The Macroeconomic Impacts of Natural Disasters: New Evidence from Floods

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Abstract

We analyze the economic impacts of floods using new data on 3,184 large flood events in 118 countries between 1985 and 2008. We use panel vector auto-regressions to trace the dynamic response of output to three types of flood shocks. Our results robustly indicate that flood shocks tend to have a positive average impact on GDP growth, that this impact is limited to developing countries, that the effect is not confined to the agricultural sector, and that it is stronger when it is accompanied by an increase in gross fixed capital formation.

1. Introduction

In addition to the immediate cost of natural disasters in terms of mortality, number of displaced people and infrastructural damage, and perhaps partly due to these immediate costs, natural disasters may have a lasting effect on economic output and growth. In this paper we investigate the macroeconomic impacts of floods using panel vector auto-regressions (panel VAR) to characterize the output growth dynamics following large flood events.

Among all the types of natural disasters, analyzing the macroeconomic impacts of floods is particularly relevant for at least two reasons. First, according to the EM-DAT global disaster database (OFDA/CRED 2010), between 1985 and 2009, floods were the most common natural disaster, accounting for 40 percent of all natural disasters (another 31 percent were storms).[1] Combined, floods and storms represented 44 percent of the deaths, 67 percent of the number of

[1] To be included in the database, an event needs to fulfill at least one of the following criteria: (i) 10 or more people killed, (ii) 100 or more people reported affected (typically displaced); (iii) a declaration of a state of emergency; (iv) a call for international assistance. Apart from floods and storms, other natural disasters recorded in the EM-DAT database are earthquakes, extreme temperatures, droughts, wildfires, wet and dry mass movements, and volcanoes. Although recorded separately, floods and storms are related disasters; for example a cyclone may generate a flood.

people affected and the bulk of economic damages caused by natural disasters. Second, if climate change results in an increase in the frequency and intensity of extreme weather events, including storms and floods, knowing whether or not floods have net permanent effects on economic output and the details of the adjustment path may prove very useful to direct adaptation efforts.

Recent attempts to evaluate the long-run impact of natural disasters on GDP offer an inconclusive picture regarding the sign of the impacts of disasters on GDP growth and whether these impacts are transitory or permanent. For example Skidmore and Toya (2002) find that climatic events have a positive relationship with long run growth (which they argue could be due to disasters providing an impetus for 'creative destruction' dynamics) while Raddatz (2009) finds the opposite effect. Hochrainer (2009) also finds that, on average, severe natural disasters have negative consequences on GDP. More recently, Cavallo et al. (2010) construct counterfactual synthetic countries unaffected by disasters, and find no significant long-run effect of disasters on per capita GDP. Cavallo and Noy (2010) provide a review of the literature.

Controlling for disaster type and size may prove to be fundamental in this context. For example, Fomby et al. (2009) find that droughts have a negative effect on economic growth. In contrast, floods tend to have a positive effect. This effect is stronger in developing countries and is present in both the agricultural and non-agricultural sectors. The authors argue that by increasing soil fertility, a typical flood increases agricultural output in the year after it strikes (though output falls in the year it occurs). The benefits from higher agricultural production spill over to other sectors, and in developing countries where the farm sector is a bigger part of the economy this may be enough to lead to faster growth in manufacturing and services in subsequent years. However, this effect comes only from moderate floods. Severe floods do not produce positive responses of GDP growth or its two components.

Our paper uses a new flood-specific disaster dataset to analyze the output growth response in the year of and the years after a flood shock. Our contribution to the literature is twofold. First, we use three alternative definitions of flood shock: experiencing an additional 'typical' large flood event, experiencing an exogenous increase in the magnitude of the average flood, and an increase in the death toll. Most of the papers on the economics of natural disasters define severity of a disaster as a function of the number of people killed or affected by floods, which, although arguably correlated with the physical intensity of a disaster, might be determined by a country's macroeconomic and institutional setting (Kahn 2005; Anbarci et al. 2005; Kellenberg and Mobarak 2008; Keefer et al. 2010). Our dataset includes information on physical measures of the magnitude of the flood events (area affected, duration in days, and length of the recurrence interval).

Second, we explore potential channels through which floods may affect economic output levels and growth. As Fomby et al. (2009), we distinguish between agricultural and non-agricultural output growth and separate our sample into developing and developed countries. In addition, we control for availability of domestic credit to the private sector to measure the degree to which households can borrow to self-protect against (and perhaps take advantage of) floods. We also control for the quality of governance proxied by indicators of corruption and ethnic conflict, as these may determine the efficiency of the public response to large flood events. Finally, we control for fixed capital formation that could follow when large floods damage preexisting infrastructure that needs to be fixed or replaced.

The rest of paper proceeds as follows. In Section 2 we describe the data. Section 3 describes the panel VAR methodology employed to construct the dynamic response of output to flood shocks. Section 4 presents the main results and Section 5 concludes.

2. Data

We compiled an unbalanced panel with annual data on the number and physical intensity of floods, and macroeconomic variables to trace the potential long-run economic effect of floods, for 118 countries during the period 1985-2008. Table 1 summarizes the variables and the data sources.

