Natural Disasters and Medium-Term Economic Growth
The Contrasting Effects of Different Events on Disaggregated Output[*]

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Abstract

Catastrophic natural events are increasingly affecting countries all over the world, causing severe damages and economic losses; yet, research on the overall impact of natural disasters on economic growth remains inconclusive. We show that the main shortcoming of existing analyses is to restrain the study to aggregate measures of disasters and of economic activity, as different types of disasters appear to have diverse (even opposite) effects on growth of different sectors. Among others, we find floods to have a positive impact on agriculture, while droughts and storms have a negative one. In developing countries, floods and droughts also adversely affect industrial growth, reflecting the importance of inter-sectoral linkages. Earthquakes and storms also affect positively industrial growth in developing countries, which is consistent with high economic activity related to reconstruction work. We also find an important caveat for these results: The potential positive effects of natural disasters, if any, disappear when they are of a severe magnitude. Our findings are consistent with traditional models of economic growth, where production depends on the provision of intermediate outputs, the capital-labor ratio, and total factor productivity.

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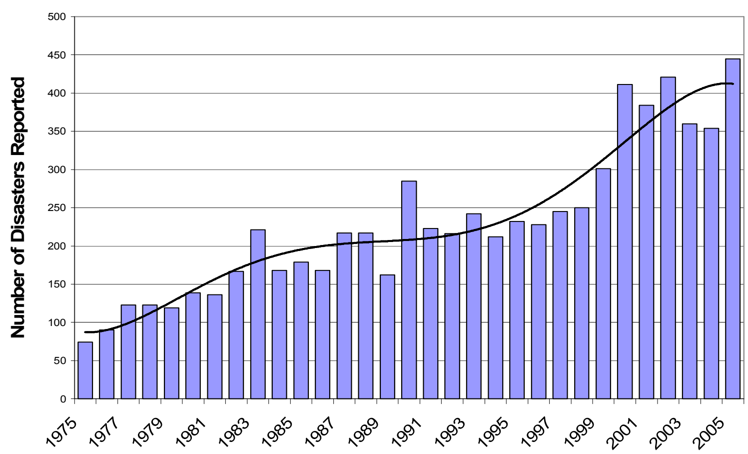
1. Introduction

Catastrophic natural events are increasingly affecting countries all over the world. Floods, droughts, storms, and earthquakes affect each year millions of people and cause severe damages and economic losses, and the ongoing climatic changes point undeniably toward an increase in both their frequency and magnitude (Figure 1). Yet, research on the impact of natural disasters on economic growth has remained inconclusive: while several studies found a negative impact of disasters on growth, many others found no effect, or even a positive one.

Figure 1: Trends in Natural Disasters, 1975-2005



Source: author's own calculations using data on natural disasters from CRED- EMDAT.

We resolve this apparent contradiction by loosening the main shortcoming of existing studies – the fact that most of them restrain the analysis to aggregate measures of disasters and of economic activity. Even from a theoretical standpoint, different types of disasters can have diverse (even opposite) effects on growth. Disasters that affect the provision of essential intermediate inputs in production, for instance, such as droughts in agriculture, should have an adverse impact on growth, but disasters that affect adversely the capital-labor ratio, such as earthquakes, can in principle have a positive impact on growth through increasing returns and high reconstruction investments. Moreover, the impact should also vary across sectors: for instance, droughts are likely to significantly affect agriculture, but less so industry, while earthquakes are more likely to affect industry and services.

In the present paper we study the disaggregated impact of disasters (i.e. droughts, floods, earthquakes and storms) on sectoral economic growth (agriculture, industry, and services). Our measure of natural disasters aims at capturing both the *frequency* and *intensity* of disasters, and consists of the rate of the population affected by a specific type of disaster over a given period of time. Our basic econometric methodology is based on a dynamic panel GMM estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998) that addresses joint endogeneity of the explanatory variables and controls for unobserved country-specific factors. The econometric specification includes other well-known growth determinants as regression controls; they are proxies for economic development, human capital, financial depth, stability of monetary and fiscal policies, and openness to trade.

Working with a sample spanning 94 developing and developed countries over the period 1960-2005, our findings present strong evidence that the relationship between natural disasters and growth depends both on the type of disaster and on the sector of the economy that is affected. In fact, not only the magnitude but also the sign of the impact can vary across disasters and sectors. Results therefore corroborate strongly the need to perform disaggregated analysis.

In particular, we find that droughts have a negative impact that is mainly observed on agricultural growth. In contrast, floods affect positively agricultural growth, and even other sectors of the economy. Storms seem to lead to lower agricultural growth, while earthquakes may bring about higher industrial growth (particularly in developing countries). This differentiated impact of disasters on growth is consistent with the implications of traditional growth models. Thus, natural disasters that lower the provision of intermediate inputs or affect total factor productivity (such as droughts for agriculture) should have a negative impact on the affected sector of the economy. On the other hand, natural disasters that decrease the capital-labor ratio (as tends to be the case with earthquakes) should have a positive growth effect in the aftermath of the event. Furthermore, in the presence of inter-sectoral linkages, the impacts of a given natural disaster should be correlated across sectors (as the impact of floods on both agriculture and services indicate).

When we restrict the sample to developing countries only, we find a stronger sensitivity of growth to natural disasters (as more sectors are affected by them). We also find evidence suggesting a more marked presence of inter-sectoral linkages, which to some extent can be explained by the more prominent role that agriculture plays in developing countries. As noted above, for this group of countries we also observe a positive impact of earthquakes on subsequent industrial growth, a relationship that is consistent with earthquakes causing stronger damages and hence higher reconstruction efforts in poorer countries.

Our last exercise examines possible non-linearities in the relationship between natural disasters and economic growth. In particular, we study whether severe disasters have a qualitatively different impact than moderate ones. It stands to reason that if a natural disaster is large enough to dislocate economic activity, all the mechanisms that could potentially make it positive for growth would be weakened. Consequently, the data ought to show that severe disasters of any type lower economic growth. This is exactly what we find: the impact of the 10 percent largest disasters in any category is either insignificant or negative.

Review of existing literature

Empirical research on the relationship between natural disasters and growth has benefited in recent years from the compilation of datasets that have extensively recorded and classified major natural disasters since the 1960's. A widely used dataset is the EM-DAT database of the Centre for Research on the Epidemiology of Disasters (CRED), which, in addition to the type of disaster, also reports the number of people affected, casualties, and in many cases estimates economic damage (see below, next section for details). As most studies use the EM-DAT database (though do not exploit the offered possibility of disaggregating the analysis by type of disaster), for the sake of consistency we shall use this dataset in our analysis.

While some studies suggest a negative impact of natural disasters on immediate growth, others find no relationship, or even a positive one. Rasmussen (2004), for instance, assesses the impact of natural disasters using a cross-country sample for the period 1970 through 2002. He finds that natural disasters lead to a median reduction of 2.2 percent in the same-year real GDP growth, and that they increase the current account deficit and public debt. Other studies that find a negative impact are, among others, Raddatz (2007), Heger, Julca, and Paddison (2008), and Noy (2009); based on reviews of events (as opposed to cross-country studies), Charveriat (2000), Crowards (2000), and Auffret (2003) also find that major events are associated with output drops. On the other hand, a similar number of studies find no or even a positive relationship between natural disasters and growth. Among others, Caselli and Malhotra (2004), testing the empirical validity of the predictions of the Solow model, fail to find a positive relationship between natural disasters and aggregate economic growth; and, in accordance to our findings, Jaramillo (2007) observes that the sign and magnitude of the relationship depends on the type of disaster.[1] Albala-Bertrand (1993, Ch. 4) and Raddatz (2007) also find no or little effect.

A related strand of literature also demonstrates that the economic impact of disasters depends on the countries' economic and social conditions: among others, a country's level of economic development, the quality of its institutions, democratic election processes, educational attainments, and greater openness have consistently been found to reduce casualties and damages, and to improve macroeconomic performance after the event (Kahn, 2003; Rasmussen, 2004; Toya and Skidmore, 2005; Skidmore and Toya, 2007; Noy, 2009).

While the mentioned studies analyze the relationship between natural disasters and medium-term growth, some studies have also attempted to study how natural disasters are related to growth and overall economic development in the long-run. Skidmore and Toya (2002), among others, consider average per capita GDP growth over the 1960-1990, and find that climatic disasters are associated with higher long-run economic growth, while geologic disasters are negatively associated with growth; Hallegatte and Ghil (2007) find that the phase of the business cycle during which a disaster occurs affects the macroeconomic response; and Cuaresma, Hlouskova, and

[1] The paper however fails to look at sectoral growth (which we find to be equally important as the type of disaster), and does not correct for potential biases using a dynamic panel specification (see next section for details).

Obersteiner (2008) find that natural catastrophic risk is negatively associated with knowledge and technology transfers from more to less developed countries. In analyzing long-term empirical relationships, causality considerations are however complicated by biases generated by the ability of countries to adopt in the long run technologies that are less sensitive to frequent disasters.

The paper is organized as follows. Section 2 discusses the data and methodology; Section 3 presents the basic results and a few extensions. Section 4 discusses these results in the light of a basic theoretical framework. Section 5 concludes.

2. Data and Methodology

The main purpose of the paper is to study the effect of different types of natural disasters --droughts, floods, earthquakes and storms-- on the medium-term economic growth rate of the aggregate economy, as well as that of its major sectors --agriculture industry and services. To perform our estimations, we use pooled cross-country and time-series data covering 94 countries over the period 1961-2005. The data is organized in non-overlapping five-year periods, with each country having at most 9 observations. The panel is unbalanced, with some countries having more observations than others. We build on the panel-data growth regression literature that uses a GMM procedure to address endogeneity and control for unobserved country-specific factors, as presented for example in Levine, Loayza, Beck (2000) and Dollar and Kraay (2004). In the next two sub-sections, we describe the definition and sources of the variables used in our growth regression analysis and provide further details on the methodology.[2]

Data and Regression Specification

This sub-section describes the empirical determinants of growth. Our point of departure is a standard growth regression equation designed for estimation using (cross-country, time-series) panel data:

$$y_{i,t} - y_{i,t-1} = \beta_0 y_{i,t-1} + \vec{\beta}_1 ' CV_{i,t} + \beta_2 ND_{i,t} + \mu_t + \eta_i + \varepsilon_{i,t} \qquad (2.1)$$

[2] Appendices 1 and 2 provide summary statistics of all variables for the all-country and developing-country samples, respectively. Appendix 3 presents a matrix of pair-wise correlations of these variables.

