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Economic Policies and the Impact of Natural Disasters on Economic Growth: A Threshold Regression Approach

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Abstract

This paper investigates the impact of natural disasters on the long-term macroeconomic performance of a country. More specifically, we want to see whether the impact of natural disasters on economic growth is uniform across countries or it is differentiated according to the macroeconomic policy environment and other structural characteristics of the countries at hand. In order to test this empirically we use the Threshold Regression (TR) approach of Hansen (2000) and data from 90 countries over the period of 1970 to 2001. Our analysis reveals several interesting patterns such as: countries with higher per capita income, higher government spending, higher degree of openness to trade, less fiscal imbalances and greater financial stability are better able to withstand the disaster shock and further prevent its impact on long-term economic growth.

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1-Introduction

Despite the increase in both frequency of natural disasters and their ensuing losses over the past decade (see United Nations (2004) report for details) our understanding of their impact on economic development and growth is still in its infancy. Much of the research in social sciences and even more so of course in natural sciences, has been devoted to increasing our ability to predict disasters and prepare for them. Interestingly, however, economic research on natural disasters and their consequences is fairly limited. According to Hewings and Okuyama (2003) the disaster-growth nexus is very complex and consists both of negative effects from damages, as well as positive ones from post-disaster reconstruction and recovery. It is because of that complexity that there has been little consensus in the literature about the impact of natural disasters on economic growth.

Since disaster risk differs substantially across countries, it is reasonable to question whether there is a relationship between natural disasters and long-term economic performance of a country. One of the channels discussed in the literature through which these disasters can affect the long-term economic growth is investment. The country where the probability of capital destruction due to natural disasters is higher experiences a reduction in investment in physical capital and this induces a negative impact on long-run growth.

It has also been observed that costs associated with natural disasters largely depend on the prevailing economic policies and institutional setup. Hence, it is expected that the impact of natural disasters across countries not to be uniform, but it will depend on economic policies and other characteristics of the countries affected.

In light of the above discussion it is important to develop an insight to how natural disasters impact economic growth as this will help reach decisions concerning disaster preparedness and disaster mitigation strategies. Further, by identifying the channels, through which these disasters can affect the macro-economy, will help the disaster planners to infer the optimal allocation of disaster response resources, which will then be directed to well targeted and efficient recovery efforts. In this paper we attempt to tackle these questions by using data on the recorded disaster events and the macroeconomic variables from 90 countries covering the period 1970 to 2001 and by using an econometric Threshold Regression (TR) methodology that classifies countries in different regimes endogenously due to differences in their economic policies, see Hansen (1996, 1999, 2000).

The remainder of the paper is organized as follows. The next section provides a brief review of the literature. In section 3 we provide the data description and the methodology. Section 4 presents the empirical results and a brief discussion of the major findings. The last section concludes.

2-Literature Review

A small but growing literature on the macroeconomic impact of natural disasters can broadly be divided into two groups: studies conducted using cross-country analysis and country case studies that examine specific natural disasters. Since, the country case studies are beyond the scope of this paper, we only review the cross-country studies below.

The body of research that examines the impact of natural disasters in a cross-country fashion can further be divided into two groups. One group considered the short-term macroeconomic impacts of natural disasters while, the other considered the long-term impacts of natural disasters on economic growth. The first study that empirically investigated the short-run macroeconomic consequences of natural disasters in cross-country framework is by Albala-Bertrand (1993). In that paper the author developed an analytical model for disaster occurrence and reaction and collected data for 28 disaster events in 26 countries over the period of 1960 to 1979. The main findings of this study were that after a natural disaster GDP increased by 0.4 percent, capital formation, fiscal and trade deficit and the stock of foreign reserves were also increased, whereas inflation did not change.