2.1. Growth variables

The main variables used in this paper are divided into three groups. First, we define three growth variables: the growth rate of real per capita GDP and, following Fomby et al. (2009), the growth rate of real per capita value added in the agricultural and the non-agricultural sectors. The three variables are measured as the log difference of per capita GDP (in PPP, constant 2005 international $). They come from the World Development Indicators (WDI 2010). Table 2 shows basic descriptive statistics for the all countries in the sample, and for the subsamples of developing and the developed countries. Overall growth was 2.2 percent (2.1 percent in developing countries, 2.3 percent in developed countries), with a decline in the agricultural sector during the period (the rate of growth in agricultural output was -1.7 percent in developing countries and -3.2 percent in developed countries).

2.2. Flood variables

The second set of variables, describing the flood events during 1985-2008, originates from the Global Archive of Large Flood Events kept by the Dartmouth Flood Observatory (DFO, now at Colorado: http://floodobservatory.colorado.edu). It covers large flood events with "significant damage to structures or agriculture, long (decades) reported intervals since the last similar event, and/or fatalities."[2] DFO reports the magnitude of the flood as the log of the product of flood duration (in days)* area affected by the flood * flood severity. Floods are divided into three severity classes depending on their estimated recurrence interval. Class 1 floods have a 10-20 year-long reported interval between similar events, class 1.5 have a 20-100 year recurrence interval, and class 2 have a recurrence interval greater than 100 years.

The unit of observation in the DFO dataset is the flood event (2,194 observations in our sample). Since the panel used in the econometric estimation consists of annual observations for 118 countries, we defined three new variables at the country-year level: total number of floods; average magnitude, computed as the log of (average area affected by flooding * average flood duration * average flood severity); and total number of deaths which is the sum of deaths in all the flood events during the year. Multi-country floods are excluded from the sample.

According to Table 2, in a given year there is an average of one flood in a given country in our sample, with no significant difference between developing and developed countries. The magnitude of the average flood, however, is slightly larger in developing countries than in developed countries (5.49 vs. 3.63) and this difference is statistically significant. The annual death toll is also larger (but not significantly so) in developing countries than in developed countries with averages of 308 and 10 annual casualties, respectively.

Table 3 shows the contemporaneous correlations between the growth and flood variables, distinguishing between developing and developed countries. As shown in the table, the contemporaneous correlations between the two physical measures of flooding (the number of floods and average magnitude) and per capita GDP growth are positive for developing countries,

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[2] DFO uses a collection of tools to detect and locate flood events, such as MODIS (Moderate Resolution Imaging Spectroradiometer, http://modis.gsfc.nasa.gov) and optical remote sensing, which provide frequent updates of worldwide surface water condition. These are complemented with data derived from a variety of news and governmental sources.

while it is negative for developed countries. These correlations are at odds with the conventional wisdom that disasters are more likely to have negative growth effects in poor countries as these may lack the material resources and organisational ability to get back to the *status quo ante*.

2.3. Other macro variables

The third set of variables comprises institutional and macroeconomic variables in order to control for country differences and investigate potential channels of transmission of the impact of a flood shock. They are two institutional indicators of corruption and ethnic tensions, domestic credit to private sector (as percentage of GDP), and gross fixed capital formation (as percentage of GDP).

The institutional indicators come from the International Country Risk Guide (ICRG) of Political Risk Services (PRS 2010).[3] Indicators take values between 0 and 6 with higher values denoting better governance. From excerpts of the variable descriptions, corruption "distorts the economic and financial environment; it reduces the efficiency of government and business by enabling people to assume positions of power through patronage rather than ability; and, [...], introduces an inherent instability into the political process"; ethnic tensions is "the degree of tension within a country attributable to racial, nationality, or language divisions. " Escaleras et al (2007) and Keefer et al. (2010) find that earthquake mortality increases with corruption; ethnic tensions can also result in reduced efficiency in the provision of public services needed for reconstruction after a natural disaster.

Domestic credit to the private sector captures access to investments by the private sector that could be used, for example, for self-protection from floods and reconstruction efforts after

[3] The ICRG is a popular source of governance indicators used in cross-country studies. It offers broad country coverage, which reduces the risk of selection bias (Kaufmann et al. 1999; Johnston 2001), and indicators are available for a relatively long time period (1984 to the present), which covers our estimation sample.

the floods, with gross fixed capital formation also capturing this second effect. Both variables come from WDI (2010).

3. Methods

The paper uses pooled observations from 118 countries over time to arrive at average responses of growth to major flood events. Like Fomby et al. (2009) and Raddatz (2007, 2009) we employ vector auto-regressions in the presence of endogenous variables and exogenous shocks (panel VARX):[4]

$$Y_{it} = \alpha_i + A(L)Y_{it} + B(L)X_{it} + \varepsilon_{it} \qquad (1)$$

where Y_{it} is a vector of endogenous variables for country *i* at time *t*, *X* is a vector of exogenous variables, α_i is a fixed effect for each country, and ε_{it} is a vector of independent error terms. A(L) and B(L) are matrix polynomials in the lag operator whose order is determined using the Akaike information criterion. The vector of endogenous variables comprises the per capita growth rate[5] (distinguishing between agricultural and non agricultural rates), and other macroeconomic variables (domestic credit to the private sector, corruption and ethnic tensions, and gross fixed capital formation). As exogenous variables, we include the flood variables defined in the previous section (number of floods, average magnitude, and number of deaths).

