Disastrous Estimation: Do Catastrophes Have Persistant Effects on Growth?

(DRAFT: Please do not cite)

Christian Jaramillo (chjarami@uniandes.edu.co)

Assistant Professor of Economics, Universidad de los Andes, Bogotá

James R. Hines, Jr. (jrhines@umich.edu)

Associate Professor of Economics, University of Michigan at Ann Arbor

Abstract

Large natural disasters (LNDs) are ubiquitous phenomena with potentially large impacts on the infrastructure and population of countries, and on their economic activity in general. Using a structural model, we examine their economic impact on a wide panel of countries with data ranging from 1960 to 1998, partitioning the sample in two ways: small, medium and large population; and low, medium and high income.

The results suggest a heterogeneous pattern of impact of LNDs, depending on the per capita income and the population of the countries studied. In general, LNDs have small long-term and somewhat larger short-term effects on GDP growth; surprisingly, these effects are positive. The (positive) long-term effects act through the fraction of the population affected by the disaster, and they are especially important in countries with a large population. The short-term effects, on the other hand, act through a variety of channels: the fraction of people killed has a negative coefficient for small countries and a positive one for large ones; the amount of damages has a negative impact on growth for high-income countries and a positive one for medium-income ones; and the fraction of the population affected has a positive impact for high-income countries. These results are robust to alternative empirical specifications.

0. Introduction

Large natural disasters (LNDs for short) are ubiquitous events with potentially large impacts on the infrastructure and population of countries, and on their economic activity in general. However, except for individual events, the exact manner and import of this impact has not been well studied in the economic literature. In this paper, we examine the issue using panel data on recorded disaster events and macroeconomic variables.

Macroeconomic theory allows for several types of possible impacts of a LND. First, a LND destroys capital stock and labor. Insofar as this raises the rates of return to these factors, one should expect increased investment activity in the economy. This should be an effect of limited duration, and it should concern the level of GDP rather than its long-term growth path. A priori, this effect should be negative on the level of GDP. Nevertheless, because capital losses due to LNDs do not show up in national accounting but the surge in investment does, one may expect to find a positive net effect in the recorded data. In this respect, the existing literature is based on individual cases, and it argues that substitution in production limits the size of the negative effects.

In view of the loss accounting issue, a country's reaction to LNDs would perhaps be best judged on the basis of its investment activity, both in absolute levels and as a share of its GDP. This investment must be financed; either through current consumption cuts (private or governmental) in the case of a credit-constrained economy, or through borrowing (which entails a smaller but permanent decrease in consumption) and foreign investment. Thus, the country will substitute away from consumption, and this level effect will be smaller but more persistent the better access to international credit the country's economy has. We examine these level effects. In this context, one must control for foreign aid flows as a type of easing of existing credit constraints.

A second and potentially more important avenue for LND impact has to do with per capita GDP growth rather than its level. One could think of a number of scenarios, all involving market imperfections, where the post-LND growth rates are different from the pre-disaster ones. Unfortunately, the literature on GDP growth suggests that one must take some subjective stand on what one views as the long run to address this question, since a definitive empirical answer cannot be obtained from a finite time series of data. In this paper, we test for the effect of a disaster on current and next-year GDP growth, under the assumption that the coefficients on the disaster measures identify short-run effects. We also test for cumulative effects of disasters, which we interpret as long-run effects. We compare our results to previous research that suggests small to non-existing long-term effects.

A third question of interest concerns the composition of the investment that may occur, in particular the role of foreign direct investment (FDI). There's no unambiguous prediction regarding this matter, as it is unclear how the aftermath of a LND or the attention a country may get from it will affect –if at all– the determinants of the choice of FDI versus other types of capital flow. In this paper, we look at the effects of several disaster measures on the share of investment that takes the form of FDI.

We use panel data from different sources, including disaster measures, national accounts, FDI and foreign aid data for a wide sample of countries. Our data on disasters comes from EM-DAT: The OFDA/CRED International Disaster Database. It contains records of estimated damages, people killed, injured, homeless and affected for occurrences of natural, technological and political disasters, as well as dates of occurrence and the countries affected. The data are a compilation from different sources, among them the UN, OFDA, reinsurance firms and several NGOs and humanitarian institutions, and it includes events starting 1900 through the present.

The time series data on macroeconomic variables comes from several sources. Whenever available, we use the Penn World Tables 6.0. These contain data from 1950-1998, albeit most countries are reported starting 1960. This period seems to coincide with the more reliable data in the EM-DAT database.

For foreign direct investment, we use self-reported data from the OECD member countries. This data includes bilateral FDI flows to and from OECD countries and estimated inward and outward positions, 1980-1998. While no data is included that involve investment between two non-OECD countries, it is a well-established fact that concentrating on OECD countries captures the majority of FDI.

Additionally, we control for foreign aid related capital flows using OECD source Foreign Aid data. This data is in a bilateral format similar to the FDI data, and it reports flows from OECD and a number of Arab countries amounting to the majority of foreign aid between 1960 and 1998.

In the next section we describe our data in detail, emphasizing various aspects that require special attention. In section 3 we state empirical specifications for the analysis of our data. Section 4 presents our results and section 5 concludes.

1. Data

The data for our yearly panel of countries comes from several sources. We use country macroeconomic time series from the Penn World Tables 6.0 (PWT).[1]

International data on official foreign aid is self-reported by the members of Development Assistance Commitee (DAC) of the Organisation for Economic Cooperation and Development (OECD). It is available in the DAC/GEO database of Geographic Distribution of Financial Flows to Aid Recipients, 1960-1998, included in the OECD publication International Development Statistics (IDS), edition 2000. Foreign direct investment data is also from an OECD publication: International Direct Investment Statistics Yearbook (IDISY), edition 1999.

Our data on disaster events comes from EM-DAT: The OFDA-CRED International Disaster Database.[2]

In the remainder of this section we describe the regression variables obtained or constructed from each data source. With the exception of EM-DAT, our sources are standard and of common use in the literature. Therefore, we concentrate our comments on the EM-DAT data.

1.1 Penn World Tables 6.0

Most of our country time series data comes from the PWT. We use the following notation:[3]

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[1] The PWT can be found at the Center for International Comparisons, University of Pennsylvania.http://pwt.econ.upenn.edu/

[2] This data can be found at \EM-DAT: The OFDA/CRED International Disaster Database." Université Catholique de Louvain- Brussels - Belgium. http://www.cred.be/emdat.

y: Real per-capita GDP (Chain Index) in constant dollars. Throughout this paper, we use this as the basic summary measure of a country's economic performance.
dln_ypc: Percentage per-capita GDP growth, based on the above measure of GDP. It is computed as the change in the natural logarithm of *y*.
i, c, g: Investment, private consumption and government consumption shares of GDP respectively, given as percentages.

open: Index of openness, calculated as (X+IM)/GDP. We control for openness prior to the occurrence of a disaster using lagged values of this indicator.

We also use the PWT as a source of yearly country population data.

1.2 DAC/GEO

The DAC/GEO database keeps separate records for two types of aid recipients: Developing Countries (part I, covers 1960-1998) and Countries in Transition (part II, 1990-1998). We do not distinguish between these two groups, so our measure of foreign aid accounts for aid received under any of these labels:

aid: This is the net total foreign official aid flow to a recipient country in a given year, expressed as a fraction of its current GDP.

As net total foreign official aid flow, we use the DAC/GEO time series on Total Official Net flows of aid by recipient. This data is the sum of Official Development Assistance (ODA) and Other Official Flows (OOF) for part I countries, and of

[3] As a general notation rule, lags of variables are denoted by the pre¯x [illegible] where [illegible] stands for the number of time periods (i.e. years) lagged. For instance, if [illegible] stands for the current year, and for a given observation [illegible] = 1972, then [illegible]2[illegible] = 1970 for that same observation.

Official Assistance (OA) and Other Official Flows (OOF) for part II countries. It represents the total net disbursements by the official sector at large to the recipient country in either case.

While the flows recorded in the DAC/GEO data are only those of OECD origin, they account for most of the international flows of official foreign aid in any given year from 1960-1998 for part I and 1990-1998 for part II. The countries of origin covered are the DAC Donor Countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

1.3 IDISY

The International Direct Investment Statistics records all bilateral direct investment flows that involve an OECD member. It spans the years 1980-1998. It does not include flows between non-OECD countries.

