Estimating the fiscal impact of extreme weather events

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Abstract

This paper constructs a panel dataset of 168 countries with information on natural disasters and macroeconomic variables for the period 2000-2015, with the objective of estimating the fiscal impact of extreme weather events. While the literature analyzing the economic incidence of natural disasters has mainly focused on their macroeconomic consequences, the fiscal dimension of this problem remains relatively neglected. Due to their adverse effect on the economy, extreme weather events tend to reduce government revenues and increase public expenditure, creating a negative pressure on the budget balance. According to the results of the present analysis, the occurrence of at least one extreme weather event is associated with an increase in the budget deficit between 0.4% and 0.9% of GDP. This impact comes primarily from an immediate reduction in government revenues, as a percentage of GDP, with some evidence pointing out to a lagged effect on public expenditure two years after the event. Moreover, the fiscal effect is larger for low-income and lower-middle income countries, but is not significant for high-income and upper-middle income countries.

Keywords: Fiscal impact of Natural Disasters, Budget Balance, Extreme Weather Events.

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1. Introduction

Since 2000, the number of reported natural disasters around the world has ranged between 300 and 450 per year (Laframboise and Acevedo, 2014). Natural disasters can cause tremendous losses of human life and substantial economic damages. For instance, the death toll of the 2010 earthquake in Haiti was estimated around 160,000, while the economic damages from Hurricane Mitch in Honduras in 1998 were calculated at 38% of GDP.

From a fiscal perspective, natural disasters can also have negative effects as they tend to decrease government revenue and increase public expenditure.[2] In a recent study on the fiscal impacts of hurricanes in the US, Deryugina (2016) finds that the present value of transfers over a ten-year period increases by as much as $780-$1,150 per capita as a result of such an event, and estimates the direct aid relief expenses to average $155-$160 per capita.[3] To the extent that the resulting imbalance is financed with debt or by substituting planned public investment, these dynamics put pressure on the long-term sustainability of governments' finances.

Surprisingly, despite its apparent importance for fiscal policy, relatively little is known about the magnitude of the fiscal response in the wake of a disaster. A large portion of the literature in the subject focuses on case studies, instead of a more systematic approach. However, there has been a renewed interest in the subject in recent years. Partly, the reason behind this change is that some studies have linked climate change with an increase in the frequency and intensity of extreme weather events.[4]

This paper is guided by two questions that arise in this context. The first one is to quantify the average impact of extreme weather events on the budget balance. While this in

[2] For a detailed discussion regarding the fiscal impact of natural disasters, see Chapter 3 of Benson and Clay (2004).
[3] These figures are expressed in 2013 dollars. As a point of comparison, the US federal expenditures per capita for 2013 are estimated at $10,910.
[4] Although the link between climate change and a higher frequency of extreme weather events is still under debate, recent studies suggest its existence. For a broader view of this literature, see Mann et al. (2017), as well as Huber and Gulledge (2011). Furthermore, IPCC (2012) provides a comprehensive review of the risks that such a relationship would imply.

itself is not a novel question, the relative lack of research on this issue makes it an area still open for debate. The present analysis attempts to answer this question by using data on extreme weather events. The focus on this type of weather events is convenient from an analytical point of view, because of their exogeneity with respect to a country's fiscal policy goals, as well as the wide availability of statistical databases with information about their occurrence.

Provided that there is a significant impact, the second question pursued in this study focuses on what the main channels of transmission are. For instance, is the deterioration of the budget balance mainly a result of lower government revenues or higher public expenditure? From a policy perspective, it would be useful to have some guidance on this aspect. To the author's knowledge, there are no systematic studies in the literature that attempt to analyze this issue simultaneously.

The paper will proceed as follows. Section 2 provides a summary of the literature on natural disasters and its link to public finance. The theoretical framework on which the analysis is based is developed in Section 3. The description of the database and other methodological aspects are presented in Section 4. The empirical results are discussed in Section 4. Finally, the conclusions of the study are summarized in Section 5.

2. Literature review

Given the potential importance of natural disasters for fiscal policy, it is surprising that the number of studies that systematically analyze their impact on the public finances is relatively limited. Most of the current literature on natural disasters centers on broader macroeconomic outcomes, while a second group analyzes the benefits of insuring against such events.[5]

[5] For a review of the literature that studies the macroeconomic effects of natural disasters, see Cavallo and Noy (2010). Yang (2008) also provides an interesting discussion on these issues, focusing on the response of

Among the studies that include the fiscal dimension, a large fraction relies on country cases. For instance, Benson and Clay (2004) look at data from Bangladesh, Dominica and Malawi, concluding that budget reallocation is a frequently used tool in the aftermath of a natural disaster. Moreover, Heipertz and Nickel (2008) use a sample of natural disasters that occurred in the US and the European Union, estimating a fiscal impact between 0.3% and 1.1% of GDP. Deryugina (2016) shows that, in the US, direct disaster-related public expenditure accounts for a relatively small proportion of the fiscal response. Instead, a more significant proportion corresponds to transfers, such as unemployment insurance and public medical payments. Besides