As a first step, and in order to justify the classification of some variables as exogenous, we pursued Granger causality tests, as a test for the weak exogenity of the flood variables. A variable is said to Granger cause another variable if there is enough evidence to reject the null

[4] In a simple VAR model all variables are assumed to be endogenous, while in a VARX model some variables can be exogenous.

[5] We analyzed the integration order of each of our variables, concluding that per capita GDP variables are all I(1) non stationary, while their first differences are I(0) stationary variables, so we include per capita GDP growth rates in our VAR setting.

hypothesis that the coefficients on the lags of variable *x* in the VAR equation of variable *y* are all equal to zero. The results, not presented here but available upon request, reveal evidence of causality between flood variables to economic growth rates, while, as expected, growth rates are not found to have significant effects on future flood occurrence.

4. Results

Based on the estimation of equation (1), we calculated the impulse response functions tracing out the reaction of per capita GDP growth and of its subcomponents, agricultural and non-agricultural per capital value-added growth, to a flood shock.

4.1 Impulse response functions

Figure 1 depicts the dynamic path of adjustment to an exogenous additional flood in year 1 and in subsequent periods (up to year 10). As in Fomby et al. (2009), our results indicate that floods tend to have a positive effect on GDP growth. The cumulative mean effect, shown in Table 4, is 1.5 percentage points.

Looking at the annual response of the growth rate, the positive effect of the flood is significant the year after the event and it peaks two years after the event. This delay in the overall growth response seems to be driven by the agricultural sector for which the effect on the year of the event is negative (although not significant). The effect on agricultural growth spikes the year after the flood which, as Fomby et al. (2009) point out, could be due to potentially beneficial effects of floods on land productivity that emerge on the following harvest cycle. Looking at the split between developing and developed countries lends support to this argument. The sharp increase on agricultural growth in the year after the flood is larger and more persistent in developing countries which typically rely on more traditional, less intensive forms of agriculture.

The cumulative mean impact of the flood shock on agricultural growth is 2.2 percentage points for developing countries and 1.2 percentage points for developed countries.

The response to a flood shock is not limited to the agricultural sector. The cumulative mean effect of the non-agricultural sector growth for the full sample is positive (2.0 percentage points), significant and slightly larger than the response of the agricultural sector (1.9 percentage points). Again, the response is different between developing and developed countries. In developed countries the industry and services sector growth does not have a significant response (neither cumulatively nor in any year of or after the shock). In developing countries the effect of the flood on non-agricultural output growth is significant (the cumulative effect is 3 pp.). It peaks the year after the event. This effect, could be due to a larger relative importance of the agricultural sector in these countries whose growth spills over to manufacturing and services. Fomby et al. (2009) point at transmission mechanisms based on supply chain relationships (for instance, larger cotton production resulting in expanded textile production) and an increase in electricity generating capacity from an increase in water supply. This second mechanism, however, requires that the infrastructure needed to generate hydroelectricity is in place. Another possible explanation that we test in the following subsection is that after a flood, reconstruction efforts result in increased industrial activity arising from the investment necessary to replace or fix damaged infrastructures.

In Figure 2, we trace the response of output growth to a different type of flood shock: an increase of one standard deviation in the magnitude of the average flood. The patterns are similar to the case of an additional flood. The effect on GDP growth is positive, transitory (it reverts to the mean after approximately 10 periods, and significant only in developing countries. As with the simple correlations in Table 3, these results are at odds with the conventional wisdom that disasters are more likely to have negative growth effects in developing countries as these may lack the material resources and human capital to get back to the *status quo ante*. At least for floods, the mean response of GDP growth for developing countries is positive.

Finally, we looked at the growth response to a shock defined as an increase of one standard deviation in the number of people killed by floods. Neither total growth nor its subcomponents are affected by shocks to this variable. The results do not change when we split the sample between developed and developing countries. As argued in the introduction, the number of people killed by floods is a noisier indicator of physical intensity than the flood magnitude variable used in this paper.

4.2 Potential Transmission Mechanisms

We present the estimates of equation (1) in order to shed some light on the possible transmission mechanisms of flood shock. Table 5.1 estimates equation (1) for the GDP growth rate using the full sample. In column (1) we only include, in addition of lagged GDP growth, the exogenous flood variables. Of those only average flood magnitude is significant at a 5 percent level and its sign is consistent with the correlations in Table 3 and the impulse response functions in Figure 1. In the second column we include lagged average magnitude, that as we would expect exhibits a larger coefficient than average in levels, which again is consistent with the flood shock having a delayed effect on GDP growth.

For column 3 we repeated the estimation including all the 'other' macroeconomic controls and their interactions with the flood variables to investigate the potential channels of transmission of flood shocks. Only the significant coefficients are reported. The results indicate that although the contemporaneous effect of the shock (in terms of an increase of average magnitude) is negative, it is less so, and becomes positive when it is accompanied by investment in fixed capital. Infrastructure replacement could be one of the channels through which floods stimulate non-agricultural output growth.