We use data on outbound and inbound direct investment flows, converted to current dollar values at year-average exchange rates and then converted to constant US dollars. We consider the following dependent variables:

sharefdi: This is the net foreign direct investment flowing into the country, expressed as a fraction of current total country GDP.
sharefdi_i: Gross inflow of FDI, given as a fraction of current country GDP.
sharefdi_o: Gross outflow of FDI, given as a fraction of current country GDP.

1.4 EM-DAT

EM-DAT records the occurence and effects of mass disasters in the world since 1900. It compiles data from several sources, and its main objective is to assist in humanitarian action in response and prevention of mass disasters. It has entries for approximately 12,800 events, and among its sources are UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies.

The disaster-event entries in EM-DAT are individual ocurrences in chronological order and include date, type of disaster, several measures of affected population, damage estimates and notes about the main sources of data for any particular event. A typical event entry is depicted in Table A1 in appendix A, along with more detailed information on each of the variables.

EM-DAT groups disasters in three broad categories (natural, technological and conflict) with several types, as listed in Table 1 below. In order for an event to qualify for the registry, it must satisfy at least one of several minimum requirements concerning the number of victims and the damage amounts.[4]

NATURAL	TECHNOLOGICAL	CONFLICT
Drought	Industrial accident	Civil disturbance
Earthquake (460)	Miscellaneous accident	Civil strife
Epidemic	Transport accident	Displaced
Extreme temperature (141)		International conflict
Famine		
Insect infestation		
Flood (1285)		
Slide (241)		
Volcano (115)		
Wave/surge (20)		
Wild fire (160)		
Wind storm (1271)		

[4] See appendix A.

TABLE 1: Disaster types

These are the types of disaster for which events are recorded in EM-DAT. Those shaded are the ones used, and the figure in parenthesis is the number of events reported in the period 1960-1998 for the countries in our sample.

Our focus is on events that can be unambiguously interpreted as exogenous. Thus, we concentrate on natural disasters. Moreover, we consider only those types of natural disasters that can be viewed as occuring at a point in time, rather than those that build up or develop through extended periods, so we discard droughts and famines. Finally, due to endogeneity concerns, we drop insect infestations and epidemics from our sample.

The remaining disaster events are earthquakes, floods, wild fires, wind storms, waves and surges, extreme temperatures, volcano episodes and slides. Figure 1 shows the geographic distribution of the disasters in our panel. As one should expect, the amount and types of disasters that occur vary across regions.

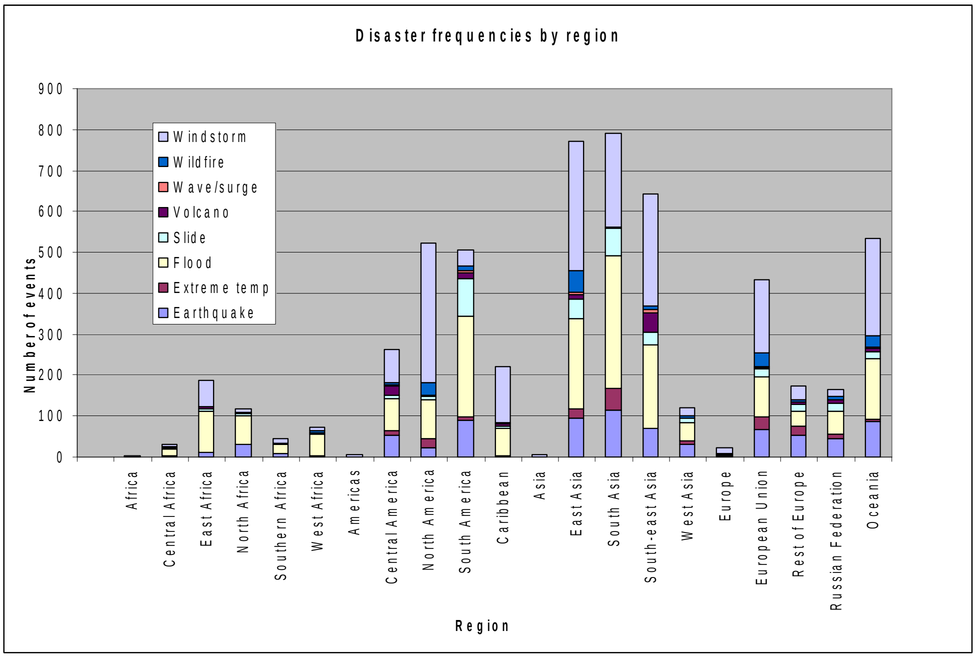

FIGURE 1: Frequency of events by type and region

These are the events used in the regressions.

From the data in EM-DAT, we construct four aggregate measures of disaster impact normalized by the relevant country "size". We concentrate on the disruptive effect of a LND rather than its physical dimension:

tpc_taff: People affected by disasters in a given year as a fraction of the current country population.
tpc_kill: People killed in a given year as a fraction of the current country population.
tpc_dama: Damages as a fraction of current GDP.
t_disd: Number of disasters in a given year.

Each of these measures is the sum over the eight types of disasters for a country in a given year. The correlation among them is reported in Table 2:

	tpc_dama	*tpc_kill*	*tpc_taff*	*t_disd*
tpc_dama	1			
tpc_kill	0.2215*	1		
tpc_taff	0.3388*	0.3478*	1	
t_disd	0.0622*	0.0558*	0.1652*	1

TABLE 2: Correlation among disaster measures
(*) significant at the 5% level.

If no disasters of any type are recorded for a given country in a certain year, *t_disd* has a value of zero for that observation. Whenever *t_disd* > 0, there exists a recorded event that has a non-zero value in at least one among the other three variables. If, for example, *tpc_kill* > 0, the other two variables may be positive, zero or missing. Suppose *tpc_dama* is missing. There is no way to decide whether this is the result of misreporting of *tpc_kill*, unavailability of damage estimates, or actual absence of significant capital losses. Our approach to this is straightforward: we replace all missing values of the three variables *tpc_taff*, *tpc_kill* or *tpc_dama* with zeros. In the cases where missing values are present but the true value is positive, this approach will generate bias in our estimation. However, it is likely that in the vast majority of cases missing data values just reflect zero values, or at most very small ones.

Additionally, we use the following cumulative measures of disasters:

cum_tpc_taff: Cumulative fraction of people affected, since the first year in the data. It is calculated as $cum\_tpc\_taff_{it} = \sum_{\tau=0}^{t} tpc\_taff_{i\tau}$.

cum_tpc_kill: Cumulative fraction of people killed by LND's since the first year in the data. This measure and the previous one are based on the country's population in the year the LNDs take place. $cum\_tpc\_kill_{it} = \sum_{\tau=0}^{t} tpc\_kill_{i\tau}$.

cum_tpc_dama: Cumulative damages as a fraction of GDP, based on GDP at the year of LND occurrence. $cum\_tpc\_dama_{it} = \sum_{\tau=0}^{t} tpc\_dama_{i\tau}$

cum_tpc_disd: Cumulative number of disasters since the first year in the data. $cum\_tpc\_disd_{it} = \sum_{\tau=0}^{t} t\_disd_{i\tau}$

Several concerns besides the missing data must be addressed with EM-DAT. First, it is difficult to assess and compare the quality of the sources, especially for earlier events. The multiple sources also account for occasional repeated entries for events, and it is not always obvious whether two entries with small differences are indeed duplicate. Moreover, different sources emphasize different data: reinsurance firms likely provide better damage estimates, but they are based on claims, while UN agents have more encompassing assessments of damages and affected population. Thus, different data sources have different strengths (and perhaps systematic biases). Additionally, some data series may be more informative than others about the true dimension of the event. This is especially the case if measurement error differs across measures.

Fortunately, this first type of concern, although difficult to address directly, is likely to be of less importance as the number and scope of international institutions that deal with LNDs increases. For the time period of our panel, we are confident that this type of noise does not systematically affect our results.

A second concern, also related to the variety of the sources, is bias over time. The institutional infrastructure for disaster aid has evolved throughout the 20th century. It is reasonable to presume that events are more likely to be registered by the authorities in any given country later in the century, and conditional on this, they are also more likely to be reported to international agencies.

The total number of disasters reported in each year by all countries in the sample is reported in Figure 2. A log-linear fit with country-specific intercepts shows a yearly increase of some 1.1% in the period 1960-1998. Since it's reasonable to believe that the actual number of cataclismic events per year is roughly steady, the increase in events reported must come, at least in part, from these reporting biases. Another part of these numbers is certainly a result of increases in population and economic activity: other things equal, the more people in a country the higher the probability of having 10 deaths in an earthquake, and the higher the GDP the larger the expected damages from a given disaster. During the period, a log-linear fit for population growth yields a 2% yearly increase; and the correlation between *t_disd* and per capita GDP, plotted in Figure 3, is positive.

