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Natural Disasters and Growth

Going beyond the Averages

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Abstract

There has been a steady increase in the occurrence of natural disasters. Yet their effect on economic growth remains unclear, with some studies reporting negative, and others indicating no, or even positive effects. These seemingly contradictory findings can be reconciled by exploring the effects of natural disasters on growth separately by disaster and economic sector. This is consistent with the insights from traditional models of economic growth, where production depends on total factor productivity, the provision of intermediate outputs, and the capital-labor ratio, as well as the existence of important intersector linkages. Applying a dynamic Generalized Method of Moments panel estimator to a 1961–2005 cross-country panel, three major insights emerge. First, disasters affect economic growth—but not always negatively, and differently across disasters and economic sectors. Second, although moderate disasters can have a positive growth effect in some sectors, severe disasters do not. Third, growth in developing countries is more sensitive to natural disasters—more sectors are affected and the magnitudes are non-trivial.

This paper—a product of the East Asia and Pacific Social Protection Unit and the Development Research Group—is part of a larger effort to study main sources of vulnerability. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at nloayza@worldbank.org, and jrigolini@worldbank.org.

Natural Disasters and Growth – Going beyond the Averages*

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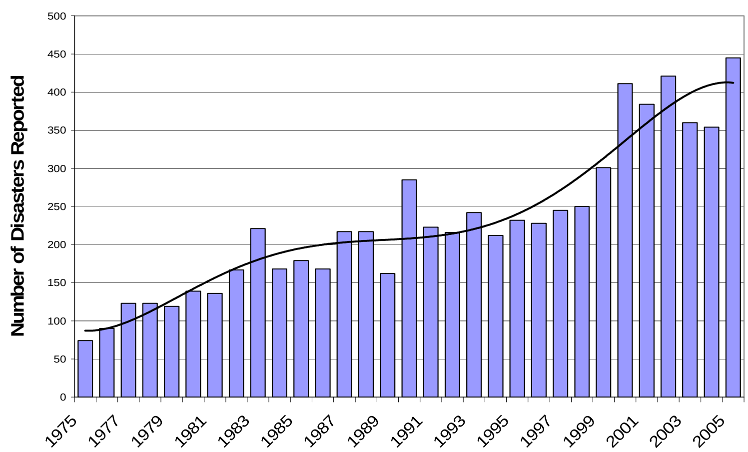
1. Introduction

Along with climate change has come an increase in the frequency of natural disasters across the world (Figure 1). This poses an important policy challenge. Natural disasters cause tremendous human suffering. Locally, they often also yield substantial physical and economic damages, which may temporarily, or even permanently, jeopardize a country's overall economic development. To help policymakers gauge the benefits from disaster risk mitigation and adaptation, it is important to better understand the economic costs associated with natural disasters.

Figure 1: Trends in Natural Disasters, 1975-2005



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

This has instigated an incipient literature on the empirical relationship between natural disasters and economic growth. As expected, several papers report a (substantive) negative effect of disasters on growth. For instance, using a cross-country sample for the period 1970-2002, Rasmussen (2004) 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.[1] Surprisingly however, many others find no

[1] Other studies that report a negative effect include Raddatz (2007), Heger, Julca, and Paddison (2008), and most recently, 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 drops in aggregate output.

effect, or at times even a positive one. Testing the empirical validity of the predictions of the Solow model, Caselli and Malhotra (2004) fail to find a negative relationship between natural disasters and medium-term aggregate economic growth. Similarly, Albala-Bertrand (1993, Ch. 4) find no or little effect.

Jaramillo (2007) observes that the sign and magnitude of the relationship depends on the type of disaster. Skidmore and Toya (2002) consider average per capita GDP growth over 1960-1990 and find that climatic disasters are associated with higher long-run economic growth, while geologic disasters are negatively associated with growth. In analyzing long-term empirical relationships, causality considerations are however substantially complicated, as countries may have adopted (less remunerative) technologies that are less sensitive to frequent disasters.

In sum, the current empirical literature remains inconclusive about the effects of natural disasters on growth. This should not necessarily come as a surprise, as theory suggests that 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. Consequently, the impact should also vary across sectors (and given their differing relative importance, also across countries): for instance, droughts are likely to significantly affect agriculture, but less so industry, while earthquakes are more likely to affect industry.

Drawing on insights on the dynamics of economic growth from the stylized Solow-Swan growth model, this paper seeks to reconcile the apparent contradictions in the current empirical literature through a more systematic recognition that different disasters affect economic sectors through different channels and that, as a result, their effects are likely to differ by the type of disaster, and also across sectors and countries, depending on their level of economic and institutional development[2].

[2] A related strand of literature demonstrates that the quality of a country's institutions, its democratic election processes, educational attainments, and openness reduce casualties and damages, and improve macroeconomic performance after the event (Kahn, 2003; Rasmussen, 2004; Toya and Skidmore, 2005; Skidmore and Toya, 2007; Noy, 2009).