A comparison of Tables 5.2 and 5.3 indicates that the positive impact of floods on overall GDP growth is driven by developing countries. None of the flood shocks or interactions are significant for the subsample of developed countries in Table 5.3 while the results of Table 5.2 are very similar to those for the full sample. In Table 5.4, we repeat the estimation for the agricultural output growth rate in developing countries. Interestingly, the positive impact of a flood shock (defined as an increase in average magnitude) does not seem to be driven by an increase in gross fixed capital formation. This is to be expected as investment goods are produced in the manufacturing sector.

5. Conclusions

The paper uses pooled observations from 118 countries between 1985 and 2008 to compute average responses of growth to major flood events. We use a unique flood-specific data set that allows us to construct three different types of flood shocks: an additional ‘typical’ large flood event, an exogenous increase in the magnitude of the average flood, and an increase in the death toll. Many papers on the economics of natural disasters define severity of a disaster as a function of the number of people killed or affected by floods, but our results suggest that the number of people killed by floods is a noisier indicator of flood shocks than average *physical* flood magnitude, or the number of floods.

Our results show that flood shocks tend to have positive impacts on GDP growth rates. As we would expect, these positive impacts are not experienced on the year of the flood. The delay in the overall growth response seems to be driven by the agricultural sector for which the and, as Fomby et al. (2009) point out, could be due to potentially beneficial effects of floods on land productivity that manifest on the following harvest cycle. Looking at the different dynamic paths in developing and developed countries lends support to this argument. The increase on agricultural growth in the year after the flood is larger and more persistent in developing countries which typically rely on more traditional, less intensive forms of agriculture. In fact, developed countries do not experience a positive impact of floods on overall growth, the positive impact on agricultural growth in developed countries does not seem to spill over to the manufacturing and service sector.

These results are consistent with the result of Fomby et. al (2009), but contradict the conventional wisdom that disasters are more likely to have negative growth effects in developing countries. At least for floods in this new dataset, the mean response of GDP growth for developing countries is positive. This could be due to the larger relative importance of the agricultural sector on overall GDP, as implicit in the argument of Fomby et al. (2009). But looking more in-depth at potential transmission mechanisms, our results suggest the importance of an investment channel: the impact of growth in developing countries is stronger when accompanied by gross capital formation.

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TABLE 1. Variable description and sources

Name	Description	Source	Notes
Growth	Growth rate of real per capita GDP	WDI (2010)	Log difference of per capita GDP (in PPP, constant 2005 intnl $)
Ag. Growth	Growth rate of real per capita agricultural value added	WDI (2010)	Log difference of agricultural VA – population growth (in PPP, constant 2005 intnl $)
Non Ag. Growth	Growth rate of real per capita non-agricultural value added	WDI (2010)	Log difference of non-agricultural VA – population growth (in PPP, constant 2005 intnl $)
Number floods	Annual number of large floods	DFO (2010)	Floods with "significant damage to structures or agriculture, long (decades) reported intervals since the last similar event, and/or fatalities." Multi-country floods excluded
Average flood magnitude	Physical intensity of the average flood	DFO (2010)	= log(average duration in days * average affected area *average severity indicator)
Number of deaths	Number of people killed by floods in a year	DFO (2010)	
Corruption	Corruption indicator	PRS (2010)	Larger values denote better institutions
Ethnic tensions	Ethnic tensions indicator	PRS (2010)	Larger values denote better institutions
Domestic credit	Domestic credit to the private sector	WDI (2010)	Expressed as percentage of GDP
GFCF	Gross fixed capital formation	WDI (2010)	Expressed as percentage of GDP

TABLE 2. Descriptive Statistics

	Mean	Std. Dev.	Min	Max
All countries (118 countries, n=2150)				
Growth	0.022	0.044	-0.40	0.285
Agricultural Growth	-0.022	0.11	-0.94	0.67
Non-agricultural growth	0.009	0.06	-0.43	0.521
Number of floods	1.14	2.63	0	32
Average magnitude	4.95	6.22	0	18.87
Total deaths	220.81	4612.07	0	160027
Domestic credit	47.53	43.04	0.68	247.65
Gross fixed capital formation	21.32	6.21	2.25	57.71
Corruption	3.06	1.33	0	6
Ethnic tensions	4.01	1.43	0	6
Developing countries (84 countries, n=1520)				
Growth	0.021	0.049	-0.40	0.285
Agricultural Growth	-0.017	0.12	-0.94	0.67
Non-agricultural growth	0.006	0.068	-0.43	0.521
Number of floods	1.19	2.458	0	24
Average magnitude	5.49	6.433	0	18.87
Total deaths	308.07	5483.26	0	160027
Domestic credit	31.08	29.90	0.68	210.42
Gross fixed capital formation	20.81	6.64	2.25	57.71
Corruption	2.56	0.99	0	6
Ethnic tensions	3.70	1.44	0	6
Developed countries (34 countries, n=630)				
Growth	0.023	0.031	-0.266	0.131
Agricultural Growth	-0.032	0.09	-0.617	0.294
Non-agricultural growth	0.016	0.04	-0.328	0.133
Number of floods	1.04	3.02	0	32
Average magnitude	3.63	5.47	0	16.88
Total deaths	10.27	53.68	0	1074
Domestic credit	87.22	44.01	20.61	247.65
Gross fixed capital formation	22.55	4.81	11.93	38.97
Corruption	4.28	1.23	2.00	6
Ethnic tensions	4.77	1.08	0.5	6