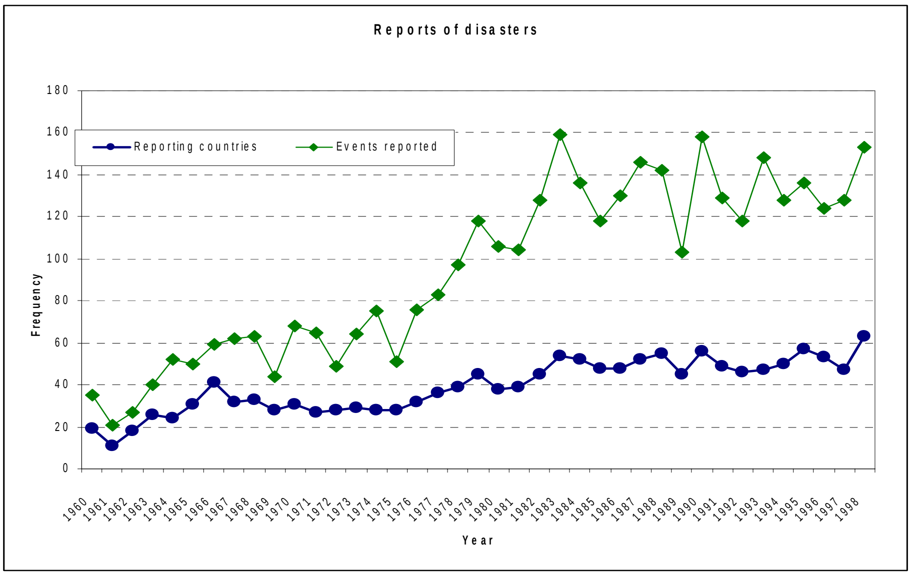

FIGURE 2: Reported events by year
These are only the types of events used in the regressions, and only for the countries included in the sample.

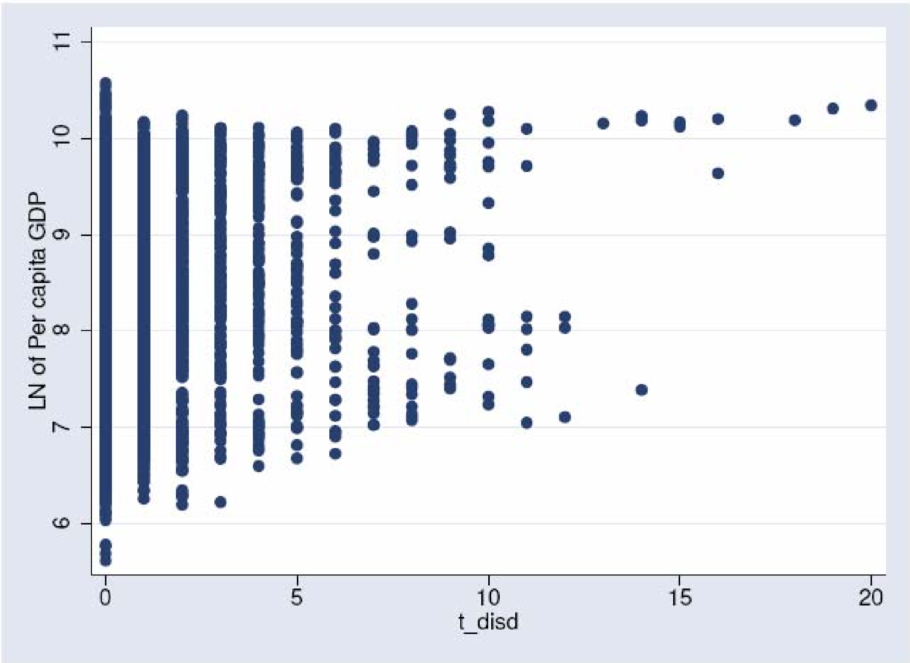

FIGURE 3: GDP per capita vs. disaster events

	Logit model with FE: Odds ratios (change in p/1-p) Dep variable: 1 if country reported a disaster in the year, 0 if not		Poisson model with FE: Incidence rate ratios (change in expected number) Dep variable: Number of disasters reported in the year	
	(1a)	(1b)	(2a)	(2b)
ln(POP)	1.569	-0.602	1.002	0.002
	(5.24)**	(1.30)	(7.21)**	(0.01)
ln(Ypc)	-0.064	-0.684	-0.090	-0.368
	(0.33)	(3.15)**	(1.11)	(3.97)**
lag of own AID (% of GDP)	-1.302	-2.953	2.937	2.502
	(0.32)	(0.73)	(1.13)	(0.97)
lag of world AID (% of GDP)	639.547	286.681	395.172	299.699
	(5.13)**	(2.08)*	(8.25)**	(5.95)**
trend		0.077		0.031
		(6.09)**		(5.90)**
Observations	3921	3921	3997	3997
Number of isogrp	106	106	108	108
R-squared				

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

TABLE 3: Reported events by year
The first model estimates the probability of a country reporting an event in a year. The second estimates the expected number of events reported.

Columns (1a) and (1b) in Table 3 show estimates of logit fixed-effects regressions for the probability of a country reporting an event in a year.[5] If p is the probability of reporting, the coefficients correspond to the change in the odds ratio ${}^{p}\!/_{1-p}$ due to a unit increase in the explanatory variable. The coefficients in columns (2a) and (2b) estimate the effect of the regressor on the expected number of events reported under a fixed-effets Poisson model. The positive and significant coefficient of the lag of world aid in both models suggests that countries do report more disasters when the

[5] Fixed effects are used to control for land area, for example, so that together with logPOP they account for population density.

world feels more generous: we reject the hyphotesis of no bias in all cases. From the last two regressions, we estimate that devoting an extra 0.1% of the world's GDP to foreign aid induces on average 0.3 to 0.4 extra disaster reports per country in the following year.

Bias stemming from the failure of a country's authorities to register a disaster is not likely a grave concern, since an unregistered event is probably one of little impact on economic activity to begin with. LNDs may be inaccurately measured, but it's difficult that they go unnoticed. To the extent that it is present, however, this usually downward error in *t_disd* is likely to generate upward bias in our estimates.

Bias due to the failure to report the disaster to international agencies, on the other hand, is potentially systematic and may affect the results in unpredictable ways. One can conceive a number of reasons for some regimes to hide the extent of disasters, or to exagerate it; and the correlation of these incentives with our dependent variables is not at all clear. In this aspect, the variety of sources of the EM-DAT database is an advantage, as it minimizes the chances that a given event goes completely unrecorded, even if no official report is filed by the affected country. Partly as a result of this possibility, we believe that any measurement error problem is likely to be less severe for the variable *t_disd* than it is for the other three measures.[6]

A third data concern includes endogeneity and timing. We partially address both issues by concentrating on events that are clearly exogenous (natural disasters) and punctual in time, i.e. they last a short time (less than a month) and give only short warning. Nevertheless, this does not completely deal with either issue, as (i) the measured impact of a given disaster is likely to vary with the economic characteristics

[6] Nevertheless, we do exclude from the panel the former communist countries that remain after merging the PWT and EM-DAT, as their incentives for reporting are particularly dubious. They are Hungary, Romania, Poland and China.

of the country itself, and (ii) the consequences of a disaster need not be punctual or immediate, even if the disaster itself is. Insofar as this is the case, the disaster counter variable *t_disd* is arguably the least affected by this endogeneity.

This point about the way a LND affects economic activity is complicated by the fact that our macroeconomic and disaster time series have different time aggregation. Suppose for instance that there is some delay in part of the impact of a type of disaster. If one such disaster happens in May, its negative impact will be recorded in this year's national accounts. If, on the other hand, it happens in November, most of that impact will show in next year's macroeconomic data. Suppose instead that the reconstruction activity after the event occurs over a long period of time. In this case, it is the spurt of investment activity that may be recorded (positively) in different years depending on the exact month of occurrence. Of course, this pattern of impact is likely to vary by disaster and by country. While the time pattern of the economic reaction to disasters is precisely what we want to inspect, this particular aggregation issue is an undesired source of error. For events that occur randomly throughout the year (e.g. earthquakes), this error is most likely white noise and causes attenuation bias in some controls of our estimation. In contrast, events that occur consistently in a given moment of the year (e.g. hurricanes) will bias our results in a systematic but unpredictable manner.