The focus is on medium-term economic growth (5-year periods) thereby mitigating potential biases due to adaptation. The effects of the different natural disasters (i.e. droughts, floods, earthquakes and storms) are examined separately by economic sector (agriculture, industry, and services), each time controlling for a series of well known growth determinants. This way the paper broadens the scope of the existing literature, which has so far largely concentrated on aggregate measures of disasters and/or economic activity. This disaggregated approach also yields preliminary insights in the distributive effects of natural disasters. Through the use of the dynamic panel GMM estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998) great care is taken in addressing endogeneity issues related to the potential correlation between explanatory variables and unobserved country-specific factors.

To maintain consistency with other studies, the data on natural disasters are obtained from the Emergency Disasters Database (EM-DAT) database of the Centre for Research on the Epidemiology of Disasters (CRED). The share of the population affected by a specific type of disaster over a given period of time is taken as measure of natural disaster. This way, both the *frequency* and *intensity* of the disaster are reflected. The sample spans 94 developing and developed countries over the period 1961-2005.

The empirical results are consistent with the implications from the traditional Solow-Swan model. Three major conclusions emerge. First, different disasters affect growth in different economic sectors differently and the insights obtained with over-aggregation are misleading. Second, while moderate disasters can have a positive growth effect on certain sectors, severe disasters don't. Third, growth in developing countries is more sensitive to natural disasters—more sectors are affected, the magnitudes are non-trivial, and the poor are likely to be more affected by disasters (both positively and negatively).

To motivate the disaggregated approach and facilitate the interpretation of the empirical results Section 2 proceeds by reviewing the Solow-Swan growth model. Section 3 discusses the estimation methodology and section 4 elaborates on the growth determinants and the natural disaster data used. The empirical findings are discussed in section 5. Section 6 concludes.

2. Conceptual Framework

To better understand through which channels natural disasters may affect economic growth across sectors and to better motivate the disaggregated approach, the basic elements of the Solow-Swan growth model are revisited. This well-known model has been used extensively in the past for its conceptual strength and clarity in elucidating the process that occurs in the transition to a long-run steady state. This is reflected in the medium-term economic growth variables and forms the relevant time horizon for this paper.

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:

$$Y = AK^{\alpha} L^{\beta} M^{1-\alpha-\beta} \qquad (2.1)$$

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, $1\text{-}\alpha\text{-}\beta$ are the corresponding factor shares (all between 0 and 1). 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. It is assumed that only one factor of production, capital, is accumulated purposively. A constant fraction of output is saved and invested in capital formation. Labor follows an exogenously fixed growth rate. Productivity and intermediate inputs can change arbitrarily. Thus,

$$\Delta K = sY - \delta K \qquad (2.2)$$

$$\Delta L = nL \qquad (2.3)$$

Where, *s* is the saving rate, δ represents the capital depreciation rate, *n* is the population growth rate, and Δ indicates change. The neoclassical production function (eq. 2.1) and the accumulation equations (eqs. 2.2 and 2.3) fully describe the dynamic behavior of the economy. The purpose is now to characterize the growth rate of capital and output along the path to the "steady state", towards which the economy converges in the long run. In the steady state, defined as the situation of constant growth rates, 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 (all denoted with lower case letters).