Some recent studies utilize more advanced econometric techniques to investigate the macroeconomic consequences of natural disasters. For example Raddatz (2007) employed a Panel-VAR technique to estimate the effect of external shocks on short-run output dynamics in developing countries. In that paper the author found that natural disasters have an adverse short-run impact on aggregate output. Loayza *et al.* (2009) used a dynamic panel GMM estimation technique to investigate the impact of four types of natural disasters floods, storms, earthquake, and droughts on different sectors across-countries. They found different impacts of different type of disasters and also different impacts of same type of disasters on different sectors. Other studies that also examine the short-term impacts of natural disasters are for example Hochrainer (2009), Leiter *et al.* (2009), Mechler (2009), Noy (2009), and Rodriguez-Oreggia *et al.* (2009).

However, there are very few studies that empirically examine the long-term impact of natural disasters on economic growth. In this group, the paper by Skidmore and Toya (2002) is considered as the first piece of empirical research[1]. In that paper the number of natural disasters was normalized by the land area in 89 countries over the period of 1960 to 1990. The authors reached the counterintuitive conclusion that disaster risk may promote long-term economic growth. They found that frequency of climatic disasters is positively correlated with human capital accumulation, growth in total factor productivity and per capita GDP growth. They tried to explain their counterintuitive finding by arguing that disasters might be speeding up a Schumpeterian "creative destruction" process.

Other studies that examine the long-term impact of natural disasters on economic growth are Noy and Nualsri (2007), Jaramillo (2009) and Raddatz (2009). Noy and Nualsri used five-year averages that covers 98 countries over the period of 1975 to 1999 and they found a negative relationship between the losses due to natural disasters and economic growth, something that was also found by Jaramillo (2009). More recently, Raddatz (2009) using cumulative response functions of the growth of real GDP per capita to different types of natural disasters found that in the long-run, per capita GDP is 0.6 percent lower as a result of single climatic event. Further, he found that more than 90 percent of the output cost occurs during the first year of the disaster.

In general, it emerges from the cross-country studies that natural disasters on average have a negative short-term impact on the economic performance of a country. However, there is no consensus regarding the long-term impact of natural disasters on economic growth and therefore, providing room for further research in that area.

3-Data and Methodology

The data set used in this paper includes 90 countries, and 5-year period averages from 1970 to 2001 (1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, and 1995-2001). It comes from two main sources WDI database of the World Bank and the EM-DATA database of the Centre for Research on the Epidemiology of Disaster (CRED) at the Catholic University of Louvain, Belgium. The EM-DAT is a unique dataset and almost all the studies on natural disasters rely on this dataset.

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[1] Cuaresma et al. (2008) state that, "To our knowledge, the article by Skidmore and Toya (2002) is the only piece of empirical research that assesses directly the long-run economic impact of natural disasters" (p.1).

The EM-DAT database records the occurrence and effects of natural disasters in the world since 1900 and it is compiled from various sources such as UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. It defines disaster as a natural situation or event which overwhelms local capacity and/or necessitates a request for external assistance. For a disaster to enter this database, at least one of the following criteria must be met: (i) 10 or more people are reported dead; (ii) 100 or more people are reported to be affected; (iii) a state of emergency is declared; or (iv) a call for international assistance is issued. The types of disasters included are: hydrological (e.g. floods, avalanches, landslides); climatological (e.g. wave surges, droughts, wildfire); Meteorological (e.g. storms); geophysical (e.g. earthquakes, tsunamis and volcanic eruptions); and biological (e.g. epidemics, insect infestations).

The damages reported in this database only consist of direct damages (e.g. damage to infrastructure, crops and housing). The data records the number of people killed (the number of people killed includes "persons confirmed as dead and persons missing and presumed dead"), the number of people affected (the people affected are those "requiring immediate assistance during a period of emergency, i.e. requiring basic survival needs such as food, water, shelter, sanitation and immediate medical assistance") and the amount of property damages in US dollars.