More recent studies attempt to carry out more systematic approaches to the problem. Lis and Nickel (2010) use a fixed-effects model with data from 138 countries, estimating an increase in the fiscal deficit of about 1.1% of GDP after the occurrence of an extreme weather event. However, their study neglects any lagged effects. Melecky and Raddatz (2011) use a vector autoregressive model (VAR), also estimating a negative effect on the budget balance, which they observe to be more widespread in lower-middle-income countries. Noy and Nualsri (2011) use a VAR model and find that, following large natural catastrophes, fiscal behavior is counter-cyclical in developed economies, but pro-cyclical in developing countries. Ouattara and Strobl (2013) analyze data from Caribbean countries, concluding that public expenditure rises after a natural disaster. Their study also estimates a lagged effect that persists up to two years after the shock. Finally, using Russian data, Leppänen et al. (2015) identify a negative non-linear relation between regional budget expenditures as a result of temperature increases.

The present study contributes to this literature in three dimensions. First, based on theoretical foundations, it expands the fixed-effects framework used by Lis and Nickel (2010) to include the possibility of lagged impacts of extreme weather events. Second, in addition to estimating the incidence of these weather events on the budget balance, it also analyzes their

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international financial flows. Additionally, see Borensztein et al (2008) for a perspective on the benefits of insurance against the risk of disasters.

impact on government revenues and public expenditure, separately. Lastly, it uses a larger dataset than previous studies, covering 168 countries for the years from 2000 to 2015. The advantage of focusing on this period is the wider availability of macroeconomic and disaster data, which allows for a larger number of observations while keeping the panel dataset relatively balanced.

3. Theoretical Framework

3.1 Basic Model

The model that provides the foundation for the empirical analysis of this paper has its roots on the government's budget balance identity. Let B_t, T_t and G_t represent the budget balance, fiscal revenue and public expenditure at time *t*, respectively. The budget balance identity is:

$$B_t \equiv T_t - G_t. \quad (1)$$

The above equation can be expanded by expressing the right-hand side in terms of fiscal, macroeconomic and other variables, as follows,

$$B_t = \tau_t f(Y_t, X_t) - \left[r_t D_{t-1} + G^p(Y_t, X_t) + \textstyle\sum_{s=0}^{n} E_{t,t-s}\right] \quad (2)$$

where,

τ_t : average tax rate in period *t*,

$f(Y_t, X_t)$: tax base as a function of GDP (Y_t) and a vector of other characteristics (X_t),

$r_t D_{t-1}$: interest payments on past debt (D_{t-1}), with an average interest rate r_t,

$G^p(Y_t, X_t)$: primary "regular" expenditures (i.e. not disaster-related) as a function of GDP and other characteristics,

$E_{t,\ t-s}$: disaster-related expenditure in period t from an extreme weather event with occurrence in period $t - s$.

The first term on the right-hand side of equation (2) captures the fiscal revenue obtained by the government. Although not explicitly stated, this term is also indirectly determined by disasters, insofar as GDP is affected by their occurrence. The second term, enclosed by brackets, contains the typical components of government expenditure –debt interest payments and primary expenditure–, plus a final component that incorporates disaster-related expenditure. In this context, it is useful to think of the latter expenditure item as those expenses needed for the emergency response and reconstruction post-disaster. Finally, the vector of other characteristics, X_t, represents variables such as inflation, interest rate, election cycles, etc. which can affect the levels of fiscal revenue and public expenditure at a given period.[6]

A helpful transformation of equation (2), for empirical purposes, is to express it in percentage of GDP, and then take a first difference. This yields,

$$\Delta b_t = \tau\, \Delta\left(\frac{f(Y_t, X_t)}{Y_t}\right) - r\Delta d_{t-1} - \Delta g_t^p - \left(\sum_{s=0}^{n} e_{t,t-s} - \sum_{u=0}^{n} e_{t-1,t-1-u}\right) \qquad (3)$$

where, for simplicity, τ and r are assumed to be constant over time, and lowercase letters indicate ratios to GDP. In words, equation (3) relates the change in the budget balance to changes in the tax base, public debt, primary expenditure, as well as current and lagged disaster-related expenses, all expressed as ratios to GDP.

3.2 Understanding the impact of disaster shocks in the budget balance

In order to complement the basic insights given by the relationship in equation (3), an understanding of the channels through which extreme weather events may affect the

[6] See Woo (2003), Tujula and Wolswijk (2004), and Zeng (2014) for a list of other budget balance determinants.

components of the budget balance is important. In what follows, the main avenues through which this impact takes place are discussed.[7]

On the one hand, the occurrence of a disaster is expected to negatively affect government revenues, on impact. This contemporary effect is a consequence of the adverse shock to GDP, which in turn automatically reduces the tax base. However, there may also be lagged effects on fiscal revenues, depending on the dynamics of GDP in the post-disaster period. For instance, there could be a positive lagged impact arising from the stimulus created by reconstruction activities, which typically extend for more than one period. Moreover, there could also be a negative lagged impact if the economy is unable to bounce back quickly from the initial shock to GDP, a situation that can potentially lead to lower-than-planned investment. A further channel to be considered is financial aid. As shown by Yang (2008), official development assistance flows –a fraction of which enters the government's budget– tend to increase as a result of disaster occurrence, but this response seems to come with a lag of about two years. All in all, a weather event shock is expected to lower government revenues on impact, with an ambiguous effect on the post-disaster period.