TABLE 3. Correlation coefficients

	Ag. growth	Non Ag. growth	Number floods	Av magnitude	Total deaths	Domestic credit	GFCF	Corrupt.	Ethnic Tensions
All countries									
Growth	0.32	0.82	0.10	0.10	0.004	0.04	0.30	-0.02	0.13
Agric growth		-0.06	0.04	0.05	-0.003	-0.02	0.03	-0.05	-0.0007
Non Ag growth			0.09	0.09	0.004	0.08	0.3	0.03	0.18
Number floods				0.55	0.13	0.21	0.14	-0.05	-0.07
Av. Magnitude					0.06	0.07	0.09	-0.12	-0.12
Total deaths						-0.02	0.004	-0.05	-0.06
Domestic credit							0.29	0.45	0.34
GFCF								0.07	0.18
Corruption									0.37
Developing countries									
Growth	0.35	0.81	0.15	0.13	0.004	0.09	0.31	-0.04	0.15
Agric growth		-0.09	0.06	0.05	-0.005	0.04	0.05	-0.03	0.04
Non Ag growth			0.14	0.12	0.007	0.09	0.32	-0.03	0.18
Number floods				0.56	0.16	0.24	0.24	-0.08	-0.08
Av. Magnitude					0.06	0.15	0.13	-0.05	-0.10
Total deaths						-0.005	0.008	-0.06	-0.06
Domestic credit							0.35	0.15	0.19
GFCF								0.06	0.16
Corruption									0.20
Developed countries									
Growth	0.20	0.93	-0.04	-0.006	0.03	-0.07	0.22	-0.05	0.01
Agric growth		0.11	-0.007	0.04	0.015	-0.05	-0.04	0.03	-0.05
Non Ag growth			-0.04	0.008	0.04	-0.061	0.17	0.06	0.06
Number floods				0.55	0.35	0.35	-0.10	0.01	-0.01
Av. Magnitude					0.31	0.26	0.017	-0.06	-0.006
Total deaths						0.19	0.008	-0.03	0.07
Domestic credit							0.12	0.17	0.18
GFCF								-0.17	0.05
Corruption									0.31

TABLE 4. Impulse response functions to shocks to flood variables

		GDP growth	Agricultural growth	Non agricultural growth
All countries				
Shocks to number of floods	Period 1	0.000583 (0.00101)	-0.002746 (0.00236)	0.001268 (0.00177)
	Period 2	0.002606** (0.00081)	0.006830** (0.00160)	0.004321** (0.00129)
	Period 3	0.002852** (0.00082)	0.004364** (0.00109)	0.003975** (0.00119)
	Period 4	0.002499** (0.00073)	0.003256** (0.00081)	0.003116** (0.00095)
	Cumulative effect (10 years)	0.015310** (0.00460)	0.019306** (0.00583)	0.020195** (0.00616)
Shocks to flood magnitude	Period 1	0.001700 (0.00101)	0.002335 (0.00236)	0.001122 (0.00177)
	Period 2	0.003854** (0.00102)	0.006380** (0.00216)	0.006507** (0.00167)
	Period 3	0.003104** (0.00078)	0.003038** (0.00077)	0.004313** (0.00102)
	Period 4	0.002125** (0.00052)	0.001850** (0.00044)	0.002478** (0.00058)
	Cumulative effect (10 years)	0.014748** (0.00352)	0.017277** (0.00445)	0.018446** (0.00462)
Developing countries				
Shocks to number of floods	Period 1	0.001240 (0.00128)	-0.000197 (0.00284)	0.002216 (0.00229)
	Period 2	0.004405** (0.00107)	0.007339** (0.00201)	0.007024** (0.00171)
	Period 3	0.004578** (0.00106)	0.004563** (0.00133)	0.006141** (0.00153)
	Period 4	0.003847** (0.00091)	0.003323** (0.00096)	0.004613** (0.00119)
	Cumulative effect (10 years)	0.023431** (0.00564)	0.022212** (0.00687)	0.030015** (0.00760)
Shocks to flood magnitude	Period 1	0.002250 (0.00128)	0.001282 (0.00284)	0.001672 (0.00229)
	Period 2	0.005323** (0.00130)	0.007786** (0.00261)	0.008880** (0.00217)
	Period 3	0.004273** (0.00097)	0.003383** (0.00090)	0.005725** (0.00127)
	Period 4	0.002932** (0.00064)	0.001986** (0.00053)	0.003289** (0.00072)
	Cumulative effect (10 years)	0.020219** (0.00440)	0.018109** (0.00528)	0.024936 (0.00582)
Developed countries				
Shocks to number of floods	Period 1	-0.000510 (0.00112)	-0.007853 (0.00399)	-0.000112 (0.00124)
	Period 2	-0.000759 (0.00087)	0.006205** (0.00245)	-0.000770 (0.00100)
	Period 3	-0.000715 (0.00085)	0.003104 (0.00167)	-0.000874 (0.00099)
	Period 4	-0.000620 (0.00080)	0.002617 (0.00132)	-0.000840 (0.00095)
	Cumulative effect (10 years)	-0.004588 (0.00553)	0.011950** (0.00998)	-0.005640 (0.00668)
Shocks to flood magnitude	Period 1	5.16E-05 (0.00112)	0.005044 (0.00399)	0.000152 (0.00124)
	Period 2	-0.000941 (0.00115)	-0.000379 (0.00362)	-0.000719 (0.00128)
	Period 3	-0.000914 (0.00096)	0.000800 (0.00146)	-0.000804 (0.00110)
	Period 4	-0.000682 (0.00068)	0.000893 (0.00076)	-0.000672 (0.00081)
	Cumulative effect (10 years)	-0.003882 (0.0044)	0.009564 (0.00780)	-0.003809 (0.00520)