Finally, even after narrowing the set of events, one might wonder what exactly is exogenous about them. A country like Colombia, for instance, may not know when an earthquake will happen, but it certainly knows that it is prone to such disasters. As a result, its infrastructure is likely to be built using anti-seismic technology, and the actual physical damages of the eventual earthquake will be smaller. Thus, it is the actual timing of the disaster that is exogenous, rather than the extent of destruction it causes. Again, this lends more credibility to the event count variable *t_disd*, and it calls for fixed country effects in the estimation.

2. Empirical Specification

We carry out estimates of three types. First, we run a naïve cross-section regression of GDP level in 1996 on its 1960 level and the number of disasters in the 36 years in between. In our second estimation we use a basic panel data specification where we regress the dependent variable on our measures of disaster severity, both instantaneous and cumulative, and on lags of the instantaneous measures.

Finally, our last type of specification is based on a structural model of growth for panel data. It comes in two flavors, depending on the identifying assumptions we make: we report the simplest flavor, and leave the more complex specification for the appendices.

2.1 Basic Reduced Form Specification

In our basic specification, we include country fixed effects on the right hand side to control for land area and other unchanging, unobservable features of the countries. We also control for year fixed effects to account for worldwide phenomena that impact all countries in any given year. This reduced form specification is

$$LHS_{it} = a_0 + a_1 X_{it} + a_2 X_{it}^{cum} + v_i + \tau_t + \eta_{it}$$

where X_{it} includes contemporary and a one-period-lagged measures of disaster, and X_{it}^{cum} are cumulative measures. In this context, we control for the effect of foreign aid, implicitly assuming that this reaction of the rest of the world to a LND is exogenous to the affected country's economy (beyond the disaster itself):

$$LHS_{it} = a_0 + a_1 X_{it} + a_2 X_{it}^{cum} + a_3 * \left(\frac{AID_{it}}{Y_{it}} \right) + v_i + \tau_t + \eta_{it}$$

and test

$H_0^{(0)} : a_1 = 0$ (no temporary effects of disasters).

$H_0^{(1)} : a_2 = 0$ (no persistent effects of disasters).

With this specification, we analyze the effects of LNDs on per-capita *GDP* growth, *C/GDP*, *G/GDP*, *I/GDP*, and *FDI/I*, and whether they are temporary or permanent.

2.2 Growth Specification

Our empirical growth specification is similar to that of Mankiw et.al (1992) and Islam (1995). Let a country's output at time *t*, denoted Y_t, be given by a Cobb-Douglas production function dependent on capital K_t, labor L_t and technology A_t:

$$Y_t = F(K_t, A_t L_T) = K_t^{\alpha} (A_t L_t)^{1-\alpha} \quad (1)$$

$$\dot{K}_t = sY_t - \delta K_t \quad (2)$$

$$A_t = A_0 e^{gt} \text{ and } L_t = L_0 e^{nt}$$

where the exogenously given *s ,n, g* are the savings rate, and the population growth rate and the technology growth rate respectively; and δ is the capital depreciation rate. A_o and L_o are the starting levels of technology, given at some time *t=0*.

Define $y_t = \frac{Y_t}{A_t L_t}$, $k_t = \frac{K_t}{A_t L_t}$. Then, Eqns.1 and 2 become:

$$y_t = k_t^{\alpha} \tag{3}$$

$$\dot{k}_t = sy_t - (n+g+\delta)k_t \tag{4}$$

and the system has a steady state defined by $\dot{k}_t = 0$

$$k^* = \left(\frac{s}{n+g+\delta} \right)^{\frac{1}{1-\alpha}} \tag{5}$$

$$y^* = \left(\frac{s}{n+g+\delta} \right)^{\frac{\alpha}{1-\alpha}} \tag{6}$$

Assuming α constant across countries, this specification implies that the steady state per capita output in a cross section of countries i should be of the form

$$\ln\left[\frac{Y_t}{L_t}\right]_i = \ln A_{0i} + g_i t + \frac{\alpha}{1-\alpha}\ln(n_i + g_i + \delta_i) \tag{7}$$

To find the total equation of motion for the variables of interest, linearize Eqn.4

$$\left[\frac{d \ln y_t}{dt}\right]_i \lambda_i \left[\ln y_i^* - \ln y_{it}\right]$$

With $\lambda_i = (1-\alpha)(n_i + g_i + \delta_i)$. If the λ_i and $\ln y_i^*$ are constant over m time periods from time $t-m$, this yields $\ln y_{i,t} - \ln y_{i,t-m} = (1 - e^{\lambda_i m})\left[\ln y_i^* - \ln y_{i,t-m}\right]$. One can then replace $\ln y_i^*$ from Eqn.6 to obtain

$$\ln y_{i,t} - \ln y_{i,t-m} = (1 - e^{\lambda_i m})\left[\frac{\alpha}{1-\alpha}\ln s_i - \frac{\alpha}{1-\alpha}\ln(n_i + g_i + \delta_i) - \ln y_{i,t-m}\right] \qquad (8)$$

Mankiw et.al. (1992) analyze the fit of Eqn.7 under the assumption that the country specific effect has the form $\ln A_{0i} = a + \varepsilon_i$ and that technology and depreciation rates are common to all countries. They then estimate a cross-country average value of λ from Eqn.8, using $t = 1985$ and $m = 25$. They find this speed of convergence to be very low in various samples of countries.[7]

We modify this specification to make use of the advantages of panel data, in a manner similar to Islam (1995). Grouping all terms with $\ln y_{i,t-m}$ in Eqn.8 on the right side, one obtains

$$\ln y_{i,t} = (1 - e^{\lambda_i m})\left[\frac{\alpha}{1-\alpha}\ln s_i - \frac{\alpha}{1-\alpha}\ln(n_i + g_i + \delta_i)\right] + e^{\lambda_i m}\ln y_{i,t-m}$$

To have the per capita GDP explicit on each side, use $\ln y_{i,t} = \ln\left[\frac{Y_t}{L_t}\right]_i - \ln A_{0i} - g_i t$.

Rearrange terms and write

$$\ln\left[\frac{Y_t}{L_t}\right]_i = (1 - e^{\lambda_i m})\ln A_{0i} + g_i m e^{\lambda_i m} + g_i(1 - e^{\lambda_i m})t$$

$$+ e^{\lambda_i m}\ln\left[\frac{Y_{t-m}}{L_{t-m}}\right]_i + (1 - e^{\lambda_i m})\left[\frac{\alpha}{1-\alpha}\ln s_i - \frac{\alpha}{1-\alpha}\ln(n_i + g_i + \delta_i)\right] \qquad (9)$$

[7] Depending on the country sample, they find average speed of convergence λ=¡0,00360 (§0,00219), λ=0,0017 (§0,00218) and λ=0,0167 (§0,0023). For comparison, a value of λ=0,02 implies a half-life of deviations from the steady state of approximately 35 years.

Under this specification, $(1-e^{\lambda_i m})\ln A_{0i} + g_i m e^{\lambda_i m}$ is a country specific fixed effect dependent on the panel periodicity, and $g_i(1-e^{\lambda_i m})t$ is a trend, also country specific. Islam (1995) applies this panel data specification to the data in the PWT dataset, setting $m=1$ for yearly data.

In this paper, however, we want to consider the possibility of changes in the steady state due to exogenous shocks. By subtracting from Eqn.9 a one-period-lagged version of itself, one obtains a specification for per capita GDP growth $d\ln\left[\frac{Y_t}{L_t}\right]_i$, absent any exogenous shocks that may change the steady-state:

$$d\ln\left[\frac{Y_t}{L_t}\right]_i = g_i(1-e^{\lambda_i m}) + e^{\lambda_i m} d\ln\left[\frac{Y_{t-m}}{L_{t-m}}\right]_i$$
$$+(1-e^{\lambda_i m})\left[\frac{\alpha}{1-\alpha} d\ln s_i - \frac{\alpha}{1-\alpha} d\ln(n_i+g_i+\delta_i)\right] \qquad (10)$$

In this specification, the term $g_i(1-e^{\lambda_i m})$ is a country-specific fixed effect that depends on the number m of time periods over which growth is considered, and $d\ln\left[\frac{Y_{t-m}}{L_{t-m}}\right]_i$ is the one-period lag of or our growth measure.

Define the shock operator Δ_t to evaluate the instantaneous change due to a disaster at time *t*. Thus, for any variable or parameter x, $\Delta_t x = x_t^+ - x_t^-$ for an event that happened at time *t*. If there's no disaster, $\Delta_t x = 0$. Direct temporary effects of LNDs in Eqn.10 are changes to the parameters n_i and $d\ln\left[\frac{Y_{t-m}}{L_{t-m}}\right]_i$. On the other hand, any long-term effect must be a change in the steady state, so that $\Delta_t e^{\lambda_t m} \neq 0$ or $\Delta_t \left[g_i (1 - e^{\lambda_t m}) \right] \neq 0$.