On the other hand, disasters are also likely to provoke additional public expenditure, both through emergency and reconstruction expenses. The former category takes place in the immediate aftermath of the disaster, while the latter is expected to start with some lag, as it typically involves the repair and rehabilitation of public infrastructure. This potential increase in government expenditure may be attenuated by the reallocation of financial resources previously committed in the budget, with such a margin of response likely to be intensified in the presence of credit constraints.

Therefore, the general conclusion is that the overall effect of a disaster on the budget balance is expected to be negative on impact, but its lagged consequences remain ambiguous.

[7] This is not intended to be an exhaustive account. For a more detailed discussion, see Chapter 3 in Benson and Clay (2004).

4. Data and Empirical Methodology

4.1 Data

The database built for this analysis merges information from three different sources, including a total of 168 countries for the period from 2000 to 2015.[8] As indicated before, the advantage of focusing on these years is the wider availability of macroeconomic and disaster data, which allows for a larger number of observations while keeping the panel dataset relatively balanced.

Detailed data on the occurrence of weather events comes from EM-DAT database. The information includes the number of deaths caused by each event, how many people were affected, as well as the estimated economic damage.

Macroeconomic and fiscal data comes from the World Economic Ouput (WEO) database, published by the International Monetary Fund. Among other variables, it contains information on a country's gross domestic product (GDP), real growth rate, and inflation rate, as well as its government's budget balance, total revenues, total expenditures, and public debt.

Finally, data on electoral years comes from the Database of Political Institutions (DPI), elaborated by the Inter-American Development Bank (IADB). This dataset includes both presidential as well as legislative election years.

4.2 Definition of extreme weather events

The EM-DAT database provides information on natural disasters, but it does not categorize the events based on their level of social or economic damage. In order to define what an extreme weather event is, three criteria were used for selection:[9]

[8] The list of countries included is shown in the appendix.
[9] Other studies have used similar criteria. See, for instance, Lis and Nickel (2010).

Criterion 1: 100,000 or more affected people,

Criterion 2: 1,000 or more deaths,

Criterion 3: At least 2% of GDP in estimated economic damages.

For the purposes of this paper, if a weather event fulfills at least one of these three criteria, then it is classified as an extreme weather event.

Furthermore, it is important to mention that only the following categories of natural disasters were considered: landslides, storms (hurricanes, cyclones, typhoons, and tropical storms), droughts and floods. These categories were selected because of their high frequency and global incidence, as well as their potential relationship with climate change.

4.3 Benchmark econometric model

The empirical estimation relies on a fixed-effects model for panel data. Its basic formulation is based on the theoretical specification shown in equation (3), adapted to fit the availability of data. The model is,

$$\Delta b_{it} = \beta_0 + \beta_1 \Delta d_{i,t-1} + \beta_2 rgdpg_{it} + \beta_3 \pi_{it} + \beta_4 election_{it} + \sum_{s=0}^{n} \gamma_{s+1} ddisaster_{i,t-s} + \mu_i + \lambda_t + \nu_{it} \quad (4)$$

where,

Δb_{it} : change in the budget deficit, as a percentage of GDP, for country i in period t,

$\Delta d_{i,t-1}$: change in the (lagged) debt-to-GDP ratio,

$rgdpg_{it}$: real GDP growth rate,

π_{it} : inflation rate, measured by the percentage change in Consumer Price Index,

$election_{it}$: election dummy variable, with $election_{it} = 1$ in the event of either presidential or legislative elections, and $election_{it} = 0$ otherwise.

$ddisaster_{i,t-s}$: disaster dummy variable, for country i in period $(t-s)$, with $ddisaster_{i,t-s} = 1$ if at least one extreme weather event took place, and $ddisaster_{i,t-s} = 0$ otherwise.

μ_i : country fixed effects

λ_t : time fixed effects

ν_{it} : random error

The adapted model is purposely similar to the one used by Lis and Nickel (2010), with the objective of allowing for comparisons. The inclusion of lags of the disaster dummy reflects the possibility of multi-period effects, as discussed in previous sections.

In the empirical exercise, fixed-effects models were also estimated using the change in government revenues, Δrev_{it}, and the change in public expenditure, Δexp_{it}, as dependent variables. The aim of this exercise is to gain some knowledge regarding the relative impact of the disaster shock on each component of the budget balance.

5. Empirical Results

This section presents the empirical results obtained from estimating the benchmark model, as well as alternative models. In order to ensure comparability with other studies, each set of estimations was carried out twice. The first time the model is run without lags in the disaster variable, while the second these lags are added.