Where the subscripts *i* and *t* represent country and time period, respectively; *y* is the log of output per capita, *CV* is a set of control variables, and *ND* represents natural disasters; μ_t and η_i denote unobserved time- and country-specific effects, respectively; and ε is the error term. The dependent variable ($y_{i,t}$-$y_{i,t-1}$) is the average rate of real output growth (i.e., the log difference of output per capita normalized by the length of the period). The regression equation is dynamic in the sense that it includes the level of output per capita ($y_{i,t-1}$) at the start of the corresponding period in the set of explanatory variables.

To study the impact of natural disasters on the three main sectors of the economy and the economy as a whole, we define four dependent variables. The first is the growth rate of real per capita Gross Domestic Product (GDP). The others are measures of the growth rate of real per capita value added in the three major sector of the economy, that is, agriculture, industry and services. All of them are measured as the five-year average of the log differences of per capita output (in 2000 US dollars), where per capita output is obtained by dividing the value added of each sector by the total population. Data for these variables was obtained from the World Bank's World Development Indicators, WDI, (2007).

Regarding these variables, a few observations deserve to be highlighted. First, we should point out that the growth performance of the different sectors has been diverse. For example, as shown in Appendix 1, during the period considered (1961-2005) the service sector has had the highest average growth rate, 1.83, whereas the agricultural sector has experience the lowest average growth rate, 0.33. Furthermore, Appendix 3 shows that, although the correlation between the growth rates of the industrial and service sectors with the aggregate economy is relatively high (0.83 and 0.82 respectively), their correlation with the agricultural sector is quite low (the correlation with the industrial sector is 0.14, with the service sector 0.21 and with aggregate output is 0.33.) The considerable disparities among the growth performance provide some grounds to suspect that natural disasters could have had diverse effects on the different sectors of the economy.

We divide the set of growth determinants in three groups. The first group is composed of variables that measure transitional convergence, structural policies, institutions and stabilization policies. Our second set of variables proxies the role of external conditions that may affect the growth performance across countries. Finally, we pay special attention to natural disasters, which represent the subject matter of the paper.

To control for transitional convergence, in each regression we use the corresponding initial value of output per capita (in logs) for the five-year period. This is crucial in order to test whether the initial position of the economy is important for its subsequent growth, all things equal. In other words, with this variable we are testing whether poor economies tend to grow faster than rich economies.

With respect to structural policies and institutions, we consider the areas of education, financial development, monetary and fiscal policy and trade openness. Of these, education is approximated by the log of the gross rate of enrollment in secondary school, which is the ratio of the number of students enrolled in secondary school to the number of persons of the corresponding age. Financial depth is measured by the ratio of private domestic credit supplied by private financial institutions to GDP. Our first proxy of macroeconomic stabilization is the consumer price index (CPI) inflation rate, with high inflation being associated with bad macroeconomic policies. Then, we measure the government burden as the ratio of general government consumption to GDP. The last structural policy that we include is associated with the outward orientation of the economy: the openness of the economy to international markets of goods. The measure of trade openness that we use is the volume of trade (exports and imports) over GDP. Financial depth, the inflation rate[3], the government consumption ratio and financial openness enter the growth regressions as the log of the average for the corresponding five-year period. As we explain in detail in the next sub-section, all the control variables presented so far are assumed to be either predetermined (independent of current disturbances, but they may be influenced by past ones) or endogenous and thus correlated with current realizations of the error term.[4] For all these variables, the source of information is the World Bank's WDI (2007).

[3] Inflation rate enters the regressions as log[100+inflation rate]

[4] One of the main reasons for using a GMM procedure is to address this endogeneity problem.

With regard to our second group of growth determinants, the regressions include two variables that are assumed to be strictly exogenous: Shocks to the Terms of Trade and period-specific dummies. Terms of trade shocks is measured by the growth rate of terms of trade (export prices relative to import prices) over each five-year period. The idea is to capture shifts in the demand for a country's exports, and since terms of trade depend mainly on world conditions, it is assumed to be exogenous to contemporaneous growth of per capita GDP of a particular country. We include period-specific dummies to capture the impact of other global shocks to growth across countries. Again, all these data are from the World Bank (WDI 2007).

Finally, our last set of variables proxies the role of natural disasters on the growth performance across countries. Data for natural disasters was obtained from the Emergency Disasters Database (EM-DAT) maintained by the Center for Research on the Epidemiology of Disasters (CRED). Since this database is not well known by most economists it deserves special attention, therefore in what follows we provide a description of the database and the variables used.

EM-DAT is a worldwide database on disasters maintained by CRED with the sponsorship of the United States Agency for International Development's Office of Foreign Disaster Assistance (OFDA). It contains data on the occurrence and effects of more than 17,000 disasters in the world from 1900 to the present. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies.

CRED defines a disaster as "a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering." For a disaster to be entered into the database, at least one of the following criteria must be fulfilled: 10 or more people reported killed; 100 or more people reported affected; declaration of a state of emergency; or call for international assistance.

CRED divides disasters according to type (for example: drought, flood, etc), and provides the dates when the disaster occurred and ended; the number of casualties (people confirmed dead and number missing and presumed dead); the number of people injured (suffering from physical injuries, trauma or an illness requiring immediate medical treatment as a direct result of a disaster) and the number of people affected. People affected are those requiring immediate assistance during a period of emergency (i.e., requiring basic survival assistance such as food, water, shelter, sanitation and immediate medical help). Also, people reported injured or homeless are aggregated with those affected to produce the total number of people affected.

Finally, EM-DAT also provides an estimate of "economic damage". Although "economic damage" could potentially be a good indicator of the gravity of a disaster, we decided not to use it in our regressions because it has two important drawbacks. First, CRED admits that there is no standard procedure to determine a global figure for economic impact. And second, the proportion of disasters for which economic losses are reported in the EM-DAT database averages to about a third and the information is better reported for some disaster categories than for others. Specifically, the bigger the disaster, the better the chances economic losses will be quantified and reported as the need for international loans for reconstruction and other financial considerations push to undertake this exercise. For example, disaster losses are reported for nearly 50% of all the windstorms entered in EM-DAT and 40% of the earthquakes. This is most likely due to the infrastructure damage that is directly and clearly attributable to these events. Floods are the third largest category, with losses reported for about one-third of the total events. For droughts, on the other hand, less than 25% of the events have losses reported. There may be several factors for this. In particular, CRED recognizes that droughts may only draw the international attention in terms of lives lost, with little consideration for economic costs. Droughts do not result in infrastructure or shelter damage but in heavy crop and livestock losses, therefore, most economic losses are of an indirect or secondary nature and difficult to quantify.

The different columns of Chart 1 show some summary statistics for victims (total people affected), economic damage and number of events across different types of disasters for the period considered. The comparison across disaster types reveals that each type produces a very different impression on the economy and/or population. In particular, it's clear that in terms of victims, droughts are the most devastating of all. On average, the seven hundreds and seventeen droughts that have been reported, generated almost three and a half million victims. On the other hand, a similar number of earthquakes have caused (on average) less that two hundred thousands victims. With respect to the estimated economic damage of the events, the numbers are reversed. Earthquakes are (on average) by far the most devastating of all the disaster types considered (almost one billion dollar per event and more than three thousands dollar per victim) whereas droughts are the less harmful of all (only cause an estimated loss of forty-nine dollars per victim). In light of this evidence, we believe that there are strong reasons to expect that different types of disasters will have diverse consequences for growth.

Chart 1: Average costs of natural disasters divided by type (1961-2005)

Disaster Type	Number of Events*	Total Affected	Economic Damage	Total Affected 2**	Economic Damage / Total Affected 2
Drought	717/216	3,583,535	$321,346,900	6,572,660	$48.89
Flood	756/367	1,190,734	$328,332,200	2,406,117	$136.46
Earthquake	2545/1107	142,374	$977,841,000	263,830	$3,706.32
Storm	2279/1074	330,873	$513,861,100	514,482	$998.79

* Number of Events / Number of events for which Economic Damage is reported
** Total Affected 2 is average of Total Affected for events where Economic Damage is reported
Source: author's own calculations using data from CRED- EMDAT.

Our aim is to analyze the effects of different types of disasters on economic growth therefore we classify disasters into four categories: earthquakes, floods, droughts and storms. For each category we create a variable that is a weighted sum of all the events that took place during the five-year period. Since a main argument of the paper is that not all natural disasters are the same for growth, it would be wrong to treat events of different magnitudes as equal. It seems natural to expect that the effect of a specific natural disaster on growth will be a function of the magnitude of the event relative to the size of the economy. To weight each natural disaster according to its intensity relative to the size of the economy we divide the sum of the number of casualties and people affected (from now on "Total Affected") by the population. As a result, if the event was very small relative to the size of the economy, its weight will be close to zero, whereas if the scale of the event was important its weight should be closer to one.

The distribution of the weighted sum of natural disasters is positively skewed, therefore, to make sure that the variable is well behaved and that the results are not driven by extreme values, we perform two additional transformations. First, to reduce the potential role of extreme values, as is done in most applied works when the sample histogram suggests that the distribution of the underlying population is positively skew, we make a logarithmic transformation of the variable scale and test whether the normal distribution fits the transform data, which is indeed the case here.

Formally, the measure of intensity of natural disasters that we use is given by:

$$ND_{i,t} = Log\left(\sum_j \frac{Total\ Affected_{i,t,j}}{Population_{i,t}}\right)$$

Where j indexes the number of events that took place in country *i* during (five-year) period *t*. But this generates a second problem. There are many observations for which no events were reported, that is the sum of total affected over population is zero and the log of zero is not defined. In order to be able to incorporate these observations in our regressions, we need to define a lower bound for this variable. Although this is an arbitrary number, it must be chosen so that it does not drive the distribution of the natural disaster indicator. For this purpose, we set this lower bound to -20, just below the lowest observation for which an event was reported.