If $m > 1$, Eqn.10 becomes rather cumbersome in the presence of changes in the steady state, as one must take into account different values of λ_i and g_i in within the m periods. The problem disappears for m =1, and our specification becomes

$$d \ln \left[\frac{Y}{L} \right]_{it} = g_{it} (1 - e^{\lambda_t}) + e^{\lambda_t} d \ln \left[\frac{Y}{L} \right]_{i,t-1} + (1 - e^{\lambda_t}) \left[\frac{\alpha}{1-\alpha} d \ln s_{it} - \frac{\alpha}{1-\alpha} d \ln(n_{it} + g_{it} + \delta_{it}) \right] \tag{11}$$

To include the possibility of disasters, we make the following assumption:

Assumption 1: *The effect of a disaster on the growth rate is of the form* $\Delta_t g_{it} = \beta_1' Z_{it}$, *where* Z_{it} *are measures of an LND.*

Unfortunately, it is not possible to separate short-term from long-term effects without identifying assumptions. We examine the data first under the assumption that the country GDPs converge to their long-term paths at a rate that is uniform across countries and constant over time. In Appendix D, we also carry out estimates under the weaker assumption that these convergence rates may vary, both across countries and over time.

Assumption 2A $(i) \lambda_{it} = \lambda$ *and* $(ii) \Delta_t \lambda = 0$

This assumption effectively replaces country-specific convergence rates by an average over the country sample λ, and ignores the effect of $\Delta_t \lambda_{it}$ on λ. Since

$\lambda_{it} = (1-\alpha)(n_{it} + g_{it} + \delta_{it})$, this implies the restriction $\Delta_t g_{it} + \Delta_t \delta_{it} + \Delta_t n_{it} = 0$, where we are controlling for the exogenous variation in n_i. Eqn.11 then becomes

$$d\ln\left[\frac{Y}{L}\right]_{it} = g_{it}(1-e^{\lambda}) + e^{\lambda} d\ln\left[\frac{Y}{L}\right]_{i,t-1} + (1-e^{\lambda})\left[\frac{\alpha}{1-\alpha} d\ln s_{it} - \frac{\alpha}{1-\alpha} d\ln(n_{it} + g_{it} + \delta_{it})\right]$$

where $g_{it} = g_{i,1960} + \sum_{s=1960}^{t} \Delta_s g_{is}$.

We can then specify the following regression:

$$d\ln\left[\frac{Y}{L}\right]_{it} = b_0' + b_1' X_{it} + b_2' X_{it}^{cum} + b_3\left(d\ln\left[\frac{Y}{L}\right]_{i,t-1}\right)$$
$$+ b_4(d\ln i_i) - b_5(d\ln n_i) + v_i + \tau_t + \eta_{it}$$

where, as before, X_{it} are instantaneous measures of disaster events for each country and year (and possibly lags thereof), $X_{it}^{cum} = \sum_{t=0}^{t} X_{it}$ are the corresponding cumulative measures, v_i are country fixed effects and τ_t are year fixed effects. $d\ln i_i$ and $d\ln n_i$ are changes in investment share of GDP and population growth rates contemporaneous with the shock. Our central testable hypotheses are

$H_0^{(0)} : b_1 = 0$ (no temporary effects of disasters)

$H_0^{(1)} : b_2 = 0$ (no persistent effects of disasters)

The identifying assumptions $\lambda_i = \lambda$ for all i and $\Delta\lambda = 0$ are unfortunately not testable. To control for foreign aid as a form of investment, we also include $d\ln\left[\frac{AID}{Y}\right]_{it}$ as an additional regressor, and test whether its effect is similar to any other type of investment, both in disaster years and otherwise.

This model makes no independent predictions for non-steady-state per capita consumption or savings, since they are exogenously determined from the savings rate s and the time path of GDP for each country: $I_t = S_t = sY_t$ and $C_t = (1-s)Y_t$. Thus, in the steady state, the shares of both consumption and savings in GDP are constant.

The model does not include exports or any other international flow of factors or goods, but we control for openness by including a one-year-lagged indicator of trade openness.

3. Results

Preliminary regression results are reported in Table 4. The dependent variable is the log of per-capita GDP in 1996 of a cross section of 104 countries, all those for which GDP and population data is available for both 1960 and 1996. The first dependent variable is the natural logarithm of per-capita GDP in 1960. The population growth is given as a percentage change. The estimation is performed by OLS. Columns (1) and (2) are displayed for comparison.

In the estimates in column (3), a disaster is related to 0.3% higher per-capita GDP at the end of the period, significant at the 5% level. However, it is possible that the effects of disasters over a long period of time have a non-linear component, either because of cumulative aspects of events over several years, or because multiple catastrophic events in a given year are compounded in a non-linear fashion. Therefore, we also run a specification including a non-linear disaster term. The coefficients on the disaster measures in regression (4) indicate that for each event recorded in the time period, the affected country has a per-capita GDP in 1996 that is on average 0.9% higher than it would otherwise be, with results significant at the 1% level. Since the median country had 11 disasters by 1996, this amounts to a median 10.2% higher GDP per capita.

Dep var: Log of per capita GDP in 1996

	(1) lnGDP1996	(2) lnGDP1996	(3) lnGDP1996	(4) lnGDP1996
Log of per capita GDP in 1960	1.166	0.963	0.948	0.941
	(20.10)**	(10.51)**	(10.42)**	(10.53)**
Population growth 1996-1996		-0.405	-0.385	-0.373
		(2.95)**	(2.82)**	(2.74)**
Number of disasters 1960-1996			0.003	0.009
			(2.44)*	(3.18)**
(Number of disasters 1960-1996)^2				-3.1 E-5
				(2.82)**
Constant	-0.702	1.377	1.376	1.328
	(1.43)	(1.58)	(1.59)	(1.58)
Observations	104	104	104	104
R-squared	**0.67**	**0.71**	**0.72**	**0.73**

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

TABLE 4: Cross country regression of GDP level in 1996

The usual precaution regarding unobserved variables is required in this analysis. The assumption that the changes in population and the initial GDP are uncorrelated with the error terms is precarious at best. Even if population growth is viewed as truly exogenous, the initial GDP is most certainly correlated with unobserved idiosyncratic country features, fixed and otherwise. We address this problem in detail later. Still, for the time being a relationship between LNDs and growth seems likely.

Table 4 reproduces the results of fixed effects regressions according to the basic specification. The dependent variable in this case is per-capita GDP growth.

Dep var: Log of per capita GDP growth

	(1)	(2)	(3)	(4)	(5)
cum_t_disd		-0.000	-0.000	-0.000	-0.000
		(0.99)	(1.21)	(1.07)	(1.16)
cum_tpc_dama		-33.583	-27.624	-26.995	-24.845
		(0.77)	(0.63)	(0.61)	(0.56)
cum_tpc_kill		-4.932	-4.082	-4.100	-4.000
		(2.28)*	(1.86)	(1.87)	(1.81)
cum_tpc_taff		0.023	0.022	0.022	0.022
		(3.48)**	(3.28)**	(3.27)**	(3.26)**
t_disd	0.001	0.001	0.001	0.001	0.001
	(1.35)	(1.31)	(1.54)	(1.54)	(1.78)
tpc_dama	100.192	134.498	133.769	133.903	136.501
	(0.92)	(1.16)	(1.11)	(1.11)	(1.14)
tpc_kill	-0.840	2.078	1.435	1.461	1.203
	(0.19)	(0.43)	(0.30)	(0.30)	(0.25)
tpc_taff	0.010	-0.008	-0.011	-0.011	-0.009
	(0.37)	(0.29)	(0.36)	(0.37)	(0.30)
t_disd [t-1]	0.002	0.002	0.002	0.002	0.002
	(3.06)**	(2.85)**	(3.10)**	(3.10)**	(3.06)**
tpc_dama [t-1]	91.741	123.042	127.843	127.952	126.276
	(1.49)	(1.72)	(1.75)	(1.75)	(1.71)
tpc_kill [t-1]	1.900	4.897	4.210	4.242	4.140
	(0.33)	(0.88)	(0.75)	(0.76)	(0.74)
tpc_taff [t-1]	-0.001	-0.019	-0.022	-0.022	-0.021
	(0.04)	(0.78)	(0.86)	(0.88)	(0.85)
open [t-1]			0.000	0.000	0.000
			(2.70)**	(2.70)**	(2.70)**
aid				0.035	-0.039
				(0.38)	(0.23)
aid*event					0.088
					(0.53)
Observations	4168	4168	4168	4168	4168
Number of isogrp	113	113	113	113	113
R-squared	0.05	0.05	0.06	0.06	0.06

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

TABLE 4: Panel regression of GDP growth on disasters, basic specification.
All regressions have country and year fixed effects. [t-1] indicates the one-period lag of the variable.