5.1 Benchmark model estimation

Table 1 shows the results of the fixed-effect model. Columns (1) and (2) correspond to the estimates of the model without and with lags, respectively, using the change in the budget balance as a dependent variable. As it can be observed, both sets of estimates provide similar results. According to the model without lags, the occurrence of at least one extreme weather event decreases the budget balance by 0.49% of GDP. This estimate is similar when allowing for lagged effects, as the coefficient on contemporary disaster occurrence implies a negative impact of 0.46% of GDP. Interestingly, the results also show an additional and significant effect two periods after the disaster took place.[10] The magnitude of this lagged effect is sizeable, at -0.56% of GDP. While the model does not allow us to distinguish the precise mechanism behind this latter impact, a hypothesis consistent with these results would be the completion of reconstruction work for public infrastructure.

The results using government revenues as a dependent variable are presented in columns (3) and (4) of Table 1.[11] In the model without lags, an extreme weather event is estimated to negatively affect government revenues by 0.58% of GDP. The model with lags provides a similar contemporary estimate, calculating the negative impact at 0.55% of GDP. There is no suggestion of statistically significant lagged effects on government revenues.

Finally, columns (5) and (6) display the estimates of the model that uses public expenditure as a dependent variable. Both the models without and with lags do not find any

[10] The results presented in this paper only consider a model with two lags of the disaster variable. However, the results of models with further lags –not shown, but available from the author upon request– are largely consistent with the estimates displayed in Table 1. Moreover, in the majority of alternative specifications, estimates of the lagged disaster dummy greater than two periods after the event are not statistically significant.

[11] All models using government revenues as a dependent variable omit the debt-to-GDP ratio as a control variable. This is because there is no theoretical foundation that justifies a relationship between the these two variables.

Table 1 – Fixed-Effects Model Estimation

Explanatory Variable	Budget Balance		Government Revenues		Public Expenditure	
	(1) FE Model	*(2) FE Model with lags*	*(3) FE Model*	*(4) FE Model with lags*	*(5) FE Model*	*(6) FE Model with lags*
$\Delta(debt/GDP)_{t-1}$	0.034*** (0.011)	0.035*** (0.011)			-0.016** (0.007)	-0.016** (0.007)
real GDP growth	0.278*** (0.080)	0.277*** (0.080)	0.155** (0.069)	0.154** (0.069)	-0.118*** (0.023)	-0.118*** (0.023)
inflation	0.031* (0.016)	0.030* (0.016)	0.011 (0.026)	0.011 (0.027)	-0.020 (0.018)	-0.020 (0.018)
ddisaster	-0.491** (0.218)	-0.457** (0.217)	-0.584*** (0.201)	-0.550*** (0.202)	-0.091 (0.195)	-0.094 (0.197)
$ddisaster_{t-1}$		0.400 (0.330)		0.365 (0.321)		0.021 (0.171)
$ddisaster_{t-2}$		-0.562* (0.299)		-0.145 (0.278)		0.402* (0.213)
election	-0.237 (0.190)	-0.241 (0.190)	-0.235 (0.170)	-0.233 (0.170)	0.007 (0.142)	0.011 (0.142)
constant	-1.265*** (0.343)	-1.235*** (0.337)	-0.406 (0.295)	-0.451 (0.288)	0.860*** (0.130)	0.788*** (0.140)
Observations	2,514	2,514	2,514	2,514	2,514	2,514
No. of countries	168	168	168	168	168	168
R-squared	0.0807	0.0829	0.0395	0.0413	0.0246	0.0275

Notes: * significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors in parenthesis.

statistically significant effect of the contemporary disaster variable on public expenditure. Instead, the model with lags finds a significant impact two periods after the event. The magnitude of this effect suggests an increase of about 0.40% of GDP in public expenditure. As commented above, this lagged impact is consistent with a hypothesis that considers the completion of reconstructed infrastructure, but cannot be verified with the current data.

5.2 Results by per capita income classification

The results for the full sample, presented in Table 1, do not take into account the possibility that economic development may play a role in how large the fiscal impact of extreme weather events is. In order to consider this, the benchmark model was estimated separating the countries into four different groups. These categories classify countries according to their income per capita.[12] A priori, developed economies are expected to be better prepared to face natural disasters than developing countries. Thus, the fiscal impact should be higher in the latter group.

Panel A of Table 2 presents the results for the change in the budget balance. Columns (1) and (2) focus on the estimates for high-income countries; columns (3) and (4) include the results for upper-middle income countries; columns (5) and (6) display the estimation for lower-middle income countries; and, lastly, columns (7) and (8) contain the results for low-income countries. As shown in the table, the negative fiscal impact of extreme weather events concentrates on the two categories with the lowest income per capita. For these groups, the model without lags estimates the contemporary deterioration of the budget balance as a result of the disaster shock at 0.76% and 0.90% of GDP, respectively. Similarly, the model with lags also shows a statistically significant negative effect on impact of 0.75% of GDP for lower-middle income countries, and of 0.77% of GDP for the low-income group. On the contrary, the model

[12] The categories used correspond to the World Bank's income classification for 2016. According to this scale, countries are considered to be low-income if their per capita GDP is below US$1,006; lower-middle income if it ranges between US$1,006 and US$3,955; upper-middle income if above US$3,955 and below US$12,235; and high income if it exceeds US$12,235.

does not show any significant effects for high-income and upper-middle income countries. Furthermore, the coefficients of the disaster lags are also not statistically significant, despite their magnitudes going in the expected direction.[13]

The results for government revenues and public expenditure are presented in panels B and C. As before, the effect on the change in government revenues concentrates on lower-middle and low-income countries, with an estimated negative impact of 0.76% and 1.05%, respectively, in the model without lags. Adding the possibility of lagged effects leaves the estimates of this contemporary impact relatively unchanged, at 0.70% for the lower-income group, and 0.94% for low-income countries. The model results do not support the existence of multi-period effects on government revenues. For the case of public expenditure, none of the estimations show statistically significant coefficients on the disaster variables.