In order to check the robustness of our findings, we construct a second variable that measures the incidence of disasters by counting the number of events in a given year that classify as large disasters according to the following criteria similar to the one established by the International Monetary Fund (see IMF, 2003), and used by Becker and Mauro (2006). The dummy variable for *disasters* takes the value of 1 if the total number of people affected times 0.3 plus the number of casualties is greater than 0.01 percent of the country's total population.[5] Then, we sum up the number of events of a given type that took place during the five year period.

Estimation Methodology

The growth regression presented above poses some challenges for estimation. The first is the presence of unobserved period- and country-specific effects. While the

[5] The IMF also considers disasters that cause damages of at least half a percent of national GDP.

inclusion of period-specific dummy variables can account for the time effects, the common methods of dealing with country-specific effects (that is, within-group or difference estimators) are inappropriate given the dynamic nature of the regression. The second challenge is that most explanatory variables are likely to be jointly endogenous with economic growth, so we need to control for the biases resulting from simultaneous or reverse causation. Although natural disasters are exogenous –and treated as such in the econometric estimation—their effects would be incorrectly estimated if the endogeneity of the remaining variables in the model is ignored. The following outlines the econometric methodology we use to control for country-specific effects and joint endogeneity in a dynamic model of panel data.

We use the generalized method of moments (GMM) estimators developed for dynamic models of panel data that were introduced by Holtz-Eakin, Newey, and Rosen (1988), Arellano and Bond (1991), and Arellano and Bover (1995). These estimators are based, first, on differencing regressions or instruments to control for unobserved effects and, second, on using previous observations of explanatory and lagged-dependent variables as instruments (which are called internal instruments).

After accounting for time-specific effects, we can rewrite equation 2.1:

$$y_{i,t} = \alpha\, y_{i,t-1} + \vec{\beta}' X_{i,t} + \eta_i + \varepsilon_{i,t} \qquad (2.2)$$

To eliminate the country-specific effect, we take first differences of equation 2.2:

$$y_{i,t} - y_{i,t-1} = \alpha\left(y_{i,t-1} - y_{i,t-2}\right) + \beta'\left(X_{i,t} - X_{i,t-1}\right) + \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right) \qquad (2.3)$$

The use of instruments is required to deal with the likely endogeneity of the explanatory variables and the problem that, by construction, the new error term, $\varepsilon_{i,t} - \varepsilon_{i,t-1}$, is correlated with the lagged dependent variable, $y_{i,t-1} - y_{i,t-2}$. The instruments take advantage of the panel nature of the data set in that they consist of previous observations of the explanatory and lagged-dependent variables. Conceptually, this assumes that shocks to economic growth (that is, the regression error term) be unpredictable given past values of the explanatory variables. The method does allow, however, for current and future values of the explanatory variables to be affected by growth shocks. It is this type of endogeneity that the method is devised to handle.

Under the assumptions that the error term, ε, is not serially correlated and that the explanatory variables are weakly exogenous (that is, the explanatory variables are assumed to be uncorrelated with future realizations of the error term), our application of the GMM dynamic panel estimator uses the following moment conditions:

$$E\left[y_{i,t-s} \cdot \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0 \quad for\ s \geq 2; t = 3,\ldots,T \quad (2.4)$$

$$E\left[X_{i,t-s} \cdot \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right)\right] = 0 \quad for\ s \geq 2; t = 3,\ldots,T \quad (2.5)$$

for $s \geq 2$ and $t = 3,\ldots, T$. Although in theory the number of potential moment conditions is large and growing with the number of time periods, T, when the sample size in the cross-sectional dimension is limited, it is recommended to use a restricted set of moment conditions in order to avoid overfitting bias (we return to this issue below). In our case, we work with the first five acceptable lags as instruments.[6] As mentioned above, the indicator of natural disasters and the measure of external shocks (i.e. growth rate of terms of trade) are treated as exogenous variables.

The GMM estimator based on the conditions in 2.4 and 2.5 is known as the difference estimator. Notwithstanding its advantages with respect to simpler panel data estimators, the difference estimator has important statistical shortcomings. Blundell and Bond (1998) and Alonso-Borrego and Arellano (1999) show that when the explanatory variables are persistent over time, lagged levels of these variables are weak instruments for the regression equation in differences. Instrument weakness influences the

[6] Specifically, regarding the difference regression corresponding to the periods *t* and *t-1*, we use the following instruments: for the variables measured as period averages --financial depth, government spending, inflation, and trade openness-- the instrument corresponds to the average of period *t-2;* for the variables measured as initial values --per capita output and secondary school enrollment-- the instrument corresponds to the observation at the start of period *t-1*.

asymptotic and small-sample performance of the difference estimator toward inefficient and biased coefficient estimates, respectively.[7]

To reduce the potential biases and imprecision associated with the difference estimator, we use an estimator that combines the regression equation in differences and the regression equation in levels into one system (developed in Arellano and Bover, 1995, and Blundell and Bond, 1998). For the equation in differences, the instruments are those presented above. For the equation in levels (equation 2.2), the instruments are given by the lagged differences of the explanatory variables.[8] These are appropriate instruments under the assumption that the correlation between the explanatory variables and the country-specific effect is the same for all time periods. That is,

$$\begin{aligned} &E[y_{i,t+p} \cdot \eta_i] = E[y_{i,t+q} \cdot \eta_i] \quad and \\ &E[X_{i,t+p} \cdot \eta_i] = E[X_{i,t+q} \cdot \eta_i] \quad for\ all\ p\ and\ q \end{aligned} \qquad (2.6)$$

Using this stationarity property and the assumption of exogeneity of future growth shocks, the moment conditions for the second part of the system (the regression in levels) are given by:

$$E[(y_{i,t-1} - y_{i,t-2}) \cdot (\eta_i + \varepsilon_{i,t})] = 0 \qquad (2.7)$$

$$E[(X_{i,t-1} - X_{i,t-2}) \cdot (\eta_i + \varepsilon_{i,t})] = 0 \qquad (2.8)$$

We thus use the moment conditions presented in equations 2.4, 2.5, 2.7, and 2.8 and employ a GMM procedure to generate consistent and efficient estimates of the parameters of interest and their asymptotic variance-covariance (Arellano and Bond 1991; Arellano and Bover 1995). These are given by the following formulas:

[7] An additional problem with the simple difference estimator involves measurement error: differencing may exacerbate the bias stemming from errors in variables by decreasing the signal-to-noise ratio (see Griliches and Hausman, 1986).

[8] The timing of the instruments is analogous to that used for the difference regression: for the variables measured as period averages, the instruments correspond to the difference between *t-1* and *t-2*; and for the variables measured at the start of the period, the instruments correspond to the difference between *t* and *t-1*.

$$\hat{\theta} = (\bar{X}'Z\hat{\Omega}^{-1}Z'\bar{X})^{-1}\bar{X}'Z\hat{\Omega}^{-1}Z'\bar{y} \qquad (2.9)$$

$$AVAR(\hat{\theta}) = (\bar{X}'Z\hat{\Omega}^{-1}Z'\bar{X})^{-1} \qquad (2.10)$$

where $\boldsymbol{\theta}$ is the vector of parameters of interest (α, $\boldsymbol{\beta}$); $\bar{\mathbf{y}}$ is the dependent variable stacked first in differences and then in levels; $\bar{\mathbf{X}}$ is the explanatory-variable matrix including the lagged dependent variable (y_{t-1}, $\mathbf{X}$) stacked first in differences and then in levels; $\mathbf{Z}$ is the matrix of instruments derived from the moment conditions; and $\hat{\Omega}$ is a consistent estimate of the variance-covariance matrix of the moment conditions.[9]

Note that we use only a limited set of moment conditions. In theory the potential set of instruments spans all sufficiently lagged observations and, thus, grows with the number of time periods, *T*. However, when the sample size in the cross-sectional dimension is limited, it is recommended to use a smaller set of moment conditions in order to avoid over-fitting bias (see Arellano and Bond 1998; for a detailed discussion of over-fitting bias in the context of panel-data GMM estimation, see Roodman 2007). This is our case, and therefore we use two steps to limit the moment conditions. First, as described in detail above, we use as instruments only five *appropriate lags* of each endogenous explanatory variable. Second, we use a common variance-covariance of moment conditions across periods. This results from substituting the assumption that the average (across periods) of moment conditions for a particular instrument be equal to zero for the assumption, conventional but more restrictive, that each of the period moment conditions be equal to zero.[10] At the cost of the reduced efficiency, our two steps decrease over-fitting bias in the presence of small samples by accommodating cases when the unrestricted variance-covariance is too large for estimation and inversion given both a large number of explanatory variables and the presence of several time-series periods.

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[9] Arellano and Bond (1991) suggest the following two-step procedure to obtain consistent and efficient GMM estimates. First, assume that the residuals, $\varepsilon_{i,t}$, are independent and homoskedastic both across countries and over time; this assumption corresponds to a specific weighting matrix that is used to produce first-step coefficient estimates. Second, construct a consistent estimate of the variance-covariance matrix of the moment conditions with the residuals obtained in the first step, and then use this matrix to re-estimate the parameters of interest (that is, second-step estimates).

[10] This uses the "collapse" option of xtabond2 for STATA.

The consistency of the GMM estimators depends on whether lagged values of the explanatory variables are valid instruments in the growth regression. We address this issue by considering two specification tests. The first is the Hansen test of overidentifying restrictions, which tests the validity of the instruments by analyzing the sample analog of the moment conditions used in the estimation process. Failure to reject the null hypothesis gives support to the model. The second test examines whether the original error term (that is, $\varepsilon_{i,t}$ in equation (2.2)) is serially correlated. The model is, therefore, supported when the null hypothesis is not rejected. In the system specification, we test in fact whether the first-differenced error term (that is, the residual of the equation in differences) is second-order serially correlated. First-order serial correlation of the differenced error term is expected even if the original error term (in levels) is uncorrelated, unless the latter follows a random walk. Second-order serial correlation of the differenced residual indicates that the original error term is serially correlated and follows a moving average process of at least order one.

3. Empirical Results

We now present and discuss the estimation results. We focus on those obtained with the GMM methodology, given its conceptual and practical advantages as outlined in the previous section. We start with the sample of all countries, but then move to consider the sample of developing countries, for which we present the basic results and all extensions. Table 1 presents the basic estimation results on the all-country sample. For the first two columns, the dependent variable is the growth rate of GDP per capita. The last three analyze GDP growth disaggregated into its major sectors, considering as dependent variables, the growth rate of agriculture, industry, and services, respectively. In all cases, the growth rate is expressed in terms of value added output per capita.