We do not report the impulse response numbers to shocks to the number of deaths, since its impact is not significant. ** denotes significant at a 5% level. The cumulative effect measures the total effect of the shock after 10 periods.

TABLE 5.1. Estimated models (per capita GDP growth rates, all countries)

	(1)	(2)	(3)
Lagged GDP growth	0.376**	0.375**	0.199**
	(22.62)	(22.95)	(10.33)
Average magnitude	0.00055**	0.00042**	-0.001**
	(2.34)	(2.11)	(-2.56)
Lagged average magnitude		0.00066**	0.0004**
		(3.29)	(2.34)
Number of floods	0.00001		
	(0.02)		
Total deaths	-0.0001		
	(-0.43)		
Domestic credit			-0.00021**
			(-4.31)
Corruption			-0.004**
			(-3.82)
Interactive efffects magnitude (with gross fixed capital formation)			7.13E-05**
			(3.39)
Cross- country Fixed effects	Yes	Yes	Yes
Adj. R^2	0.207	0.211	0.25

Equation (1): we only include exogenous flood variables as explanatory variables of per capita GDP growth rates, jointly with the lagged growth rate.

Equation (2): we also include lag values of the exogenous flood variables, obtaining only significant effects for the variable measuring the average magnitude of the flood.

Equation (3): we estimate the model including interactive effects of each of the flood variables with the macroeconomic variables, finding significants effects only for the interaction of the average magnitude of the flood with the gross fixed investment.

* and ** indicate significant at the 10 and 5% level, respectively. In parenthesis, the statistic for testing the non-significance null hypothesis.

TABLE 5.2. Estimated models (per capita GDP growth rates, developing countries)

	(1)	(2)	(3)
Lagged GDP growth	0.370**	0.37**	0.177**
	(19.29)	(19.55)	(7.79)
Average magnitude	0.0006**	0.0005**	-0.0014**
	(2.14)	(2.02)	(-2.45)
Lagged average magnitude		0.00084**	0.0005**
		(3.44)	(2.45)
Number of floods	0.0003		
	(0.26)		
Total deaths	-1.2E-07		
	(-0.42)		
Domestic credit			-0.0002**
			(-2.98)
Corruption			-0.004**
			(-3.02)
Ethnic tensions			
Gross Fixed capital formation			
Interactive efffects magnitude (with gross fixed capital formation)			8.26E-05**
			(3.32)
Cross- country Fixed effects	Yes	Yes	Yes
Adj. R^2	0.20	0.21	0.252

Equation (1): we only include exogenous flood variables as explanatory variables of per capita GDP growth rates, jointly with the lagged growth rate.

Equation (2): we also include lag values of the exogenous flood variables, obtaining only significant effects for the variable measuring the average magnitude of the flood.

Equation (3): we estimate the model including interactive effects of each of the flood variables with the macroeconomic variables, finding significants effects only for the interaction of the average magnitude of the flood with the gross fixed investment.

* and ** indicate significant at the 10 and 5% level, respectively. In parenthesis, the statistic for testing the non-significance null hypothesis.

TABLE 5.3. Estimated models (per capita GDP growth rates, developed countries)

	(1)	(2)	(3)
Lagged GDP growth	0.44	0.44**	0.344**
	(13.77)	(13.99)	(9.35)
Average magnitude	0.0001	0.0001	-0.0001
	(0.36)	(0.43)	(-0.10)
Lagged average magnitude		-0.0001	-4.1E-05
		(-0.57)	(-0.17)
Number of floods	-0.0003		
	(-0.43)		
Total deaths	4.6E-06		
	(0.18)		
Domestic credit			-0.00014**
			(-3.25)
Corruption			-0.003**
			(-2.10)
Interactive efffects magnitude (with gross fixed capital formation)			7.45E-06
			(0.17)
Cross- country Fixed effects	Yes	Yes	Yes
Adj. R^2	0.257	0.26	0.25

Equation (1): we only include exogenous flood variables as explanatory variables of per capita GDP growth rates, jointly with the lagged growth rate.

Equation (2): we also include lag values of the exogenous flood variables, obtaining no significant effects for any of the flood variables.

Equation (3): we estimate the model including interactive effects of each of the flood variables with the macroeconomic variables, finding significants effects only for the interaction of the average magnitude of the flood with the gross fixed investment.