5.3 Robustness checks

Besides the benchmark specification, alternative models were estimated to validate the robustness of the results. A known problem of the benchmark model is that it may suffer from endogeneity due to the inclusion of the real GDP growth variable (Zeng, 2014). To avoid this problem, a common solution in the literature has been to estimate the model using lags of real GDP growth as instrumental variables. Table 3, in the appendix, displays the results of this alternative estimation. The general conclusions regarding the contemporary effect of disasters on the budget balance, government revenue and public expenditure, remain largely unchanged when compared to the benchmark model. However, this alternative model does not provide evidence of multi-period effects, as the coefficients on the lagged disaster variables are not statistically significant.

[13] The coefficient on the second disaster lag is statistically significant if the model is estimated pooling together the lower-middle and low-income groups. This suggests that splitting the sample by income groups may have an important effect on the precision of the estimates.

Table 2 – Fixed-effects model estimation, by per capita income classification

Panel A - Dependent variable: Change in the Budget Balance

	High-income		**Upper-middle income**		**Lower-middle income**		**Low-income**	
	(1) FE Model	*(2) FE Model with lags*	*(3) FE Model*	*(4) FE Model with lags*	*(5) FE Model*	*(6) FE Model with lags*	*(7) FE Model*	*(8) FE Model with lags*
Δ(debt/GDP)$_{t-1}$	0.109 ***	0.109***	0.028	0.028	0.032***	0.033***	0.028	0.028
	(0.030)	(0.030)	(0.019)	(0.020)	(0.011)	(0.011)	(0.018)	(0.017)
real GDP growth $_{t-1}$	0.508 ***	0.509***	0.294**	0.294**	0.143***	0.144***	0.138***	0.123***
	(0.090)	(0.090)	(0.123)	(0.123)	(0.037)	(0.037)	(0.043)	(0.037)
inflation	-0.028	-0.029	0.016	0.016	0.023	0.021	0.064**	0.066**
	(0.113)	(0.113)	(0.017)	(0.017)	(0.023)	(0.023)	(0.025)	(0.029)
ddisaster	-0.006	-0.040	-0.033	-0.042	-0.756**	-0.747**	-0.898**	-0.767*
	(0.235)	(0.219)	(0.471)	(0.450)	(0.369)	(0.349)	(0.423)	(0.419)
ddisaster $_{t-1}$		-0.324		0.341		0.087		1.046
		(0.387)		(0.508)		(0.439)		(0.913)
ddisaster $_{t-2}$		-0.315		-0.425		-0.501		-1.105
		(0.711)		(0.295)		(0.361)		(0.873)
election	-0.204	-0.214	-0.546*	-0.535*	-0.164	-0.176	-0.142	-0.130
	(0.231)	(0.229)	(0.312)	(0.309)	(0.421)	(0.423)	(0.862)	(0.862)
constant	-1.443 ***	-1.412***	-1.579***	-1.560***	-0.650**	-0.516	-0.743**	-0.707**
	(0.401)	(0.398)	(0.588)	(0.569)	(0.313)	(0.419)	(0.308)	(0.311)
Observations	773	773	693	693	644	644	404	404
No. of countries	49	49	46	46	44	44	29	29
R-squared	0.0900	0.0900	0.1856	0.1864	0.0284	0.276	0.0400	0.0538

Notes: * significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors in parenthesis.

Panel B - Dependent variable: Change in Government Revenues

	High-income		Upper-middle income		Lower-middle income		Low-income	
	(1) FE Model	*(2) FE Model with lags*	*(3) FE Model*	*(4) FE Model with lags*	*(5) FE Model*	*(6) FE Model with lags*	*(7) FE Model*	*(8) FE Model with lags*
real GDP growth $_{t-1}$	0.102	0.103	0.198**	0.197**	0.052	0.053	0.096*	0.085*
	(0.070)	(0.071)	(0.098)	(0.098)	(0.039)	(0.039)	(0.051)	(0.049)
inflation	0.025	0.024	-0.029*	-0.028*	-0.014	-0.014	0.136*	0.137*
	(0.058)	(0.058)	(0.015)	(0.014)	(0.021)	(0.021)	(0.069)	(0.071)
ddisaster	-0.357	-0.416	-0.161	-0.166	-0.762**	-0.703**	-1.050**	-0.944*
	(0.314)	(0.345)	(0.155)	(0.176)	(0.371)	(0.345)	(0.456)	(0.493)
ddisaster $_{t-1}$		-0.396		0.217		0.279		0.857
		(0.321)		(0.469)		(0.398)		(0.956)
ddisaster $_{t-2}$		0.138		0.071		-0.151		-0.708
		(0.489)		(0.288)		(0.320)		(0.781)
election	-0.308*	-0.304*	-0.101	-0.096	-0.114	-0.119	-0.612	-0.605
	(0.170)	(0.166)	(0.245)	(0.250)	(0.383)	(0.382)	(0.824)	(0.817)
constant	-0.222	-0.213	-0.646	-0.697	0.247	0.181	-0.586	-0.606
	(0.248)	(0.245)	(0.437)	(0.431)	(0.288)	(0.308)	(0.527)	(0.561)
Observations	773	773	693	693	644	644	404	404
No. of countries	49	49	46	46	44	44	29	29
R-squared		0.0096		0.1659		0.0088		0.0651