For the first column, the explanatory variable of interest is a single index of natural disasters, which aggregates over the four types of events. The remaining columns consider the four types of natural disasters individually but simultaneously in the regression. In addition, the set of explanatory variables always includes the same control variables, except that initial output corresponds to the initial valued-added of the respective sector.

Let's start by analyzing the results corresponding to the standard growth determinants (in Cols. 1 and 2) and the regression specification tests. Most of them are consistent with the received empirical literature. Suggesting a beneficial impact on economic growth, the proxies of educational investment, depth of financial intermediation, and trade openness have positive coefficients, though not statistically significant for the first two variables. Government consumption and price inflation, on the other hand, carry negative coefficients, indicating the harmful consequence of a large fiscal burden and macroeconomic price instability. External shocks are also important growth determinants. Specifically, more favorable terms of trade tends improve economic growth performance. Representing global conditions, the period shifts (not shown in the tables to save space) indicate that the international trend in economic growth experienced a declining drift over 1960-2000, resulting in less favorable external environment in the 1980s and 1990s than in the previous decades.

Perhaps surprisingly, initial output per capita shows a positive though not significant coefficient (which tends to change in sign and significance for different samples and growth specifications). In the next footnote, we offer some conjectures as to why some of our results appear to differ from the previous literature. There we argue that they are related to important changes that have occurred in the most recent decade regarding the roles of macroeconomic volatility and public infrastructure.[11]

Finally, regarding the specification tests, the Hansen and serial-correlation tests indicate that the null hypothesis of correct specification cannot be rejected, lending

[11] Using data only up to the years 1995 or 2000 (as most previous studies do), secondary school enrollment and private credit ratio do carry positive and statistically significant coefficients. Moreover, in those exercises, the initial level of output per capita has a negative and significant coefficient. So it seems that in the last decade, the relationship of these variables with economic growth has changed in important ways. In preliminary exercises (not reported here), we have found that accounting for macroeconomic volatility and infrastructure provision may be important to understand the role of education, financial intermediation, and initial output. Financial depth, particularly since 1995, has a positive and a negative effect. On the one hand, it represents better intermediation from savings to investment; but on the other, it may be a source of banking crisis. Therefore, controlling for volatility would isolate the beneficial effect. In the case of education and initial output, since both are highly correlated, they would tend to partially capture the convergence effect (negative coefficient) and the better initial conditions effect (positive coefficient). It seems that when an infrastructure proxy is included in the explanatory set, these effects are duly separated: initial output carries a negative (convergence) coefficient, while education and infrastructure capture a positive coefficient. However, we should stress that the results concerning the growth effects of natural disasters are robust to the inclusion of these additional controls. For this reason, we maintain the simpler specification to keep sample size (country coverage and time span) acceptably large.

support to our estimation results. This is also the case for the remaining exercises presented below, and we only mention it here in order to avoid redundancy.

Let's now focus the discussion on the growth effects of natural disasters. The combined index of natural disasters carries a positive but not statistically significant coefficient in the GDP growth regression (Col. 1). The lack of a significant effect reflects well the theoretical ambiguity and the inconsistent empirical evidence in the received literature on the growth impact of natural disasters. The remaining exercises, consisting of disaggregating the growth variable and the natural disaster index, attempt to disentangle this ambiguity. The next column (Col. 2) starts by disaggregating by type of natural disaster.[12] They show coefficients of contrasting signs. However, they fail to be statistically significant, except for floods that carry a somewhat surprising positive coefficient. The statistical weakness of these results prevents any conclusive interpretation. We should therefore consider the next pieces of information: what areas of economic activity do these types of natural disasters have an impact on? And, are these impacts stronger for developing countries?

Analyzing the remaining columns of Table 1, we find evidence of heterogeneous results by area of economic activity. In contrast to the weak effects on overall GDP growth, three types of natural disasters seem to be statistically relevant for the growth of agricultural output (Col. 3): droughts and storms carry negative coefficients, while floods a positive one. On the other hand, the effects on industrial and service output growth are rather weak for the sample of all countries. In the case of industrial growth (Col. 4) no coefficient appears to be statistically significant. For service growth, floods are the only natural disaster that carries a significant coefficient, with a positive sign that starts to become robust.

We then consider the results on the sample of developing countries only (Table 2). There, the growth effects of natural disasters are stronger in significance and, in some cases, magnitude. When neither GDP growth nor the index of natural disasters is disaggregated by sector or type (Col. 1), the coefficient on natural disasters is negative but not statistically significant. As before, the results gain significance and diversity once

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[12] The results are basically the same whether we consider the types of natural disasters one-by-one or simultaneously in the regression, which indicates that their respective effect is practically independent from that of the rest.

we disaggregate. When we consider the four types of natural disasters individually but jointly in the regression, both droughts and floods appear to have a significant effect on per capita GDP growth, with droughts decreasing and floods raising growth (Col. 2).

Next, we consider the effects on agricultural growth (Col. 3). The largest correspond to droughts and floods, which, as in the case of aggregate growth, have opposite effects: the impact of droughts is clearly negative on agricultural growth while that of floods is strongly positive. It would seem that having a plentiful supply of water benefits overall agriculture in the affected country, even if in some areas and for some products its over-abundance may be hurtful. Interestingly, holding constant droughts and floods, the effect of storms is negative and significant for agricultural growth. This would imply that when the provision of water is controlled for, the destruction and dislocation borne by storms can only harm agriculture. Although our analysis does not allow us to discern the mechanisms through which the growth effects of natural disasters are realized, the results on agricultural growth suggest two keys understand the contrasting effects of natural disasters. The first is related to the provision of raw materials and intermediate inputs: if an event increases the availability of this resource (say, water for farming), it is likely to have a positive growth effect, and *vice versa*. The second key is related to total factor productivity: if an event destroys public infrastructure (say, water dams or irrigation canals) or any other productivity determinant, its growth effect is likely to be negative.

Next we evaluate the impacts on the growth of industrial output (Col. 4). Droughts and floods have significant yet opposite effects on industrial growth. Although they are analogous to the case of agriculture, their mechanisms are likely to be different. Thus, the provision of water (or lack thereof) is also crucial for industrial growth but for a different reason: it often determines the electricity generating capacity of the country. Another mechanism through which droughts and floods affect industrial growth consists of the inter-sector linkages between agriculture and industry. Since in developing countries industrial production is heavily dependent on agricultural inputs (for example, cotton for textiles and grapes for wines), natural disasters that improve or harm agricultural growth are likely to operate in the same direction for industrial growth. This mechanism highlights the first key mentioned above: the effect of a natural disaster on a sector of economic activity depends on its impact on the sector's intermediate inputs.

For industrial growth, the other two natural disasters also carry statistically significant coefficients. Perhaps surprisingly, both earthquakes and storms seem to lead to higher industrial growth. Particularly in developing countries the damage to infrastructure inflicted by earthquakes and storms can be substantial due to lack of preparation. However, except for severe cases, the negative impact of this destruction is likely to be diffused as unused capacity compensates for the destroyed capital. This allows a potential positive impact to dominate. Its mechanism is likely to reside on the capital reconstruction that follows earthquakes and storms in areas including housing, infrastructure, and manufacturing. In terms of damage resulting from natural disasters, earthquakes and storms are different from the rest in that their impact on physical capital is the strongest, relative to population affected (see Chart 1). This argument suggests a third key to explain the differences of the effects of natural disasters: If an event produces a sharp reduction in the capital-labor ratio, it is likely to be followed by higher growth, and *vice versa*.

Lastly, we assess the effects on the growth of service output. In this case, only floods carry a significant coefficient, indicating a positive effect of floods on services output growth. Given that this sector includes commerce and retailing, among other cross-cutting economic activities, services has strong links with both agriculture and industry. Therefore, the positive impact of floods may be partly the result of its beneficial impact on agricultural and industrial outputs. Another mechanism through which services may be affected by natural disasters is that relief resources and activities increase the demand for service-related sectors, such as transport and communications, banking, and government. This effect will complement the effects coming through other mechanisms, adding size to the positive ones and reducing the magnitude of the negative ones. Thus, in the case of floods, the positive effect of relief activities increases the beneficial spill-over of agriculture and industry. Interestingly, this may be the reason why the effect of droughts on service output growth is not statistically significant: the positive relief effect counteracts the negative spill-over effect coming from agriculture and industry. The spill-over mechanism point to the importance of inter-sector linkages, manifested through supply-chain relationships. It supports the first key, mentioned above, to understand the effects of natural disasters. The disaster-relief mechanism can be interpreted as an increase in the total factor productivity of the service sector, in the sense that higher demand induces an increase in utilized capacity and an increase in the relative price of service-sector goods. This is the second key to understand the effects of natural disasters, as suggested above.

When the growth effects of natural disasters are statistically significant, they are also economically important. To show this, Chart 2 presents the estimates of the growth effect of a natural disaster of "typical" or median intensity, disaggregated by type of disaster and sector of economic activity. The calculations are made using the point estimates of the coefficients, presented in Table 2, and the median intensities in the sample of developing countries, as reported in Appendix 3. A typical drought produces a reduction of agricultural and industrial annual growth rate of the order of 1 percentage point, leading to a decline of GDP growth by 0.6 percentage points. A typical flood increases growth in each major sector by about 0.8-0.9 percentage points, producing an increase of GDP growth by around 1 percentage point. A typical earthquake leads to a rise in industrial growth of about 0.9 percentage points, which, however, does not translate into an increase in aggregate growth. Finally, a typical storm has a dual effect, reducing agricultural growth by 0.6 percentage points and increasing industrial growth by 0.8 percentage points.