Column (1) includes only current and one-period-lagged measures disaster magnitude; these we interpret as short-term effects.[8] In column (2) we add cumulative measures of disasters. Columns (3) and (4) include controls for openness (one-period-lagged) and the foreign aid received as percentage of the country's GDP. Finally, column(5) includes an interaction between the dummy *event*, which is one if there a disaster in the year, and the *aid* variable, to separate the effect of aid in disaster years from its effect in other years. In all cases, the coefficient on the cumulative fraction of people affected is positive and significant at the 1% level, suggesting a persistent effect: a disaster that affects 1% of the population raises GDP growth by 0.02% in the long run.

The regressions suggest also a positive short-term effect through the count measure *t_disd*. However, one must be careful in the interpretation of these estimates because capital losses are usually not considered in national accounts. The interaction between foreign aid and *event* does not have a statistically significant coefficient.[9]

The results with the structural specification are reported in Table 5. Column (1) estimates the model without including any disaster measures. Column(2) adds the short-term measures, and column (3) has the full specification with cumulative measures. The results are similar to those in Table 4: persistant positive effects of the fraction of people affected, and positive coefficient on the one-period-lagged count of disasters. Although we do not report it, if an interaction between aid change and event is added, aid still doesn't show any additional effect in disaster years.

[8] We include all measures of disaster simultaneously to capture as much of the disaster effect. However, the estimated coefficients do not change if we run regressions one type of measure at the time.

[9] Neither does the interaction between openness and event in regressions not reported here.

Dep var: Log of per capita GDP growth			
	(1)	**(2)**	**(3)**
Ypc growth [t-1]	0.041	0.039	0.036
	(1.58)	(1.48)	(1.40)
cum_t_disd			-0.000
			(1.01)
cum_tpc_dama			-8.579
			(0.19)
cum_tpc_kill			-3.946
			(1.82)
cum_tpc_taff			0.021
			(3.08)**
t_disd		0.001	0.001
		(1.82)	(1.76)
tpc_dama		112.851	122.427
		(0.91)	(0.95)
tpc_kill		1.409	4.044
		(0.29)	(0.77)
tpc_taff		-0.001	-0.018
		(0.05)	(0.55)
t_disd [t-1]		0.002	0.002
		(3.17)**	(2.92)**
tpc_dama [t-1]		102.890	111.513
		(1.66)	(1.53)
tpc_kill [t-1]		-0.846	1.854
		(0.17)	(0.40)
tpc_taff [t-1]		0.000	-0.016
		(0.01)	(0.68)
% change in savings rate	0.300	0.300	0.302
	(3.14)**	(3.14)**	(3.16)**
% change in population growth	-0.390	-0.390	-0.388
	(1.56)	(1.56)	(1.55)
open [t-1]	0.000	0.000	0.000
	(2.60)**	(2.70)**	(2.62)**
% change in aid	-0.689	-0.692	-0.689
	(3.89)**	(3.90)**	(3.89)**
Observations	4055	4055	4055
Number of isogrp	113	113	113
R-squared	0.08	0.08	0.08

Robust t statistics in parentheses
* significant at 5%; ** significant at 1%

TABLE 5: Panel regression of GDP growth on disasters, structural specification.
All regressions have country and year fixed effects. [t-1] indicates the one-period lag of the variable.

One should expect that the impact of disasters be different for small and large countries, and for poor and rich ones. Table 6 reports the estimates of the specification A for the subsamples of countries described in Appendix C. The first column, (Small), refers to the countries in the lowest 33% according to their population in 1960. Columns (Medium) and (Large) refer to the middle and highest 33%, respectively. In columns (Low), (Middle) and (High) the grouping is according to the level of per capita GDP in 1960.

The results in the subsamples are indeed richer. The persistant effects of *cum_tpc_taff* stem from large countries, whereas the short-term effects through *t_disd* are more or less across the board. Additionally, high-income countries show positive effects of the current fraction of people affected, and negative effects of the amount of current damages. They also show a small long-term effect of the count of disasters. In contrast, middle-income countries experience a positive effect of one-period-lagged damages. Finally, while the fraction of people killed has a positive short-term impact in large countries, it has a negative one in small countries.

Dep var: Log of per capita GDP growth	(Small)	(Medium)	(Large)	(Low)	(Middle)	(High)
Ypc growth [t-1]	0.025	0.032	0.093	-0.009	0.041	0.062
	(0.59)	(0.79)	(1.57)	(0.23)	(0.89)	(1.15)
cum_t_disd	0.001	-0.000	0.000	0.000	-0.000	-1.24 E-4
	(1.66)	(1.50)	(0.26)	(1.01)	(1.46)	(2.37)*
cum_tpc_dama	-58.491	78.230	-105.878	158.791	-101.666	219.802
	(0.42)	(0.54)	(0.56)	(1.29)	(1.02)	(1.40)
cum_tpc_kill	-2.138	-14.085	-5.150	-1.762	-1.336	-16.136
	(0.41)	(2.27)*	(1.62)	(0.35)	(0.50)	(0.44)
cum_tpc_taff	0.017	0.052	0.023	0.008	0.017	0.010
	(0.85)	(1.52)	(2.77)**	(0.61)	(1.27)	(0.40)
t_disd	-0.004	0.002	0.001	0.002	0.001	0.001
	(1.30)	(0.95)	(1.27)	(1.41)	(1.06)	(1.74)
tpc_dama	54.675	-540.678	-532.158	-423.133	91.067	-720.778
	(0.27)	(1.70)	(1.33)	(0.78)	(0.39)	(3.94)**
tpc_kill	-15.230	19.304	16.294	5.896	4.005	1.089
	(2.43)*	(1.41)	(3.60)**	(0.88)	(0.61)	(0.02)
tpc_taff	0.041	-0.021	0.054	0.059	-0.052	0.097
	(1.22)	(0.31)	(0.95)	(1.25)	(1.65)	(3.11)**
t_disd [t-1]	0.002	0.003	0.001	0.003	0.002	0.001
	(0.59)	(1.74)	(1.10)	(1.78)	(1.96)	(1.52)
tpc_dama [t-1]	-15.342	-294.002	518.265	-280.162	498.096	-480.891
	(0.05)	(0.77)	(1.10)	(0.37)	(1.98)*	(1.94)
tpc_kill [t-1]	3.696	25.597	-3.647	-6.523	0.647	164.001
	(0.46)	(1.04)	(1.01)	(0.96)	(0.13)	(1.13)
tpc_taff [t-1]	0.029	-0.036	-0.039	-0.021	-0.054	0.056
	(0.74)	(0.27)	(1.64)	(0.64)	(1.08)	(1.26)
% change in savings rate	0.123	0.268	0.975	0.038	0.334	0.792
	(0.89)	(1.68)	(6.83)**	(0.20)	(1.93)	(6.67)**
% change in population growth	-0.520	-0.561	-0.533	1.454	-1.003	0.017
	(1.26)	(1.60)	(0.83)	(0.92)	(3.58)**	(0.05)
open [t-1]	0.000	0.000	0.000	0.000	0.000	0.001
	(2.94)**	(0.98)	(0.93)	(0.78)	(2.19)*	(3.26)**
% change in aid	-0.501	-0.912	-2.764	-1.068	-0.542	-1.174
	(2.13)*	(2.46)*	(4.02)**	(3.12)**	(2.53)*	(1.82)
Observations	1286	1286	1294	1294	1287	1255
Number of isogrp	35	35	35	35	35	34
R-squared	0.10	0.10	0.25	0.08	0.11	0.30

Robust t statistics in parentheses

* significant at 5%; ** significant at 1%

TABLE 6: Panel regression of GDP growth on disasters, structural specification, by subsamples. All regressions have country and year fixed effects. [t-1] indicates the one-period lag of the variable.

4. Concluding remarks

This paper attempts to determine if there are short and long-term effects of large natural disasters (LNDs) on GDP growth and other macroeconomic variables in a large panel of countries.