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

$$Gr(k) = \frac{\Delta(k)}{k} = s\frac{y}{k} - (\delta + n) \qquad (2.4)$$

$$Gr(y) = \frac{\Delta(y)}{y} = \alpha Gr(k) \qquad (2.5)$$

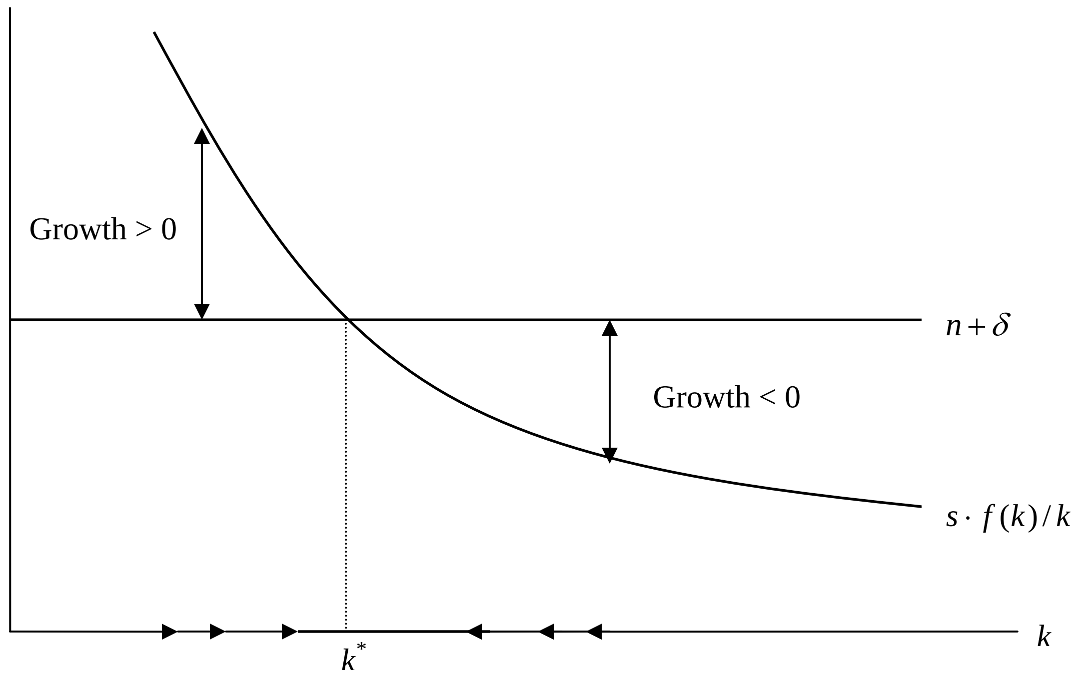
The growth rate of output goes hand-in-hand with the capital growth rate. Both depend crucially on the average product of capital (*y/k*), which is a decreasing function of capital per worker (*k*):

$$\frac{y}{k} = Am^{1-\alpha-\beta}k^{\alpha-1} \qquad (2.6)$$

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, they are both plotted as a 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



Three important channels emerge through which natural disasters could affect (transitional) growth[3]; they may affect 1) total factor productivity (A), (2) the supply of materials and intermediate inputs (m), and (3) the relative endowment of capital and labor (k). If a natural disaster 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. However, if a natural disaster destroys more capital than labor, thus reducing *k*, growth is expected to increase (with respect to normal, steady-state conditions).

[3] The model can also inform regarding the growth effects of other variables, such as factor intensities, population growth, and capital depreciation rates, but these variables seem less relevant in explaining the effects of natural disasters.

Building on these basic insights, droughts are expected to have a negative effect on agricultural growth because they entail a drastic reduction of water, a vital input in agricultural production. These negative effects likely extend to industrial growth through two mechanisms both 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 the (agro-processing) industry. The second is by hampering electricity generation, particularly where hydropower is a major source of electricity. 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 induce a disruption of farming, urban activities, and transportation in the areas most affected by them, negatively affecting overall productivity. When floods are severe and long lasting, the emergence of water borne diseases may further exacerbate this decline in TFP. However, when floods are localized and moderate, they could also be associated with higher growth through a variety of mechanisms. In agriculture, floods may raise growth by increasing both the supply of water for future irrigation and land productivity. They may also reflect more abundant rainfall nationwide. In 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).

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 may 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 destroy the seedlings and plants (or the harvest) on the fields, which are intermediate inputs in the final product. Storms also destroy considerable amounts of physical capital important in industrial production, devastating capital relatively more than incapacitating workers. As the capital-worker ratio drops, this mechanism would suggest a growth expansion in industry.

3. Estimation Methodology

The point of departure is a standard growth regression equation designed for estimation using (cross-country, time-series) panel data:

$$y_{i,t} - y_{i,t-1} = \beta_0 y_{i,t-1} + \beta_1 CV_{i,t} + \beta_2 ND_{i,t} + \mu_t + \eta_i + \varepsilon_{i,t} \qquad (3.1)$$

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 growth 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. This poses a challenge for estimation given the presence of unobserved period- and country-specific effects. While the 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 when a regression is dynamic in nature.

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[4]—their effects would be incorrectly estimated if the endogeneity of the remaining variables in the model is ignored.

[4] The measure of external shocks (i.e. growth rate of terms of trade—see below) is also considered exogenous.

Following Levine, Loayza, Beck (2000) and Dollar and Kraay (2004), the generalized method of moments (GMM) estimators developed for dynamic models of panel data introduced by Holtz-Eakin, Newey, and Rosen (1988), Arellano and Bond (1991), and Arellano and Bover (1995) are used to control for country-specific effects and joint endogeneity in this dynamic panel growth regression model. These estimators are based, first, on differencing regressions to control for (time invariant) 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, equation 3.1 can be rewritten as:

$$y_{i,t} = \alpha\, y_{i,t-1} + \beta X_{i,t} + \eta_i + \varepsilon_{i,t} \qquad (3.2)$$

with $X_{i,t}$ including $CV_{i,t}$ and $ND_{i,t}$. To eliminate the country-specific effect, take first differences of equation 3.2:

$$y_{i,t} - y_{i,t-1} = \alpha\left(y_{i,t-1} - y_{i,t-2}\right) + \beta'\left(X_{i,t} - X_{i,t-1}\right) + \left(\varepsilon_{i,t} - \varepsilon_{i,t-1}\right) \qquad (3.3)$$