3.1-Construction of disaster cost measures

Following previous studies (Jaramillo (2009); Noy (2009); Noy and Nualsri (2007)) we also assume that the impact of a specific natural disaster on the macro-economy depends on the magnitude of the disaster relative to the size of the economy. Therefore, we also standardize the three cost variables mentioned above, the number of people killed, the number of people affected and the amount of property damages by dividing the number of people killed and the number of people affected by the population size in the year prior to the disaster year and the amount of property damages by the last year's GDP. The intuition for using lagged population and lagged GDP is that the current year's population and GDP have been affected by the disaster itself which would cause an upward bias if we were to use the current population and GDP to compute the disasters cost measures. Further, we weight these measures by the month in which these events occurred. The reason is that disasters that occurred at the beginning of the year would have a bigger impact on the macro-indicators of the same year than disasters that occurred towards the end of the year and as such they should receive a higher weight. Hence, the adjusted disaster cost variables we use in the regression analysis are calculated using the disaster cost (DC) variables weighted by the month the natural disaster occurred (M), defined as:

$$DCM_{i,t}^{j} = \sum_{\tau=1}^{n}[(12 - M_{\tau})/12]DC_{i,t,\tau}^{j} \quad (1)$$

where, τ is the number of events in a given year, in a given country (there are more than one events in some countries in one year) and j (=1,2,3) is the type of the disaster cost measures: the number of people killed, the number of people affected divided by the lagged population and the amount of property damages divide by the lagged GDP. Given the focus of this paper on the time dimension of disaster impact rather on the differential impact of different types of disasters, all measure have been aggregated over the four major types of disasters (Geophysical, Hydrological, Climatological and Meteorological) for a given country in a given year. Further, we calculate the cumulative measure of the disaster cost for each country i, in a given year t, as the sum of all the events (τ). We then compute the 5-year period averages for each disaster cost variable to include in our growth regression.

Our econometric estimation is based on the simple adaptation of the extended Solow-growth model as in Mankiw, Romer and Weil (1992) (later on M-R-W) and Islam (1995). The way we incorporate natural disasters is by adding an additional term for the measure of disaster cost. As it is common in the recent empirical growth literature to employ panel data over 5-year periods averages[2]. We estimate the following unrestricted version of the M-R-W model:

$$gy_{i,t} = \alpha_0 D_t + \alpha_1 D_k + \alpha_2 x_{i,t} + \alpha_3 \ln(I/Y)_{i,t} +$$
$$\alpha_4 \ln(HC_{i,t}) + \alpha_5 \ln\left(n_{i,t} + \varphi + \delta\right) + \alpha_6 DCM_{i,t}^{j} + \varepsilon_{i,t} \quad (2)$$

where $gy_{i,t}$ refers to the average growth rate of income per capita during each 5-year period, D_t and D_k are the periods (1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, and 1995-2001) and regional dummies respectively, $x_{i,t}$ is per capita income at the beginning of each period, $(I/Y)_{i,t}$ is the Gross Domestic Investment to GDP ratio, $HC_{i,t}$ is the Barro and Lee (1996, 2010) measure of human capital, $n_{i,t}$ is the average population growth where $\varphi + \delta = 0.05$ according to Mankiw, Romer and Weil (1992), and $DCM_{i,t}^{j}$ is the disaster cost variable. As mentioned earlier, in this paper we want to examine whether the impact of natural disasters on

[2] The annual data may have strong time dependence or non-stationary behaviour, using 5-year period averages one can suppress time dependence properties of the series.

economic growth is conditional on economic policies and other characteristics of the countries in question. To do that we use the Threshold Regression approach, which unlike standard linear techniques such as ordinary least squares, allows for a data driven way of identifying potential thresholds that classify countries into different regimes.

3.2- Threshold Regression Approach

Threshold regression approach is developed by Hansen (2000) allows to split up the sample into two groups which may call “classes” or “regimes” depending on the context. The idea is based on the change point model. However, the change point literature has only focused to the sampling distribution of the threshold estimate where as Hansen in his paper focuses on the test statistic and he is the first to develop the likelihood ratio test for the threshold parameter. The procedure is as follows.

