-0.003		-0.001
		(0.002)		(0.004)		(0.003)		(0.001)
Initial per capita GDP	-0.574***	-0.537***	-0.693***	-0.686***	-0.205***	-0.221***	-0.688***	-0.665***
	(0.108)	(0.108)	(0.113)	(0.111)	(0.073)	(0.069)	(0.111)	(0.120)
Specification tests (p-values)								
Hansen test of overidentification	0.329	0.265	0.094	0.177	0.620	0.203	0.443	0.390
Arellano-Bond test for AR(1) in 1st Diff.	0.000	0.000	0.000	0.000	0.000	0.000	0.044	0.045
Arellano-Bond test for AR(2) in 1st Diff.	0.475	0.387	0.147	0.165	0.899	0.683	0.196	0.181
Number of Instruments	44	49	51	57	51	57	51	57
Municipalities	150	150	150	150	150	150	150	150
Observations	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350

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 8: 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 9: 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.