Instruments are 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 and 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) are unpredictable given past values of the explanatory variables. The method allows, 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), the following moment conditions emerge:

$$E\left[y_{i,t-s}\cdot\left(\varepsilon_{i,t}-\varepsilon_{i,t-1}\right)\right] = 0 \quad for\ s \geq 2; t = 3,\ldots,T \qquad (3.4)$$

$$E\left[X_{i,t-s}\cdot\left(\varepsilon_{i,t}-\varepsilon_{i,t-1}\right)\right] = 0 \quad for\ s \geq 2; t = 3,\ldots,T \qquad (3.5)$$

The GMM estimator based on the conditions in 3.4 and 3.5 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 asymptotic and small-sample performance of the difference estimator toward inefficient and biased coefficient estimates, respectively.[5]

To reduce the potential biases and imprecision associated with the difference estimator, the estimator developed in Arellano and Bover (1995) and Blundell and Bond (1998) is used. It combines the regression equation in differences and the regression equation in levels into one system. For the equation in differences, the instruments are those presented above (i.e. lagged levels of the explanatory variables). For the equation in levels (equation 3.2), the instruments are given by the lagged differences of the explanatory variables.[6] 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,

$$\begin{aligned} &E[y_{i,t+p}\cdot\eta_i] = E[y_{i,t+q}\cdot\eta_i] \quad and \\ &E[X_{i,t+p}\cdot\eta_i] = E[X_{i,t+q}\cdot\eta_i] \quad for\ all\ p\ and\ q \end{aligned} \qquad (3.6)$$

[5] 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).

[6] 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*.

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:

$$E[(y_{i,t-1} - y_{i,t-2}) \cdot (\eta_i + \varepsilon_{i,t})] = 0 \qquad (3.7)$$

$$E[(X_{i,t-1} - X_{i,t-2}) \cdot (\eta_i + \varepsilon_{i,t})] = 0 \qquad (3.8)$$

The moment conditions presented in equations 3.4, 3.5, 3.7, and 3.8 are thus used in the 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:

$$\hat{\theta} = (\overline{X}' Z \hat{\Omega}^{-1} Z' \overline{X})^{-1} \overline{X}' Z \hat{\Omega}^{-1} Z' \overline{y} \qquad (3.9)$$

$$AVAR(\hat{\theta}) = (\overline{X}' Z \hat{\Omega}^{-1} Z' \overline{X})^{-1} \qquad (3.10)$$

where θ is the vector of parameters of interest (α, β); $\bar{\mathbf{y}}$ 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.[7]

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.[8] (). Two steps are taken to limit the moment conditions. First, only five *appropriate lags* of each endogenous explanatory

[7] 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).

[8] Roodman (2007) provides a detailed discussion of over-fitting bias in the context of panel-data GMM estimation.

variable are used. Second, the procedure uses 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 conventional, but more restrictive, assumption that each of the period moment conditions be equal to zero.[9] At the cost of reduced efficiency, these two steps decrease over-fitting bias in the presence of small samples by accommodating cases where 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.

The consistency of the GMM estimators depends on whether lagged values of the explanatory variables are valid instruments in the growth regression. Two specification tests are run to verify this. 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 (3.2)) is serially correlated. The model is supported when the null hypothesis is not rejected.[10]

4. Growth Determinants and Natural Disasters

To perform the estimations, a pooled cross-country and time-series data panel is compiled covering 94 developing and developed countries over the period 1961-2005. The data are 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. Appendices 1 and 2 provide summary statistics of the variables both for the pooled sample and developing countries only. Appendix 3 presents a matrix

[9] The "collapse" option of xtabond2 for STATA is used to do so.

[10] In the system specification, it is in fact tested 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.

of pair-wise correlations of these variables. All data except the data on natural disasters are from World Bank's World Development Indicators, WDI, (2007).

Four dependent variables are considered. For comparison with other studies, regressions are first run using the growth rate of real per capita Gross Domestic Product (GDP) as dependent variable. Subsequently 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 are used. All of them are measured as the five-year average of the log differences of per capita output (in 2000 US dollars). Per capita output is obtained by dividing the value added of each sector by the total population.

From Appendix 1 it emerges that the growth performance of different sectors has been diverse: the service sector has grown the fastest (1.83 percent per year), followed by industry (1.73%), and agriculture (0.33%). The disparity across sectoral growth performance would be consistent with the view that natural disasters have diverse effects on the different sectors of the economy.