Notes: * significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors in parenthesis.

Panel C - Dependent variable: Change in Public Expenditure

	High-income		**Upper-middle income**		**Lower-middle income**		**Low-income**	
	(1) FE Model	*(2) FE Model with lags*	*(3) FE Model*	*(4) FE Model with lags*	*(5) FE Model*	*(6) FE Model with lags*	*(7) FE Model*	*(8) FE Model with lags*
Δ(debt/GDP)$_{t-1}$	-0.097***	0.097***	-0.021	-0.022	-0.013**	-0.013**	-0.010	-0.010
	(0.024)	(0.024)	(0.021)	(0.021)	(0.006)	(0.006)	(0.009)	(0.009)
real GDP growth $_{t-1}$	-0.400 ***	0.401***	-0.096***	-0.096***	-0.084*	-0.084*	-0.028	-0.024
	(0.041)	(0.041)	(0.030)	(0.300)	(0.043)	(0.043)	(0.050)	(0.050)
inflation	0.053	-0.054	-0.044**	-0.043**	-0.044**	-0.044**	0.072	0.072
	(0.080)	(0.080)	(0.017)	(0.017)	(0.020)	(0.020)	(0.046)	(0.045)
ddisaster	-0.342	-0.385	-0.128	-0.122	0.021	0.070	-0.159	-0.184
	(0.353)	(0.357)	(0.467)	(0.475)	(0.260)	(0.287)	(0.383)	(0.386)
ddisaster $_{t-1}$		-0.075		-0.117		0.208		-0.187
		(0.332)		(0.236)		(0.296)		(0.443)
ddisaster $_{t-2}$		0.461		0.493		0.304		0.407
		(0.575)		(0.352)		(0.353)		(0.477)
election	-0.109	-0.095	0.434	0.427	0.058	0.062	-0.373	-0.379
	(0.195)	(0.194)	(0.336)	(0.336)	(0.257)	(0.257)	(0.417)	(0.424)
constant	1.194***	1.171***	0.933**	0.863***	0.937***	0.752**	0.167	0.108
	(0.203)	(0.206)	(0.207)	(0.231)	(0.261)	(0.332)	(0.325)	(0.361)
Observations	773	773	693	693	644	644	404	404
No. of countries	49	49	46	46	44	44	29	29
R-squared		0.1671		0.0415		0.0166		0.0496

Notes: * significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors in parenthesis.

Additionally, two dynamic panel models were also estimated, using the methods of Arellano-Bond and Arellano-Bover/Blundell-Bond.[14] One of the advantages of these alternative specifications is that they allow the inclusion of lags of the depend variable. The results of these models are presented in Tables 4 and 5, included in the appendix. As was the case of the fixed-effects model with instrumental variables, the conclusions derived from these results are largely consistent with the benchmark model. In other words, the coefficients on the contemporary disaster variable are statistically significant for the change in the budget balance and government revenues, but not for public expenditure. Interestingly, the dynamic panel models also support the existence of lagged effects from extreme weather events, particularly on public expenditure.

5.4 Other potential identification threats

Besides the endogeneity issue of the real GDP growth variable, and the inclusion of lags of the dependent variable as covariates, other potential identification threats are listed and discussed below:

- Misreporting of disaster severity: Yang (2008) argues that countries may have incentives to misreport the severity of disasters in order to receive more international aid. In the context of this analysis, this would result in the possibility of natural disasters being misclassified as extreme weather events. Thus, systematic misreporting of this sort would bias down the estimates of the fiscal impact, making the empirical estimates shown a lower bound of their true value.[15]
- Definition of the disaster variable: The definition of which disasters are identified as extreme weather events is key for the empirical analysis. Hence, it could be argued that results may be driven by the somewhat arbitrary definition of an extreme weather event. For instance, the criteria based in levels, and not proportions, may have very different consequences depending on population size. Changing Criterion 1 to "at least

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[14] See Arellano and Bond (1991), and Blundell and Bond (1998), respectively.

[15] Future work will deal with this issue by incorporating a hurricane index representing the average hurricane exposure of residents of a given country in a particular year, as in Yang (2008).

1% of the population" removes the statistical significance of the expenditure lagged effect found in the benchmark model, but the contemporary effect on government revenues remains consistent with previous results.