* and ** indicate significant at the 10 and 5% level, respectively. In parenthesis, the statistic for testing the non-significance null hypothesis.

TABLE 5.4. Estimated models (agricultural per capita GDP growth rates, developing countries)

	(1)	(2)	(3)
Lagged GDP growth	-0.09**	-0.10**	-0.18**
	(-4.93)	(-4.53)	(-7.13)
Average magnitude	0.0009	0.0009	0.0016
	(1.42)	(1.57)	(0.83)
Lagged average magnitude		0.0018**	0.0018**
		(3.18)	(3.00)
Number of floods	0.0013		
	(0.55)		
Total deaths	-2.6E-07		
	(-0.42)		
Domestic credit			-0.00016
			(-0.57)
Corruption			-0.007*
			(-1.66)
Ethnic tensions			-0.0002
			(-0.05)
Gross Fixed capital formation			-0.0009
			(-1.05)
Interactive efffects magnitude (with gross fixed capital formation)			-4.8E-05
			(-0.57)
Cross- country Fixed effects	Yes	Yes	Yes
Adj. R^2	-0.004	0.001	0.03

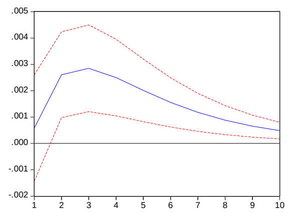
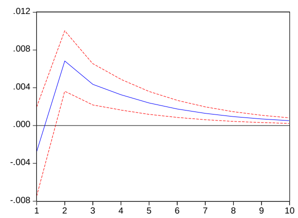
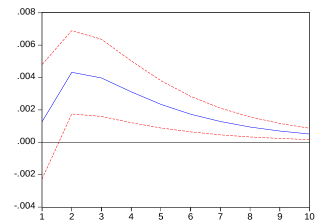
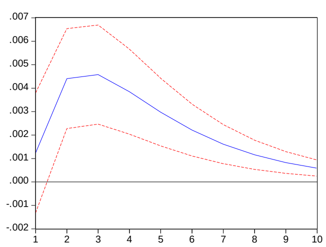
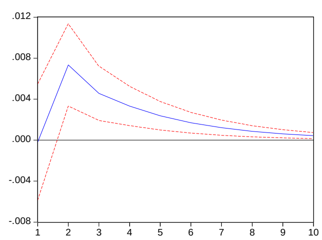
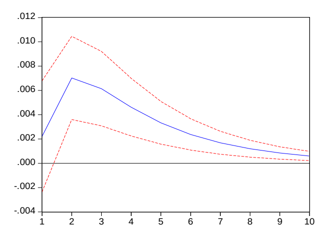
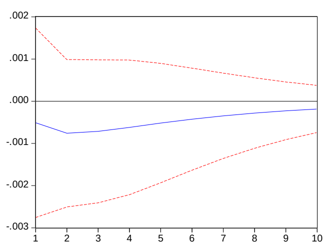
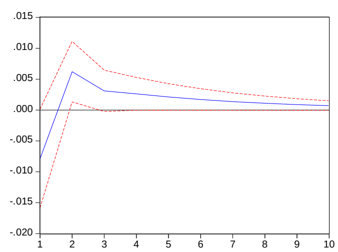
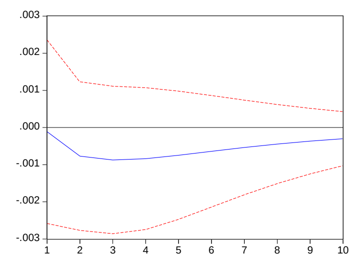
Equation (1): we only include exogenous flood variables as explanatory variables of per capita GDP growth rates, jointly with the lagged growth rate.

Equation (2): we also include lag values of the exogenous flood variables, obtaining only significant effects for the variable measuring the average magnitude of the flood.

Equation (3): we estimate the model including interactive effects of each of the flood variables with the macroeconomic variables, finding significants effects only for the interaction of the average magnitude of the flood with the gross fixed investment.

* and ** indicate significant at the 10 and 5% level, respectively. In parenthesis, the statistic for testing the non-significance null hypothesis.

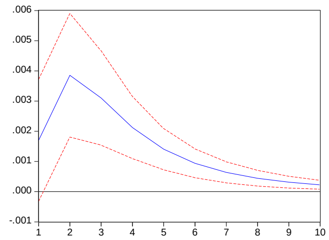
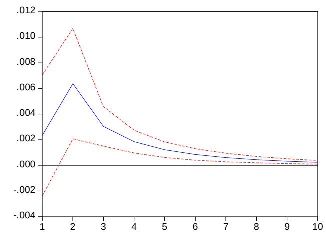
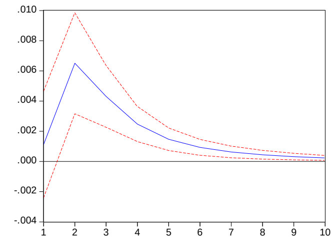
FIGURE 1. Response of growth rates to a Shock (Number of floods)