Three groups of growth determinants are considered: 1) variables that measure transitional convergence, structural and stabilization policies, and institutions; 2) variables that proxy the role of external conditions that may affect the growth performance across countries; and 3) natural disasters, which form the subject matter of the paper. To control for transitional convergence, in each regression the corresponding initial value of output per capita (in logs) for the five-year period is used. This is crucial to test whether the initial position of the economy is important for its subsequent growth, all things equal. A negative sign would suggest that poor economies tend to catch up and grow faster than rich economies.

Similar to the cross-country growth specifications by Levine, Loayza, Beck (2000) and Dollar and Kraay (2004) the areas of education, financial development, monetary and fiscal policy, and trade openness are considered to capture the role of structural and stabilization policies, and institutions. 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. The government burden is measured as the ratio of general government consumption to GDP. Openness to international trade is proxied by the volume of trade (exports and imports) over GDP.

The consumer price index (CPI) inflation rate is a proxy for macroeconomic stabilization, with high inflation being associated with bad macroeconomic policies. Financial depth, the government consumption ratio, trade openness, and the inflation rate[11] enter the growth regressions as the log of the average for the corresponding five-year period. All these control variables 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, one of the main reasons for using the GMM procedure outlined above.[12]

With regard to the 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 are 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.

Finally, to maintain consistency with the literature, data for natural disasters were obtained from the Emergency Disasters Database (EM-DAT). 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.

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

[12] Specifically, regarding the difference regression corresponding to the periods *t* and *t-1*, the following instruments are used: 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*.

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). 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 be a good indicator of the gravity of a disaster, it has important drawbacks both from a measurement and estimation perspective. First, CRED admits that there is no standard procedure to determine economic impact. Second, economic losses are reported for only one third of the disasters, with the proportion differing substantially across the types of disasters.[13] Third, such a measure would make the exogeneity assumption tenuous, as the amount of damage may be correlated with the growth during the period under consideration.

[13] For example, economic 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.

Chart 1: Average costs of natural disasters per reported event (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.

From Chart 1 it becomes clear that each type of disaster leaves a very different impression on the economy and its population. For example, the number of people affected by earthquakes (about 142,000 per event) pales in comparison with the number of people affected by droughts (almost 3.6 million per reported event). However, the picture reverses when looking at the estimated economic damage. Earthquakes are by far the most devastating of all the disaster types considered (almost one billion dollar estimated damage per event) compared with US$ 321,000 per drought[14]. The contrast is even sharper when expressed in terms of damage per person affected (dK/dL) which is 75 times larger for earthquakes (estimated at $3,706 per person affected) than for droughts (estimated at $49 per person affected). In light of the Solow-Swan model, these figures suggest that it is quite plausible to expect a positive effect of earthquakes (and also storms) on (industrial) growth (which happens if $\frac{K}{L} < \left.\frac{dK}{dL}\right|_{earthquake}$) and a negative effect of droughts on (agricultural) growth (which happens if $\left.\frac{dK}{dL}\right|_{drought} < \frac{K}{L}$).[15]

Four types of disasters will be considered: droughts, floods, storms and earthquakes. In particular, for each of these disasters the log of the sum of the total number of people affected in each event over the five -year period, divided by the total

[14] This is likely even an overestimate as economic damage has only been reported for 25 percent of the droughts, arguably the more damaging ones.

[15] According to the Solow-Swan model, growth is negative if $d(\frac{K}{L}) = \frac{LdK - KdL}{L^2} > 0$ which happens if $\frac{dK}{dL} < \frac{K}{L}$ (note that dL<0), and vice versa, growth is positive if $\frac{K}{L} < \frac{dK}{dL}$.

population, is taken as measure of disaster, or formally, $ND_{i,t} = Log\left(\sum_j \frac{Total\ Affected_{i,t,j}}{Population_{i,t}}\right)$ where j indexes the number of events that took place in country *i* during (five-year) period *t*. By considering the sum of the number of people affected per event, the measure explicitly accounts for both the *frequency* and the *intensity* of the shock, contrary to many of the measures used in the literature. To enable comparison across countries, further normalization by the total population is undertaken to correct for differences in population size.

Inspection of the distribution of the weighted sum of natural disasters shows that it is positively skewed. Consequently the log is taken to avoid that the empirical results are driven by extreme values. Not to lose too many observations (observations for which no event has been reported result in an undefined value of the log of the disaster measure), these observations are assigned a value of to -20, which is just below the lowest observation for which an event was reported.[16] Finally, natural disasters such as storms and floods often occur in tandem—Appendix 3 indicates a correlation of 0.22 between floods and storms, and a correlation of 0.24 between floods and earthquakes. To isolate the effects of each natural disaster, the four natural disaster measures are included simultaneously in the regressions.