- Period of analysis: As explained in previous sections, the 2000-2015 period was chosen to maximize data availability for the 168 countries in the analysis. The concern of extending this period was that an unbalanced panel could reduce the precision of the estimates. However, restricting the sample to these years may limit the external validity of the results, as the empirical evidence may be capturing what could be a temporary fiscal impact. Nonetheless, estimates obtained from extending the period of analysis (1980-2015, 1985-2015 and 1990-2015) yield similar results to the benchmark model, with some minor adjustments in the point estimates.

6. Conclusions

The occurrence of natural disasters can have large costs in terms of human lives and economic damages. While the literature analyzing the incidence of natural disasters has mainly focused on their macroeconomic consequences, the fiscal dimension of this problem has remained relatively unexplored. The few available studies analyzing this issue point out that the effect on the public accounts can be important. This paper finds evidence consistent with this conclusion.

According to the empirical results, the occurrence of at least one extreme weather event is associated with an immediate deterioration of the budget balance of the order of 0.4%-0.9% of GDP. The estimated impact comes primarily from an immediate reduction in government revenues, as a percentage of GDP, with adverse effects ranging between 0.5% to 1.1% of GDP. This effect is larger for low-income and lower-middle income countries, but is not significant for high-income and upper-middle income countries.

Moreover, the models support some evidence of a lagged effect on the budget balance two years after the event, with a benchmark estimate of 0.6% of GDP. This multi-period effect comes mainly from an estimated increase of 0.4% of GDP in public expenditure and seems consistent with the post-disaster completion of reconstruction work on public infrastructure. However, due to data limitations, this paper is unable to test this hypothesis.

It is important to remark that, despite showing significant fiscal impacts, there are margins of response that are not captured by the empirical evidence. For instance, to the extent that countries reallocate planned expenditure in the wake of a disaster, this response would tend to decrease the observed incidence of extreme weather events on total public expenditure.[16] Indeed, the lack of statistically significant effects for the contemporary impact of disasters on the expenditure seems likely to point in this direction.

[16] As mentioned earlier, Benson and Clay (2004) found strong evidence of reallocation in their country-specific analyses.

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Appendix

List of countries included in the analysis

Afghanistan
Albania
Algeria
Angola
Argentina
Armenia
Australia
Austria
Azerbaijan
Bahrain
Bangladesh
Barbados
Belarus
Belgium
Belize
Benin
Bhutan
Bolivia
Bosnia and Herzegovina
Botswana
Brazil
Brunei Darussalam
Bulgaria
Burkina Faso
Burundi
Cabo Verde
Cambodia
Cameroon
Canada
Central African Republic
Chad
Chile
China
Colombia
Comoros
Costa Rica
Croatia
Cyprus
Czech Republic
Côte d'Ivoire
Democratic Republic of the Congo
Denmark
Djibouti
Dominican Republic
Ecuador
Egypt
El Salvador
Equatorial Guinea
Eritrea
Estonia
Ethiopia
FYR Macedonia
Fiji
Finland
France
Gabon
Georgia
Germany
Ghana
Greece
Grenada
Guatemala
Guinea
Guinea-Bissau
Guyana
Haiti
Honduras
Hungary
Iceland
India
Indonesia
Iraq
Ireland
Iran
Israel
Italy
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Korea
Kuwait
Kyrgyz Republic
Lao P.D.R.
Latvia
Lebanon
Lesotho
Liberia
Libya
Lithuania
Luxembourg
Madagascar
Malawi
Malaysia
Maldives
Mali
Malta
Mauritania
Mauritius
Mexico
Moldova
Morocco
Mozambique
Myanmar
Namibia
Nepal
Netherlands
New Zealand
Nicaragua
Niger
Nigeria
Norway
Oman
Pakistan
Panama
Papua New Guinea
Paraguay
Peru
Philippines
Poland
Portugal
Republic of Congo
Russia
Rwanda
Samoa
Saudi Arabia
Senegal
Sierra Leone
Singapore
Slovak Republic
Slovenia
Solomon Islands
South Africa
South Sudan
Spain
Sri Lanka
St. Lucia
Sudan
Suriname
Swaziland
Sweden
Switzerland
Syria
Taiwan
Tajikistan
Tanzania
Thailand
The Bahamas
The Gambia
Togo
Trinidad and Tobago
Tunisia
Turkey
Turkmenistan
Uganda
Ukraine
United Arab Emirates
United Kingdom
United States
Uruguay
Uzbekistan
Vanuatu
Venezuela
Vietnam
Yemen
Zambia
Zimbabwe