All countries		
GDP growth	Agricultural growth	Non agricultural growth
		
Developing countries		
GDP growth	Agricultural growth	Non agricultural growth
		
Developed countries		
GDP growth	Agricultural growth	Non agricultural growth
		

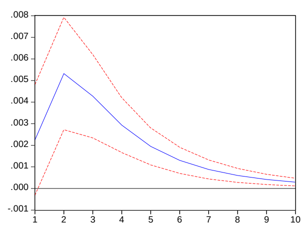
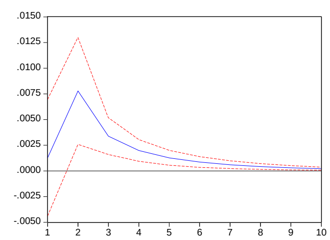
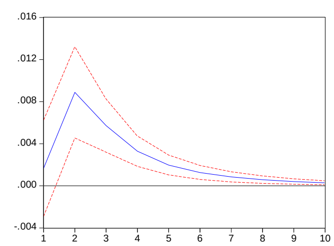
The solid lines denote impulse-responses and the doted lines are 95% error bands.

FIGURE 2. Response of growth rates to a Shock (Average magnitude)

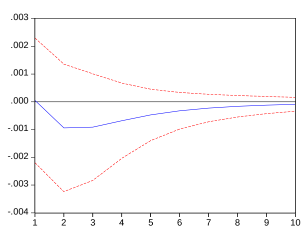
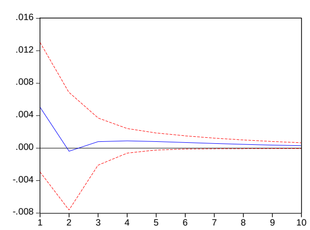
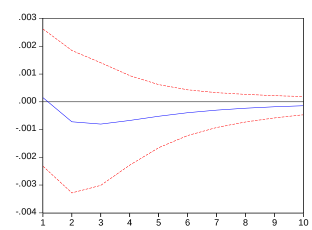
All countries

GDP growth	Agricultural growth	Non agricultural growth
		

Developing countries

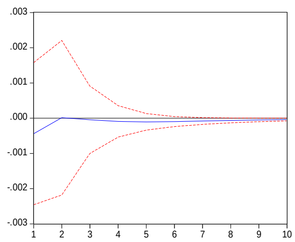
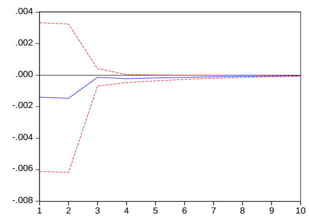
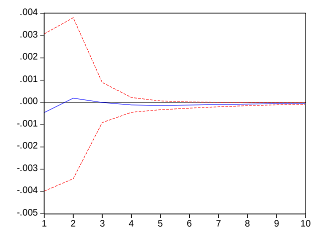
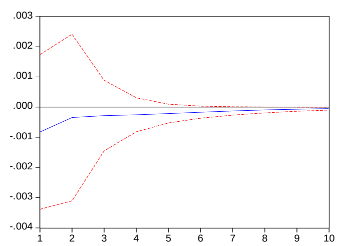
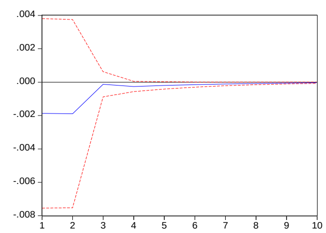
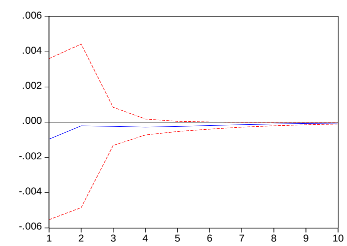
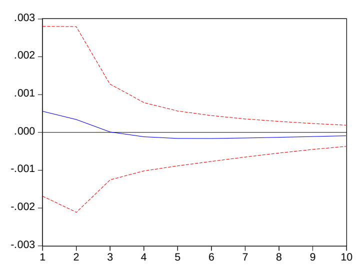
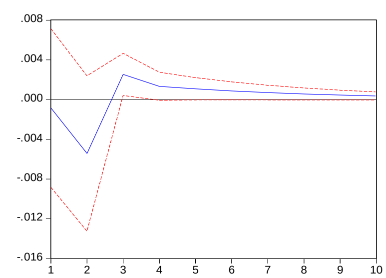
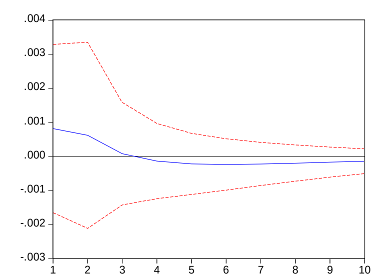
GDP growth	Agricultural growth	Non agricultural growth
		

Developed countries

GDP growth	Agricultural growth	Non agricultural growth
		

The solid lines denote impulse-responses and the doted lines are 95% error bands.

FIGURE 3. Response of growth rates to a Shock (Number of deaths by floods)

All countries		
GDP growth	Agricultural growth	Non agricultural growth
		
Developing countries		
GDP growth	Agricultural growth	Non agricultural growth
		
Developed countries		
GDP growth	Agricultural growth	Non agricultural growth
		

The solid lines denote impulse-responses and the doted lines are 95% error bands.