The results suggest a heterogeneous pattern of impact of LNDs, depending on the per capita wealth and the size of the countries studied. Overall, LNDs have small but positive long-term effects on *GDP* growth. Those persistant effects stem from large countries, whereas the short-term effects through are more or less across the board. Additionally, high-income countries show positive effects of the current fraction of people affected, and negative effects of the amount of current damages. They also show a small long-term effect of the count of disasters. In contrast, middle-income countries experience a positive effect of one-period-lagged damages. Finally, while the fraction of people killed has a positive short-term impact in large countries, it has a negative one in small countries.

An important clarification is necessary about the interpretation of our results. By no means are we suggesting that the overall welfare effects of LNDs are positive. We focus our analysis on variables that are indirectly –and imperfectly– correlated with welfare. Moreover, we point out in the data section that their measurement is particularly biased in the aftermath of a LND, since the capital losses of a catastrophe are not registered in *GDP*. For example, it could be that positive investment effects that are a response to the destruction of physical capital, and thus a sign of a decrease in permanent consumption, drive the short-term results.

More research is required on this topic, particularly in disentangling the effects of specific types of disasters. Their different build-up times and aftermaths may imply significant differences in their impact on growth. Similarly, the role of institutions in the affected country needs to be accounted for explicitly. In the area of investment, the differential effects on the types of physical capital are of interest. Is it the case that reconstruction after a disaster concentrates in different economic activities from those before? Also, the potential consequences on human capital investment and –more controversial perhaps– on existing social networks present a challenge for future research.

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Appendix A: Disaster Data

The format of a disaster event entry in EM-DAT is exemplified by Table 1. The data it may contain depends on availability:[10]

DisNo	19670020
Country	Colombia
ISOCode	COL
Region	South America
Continent	Americas
DisGroup	Natural
DisType	Earthquake
DisSubset	Earthquake
DisName	
Year	1967
Month	2
Day	9
Killed	61
Injured	200
Homeless	
Affected	40000
TotAff	40200
DamageUS(000s)	600
DamageEuros(000s)	
DamageLocal(000s)	
Local Currency	Colombia, Peso (COP)
Location	Huila Dep. Coordinates for Neiva.
Latitude	2.58N
Longitude	75.15W
DisScaleVal	
DisScale	Richter
TimeLocal	
TimeGMT	
PrimarySource	US Gov:OFDA
AddSource1	UN:OCHA
AddSource2	Priv:RFF
AddSource3	UN
AddSource4	
AddSource5	
AddSource6	
OFDAresp	TRUE
Reason	Kill
LastMod	7/25/1999
Comments	US GOV:OFDA: + UN:OCHA:b: Huila Dept, Neiva; Nbr Kill and Homel UN:OCHA:b: Feb 1967 US GOV:OFDA: Nbr Affect, Inj; K,Dam: 600 PRIV:RFF: Feb 1967; Rep Deaths: Max: 1 UN: Min: 61

TABLE A1: Typical entry in EM-DAT

[10] This variable description is quoted directly from the webpage of the EM-DAT Guidelines at http://www.cred.be/emdat/intro.htm

The following is a short explanation for each of these variables, quoted from the EM-DAT Guidelines:

- Country: Country in which the disaster has occurred (see Country list). If a disaster has affected more than one country, there is one entry for each country. If the quantitative data (killed, injured, homeless, affected, estimation of damage) are not given by country, they will be entered under the NA-related region/continent and an entry will be made for each country without data.
- ISO Code: Automatically linked to the country (see ISO Code list). The International Organization for Standardization has attributed a 3-letter code to each country. CRED is using the ISO 3166.
- Region: Automatically linked to the country (see Region list).
- Continent: Africa, Americas, Asia, Europe and Oceania are the five continents. This field is automatically linked to the country.
- Disaster group: Three groups of disasters are distinguished in EM-DAT: natural disasters, technological disasters and conflict. This field is automatically linked to the disaster type.
- Disaster type: Description of the disaster according to a pre-define classification scheme scheme (See Disaster type list). Two or more disasters may be related, i.e. a disaster may occur as a consequence of a primary event. For example, a cyclone may generate a flood or a landslide; or an earthquake may cause a gas line to rupture, causing an ecological disaster. The primary disaster type is recorded first, followed in the comments field by a related disaster description.
- Disaster subset: Specific information related to the disaster type (see Dissubset list).
- Date: When the disaster occurred. The date is entered as follow: Year/Month/Day. This date is easily defined for all sudden disasters, but for disaster situations developing gradually over a longer time period, only month and/or year are recorded. The data available for long-term disaster are divided by

the number of affected years (in the chronological table of the profiles, and in the raw data). The totals of people reported killed or affected or estimated damage are only used in the TOP 10 tables in the disaster profiles.

- Killed: Persons confirmed as dead and persons missing and presumed dead (official figures when available).
- Injured: The number of injured is entered when the term "injured" is written in the source. Injured people are always part of the affected population. Any related word like "hospitalized" is considered as injured. If there is no precise number like "hundreds of injured", 200 injured will be entered (although it is probably underestimated). Any other specification will be written in the comments field.
- Homeless: They are always part of the affected population. Reporting from the field should give the number of individuals that are homeless; if only the number of families or houses is reported, the figure is multiplied by the average family size for the affected area (x5 for the developing countries, x3 for the industrialised countries, according to UNDP country list). Any other specification will be written in the comments field. Specific examples: Number of houses destroyed = 50 x 5 = 250 homeless (although it is probably underestimated) If the value ranging from a minimum to a maximum: take the average Thousands of homeless = 2000 homeless (although it is probably underestimated) Affected: People requiring immediate assistance during a period of emergency; it can also be displaced or evacuated people. Any other specification will be written in the comments field.
- Total affected: Sum of injured, homeless, and affected.
- Estimated Damage: Although several institutions have developed methodologies to quantify these losses in their specific domain, no standard procedure to determine a global figure for the economic impact exists up to now. Estimated damage are (if available) given in 3 different currencies (in thousand):

- Dam US Dam Euros DamLocal: the local currency field is automatically linked to the country. If cost damage is given in the local currency, it will be directly converted in US and in EURO for European countries. For each disaster, the registered figure corresponds to the damage value at the moment of the event, i.e. the figures are shown true to the year of the event
- Primary source: Primary source of disaster information. A priority list as been established (see Source list). In some specific case, a secondary source can become a primary one according to the relevance of the data given by the source or the updating of a report.
- Additional source: All other data sources.
- Reason: Reason for taking into account the disaster
    - Code Reason Kill 10 or more people killed
    - Affected 100 or more people affected/injured/homeless
    - SigDis Significant disaster (e.g. second worst)
    - SigDam Significant damage
    - Decla/int Declaration of a state of emergency or/and appeal for an international assistance
    - Regional Disaster entered at the country level without data, because it has affected several countries/regions.
    - Unknown Reason not known (old entries)

Appendix B: Foreign Aid Data

We use three data series from the DAC/GEO database of Geographic Distribution of Financial Flows to Aid Recipients, 1960-1998, included in the OECD publication International Development Statistics (IDS), edition 2000. We reproduce here the database descriptions of this series.

Total Official Net Flows The sum of Official Development Assistance (ODA) and Other Official Flows (OOF) represents the total net disbursements by the official sector at large to the recipient country.

Official Development Assistance (ODA) Includes grants or loans to countries and territories on Part I of the DAC List of Aid Recipients (developing countries) which are a) undertaken by the official sector; b) with promotion of economic development and welfare as the main objective, and c) at concessional financial terms (if a loan, have a grant element of at least 25 per cent).
In addition to financial flows, Technical Co-operation is included in official aid. Grants, loans and credits for military purposes are excluded.

Other Official Flows (OOF) Transactions by the official sector whose main objective is other than development motivated, or, if development motivated, whose grant element is below the 25% threshold which would make them eligible to be recorded as ODA. The main classes of transactions included here are official export credits, official sector equity and portfolio investment, and debt reorganisation undertaken by the official sector at non-concessional terms (irrespective of the nature or the identity of the original creditor).