The observed sample is $\{y_t, x_t, q_t\}_{t=1}^{n}$ where y_t and q_t are real-valued and x_t is an m-vector. The threshold variable q_t may be an element of x_t and is assumed to have a continuous distribution. The model allows the regression parameters to differ depending on the value of q_t. Hence, a threshold regression model takes the form:

$$y_t = \theta_1' x_t + \varepsilon_t \qquad q_t \leq \gamma \qquad (3)$$

$$y_t = \theta_2' x_t + \varepsilon_t \qquad q_t > \gamma \qquad (4)$$

The equations (3)-(4) can be written as a single equation form by introducing a dummy variable d_t = I ($q_t \leq \gamma$) where I(.) denotes the indicator function. By setting $x_t(\gamma)$= $x_t d_t(\gamma)$ equation (3)-(4) become:

$$y_t = \theta' x_t + \delta' x_t(\gamma) + \varepsilon_t \qquad (5)$$

The above equation allows all regression parameters to differ between the two regimes. Hansen develops an algorithm based on a sequential Least Square estimation which searches over all values of γ (γ =q_t, for t=1,2,....,T). The procedure also provide the estimates for θ and δ. Since the value of γ is determined endogenously within the model, Hansen proposed a fixed bootstrap procedure to compute the p-value of the test statistic to test the presence of threshold effect in the model. He showed that this bootstrap procedure yields asymptotically correct p-values. For further details about the estimation of the slope parameters and the threshold see Hansen (1996; 1999; 2000).

4-Summary of the Findings

We begin our empirical analysis by testing the presence of threshold effect in terms of economic policy variables (such as government budget deficit, current account balance, government consumption expenditure, total foreign reserves to imports ratio and exports to GDP ratio) using the Hansen threshold testing procedure. The null hypothesis here is that there is no threshold effect. The LM-test statistic for testing the null of no threshold effect and the corresponding p-values are reported in table 1. As we can see that for all economic policy variables we strongly reject the null of no threshold effect as all the estimated p-values are all close to zero. Therefore, the results in table 1 provide strong evidence for the presence of threshold effects instigated by the list of economic policy variables considered here. Once the presence of threshold effect is confirmed the next step is to estimate the model at the different regimes, below and above the threshold.

The threshold estimation results are summarized in tables 2 and 3[3]. In table 2 we report the estimated coefficients of the three disaster cost measures constructed in this paper by using budget deficit, current account balance and total exports to GDP ratio as threshold variables[4]. The hypotheses we are testing here is that countries with lower fiscal deficit and higher current account balance, and higher degree of openness to trade are better able to absorb the negative shock due to natural disasters. More specifically, our hypotheses here is that better fiscal and external policies will moderate the impact natural disasters on economic performance of a country such that natural disaster will be more detrimental for countries with higher level of fiscal deficit or lower current account balance. Further, countries open to trade will experience smaller negative impact of natural disaster on economic growth as they are more likely to receive larger international capital inflows during the reconstruction efforts. The results reported in table 2 confirm these hypotheses as we find that the higher budget deficit is associated with a statistically significant macroeconomic cost of natural disaster. The estimated threshold value for the budget deficit is around 4 percent of GDP and the countries above this threshold there is a negative and significant impact of natural disasters on economic growth. Similarly, in the

[3] To conserve space we only report the threshold variables for each disaster measure and we ignore the estimates of the other variables in the model such as investment, human capital and population growth.

[4] We also tried the total trade (exports + imports) to GDP ratio instead of exports to GDP ratio, but our results remain qualitatively similar.

countries where the current account balance is below the estimated threshold of 0.63 percent of GDP there is a negative impact of natural disasters on economic growth. Therefore, our results here provide some evidence that the fiscal and external policies are important in moderating the impact of natural disasters on economic growth.