5. Empirical Results

Table 1 presents the basic estimation results using the full sample. The results in the first two columns pertain to the growth rate of GDP per capita, while those in the last three columns pertain to per capita valued added output growth rates in agriculture, industry, and services, respectively. The same set of set of explanatory variables is included as control variables across all regressions, except that initial output corresponds to the initial valued-added of the respective sector. The Hansen specification and serial-correlation tests indicate that the null hypothesis of correct specification cannot be

[16] This number has been (arbitrarily) chosen to be low enough not to affect the distribution of the natural disaster indicator.

rejected, lending support to the findings. This also holds across the different follow up regressions presented in Tables 2-5.

The empirical results corresponding to the standard growth determinants (see Table 1, columns 1 and 2) are broadly consistent with the literature. Suggesting a beneficial impact on economic growth, the proxies of educational investment, depth of financial intermediation, and trade openness have positive coefficients, though they are 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. More favorable terms of trade (representing external shocks) tend to 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 a 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). It is conjectured that the important changes that have occurred in the most recent decade regarding the roles of macroeconomic volatility and public infrastructure may explain why some of the results appear to differ from the previous literature (see footnote for a more elaborate explanation).[17] Most importantly, the results regarding the growth effects of natural

[17] Using data up to 1995 or 2000 (as most previous studies have done), secondary school enrollment and private credit ratio do carry positive and statistically significant coefficients, and 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), it was 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, most importantly, the results concerning the growth effects of natural disasters are robust to the inclusion of these additional controls. For this reason, the simpler specification is maintained to keep sample size (country coverage and time span) as large as possible.

disasters are robust to these alternative specifications of the traditional growth control variables.

Turning to the growth effects of natural disasters, natural disasters are found not to affect GDP growth when using a combined index of natural disasters—the sign of the coefficient is positive but statistically insignificant (Col. 1). The lack of a significant effect reflects well the theoretical ambiguity and the diverging empirical findings reported in the literature to date. Indeed, when disaggregating by type of natural disaster (col 2), coefficients of contrasting signs emerge (negative for droughts and earthquakes, and positive for floods and storms). However, except for floods, they fail to be statistically significant. To better understand how the different disaster affect growth (and also poverty), further disaggregation of growth by economic activity is warranted.

In contrast to the weak effects on overall GDP growth, three types of natural disasters appear 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.

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

The effects on agricultural growth are given in Col. 3. As in the full sample, droughts and floods have the largest but opposite effects. . The impact of droughts is clearly negative on agricultural growth while that of floods is positive, though somewhat smaller than that for the sample as a whole. 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 plant destruction borne by storms can only harm agriculture.

Although the empirical analysis does not allow discerning the mechanisms through which the growth effects of natural disasters are realized as such, two channels identified in the Solow-Swan model seem especially relevant in interpreting the contrasting effects of natural disasters on agricultural growth. The first channel through which the natural disasters affect agricultural growth relates to the provision of raw materials and intermediate inputs (m): if an event decreases the availability of this resource (such as water, seedlings or unharvested plants/fruits on the fields for farming), it is likely to have a negative growth effect, and *vice versa.* The second key is related to total factor productivity (A): 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.

Given the critical importance of water for agriculture, the strong negative effect of droughts on agricultural growth does not come as a surprise and is consistent with the evidence from growth studies based on micro-household data (Dercon, 2004; Christiaensen and Subbarao, 2005). Similarly, storms can have devastating effects on harvests by destroying seedlings and/or unharvested products on the field as well as irrigation infrastructure. While storms cause substantial economic damage (especially infrastructure and buildings), their effect on agricultural capital (which consists largely of tools and machinery) is likely more muted, thereby leaving the capital/labor largely unaffected (or decreasing it if anything).

Within this perspective, the positive effect of floods on growth comes a bit as a surprise. Too much water is clearly damaging. Yet, when floods are localized, and if they are also associated with plentiful supply of water nationwide which would positively affect agriculture including through the collection of irrigation water, the latter effect may well outweigh the former, resulting in a positive overall effect of floods on agricultural growth, or no effect or a small negative one if floods are more widespread and severe.[18] Given much larger frequency of reported flood events (30 percent) compared to drought

[18] Both Pooled OLS and Fixed-Effects regressions (whose results are available upon request) confirm the positive and significant association between annual rainfall (relative to the corresponding country average) and the flood intensity measure used in the paper.

events (only 8 percent) (Appendix 2B), it is indeed quite plausible that the reported floods are often moderate floods and also associated with abundant rainfall nationwide.

The impacts on the growth of industrial output are evaluated in Col. 4. Unlike for the full sample, droughts and floods have again significant and opposite effects on industrial growth. Although the effects are analogous to the case of agriculture, their mechanisms are likely different. First, the provision of water (or lack thereof) is often also a crucial input in industrial growth but for a different reason: it often determines the electricity generating capacity of the country. A second mechanism through which droughts and floods affect industrial growth relates to the inter-sector linkages between agriculture and industry. These (forward and backward) linkage effects are typically stronger from agriculture to nonagriculture and they are also stronger in agriculture based developing than in industry and service based developed economies, consistent with the observed absence of an effect of droughts and floods on industrial growth when looking at the full sample.