Chart 2: Growth effect of a "typical" (median) natural disaster

		Effect on:			
		GDP Growth	Agricultural Growth	Industrial Growth	Service Growth
Median intensity:	Droughts	-0.606 ***	-1.071 ***	-1.029 **	-0.127
	Floods	0.996 ***	0.802 ***	0.935 ***	0.911 ***
	Earthquakes	-0.091	0.091	0.938 *	-0.071
	Storms	-0.093	-0.559 ***	0.838 *	-0.207

Note: The effects on growth are calculated using the coefficients reported in Table 2.
** significant at 10%; ** significant at 5%; *** significant at 1%*

Having presented the basic results, we now conduct an extension that helps qualify their interpretation. Specifically, we analyze whether severe natural disasters have different growth consequences than moderate ones. This is an important analysis particularly because some natural disasters appear to have a positive effect on the economy. The linearity of our basic specification implies that the larger (more intense) the event, the larger the magnitude of its effect (whether positive or negative). This simple specification may be a good representation of the effects of the majority of natural disasters but may distort the true effects of the most severe ones.

To examine this issue, we interact the corresponding natural disaster measure with a dummy variable that has the value of 1 for the top 10% of natural disasters according to intensity, and 0 for the rest. We then add four interaction terms (one per natural disaster) to our basic regression equation and estimate the regression with the same methodology as before (see Table 3, where the interaction terms are called “Droughts Severe”, “Floods Severe”, etc.). The coefficients on the interaction terms will then indicate how and by how much severe natural disasters have different effects on growth, with respect to those of moderate ones. Clearly, the coefficients on the simple disaster measures (“Droughts”, “Floods”, etc.) will denote the effects of moderate disasters, and the sum of the coefficients of the simple measure and the interaction term will denote the effects of severe disasters.

The results are quite revealing. In the case of droughts, severe events intensify the negative effect on agricultural growth by a factor of two. In the case of floods, the positive effect that we estimated above seems to apply to only moderate events. In fact, all the potential gains for aggregate GDP, agriculture, industry, and services growth disappear when floods are severe (the positive coefficient on the simple measure of floods is about the same size of the negative coefficient on the interaction term). Interestingly, something similar happens with earthquakes and storms in the case of industrial growth. Both of them carried significantly positive coefficients in our basic specification. Now, the simple measures of earthquakes and storms retain those positive coefficients, but their corresponding interaction terms are now negative (and significantly so in the case of storms). This implies that while moderate earthquakes and storms can have a beneficial “reconstruction” effect on industrial growth, severe events are so devastating that the loss of capital cannot be compensated by increasing capacity, thus dissipating the potential gains.

Finally, we conduct two exercises that check the robustness of the results on two important issues of the econometric specification: the estimation methodology and the measure of natural disasters. The first exercise consists of estimating the growth regressions using a standard least-squares (LS) methodology, rather than the more complex GMM estimator (see Table 4). In this case, the statistically significant results are a subset of those under the preferred GMM methodology. That is, there is no contradiction between the LS and GMM results, but the latter are more precise particularly in the cases of earthquakes and storms. Under LS, only droughts and floods carry statistically significant coefficients, with droughts producing a substantial drop in agricultural growth and floods causing an increase in growth of all major sectors and, thus, aggregate GDP.

The second exercise consists of using a count (incidence) variable to measure natural disasters, rather than the continuous (intensity) variable used in the main specification (see Table 5). As explained in section 2, the count variable is the average number of events in the corresponding country and five-year window. Following previous literature, a natural disaster qualifies as an "event" if the number of affected (as defined in section 2) is larger than 0.01% of the population. The results are remarkably similar to those obtained with the continuous measure of natural disasters. In fact, for droughts and floods the results are the same, in terms of sign and statistical significance, for the two disaster measures. For earthquakes and storms, the count or incidence variable fails to identify a significant effect on industrial growth. In a sense, this reflects the tension of the industrial growth effects of these two variables –as we discussed above, they are positive only if earthquakes and storms are not severe. The count variable does not contain enough information to discern the positive effects that apply to the majority of these natural disasters.

4. Theoretical Discussion

There are a variety of economic models that may help explain the growth effects of natural disasters. A simple model that accounts for the contrasting effects of different types of natural disasters on various sectors of economic activity is the Solow-Swan model. In particular, it considers the three "keys" identified in our discussion of the estimation results. The Solow-Swan model has been used extensively for its conceptual strength and clarity to understand the determinants of medium-term economic growth, that is, the process that occurs in the transition to a long-run steady state. This is the time horizon that is relevant for this paper. The Solow-Swan model is well known and here we present only the basic elements to organize the discussion.

Consider a production function with decreasing marginal returns, constant returns to scale, three production factors, and a general productivity parameter. For simplicity, assume a production function of the Cobb-Douglas form:

$$Y = AK^{\alpha} L^{\beta} M^{1-\alpha-\beta} \qquad (3.1)$$

Where, Y is output, A represents the general productivity parameter, K is capital, L is labor, M represents materials and other intermediate inputs, and α, β, 1-α-β are the corresponding factor shares (all between 0 and 1). Note that the marginal product of each factor is positive but decreasing (with limits of ∞ and 0 as the factor approaches 0 and ∞, respectively).

The action in the Solow model is given by its dynamic equations. In its simple form, only one factor of production, capital, is accumulated purposively. It is assumed that a constant fraction of output is saved and invested in capital formation. Regarding the other production factors, labor follows an exogenous fixed growth rate, and productivity and intermediate inputs can change arbitrarily. Thus,

$$\Delta K = sY - \delta K \qquad (3.2)$$

$$\Delta L = nL \qquad (3.3)$$

Where, s is the saving rate, δ represents the capital depreciation rate, n is the population growth rate, and Δ indicates change.

We can now analyze the dynamic behavior of the economy described by the neoclassical production function (eq. 3.1) and the accumulation equations (eqs. 3.2 and

3.3). The purpose is to characterize the growth rate of capital and output along the path to the "steady state," which is defined as the situation of constant growth rates towards which the economy converges in the long run. In the steady state, capital and output *per worker* will be constant (implying that K and Y will grow at rate n). For this reason, it is convenient to transform all variables to per-worker terms, after which they are denoted with lower case letters.

After some algebra, the growth rate of capital and output per worker are given by,

$$Gr(k) = \frac{\Delta(k)}{k} = s\frac{y}{k} - (\delta + n) \qquad (3.4)$$

$$Gr(y) = \frac{\Delta(y)}{y} = \alpha Gr(k) \qquad (3.5)$$

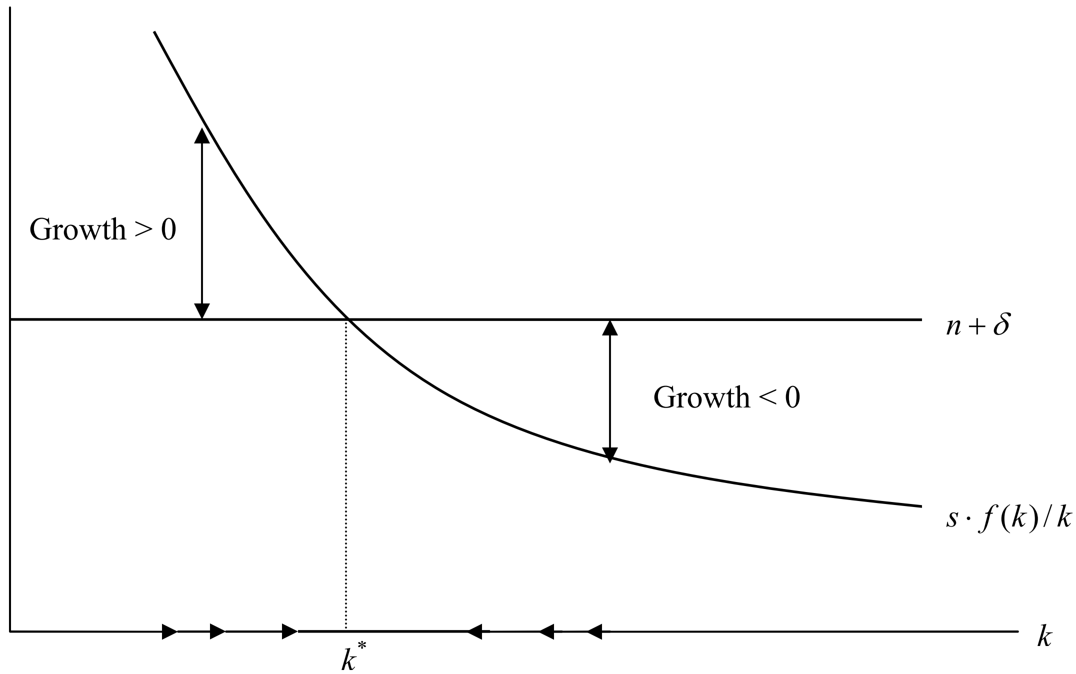
The growth rate of output goes hand-in-hand with the capital growth rate. Both depend crucially on the average product of capital (y/k), which is a decreasing function of capital per worker (k):

$$\frac{y}{k} = Am^{1-\alpha-\beta}k^{\alpha-1} \qquad (3.6)$$

The growth of capital per worker (and, thus, output per worker) is then given by the difference between two terms, $s(y/k)$ and $(\delta+n)$. For illustration purposes, we plot them as function of capital per worker (k) in Figure 2.

The steady-state level of capital per worker, k^*, is given by the intersection of the two lines. When capital per worker is below k^*, capital is relatively scarce and therefore more productive, leading to capital accumulation and output growth (per worker). This occurs at gradually slower rates until capital per worker reaches k^*, and the economy grows at the rate of population growth. If, on the other hand, capital per worker is above k^*, capital is relatively abundant and less productive, producing a capital and output contraction (per worker). Again, this occurs at declining rates until reaching the steady state.

Figure 2: Economic Growth in the Transition to the Steady-State



How can the analytical framework provided by the Solow-Swan model help us understand the growth effects of natural disasters? It can tell us the effect on (transitional) growth of any change in factor productivity, the endowment of capital and labor, and the supply of materials and intermediate inputs.[13] If a natural disaster destroys more capital than labor, thus reducing k, growth is expected to increase (with respect to normal, steady-state conditions). If it hurts general productivity (decreasing A), the average product of capital declines for every level of capital per worker (i.e., a left shift of the downward sloping curve) and growth is expected to decrease. The same occurs if the supply of intermediate inputs declines as a consequence of a natural disaster.