Table 3 – Fixed-Effects Model Estimation with Instrumental Variables

	Budget Balance		Government Revenues		Public Expenditure	
	(1) IV-FE Model	*(2) IV-FE Model with lags*	*(3) IV-FE Model*	*(4) IV-FE Model with lags*	*(5) IV-FE Model*	*(6) IV-FE Model with lags*
Δ(debt/GDP)$_{t-1}$	0.016 (0.013)	0.016 (0.013)			-0.004 (0.007)	-0.004 (0.007)
real GDP growth $_{t-1}$	-0.079 (0.080)	-0.077 (0.081)	-0.013 (0.036)	-0.012 (0.036)	0.073* (0.043)	0.072* (0.043)
inflation	0.022 (0.017)	0.022 (0.017)	0.005 (0.027)	-0.005 (0.027)	-0.017 (0.018)	-0.017 (0.018)
ddisaster	-0.617*** (0.210)	-0.576*** (0.207)	-0.643*** (0.201)	-0.607*** (0.200)	-0.026 (0.184)	-0.029 (0.186)
ddisaster $_{t-1}$		0.476 (0.330)		0.430 (0.318)		-0.033 (0.170)
ddisaster $_{t-2}$		-0.502 (0.310)		-0.137 (0.276)		0.350 (0.216)
election	-0.174 (0.198)	-0.177 (0.199)	-0.196 (0.169)	-0.196 (0.169)	-0.026 (0.184)	-0.016 (0.146)
constant	0.240 (0.372)	0.231 (0.377)	0.318 (0.246)	0.255 (0.246)	0.019 (0.211)	-0.008 (0.216)
Observations	2,513	2,513	2,513	2,513	2,513	2,513
No. of countries	168	168	168	168	168	168

Notes: * significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors in parenthesis.

Table 4 – Dynamic Panel Estimation (Arellano-Bond)

	Budget Balance		Government Revenues		Public Expenditure	
	(1) A-B Model	*(2) A-B Model with lags*	*(3) A-B Model*	*(4) A-B Model with lags*	*(5) A-B Model*	*(6) A-B Model with lags*
LD. balance	-0.243*** (0.033)	-0.238*** (0.032)				
LD. revenue			-0.287*** (0.040)	-0.285*** (0.039)		
LD. expenditure					-0.139*** (0.043)	-0.137*** (0.044)
LD. debt	0.022** (0.010)	0.023** (0.010)			-0.013* (0.008)	-0.014* (0.008)
realgdp_growth	0.271*** (0.068)	0.275*** (0.070)	0.139** (0.060)	0.143** (0.060)	-0.126*** (0.019)	-0.130*** (0.020)
inflend	0.039* (0.020)	0.042** (0.021)	0.007 (0.027)	0.008 (0.026)	-0.033 (0.022)	-0.036 (0.028)
ddummy	-0.391* (0.206)	-0.470* (0.284)	-0.458** (0.189)	-0.524** (0.234)	-0.128 (0.203)	-0.072 (0.283)
L.ddummy		0.656 (0.498)		0.323 (0.448)		-0.190 (0.278)
L2.ddummy		-0.392 (0.261)		-0.009 (0.234)		0.467** (0.218)
election	-0.311* (0.169)	-0.331* (0.173)	-0.201 (0.148)	-0.186 (0.146)	0.084 (0.132)	0.080 (0.133)
constant	-1.294*** (0.313)	-1.359*** (0.329)	-0.293 (0.268)	-0.362 (0.273)	0.987*** (0.133)	0.958*** (0.153)
Observations	2,440	2,440	2,486	2,486	2,442	2,442
No. of countries	168	168	168	168	168	168

Notes: * significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors in parenthesis.

Table 5 – Dynamic Panel Estimation (Arellano-Bover/Blundell-Bond)

	Budget Balance		Government Revenues		Public Expenditure	
	(i) System GMM model	*(ii) System GMM model with lags*	*(i) System GMM model*	*(ii) System GMM model with lags*	*(i) System GMM model*	*(ii) System GMM model with lags*
LD. balance	-0.215*** (0.030)	-0.208*** (0.030)				
LD. revenue			-0.267*** (0.041)	-0.265*** (0.041)		
LD. expenditure					-0.099** (0.044)	-0.096** (0.045)
LD. debt	0.025** (0.011)	0.027** (0.012)			-0.017* (0.009)	-0.017* (0.010)
realgdp_growth	0.297*** (0.076)	0.301*** (0.078)	0.139** (0.068)	0.140** (0.069)	-0.128*** (0.019)	-0.133*** (0.020)
inflend	0.047** (0.022)	0.050** (0.023)	0.016 (0.036)	0.017 (0.036)	-0.022 (0.029)	-0.024 (0.030)
ddummy	-0.575** (0.226)	-0.805** (0.316)	-0.535** (0.211)	-0.713*** (0.252)	-0.058 (0.188)	0.083 (0.269)
L.ddummy		0.539 (0.490)		0.638 (0.437)		0.058 (0.262)
L2.ddummy		-0.521* (0.276)		0.180 (0.259)		0.696*** (0.237)
election	-0.384** (0.172)	-0.405** (0.176)	-0.196 (0.146)	-0.192 (0.146	0.129 (0.135)	0.132 (0.136)
constant	-1.393*** (0.344)	-1.387*** (0.377)	-0.334 (0.323)	-0.462 (0.353)	0.897*** (0.166)	0.765*** (0.191)
Observations	2,508	2,508	2,510	2,510	2,509	2,509
No. of countries	168	168	168	168	168	168

Notes: * significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard errors in parenthesis.