In developing countries agricultural sectors make up a larger share of the economy and industrial production is often more dependent on agro-processing and thus inputs from agriculture (for example, cotton for textiles and grapes for wines). Similarly, robust agricultural growth fosters the demand for intermediate inputs (such as tools and fertilizer) produced by the industry (so-called forward linkages). Yet, backward linkages, which happen through the increased/decreased demand for (income elastic) locally produced goods and services following a widely shared increase/decline in income, are typically the more important channel through which agricultural growth affects growth outside agriculture (Tiffin and Irz, 2006; Haggblade, Hazell, and Dorosh, 2007). The importance of hydropower and the existence of intersectoral linkages, explains why natural disasters that improve or harm agricultural growth are likely to operate in the same direction for industrial growth, at least in developing countries.

Perhaps surprisingly, both earthquakes and storms seem to lead to higher industrial growth. 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). Particularly in developing countries the damage to infrastructure inflicted by earthquakes and storms can be substantial due to lack of preparation. As discussed above, if an event produces a sharp reduction in the capital-labor ratio, it is likely to be followed by higher growth, and *vice versa*. The industrial sector further stands to receive a growth boost from the demand for capital reconstruction that follows earthquakes and storms in areas including housing, infrastructure, and manufacturing.

Lastly, the effects on the growth of service output are assessed (Col. 5). 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 have strong links with both agriculture and industry, especially in developing countries, as suggested by the larger coefficient for the sample of developing countries than for the full sample. Therefore, the positive impact of floods may be partly the result of its beneficial impact on agricultural and industrial outputs.

Another mechanism through which service growth 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. This may also 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. Finally, unlike industry, services tend to be less intensive in physical capital, and more intensive in telecommunication and infrastructure. As a result, it is less likely to receive growth support from a decline in its capital/labor ratio, and more likely to suffer from a decline in its total factor productivity following an earthquake or a storm.

Two further robustness tests were conducted using the sample of developing countries only. The first exercise concerns the estimation methodology and re-estimates the growth regressions using a standard least-squares (LS) methodology, rather than the more complex GMM estimator (see Table 3). 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 checks the robustness of the findings against the disaster measurement method. In particular, a count (incidence) variable commonly used in the literature (e.g. IMF, 2003; Becker and Mauro, 2006) is taken to measure natural disasters, rather than the continuous (intensity) variable used in the main specification. The count variable used is the average number of events in the corresponding country and five-year window. A natural disaster qualifies as an "event" if the number of people affected times 0.3 plus the number of casualties is greater than 0.01% of the population. [19]

The results (Table 4) 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 earthquakes and storms, the count or incidence variable fails to identify a significant effect on industrial growth. As will be seen below, this reflects in a sense, the tension of the industrial growth effects of these two variables, i.e. 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.

Are the effects of natural disasters linear?

So far, the analysis has focused on the average effect of a disaster. Yet, their intensity differs substantially, and there is a priori no reason to believe that their effects should be linear. The simple specification used so far may be a good representation of the effects of the majority of natural disasters, but it may also distort the true effects of the most severe ones. To examine this issue, the corresponding natural disaster measure is interacted 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. One interaction term per natural

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

disaster is then added to the basic regression equation, which is estimated with the same methodology as before (Table 5, where the interaction terms are called "Droughts Severe", "Floods Severe", etc.). The coefficients on the simple disaster measures ("Droughts", "Floods", etc.) denote the effects of moderate disasters, and the sum of the coefficients of the simple measure and the interaction term indicate the effects of severe disasters.

The results are revealing. Severe events intensify the negative effect of droughts on agricultural growth by a factor of two. In the case of floods, the positive effect estimated above seems to apply only to moderate events. In fact, 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 as the negative coefficient on the interaction term). Something similar happens with earthquakes and storms in the case of industrial growth. Both of them carried significantly positive coefficients in the basic specification. Now, the simple measures of earthquakes and storms retain those positive coefficients, but their corresponding interaction terms are 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. Overall, any potential positive effects on growth from natural disasters appear to disappear when natural disasters are extreme.

Is the effect quantitatively important?

Finally, the question remains whether the effect of the natural disasters also matters quantitatively, both in terms of their effects on growth and their likely effects on the distribution of that growth. To explore 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 2C.

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%*

In developing countries, 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 per year or 3 percentage points over a period of 5 years.[20] This compares with an average annual per capita growth in developing countries of 1.35 percent during the 1961-2005 period. 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, which given the larger share of agriculture in developing economies results in a zero net effect on overall growth.