Droughts have a negative effect on agricultural growth because they entail the drastic reduction of water, a vital input in agricultural production. Droughts also affect negatively industrial growth. This may occur through two mechanisms related to the provision of raw materials and intermediate inputs. The first is by reducing the supply of agricultural products that serve as inputs to industry. The second is by hampering power

[13] Of course, the model can inform as to the growth effects of other variables, such as factor intensities, population growth, and capital depreciation rates, but they seem less relevant to explaining the effects of natural disasters.

generation, particularly when this is based on hydroelectricity. In addition, their negative effect may be compounded by the fact that droughts affect people and workers much more than they destroy physical capital, thus increasing *k* beyond its steady state level.

Floods, on the other hand, have a positive effect on all sectors of the economy if they are not severe or widespread. They induce a disruption of farming, urban activities, and transportation in the areas most affected by them. However, when floods are moderate, they may lead to higher growth through a variety of mechanisms in less affected areas and in subsequent years. Some of these mechanisms are the opposite to those of droughts. On agriculture, floods may raise growth by increasing both land productivity and the supply of water for irrigation. On industry, floods may increase growth by raising the supply of agricultural products and electric power, both important intermediate inputs for industrial production. The positive effect of floods on services growth may also come through inter-linkages with other sectors (e.g., a larger supply of inputs for commerce and retail). In addition, disaster relief activities may increase the demand for services in transportation, banking, and government, leading to an increase, albeit temporary, in factor productivity.

Except if they are severe, earthquakes may have a positive impact on industrial growth. Although they severely affect both workers and capital, earthquakes particularly destroy buildings, infrastructure, and factories. The capital-worker ratio is then sharply diminished, the average (and marginal) product of capital increases, and output grows as the economy enters a cycle of reconstruction. Moreover, if destroyed capital is replaced by a vintage of better quality, factor productivity increases, leading to a further push to higher growth.

Storms have a negative effect on agricultural growth, but, if they are not severe, a positive one on industrial growth. Agricultural growth declines after storms because they disrupt communications, public utilities, and transportation, thus harming inputs and services that are keys to the productivity of the sector. The same mechanisms should lead to a reduction in industrial growth. However, in this case, a positive effect seems to counteract and dominate the negative productivity impact. The mechanism is akin to that of earthquakes, working through a reduction of the capital-labor ratio. Storms destroy considerable amounts of physical capital, devastating capital relatively more than incapacitating workers. As the capital-worker ratio drops, this mechanism would suggest a growth expansion.

4. Conclusions

Disasters do affect economic growth – but not always negatively, and often only specific sectors of the economy. Our analysis, by documenting a differentiated impact where both the sign and magnitude varies with the type of disaster and the affected sector, points to the need to look at disaggregated relationships in expanding the scope of research. For instance, the time path of recovery and adjustment ought to vary by shock and sector – and could also potentially be affected by country-dependant institutional factors. Our findings also hint at the presence of linkages transmitting shocks across sectors (in particular in developing countries), but cross-country regression are not able to isolate these transmission mechanisms. Country case-studies would therefore be a good complement, and would permit developing detailed policy actions that would ease recovery and adjustment. In that context, an analysis of the distributional impact of disasters (both in terms of geographic impact, and impact across income categories) would also permit better policy development.

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Table 1
Growth and Major Natural Disasters
Sample: 94 countries, 1961-2005 (5-year period observations)
Estimation Method: System GMM

	Dependent Variable:				
	[1] GDP Growth	**[2] GDP Growth**	**[3] Agricultural Growth**	**[4] Industrial Growth**	**[5] Service Growth**
Natural Disaster Variables:					
All Disasters	0.025				
intensity: log(avg. affected/population)	[1.166]				
Droughts		-0.024	-0.080 ***	0.008	0.005
intensity: log(avg. affected/population)		[-1.505]	[-3.874]	[0.297]	[0.273]
Floods		0.075 ***	0.094 ***	0.034	0.048 **
intensity: log(avg. affected/population)		[4.045]	[4.787]	[1.165]	[2.351]
Earthquakes		-0.002	-0.018	0.007	-0.012
intensity: log(avg. affected/population)		[-0.098]	[-0.747]	[0.173]	[-0.566]
Storms		0.011	-0.051 **	-0.012	-0.021
intensity: log(avg. affected/population)		[0.425]	[-2.321]	[-0.291]	[-0.776]
Control Variables					
Initial Output per capita[1]	0.560	0.575	-0.590	0.637	-0.141
in logs	[1.541]	[1.641]	[-0.948]	[1.147]	[-0.598]
Education	0.596	0.280	2.302 ***	-0.791	2.712 ***
secondary school enrollment rate, in logs	[0.887]	[0.434]	[3.758]	[-0.701]	[5.461]
Financial Depth	0.142	0.119	-0.519	0.668 *	0.064
private credit/GDP, in logs	[0.719]	[0.644]	[-1.490]	[1.652]	[0.241]
Government Burden	-4.267 ***	-4.007 ***	-1.008 *	-4.736 ***	-4.307 ***
government consumption/GDP, in logs	[-7.303]	[-6.604]	[-1.663]	[-5.087]	[-6.536]
Inflation	-6.840 ***	-5.961 ***	-3.240 ***	-6.390 ***	-5.633 ***
100+%Growth rate of CPI, in logs	[-5.247]	[-4.729]	[-2.825]	[-2.950]	[-4.211]
Trade Openness	1.494 ***	2.025 ***	0.524	1.859 *	1.379 *
(exports+imports)/GDP, in logs	[2.621]	[3.222]	[0.760]	[1.945]	[1.910]
Growth rate of Terms of Trade	0.046 ***	0.042 ***	0.067 ***	0.033	0.076 ***
log differences of terms of trade index	[2.849]	[2.980]	[3.105]	[1.197]	[4.747]
Constant	33.288 ***	28.142 ***	12.507 **	35.992 ***	27.026 ***
	[4.361]	[3.749]	[2.012]	[3.114]	[3.443]
Observations	545	545	545	545	545
Number of Countries	94	94	94	94	94
Number of Instruments	47	50	50	50	50
Arellano-Bond test for AR(1) in first differences	0.000	0.000	0.000	0.000	0.000
Arellano-Bond test for AR(2) in first differences	0.385	0.277	0.139	0.354	0.453
Hansen test of overidentifying restrictions	0.490	0.569	0.263	0.245	0.453

Numbers in brackets are the corresponding t-statistics.
** significant at 10%; ** significant at 5%; *** significant at 1%*
Period fixed effects were included (coefficients not reported).
[1] Output corresponds to GDP, agricultural value added, industrial value added, and service value added, respectively.

Table 2
Growth and Major Natural Disasters: Developing Countries

Sample: 68 developing countries, 1961-2005 (5-year period observations)
Estimation Method: System GMM

	Dependent Variable:				
	[1] GDP Growth	[2] GDP Growth	[3] Agricultural Growth	[4] Industrial Growth	[5] Service Growth
Natural Disaster Variables:					
All Disasters	0.002				
intensity: log(avg. affected/population)	[0.085]				
Droughts		-0.043 ***	-0.076 ***	-0.073 **	-0.009
intensity: log(avg. affected/population)		[-2.947]	[-4.331]	[-2.270]	[-0.457]
Floods		0.082 ***	0.066 ***	0.077 ***	0.075 ***
intensity: log(avg. affected/population)		[4.627]	[3.570]	[2.737]	[4.015]
Earthquakes		-0.009	0.009	0.093 *	-0.007
intensity: log(avg. affected/population)		[-0.350]	[0.389]	[1.750]	[-0.249]
Storms		-0.009	-0.054 ***	0.081 *	-0.020
intensity: log(avg. affected/population)		[-0.346]	[-2.579]	[1.656]	[-0.638]
Control Variables:					
Initial Output per capita[1]	0.480	0.207	0.201	-2.280 **	0.159
in logs	[0.964]	[0.377]	[0.261]	[-2.438]	[0.324]
Education	0.006	0.011	1.292 **	-0.344	1.651 ***
secondary school enrollment rate, in logs	[0.010]	[0.019]	[2.264]	[-0.350]	[2.807]
Financial Depth	0.706 ***	0.409 *	-0.141	0.693 *	0.485 *
private credit/GDP, in logs	[3.187]	[1.807]	[-0.483]	[1.738]	[1.795]
Government Burden	-3.545 ***	-3.49 ***	-1.040 *	-6.311 ***	-3.612 ***
government consumption/GDP, in logs	[-5.749]	[-5.876]	[-1.798]	[-6.584]	[-5.596]
Inflation	-6.304 ***	-5.536 ***	-3.712 ***	-4.929 ***	-3.234 ***
100+%Growth rate of CPI, in logs	[-5.328]	[-4.864]	[-5.317]	[-2.860]	[-2.852]
Trade Openness	1.151 *	1.857 ***	-0.214	4.998 ***	2.474 ***
(exports+imports)/GDP, in logs	[1.888]	[2.695]	[-0.379]	[4.829]	[2.874]
Growth rate of Terms of Trade	0.046 ***	0.046 ***	0.074 ***	0.057 ***	0.068 ***
log differences of terms of trade index	[3.054]	[3.457]	[4.032]	[2.640]	[3.079]
Constant	30.254 ***	26.985 ***	15.548 ***	36.394 ***	10.466
	[4.226]	[3.750]	[3.170]	[3.634]	[1.577]
Observations	407	407	407	407	407
Number of Countries	68	68	68	68	68
Number of Instruments	47	50	50	50	50
Arellano-Bond test for AR(1) in first differences	0.000	0.000	0.000	0.000	0.001
Arellano-Bond test for AR(2) in first differences	0.386	0.198	0.172	0.710	0.216
Hansen test of overidentifying restrictions	0.333	0.498	0.272	0.417	0.308

Numbers in brackets are the corresponding t-statistics.
** significant at 10%; ** significant at 5%; *** significant at 1%*
Period fixed effects were included (coefficients not reported).

[1] Output corresponds to GDP, agricultural value added, industrial value added, and service value added, respectively.