In table 3 we considered government consumption expenditure as a proxy for the size of the government and the percentage of foreign exchange reserves to total imports as a proxy for the financial stability of a country, as our threshold variables. Our expectation here is that a bigger government is able to mobilize more resources more rapidly for reconstruction, and therefore, reduces the macro-cost of natural disasters. Also the financial stability of the country is expected to be important in moderating the impact of natural disasters on economic growth. Our results provide support to the hypotheses that for countries where government consumption expenditure is above the threshold level, 18 percent of GDP, there is no significant impact of natural disasters on economic growth. Similarly, for financial stability variable we find that countries with higher foreign reserves to imports ratio there is no significant negative impact of natural disasters on economic growth. These results provide support to our initial hypothesis that the financial stability of a country is also important for moderating the impact of natural disasters on economic growth.

5-Conclusion

This paper explores one of the important issues in economic development, the impact of natural disasters on economic growth. We find that the impact of natural disasters on economic growth is not uniform across countries, but it is differentiated according to the macroeconomic policies of the country in question which is struck by a natural disaster. Using a TR approach we find strong evidence for the presence of threshold effects with respect to the macro-policy variables. More specifically, our empirical investigation provides the following evidence: countries with larger government, higher degree of openness to trade, less fiscal and external deficits, and greater financial stability are more capable to endure natural disasters with less impact on their long-term economic growth. Our paper provides some evidence that the cost associated with natural disasters is largely determined by economic forces, which may not only reduce the initial disaster damages but can also reduce the negative long-term economic consequences that a disaster can produce.

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Table 1: LM test results for threshold effects

Disaster Cost Measures / **Thresholds**	**DCM1**	**DCM2**	**DCM3**
Budget Deficit/GDP	47.62 [0.00]	48.26 [0.00]	47.76 [0.00]
Current account balance/GDP	22.00 [0.02]	21.53 [0.02]	26.38 [0.00]
Government consumption expenditure/GDP	27.22 [0.00]	26.58 [0.00]	26.33 [0.00]
Total foreign reserves/imports	30.42 [0.00]	30.23 [0.00]	34.12 [0.00]
Exports/GDP	32.27 [0.00]	33.13 [0.00]	33.95 [0.00]

Note: the values in [ ] are the Bootstrap p-values of the LM test statistics of no threshold effect.

Table 2: Summary of threshold estimation results

Disaster cost measures	Threshold Variables					
	Budget Deficit		Current Account Balance		Exports	
	<= 4.1%	*> 4.1%*	*<= 0.63%*	*> 0.63%*	*<= 20.41%*	*> 20.41%*
DCM1	-0.15 (0.24)	-0.11*** (0.05)	-0.19*** (0.09)	0.07 (0.12)	-0.22 (0.17)	-0.09 (0.06)
DCM2	0.01 (0.01)	-0.02** (0.01)	-0.013*** (0.006)	-0.11 (0.07)	-0.02** (0.01)	-0.01 (0.01)
DCM3	-0.02 (0.10)	-0.07*** (0.03)	-0.07*** (0.03)	0.10 (0.12)	-0.05 (0.05)	-0.05 (0.04)

Note: values in ( ) are the heteroskedasticity consistent standard errors. "***", "**" and "*" represents the 1%, 5% and 10% significance levels respectively

Table 3: **Summary of threshold estimation results**

Disaster cost measures	Threshold Variables			
	Government Consumption Expenditure		Foreign Reserves	
	<= 17.48%	*> 17.48%*	*<= 3.33%*	*> 3.33%*
DCM1	-0.10** (0.05)	-0.18 (0.23)	-0.39 (0.27)	-0.07 (0.05)
DCM2	-0.02** (0.01)	-0.07 (0.08)	-0.02** (0.01)	-0.01 (0.01)
DCM3	-0.06 (0.05)	0.02 (0.05)	-0.04 (0.05)	-0.05 (0.04)

Note: values in ( ) are the heteroskedasticity consistent standard errors.
"***", "**" and "*" represents the 1%, 5% and 10% significance levels respectively