Clearly, the negative effects of droughts on aggregate and sectoral growth in developing countries can be substantial, while reports of moderate floods would in effect correspond to positive aggregate growth experiences (related to nationwide abundant rainfall). Moreover, given that the poverty to GDP elasticity is much larger for growth originating in agriculture (Christiaensen and Demery, 2007; Ligon and Sadoulet, 2007) and labor intensive (industrial) sectors (Loayza and Raddatz, 2006), the poor stand to be

[20] Note: $y_{\text{median drought}} - y_{\text{no drought}}$ = -0.076*(-5.90 – (-20))= - 1.071

especially affected by natural disasters. In particular, Christiaensen and Demery (2007) estimate that 1 percentage point of (aggregate) GDP growth originating in agriculture is on average about twice as effective in reducing 1$-day poverty than 1 percentage point of GDP growth originating outside agriculture, with the difference in poverty reducing performance further increasing for less developed countries. As a result, the poor are likely to suffer disproportionately from droughts and storms, with their effects often felt many years thereafter, especially in case of severe droughts as in the 1984-85 Ethiopian famine (Dercon, 2004). On the other hand, nationwide, the poor may also be benefitting disproportionately when *moderate* floods are reported. To the extent that earthquakes and storms result in labor intensive reconstruction efforts, the poorer segments of the population could benefit as well. While informative, these preliminary insights regarding the distributional effects of natural disasters must be tested further against the poverty data, an important agenda for future research.

6. Concluding Remarks

Over the past couple of decades there has been a steady increase in the occurrence of natural disasters. This has instigated an interest in a better understanding of their effects on economic growth to inform policymakers of the benefits from disaster risk reduction and mitigation. The literature has so far remained inconclusive regarding the effects of natural disasters on growth. While several studies point to negative effects, others also report no effects or even positive effects of natural disasters on growth. Guided by insights from the traditional Solow-Swan growth model on the channels through which natural disasters may affect economic growth as well as the extensive literature on intersectoral linkages, this study went beyond the averages and explored the effects of natural disasters separately by disaster and economic sector in both developed and developing countries.

Three major insights emerged. First, disasters do affect economic growth – but not always negatively, and the effects differ substantially across disaster and economic sector, confirming the gains from a richer disaggregated analysis that looks beyond the averages. In particular, droughts are found to have a negative impact that is mainly observed on agricultural growth (and also industry in developing countries). Storms also lower agricultural growth, but in developing countries, they also increase industrial growth. Similarly, earthquakes are found to bring about higher industrial growth in developing countries. In contrast, moderate (though not severe) floods have on average a positive effect on agricultural growth, and even other sectors of the economy, likely because localized flooding reflects broader nationwide abundance of rainfall.

Second, further underscoring the importance of disaggregation, while moderate disasters can have a positive growth effect on certain sectors, severe disasters don't. The impact of the 10 percent largest disasters in any category is found to be either insignificant or negative. When a natural disaster is severe enough, all the mechanisms that would potentially make it positive for growth are likely weakened. This also holds for severe floods and clarifies the seemingly surprising positive effect of floods. To the extent that reported floods are localized and reflective of more abundant national rainfall patterns, they would foster agriculture. Otherwise, the disruptions and damage caused by floods would cancel or outweigh the positive effects derived from plentiful rainfall.

Third, growth in developing countries is more sensitive to natural disasters—more sectors are affected and the magnitudes are non-trivial. This is consistent with the more marked presence of inter-sectoral linkages, following the more prominent role that agriculture plays in developing countries. Simulations indicate that a typical (median) drought reduces the annual per capita agricultural and industrial growth rate in developing countries by about 1 percentage point, together resulting in a reduction of annual per capital overall growth of 0.6 percentage points. A typical earthquake and storm increase industrial growth by about 1 percentage point each, consistent with the growth pattern predicted by theory when the capital labor ratio declines substantially, and further supported by the need for reconstruction following earthquakes and storms. As the elasticity of poverty to growth generated in agriculture and labor intensive sectors (such as construction and manufacturing) is substantially higher than the elasticity of poverty to growth generated outside agriculture in more capital intensive sectors, these results also suggest that the poor stand to be disproportionately affected.

Clearly, the time path of recovery and adjustment varies by shock and sector – and will likely be further affected by country-dependant institutional factors. Our findings also suggest the presence of linkages transmitting shocks across sectors (in particular in developing countries), but cross-country regressions are not able to isolate these transmission mechanisms. While the cross-country analysis presented here provides estimates of the loss (or gains) of economic growth associated with different natural disasters, country case-studies will be needed to develop detailed policy actions that would ease recovery and adjustment. Such analysis would also help shed further light on the distributional impact of disasters (both in terms of geographic impact, and impact across income categories) and thus the optimal targeting of natural disaster related interventions.

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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
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 4
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.

Table 5
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.

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