Table 3
Severe Natural Disasters: Developing Countries
Sample: 68 developing countries, 1961-2005 (5-year period observations)
Estimation Method: System GMM

	Dependent Variable:				
	[1] GDP Growth	[2] GDP Growth	[3] Agricultural Growth	[4] Industrial Growth	[5] Service Growth
Natural Disaster Variables:					
All Disasters	0.002				
intensity: log(avg. affected/population)	[0.0931]				
All Disasters Severe	-0.043 *				
All Disasters*Top 10% drought dummy	[-1.673]				
Droughts		-0.035 **	-0.049 ***	-0.035	-0.016
intensity: log(avg. affected/population)		[-2.361]	[-2.896]	[-1.147]	[-0.797]
Droughts Severe		-0.025	-0.086 ***	-0.026	0.037
Droughts*Top 10% drought dummy		[-0.973]	[-2.793]	[-0.714]	[1.332]
Floods		0.105 ***	0.073 ***	0.100 ***	0.099 ***
intensity: log(avg. affected/population)		[5.488]	[4.252]	[3.376]	[4.581]
Floods Severe		-0.083 ***	-0.038 *	-0.091 **	-0.075 **
Floods*Top 10% flood dummy		[-3.072]	[-1.739]	[-2.222]	[-2.048]
Earthquakes		-0.028	0.005	0.081 *	-0.003
intensity: log(avg. affected/population)		[-1.139]	[0.171]	[1.685]	[-0.119]
Earthquakes Severe		0.026	-0.012	-0.058	0.005
Earthquakes*Top 10% earthquake dummy		[0.905]	[-0.427]	[-1.210]	[0.150]
Storms		-0.002	-0.062 ***	0.084 **	-0.010
intensity: log(avg. affected/population)		[-0.0625]	[-2.893]	[2.021]	[-0.280]
Storms Severe		-0.054 *	0.011	-0.143 **	-0.050
Storms*Top 10% storm dummy		[-1.662]	[0.527]	[-2.410]	[-1.370]
Control Variables:					
Initial Output per capita[1]	0.216	0.290	0.191	-1.411 *	0.195
in logs	[0.409]	[0.591]	[0.244]	[-1.883]	[0.505]
Education	0.315	0.333	1.539 **	0.134	1.607 ***
secondary school enrollment rate, in logs	[0.456]	[0.548]	[2.526]	[0.127]	[3.020]
Financial Depth	0.629 ***	0.373	-0.176	0.316	0.497 *
private credit/GDP, in logs	[2.867]	[1.488]	[-0.593]	[0.657]	[1.695]
Government Burden	-3.579 ***	-3.380 ***	-0.563	-5.922 ***	-3.514 ***
government consumption/GDP, in logs	[-5.891]	[-5.827]	[-0.981]	[-6.450]	[-5.443]
Inflation	-6.356 ***	-4.977 ***	-3.067 ***	-5.991 ***	-2.933 **
100+%Growth rate of CPI, in logs	[-5.635]	[-4.842]	[-4.270]	[-3.244]	[-2.224]
Trade Openness	1.228 **	1.832 ***	-0.520	4.486 ***	2.632 ***
(exports+imports)/GDP, in logs	[2.021]	[2.804]	[-0.962]	[4.648]	[2.792]
Growth rate of Terms of Trade	0.041 ***	0.046 ***	0.074 ***	0.025	0.065 ***
log differences of terms of trade index	[2.671]	[3.366]	[3.882]	[1.010]	[2.829]
Constant	31.305 ***	22.427 ***	13.460 ***	34.401 ***	7.343
	[4.604]	[3.510]	[2.741]	[3.203]	[0.949]
Observations	407	407	407	407	407
Number of Countries	68	68	68	68	68
Number of Instruments	48	54	54	54	54
Arellano-Bond test for AR(1) in first differences	0.000	0.000	0.000	0.000	0.001
Arellano-Bond test for AR(2) in first differences	0.332	0.247	0.204	0.663	0.229
Hansen test of overidentifying restrictions	0.394	0.669	0.322	0.444	0.311

Numbers in brackets are the corresponding t-statistics.
** significant at 10%; ** significant at 5%; *** significant at 1%*
Period fixed effects were included (coefficients not reported).
[1] Output corresponds to GDP, agricultural value added, industrial value added, and service value added, respectively.

Table 4
Ordinary Least Squares: Developing Countries
Sample: 68 developing countries, 1961-2005 (5-year period observations)
Estimation Method: OLS Robust Regression

	Dependent Variable:				
	[1] GDP Growth	[2] GDP Growth	[3] Agricultural Growth	[4] Industrial Growth	[5] Service Growth
Natural Disaster Variables:					
All Disasters	0.021				
intensity: log(avg. affected/population)	[0.721]				
Droughts		-0.017	-0.070 ***	-0.007	0.000
intensity: log(avg. affected/population)		[-0.806]	[-2.959]	[-0.196]	[0.009]
Floods		0.092 ***	0.083 ***	0.087 **	0.081 **
intensity: log(avg. affected/population)		[3.632]	[2.828]	[2.032]	[2.566]
Earthquakes		-0.027	0.005	-0.018	-0.022
intensity: log(avg. affected/population)		[-1.158]	[0.180]	[-0.463]	[-0.813]
Storms		-0.032	-0.008	-0.055	-0.022
intensity: log(avg. affected/population)		[-1.362]	[-0.329]	[-1.416]	[-0.800]
Control Variables					
Initial Output per capita[1]	-0.269	-0.212	-0.251	-0.537 **	-0.524 ***
in logs	[-1.601]	[-1.160]	[-0.735]	[-2.336]	[-2.620]
Education	0.911 ***	0.875 ***	0.368	0.944 **	1.206 ***
secondary school enrollment rate, in logs	[4.058]	[3.791]	[1.267]	[2.194]	[3.938]
Financial Depth	0.781 ***	0.720 ***	0.131	0.951 ***	1.002 ***
private credit/GDP, in logs	[3.464]	[3.046]	[0.589]	[2.684]	[3.498]
Government Burden	-1.470 ***	-1.372 ***	-0.099	-2.218 ***	-1.288 **
government consumption/GDP, in logs	[-3.827]	[-3.450]	[-0.210]	[-3.431]	[-2.552]
Inflation	-3.464 ***	-3.620 ***	-0.992	-4.886 ***	-3.017 ***
100+%Growth rate of CPI, in logs	[-4.254]	[-4.295]	[-1.443]	[-3.656]	[-3.042]
Trade Openness	0.358	0.478 *	-0.574 *	1.021 **	0.226
(exports+imports)/GDP, in logs	[1.534]	[1.909]	[-1.823]	[2.479]	[0.732]
Growth rate of Terms of Trade	0.059 **	0.060 **	0.086 ***	0.033	0.100 ***
log differences of terms of trade index	[2.399]	[2.461]	[3.199]	[0.658]	[3.555]
Constant	17.861 ***	17.890 ***	7.346 **	25.890 ***	16.204 ***
	[4.564]	[4.375]	[2.024]	[3.865]	[3.362]
Observations	407	407	407	407	407
Number of Countries	68	68	68	68	68
R-squared	0.276	0.308	0.128	0.223	0.258

Numbers in brackets are the corresponding t-statistics.
** significant at 10%; ** significant at 5%; *** significant at 1%*
Period fixed effects were included (coefficients not reported).
[1] Output corresponds to GDP, agricultural value added, industrial value added, and service value added, respectively.

Table 5
Incidence of Natural Disasters: Developing Countries
Sample: 68 developing countries, 1961-2005 (5-year period observations)
Estimation Method: System GMM

	Dependent Variable:				
	[1] GDP Growth	[2] GDP Growth	[3] Agricultural Growth	[4] Industrial Growth	[5] Service Growth
Natural Disaster Variables:					
All Disasters	-0.090				
avg. number of events[1]	[-0.383]				
Droughts		-2.084 ***	-2.966 ***	-2.733 ***	-0.737
avg. number of events[1]		[-4.045]	[-3.716]	[-2.587]	[-1.118]
Floods		1.048 ***	1.254 ***	1.078 **	1.627 ***
avg. number of events[1]		[3.674]	[4.025]	[2.202]	[6.235]
Earthquakes		-0.890	0.717	1.035	-1.190
avg. number of events[1]		[-1.264]	[0.745]	[0.632]	[-1.516]
Storms		-0.754 ***	-0.778 ***	-0.279	-0.819 ***
avg. number of events[1]		[-3.766]	[-4.910]	[-0.604]	[-2.839]
Control Variables:					
Initial Output per capita[2]	0.551	0.265	0.207	-1.561 *	0.110
in logs	[1.069]	[0.488]	[0.305]	[-1.807]	[0.221]
Education	0.002	0.079	1.807 **	-1.451	1.597 ***
secondary school enrollment rate, in logs	[0.004]	[0.123]	[2.483]	[-1.361]	[2.934]
Financial Depth	0.769 ***	0.641 ***	-0.389	1.131 **	0.523 **
private credit/GDP, in logs	[3.685]	[3.293]	[-1.296]	[2.397]	[2.178]
Government Burden	-3.495 ***	-3.366 ***	-0.512	-5.869 ***	-3.200 ***
government consumption/GDP, in logs	[-5.857]	[-5.355]	[-0.990]	[-5.792]	[-5.028]
Inflation	-6.308 ***	-5.626 ***	-3.553 ***	-4.833 ***	-2.692 ***
100+%Growth rate of CPI, in logs	[-5.340]	[-5.611]	[-5.669]	[-3.073]	[-3.089]
Trade Openness	1.102 *	1.138	-0.833	4.363 ***	2.171 ***
(exports+imports)/GDP, in logs	[1.695]	[1.585]	[-1.479]	[4.021]	[2.897]
Growth rate of Terms of Trade	0.048 ***	0.037 **	0.066 ***	0.043	0.066 ***
log differences of terms of trade index	[3.179]	[2.466]	[3.249]	[1.571]	[3.413]
Constant	29.693 ***	28.094 ***	16.364 ***	32.030 ***	7.771
	[4.061]	[4.214]	[3.589]	[3.213]	[1.412]
Observations	407	407	407	407	407
Number of Countries	68	68	68	68	68
Number of Instruments	47	50	50	50	50
Arellano-Bond test for AR(1) in first differences	0.000	0.000	0.000	0.000	0.000
Arellano-Bond test for AR(2) in first differences	0.371	0.144	0.167	0.758	0.391
Hansen test of overidentifying restrictions	0.328	0.388	0.497	0.485	0.314

Numbers in brackets are the corresponding t-statistics.
** significant at 10%; ** significant at 5%; *** significant at 1%*
Period fixed effects were included (coefficients not reported).

[1] An event counts as 1 if affected > 0.01% of population.

[2] Output corresponds to GDP, agricultural value added, industrial value added, and service value added, respectively.

Appendix 1
Descriptive Statistics
Sample: 94 countries, 1961-2005 (5-year period observations)

A) Economic Growth & Basic Determinants

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Growth GDP pc (%)	545	1.58	1.74	2.52	-5.75	9.86
Growth Agricultural Sector (%)	545	0.33	0.41	2.83	-13.17	11.49
Growth Industrial Sector (%)	545	1.73	1.62	3.84	-13.43	19.10
Growth Service Sector (%)	545	1.83	2.12	2.90	-13.14	12.33
Initial GDP pc (in logs)	545	7.61	7.48	1.55	4.44	10.53
Initial Agricultural Output pc (in logs)	545	5.25	5.26	0.79	2.87	7.97
Initial Industrial Output pc (in logs)	545	6.28	6.20	1.70	2.79	9.53
Initial Service Output pc (in logs)	545	6.92	6.82	1.69	3.22	10.09
Education (in logs)	545	3.62	3.80	0.90	0.11	4.97
Financial Depth (in logs)	545	3.42	3.38	0.87	0.14	5.40
Government Burden (in logs)	545	2.62	2.61	0.37	1.42	3.36
Inflation (log(100+%Growth rate of CPI))	545	4.71	4.67	0.14	4.57	5.78
Trade Openness (in logs)	545	4.00	4.01	0.58	2.21	6.00
Growth rate of Terms of Trade	545	-0.38	-0.36	4.74	-18.86	21.42

B) Natural Disasters: Unconditional summary statistics

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
All Disasters (intensity in logs)	545	-9.81	-8.09	5.34	-20.00	-2.74
Droughts (intensity in logs)	545	-16.89	-20.00	5.84	-20.00	-2.74
Floods (intensity in logs)	545	-12.31	-10.09	5.73	-20.00	-3.52
Earthquakes (intensity in logs)	545	-17.19	-20.00	4.65	-20.00	-3.04
Storms (intensity in logs)	545	-15.66	-20.00	5.28	-20.00	-3.53
All Disasters (incidence: avg. num. of events)	545	0.47	0.20	0.66	0.00	5.40
Droughts (incidence: avg. num. of events)	545	0.06	0.00	0.14	0.00	0.80
Floods (incidence: avg. num. of events)	545	0.24	0.20	0.36	0.00	2.20
Earthquakes (incidence: avg. num. of events)	545	0.04	0.00	0.11	0.00	0.80
Storms (incidence: avg. num. of events)	545	0.12	0.00	0.37	0.00	3.40

C) Natural Disasters: Conditional on the occurrence of natural disasters

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
All Disasters (intensity in logs)	454	-7.76	-7.33	3.03	-17.66	-2.74
Droughts (intensity in logs)	125	-6.45	-5.90	2.63	-16.43	-2.74
Floods (intensity in logs)	374	-8.79	-8.47	2.88	-19.09	-3.52
Earthquakes (intensity in logs)	163	-10.60	-10.22	3.23	-18.97	-3.04
Storms (intensity in logs)	254	-10.70	-10.39	3.67	-19.50	-3.53
All Disasters (incidence: avg. num. of events)	375	0.68	0.40	0.69	0.20	5.40
Droughts (incidence: avg. num. of events)	114	0.30	0.20	0.16	0.20	0.80
Floods (incidence: avg. num. of events)	284	0.47	0.40	0.38	0.20	2.20
Earthquakes (incidence: avg. num. of events)	88	0.25	0.20	0.13	0.20	0.80
Storms (incidence: avg. num. of events)	132	0.50	0.20	0.60	0.20	3.40

Appendix 2
Descriptive Statistics: Developing Countries
Sample: 68 developing countries, 1961-2005 (5-year period observations)

A) Economic Growth & Basic Determinants

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
Growth GDP pc (%)	407	1.35	1.46	2.71	-5.75	8.49
Growth Agricultural Sector (%)	407	0.12	0.30	2.83	-13.17	8.76
Growth Industrial Sector (%)	407	1.68	1.68	4.19	-13.43	19.10
Growth Service Sector (%)	407	1.58	1.90	3.18	-13.14	12.33
Initial GDP pc (in logs)	407	6.92	6.92	1.12	4.44	10.14
Initial Agricultural Output pc (in logs)	407	4.95	4.98	0.60	2.87	6.20
Initial Industrial Output pc (in logs)	407	5.58	5.69	1.35	2.79	9.35
Initial Service Output pc (in logs)	407	6.17	6.18	1.24	3.22	9.94
Education (in logs)	407	3.32	3.47	0.84	0.11	4.73
Financial Depth (in logs)	407	3.15	3.16	0.78	0.14	5.27
Government Burden (in logs)	407	2.52	2.49	0.35	1.42	3.32
Inflation (log(100+%Growth rate of CPI))	407	4.73	4.69	0.16	4.57	5.78
Trade Openness (in logs)	407	4.00	3.99	0.60	2.21	6.00
Growth rate of Terms of Trade	407	-0.58	-0.61	5.27	-18.86	21.42

B) Natural Disasters: Unconditional summary statistics

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
All Disasters (intensity in logs)	407	-8.76	-7.27	5.02	-20.00	-2.74
Droughts (intensity in logs)	407	-15.95	-20.00	6.37	-20.00	-2.74
Floods (intensity in logs)	407	-11.42	-8.95	5.77	-20.00	-3.52
Earthquakes (intensity in logs)	407	-17.09	-20.00	4.77	-20.00	-3.04
Storms (intensity in logs)	407	-15.55	-20.00	5.51	-20.00	-3.53
All Disasters (incidence: avg. num. of events)	407	0.57	0.40	0.72	0.00	5.40
Droughts (incidence: avg. num. of events)	407	0.08	0.00	0.16	0.00	0.80
Floods (incidence: avg. num. of events)	407	0.30	0.20	0.39	0.00	2.20
Earthquakes (incidence: avg. num. of events)	407	0.04	0.00	0.10	0.00	0.80
Storms (incidence: avg. num. of events)	407	0.14	0.00	0.41	0.00	3.40

C) Natural Disasters: Conditional on the occurrence of natural disasters

Variable	Obs	Mean	Median	Std. Dev.	Min	Max
All Disasters (intensity in logs)	354	-7.07	-6.76	2.67	-16.38	-2.74
Droughts (intensity in logs)	122	-6.48	-5.91	2.65	-16.43	-2.74
Floods (intensity in logs)	292	-8.03	-7.85	2.43	-16.38	-3.52
Earthquakes (intensity in logs)	122	-10.31	-9.91	3.16	-18.97	-3.04
Storms (intensity in logs)	181	-10.00	-9.65	3.56	-18.83	-3.53
All Disasters (incidence: avg. num. of events)	318	0.73	0.40	0.74	0.20	5.40
Droughts (incidence: avg. num. of events)	111	0.30	0.20	0.15	0.20	0.80
Floods (incidence: avg. num. of events)	252	0.49	0.40	0.40	0.20	2.20
Earthquakes (incidence: avg. num. of events)	71	0.25	0.20	0.11	0.20	0.80
Storms (incidence: avg. num. of events)	107	0.54	0.20	0.66	0.20	3.40

Appendix 3
Pair-Wise Correlations
Sample: 94 countries, 1961-2005 (5-year period observations)

variable	Growth GDP pc	Growth Agr.	Growth Industry	Growth Services	All Disast.	Drought	Flood	Earth-quake	Storm	Initial GDP	Initial Agr.	Initial Industry	Initial Service	Educ.	Fin. Depth	Gvmnt. Burden	Inflation	Trade Open.	Growth Terms of Trade
Growth GDP pc (%)	1.00																		
Growth Agricultural Sector (%)	0.33	1.00																	
Growth Industrial Sector (%)	0.83	0.14	1.00																
Growth Service Sector (%)	0.82	0.21	0.54	1.00															
All Disasters (intensity in logs)	-0.04	-0.01	-0.03	-0.02	1.00														
Droughts (intensity in logs)	-0.17	-0.15	-0.09	-0.09	0.47	1.00													
Floods (intensity in logs)	0.08	0.10	0.04	0.07	0.71	0.17	1.00												
Earthquakes (intensity in logs)	0.02	0.02	-0.01	0.02	0.33	0.07	0.24	1.00											
Storms (intensity in logs)	0.07	0.03	0.02	0.09	0.42	0.15	0.22	0.13	1.00										
Initial GDP pc (in logs)	0.21	0.10	0.03	0.19	-0.30	-0.38	-0.22	0.06	0.07	1.00									
Initial Agricultural Output pc (in logs)	0.21	0.05	0.11	0.19	-0.19	-0.34	-0.12	0.13	0.08	0.74	1.00								
Initial Industrial Output pc (in logs)	0.22	0.11	0.01	0.20	-0.28	-0.38	-0.19	0.09	0.07	0.98	0.71	1.00							
Initial Service Output pc (in logs)	0.20	0.10	0.03	0.17	-0.29	-0.38	-0.21	0.07	0.09	0.99	0.73	0.97	1.00						
Education	0.24	0.14	0.02	0.23	-0.12	-0.26	-0.02	0.11	0.21	0.79	0.60	0.81	0.78	1.00					
Financial Depth	0.26	0.06	0.10	0.24	-0.18	-0.23	-0.08	0.01	0.16	0.73	0.51	0.72	0.74	0.62	1.00				
Government Burden	-0.06	0.02	-0.13	-0.04	-0.27	-0.10	-0.28	-0.18	-0.18	0.40	0.22	0.39	0.38	0.32	0.38	1.00			
Inflation (log(100+%Growth rate of CPI))	-0.25	-0.06	-0.22	-0.19	0.16	0.13	0.17	0.15	-0.08	-0.08	-0.08	-0.05	-0.08	-0.01	-0.24	-0.20	1.00		
Trade Openness (in logs)	0.09	-0.03	0.06	0.05	-0.21	-0.09	-0.23	-0.23	-0.12	0.15	-0.02	0.17	0.15	0.22	0.24	0.33	-0.28	1.00	
Growth rate of Terms of Trade	0.15	0.13	0.05	0.19	-0.07	-0.03	-0.05	0.01	-0.03	0.11	0.07	0.13	0.09	0.08	0.06	0.05	-0.08	0.06	1.00