Appendix C: Countries in the sample

According to their population in 1960, the countries in the sample are:

Small		Medium		Large		Not included	
barbados	4	angola	1	algeria	30	antigua and	5
benin	9	austria	20	argentina	47	dominica	8
botswana	3	bolivia	22	australia	169	grenada	4
cape verde	4	burkina faso	4	bangladesh	136	saint kitts	5
central afri	4	burundi	1	belgium	20	saint vincen	9
comoros	6	cameroon	5	brazil	84	sao tome and	0
congo	1	chad	6	canada	53	sierra leone	3
costa rica	31	chile	44	colombia	80	tunisia	11
cyprus	4	cote d'ivoir	2	egypt	15		
equatorial g	0	denmark	9	france	66		
fiji	30	dominican re	20	greece	44		
gabon	1	ecuador	52	india	236		
gambia	2	el salvador	12	indonesia	153		
guinea-bissa	2	finland	1	italy	65		
guyana	3	ghana	5	japan	132		
honduras	25	guatemala	20	kenya	7		
iceland	10	guinea	3	korea, repub	44		
israel	7	haiti	28	mexico	92		
jamaica	17	hong kong	184	morocco	18		
jordan	9	ireland	6	nepal	41		
lesotho	6	madagascar	21	netherlands	11		
luxembourg	3	malawi	8	nigeria	6		
mauritania	3	malaysia	16	pakistan	58		
mauritius	18	mali	2	peru	68		
namibia	0	mozambique	15	philippines	215		
new zealand	66	niger	3	south africa	29		
nicaragua	20	norway	5	spain	40		
panama	13	senegal	7	sri lanka	32		
papua new gu	33	sweden	7	taiwan, prov	31		
paraguay	11	switzerland	25	tanzania, un	16		
seychelles	0	syrian arab	3	thailand	36		
singapore	0	uganda	5	turkey	50		
togo	3	venezuela	13	united kingd	31		
trinidad and	9	zambia	2	united state	272		
uruguay	4	zimbabwe	2	zaire	0		
TOTAL	361		579		2427		45

TABLE C1: Countries in the sample
The countries are classified according to their 1960 population. Those under "Not Included" are in the sample but there was no population data for that year. The number in front of the country is the number of disasters it had in the period of analysis.

According to their per capita GDP in 1960, the countries in the sample are:

Poor		Medium		Rich		Not included	
bangladesh	136	algeria	30	argentina	47	antigua and	5
benin	9	angola	1	australia	169	dominica	8
botswana	3	bolivia	22	austria	20	grenada	4
burkina faso	4	brazil	84	barbados	4	haiti	28
burundi	1	cameroon	5	belgium	20	saint kitts	5
cape verde	4	central afri	4	canada	53	saint vincen	9
chad	6	colombia	80	chile	44	sao tome and	0
congo	1	comoros	6	costa rica	31	sierra leone	3
dominican re	20	cote d'ivoir	2	denmark	9	tunisia	11
egypt	15	cyprus	4	el salvador	12		
gambia	2	ecuador	52	finland	1		
ghana	5	equatorial g	0	france	66		
guinea-bissa	2	fiji	30	greece	44		
india	236	gabon	1	iceland	10		
indonesia	153	guatemala	20	ireland	6		
kenya	7	guinea	3	israel	7		
korea, repub	44	guyana	3	italy	65		
lesotho	6	honduras	25	japan	132		
madagascar	21	hong kong	184	luxembourg	3		
malawi	8	jamaica	17	mauritius	18		
mali	2	jordan	9	mexico	92		
mauritania	3	malaysia	16	namibia	0		
morocco	18	mozambique	15	netherlands	11		
nepal	41	nicaragua	20	new zealand	66		
niger	3	panama	13	norway	5		
nigeria	6	papua new gu	33	south africa	29		
pakistan	58	paraguay	11	spain	40		
sri lanka	32	peru	68	sweden	7		
syrian arab	3	philippines	215	switzerland	25		
taiwan, prov	31	senegal	7	trinidad and	9		
tanzania, un	16	seychelles	0	united kingd	31		
thailand	36	singapore	0	united state	272		
togo	3	turkey	50	uruguay	4		
uganda	5	zambia	2	venezuela	13		
zaire	0	zimbabwe	2				
TOTAL	940		1034		1365		73

TABLE C2: Countries in the sample by per capita GDP level
The countries are classified according to their 1960 per capita GDP. Those under "Not Included" are in the sample but there was no GDP data for that year. The number in front of the country is the number of disasters it had in the period of analysis.

Appendic C: Alternative Identifying Restriction (variable convergence rates)

For this specification, we assume the depreciation rate to be constant in time. We also assume the convergence rate of country *i* to be a function of the exogenous average population growth rate over the whole period, denoted n_i, rather than over yearly intervals of time:

Assumption 2B *(i)* $\delta_{it} = \delta_i$ *constant over the time period. (ii) The convergence rate can be expressed as* $\lambda_{it} = (1-\alpha)(n_i + g_{it} + \delta_i)$ *where* n_i *is the average population growth rate over the sample period.*

As before, $g_{it} = g_{i,1960} + \sum_{s=1960}^{t} \Delta_s g_{is}$ so that

$$\lambda_{it} = \lambda_i + (1-\alpha)\sum_{s=0}^{t} \Delta_s g_{is}$$

$$g_{it}\lambda_{it} = g_i\lambda_i + \left[(1-\alpha)g_i + \lambda_i\right]\sum_{s=0}^{t} \Delta_s g_{is} + (1-\alpha)\left[\sum_{s=0}^{t} \Delta_s g_{is}\right]^2$$

Thus, the steady state convergence rate λ_{it} varies across countries, but its only source of short-term variation are changes in productivity $\Delta_t g_{it}$ due to LNDs.

We also make use of Ass.1, so that $\Delta_t g_{it} = \beta_1' X_{it}$, and assume that λ_i is the same for all countries in 1960:[11]

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[11] Since □□= (1 ¡ □) (□□+ □□+ □□), this assumption implies that countries with high average population growth are constrained to have low □□+ □□. Alternatively, one could demand that □□¡(1 ¡ □) □□be equal across countries in the base year 1950. Then, □□+□□= 0 and country technology growth and depreciation rates would be negatively correlated by assumption.

Assumption 3B *[Initial Conditions] In* 1960*, all countries share the same convergence rate* $\lambda_{i,1960} \equiv \lambda$.

Rewrite Eqn.10, linearizing $e^{\lambda_i m} \approx 1 + \lambda_i m$ and setting *m = 1*

$$d \ln\left[\frac{Y}{L}\right]_{it} = -g_{it}\lambda_{it} + (1+\lambda_{it}) d \ln\left[\frac{Y}{L}\right]_{i,t-1}$$
$$+ \lambda_{it}\left[\frac{\alpha}{1-\alpha} d \ln s_{it} - \frac{\alpha}{1-\alpha} d \ln(n_{it} + g_{it} + \delta_{it})\right]$$

Under Ass.2B and Ass.3B, $\lambda_{it} = \lambda + \beta_1' X_{it}^{cum}$ and $g_{it}\lambda_{it} = g_i\lambda + \gamma_1' X_{it}^{cum} + \left[\gamma_2' X_{it}^{cum}\right]^2$ or, without the non-linear term $g_{it}\lambda_{it} = g_i\lambda + \gamma_1' X_{it}^{cum}$. Thus:

$$d \ln\left[\frac{Y}{L}\right]_{it} = g_i\lambda + \gamma_1' X_{it}^{cum} + (1+\lambda) d \ln\left[\frac{Y}{L}\right]_{i,t-1} + (1+\lambda)\beta_1' X_{it}^{cum} d \ln\left[\frac{Y}{L}\right]_{i,t-1}$$
$$-\lambda\left[\frac{\alpha}{1-\alpha} d \ln s_{it} - \frac{\alpha}{1-\alpha} d \ln\left(n_{it} + g_{it} + \delta\right)\right]$$
$$-\lambda\beta_1' X_{it}^{cum}\left[\frac{\alpha}{1-\alpha} d \ln s_{it} - \frac{\alpha}{1-\alpha} d \ln\left(n_{it} + g_{it} + \delta\right)\right]$$

We then regress the empirical model

$$d \ln\left[\frac{Y}{L}\right]_{it} = a_0' + a_1' X_{it} + a_2' X_{it}^{cum} + a_3 d \ln\left[\frac{Y}{L}\right]_{i,t-1}$$
$$+ a_4' X_{it}^{cum} d \ln\left[\frac{Y}{L}\right]_{i,t-1} - a_5 d \ln i_{it} + a_6 d \ln n_{it}$$
$$- a_7' X_{it}^{cum} d \ln i_{it} + a_8' X_{it}^{cum} d \ln n_{it} + v_i + \tau_t + \eta_{it}$$

Our central testable hypotheses are

$$H_0^{(0)} : a'_1 = 0 \text{ (no temporary effect of disasters)}$$

$$H_0^{(1)} : a'_2 = 0 \text{ (no effect of disasters on the long-term growth rate)}$$

$$H_0^{(2)} : a'_4 = 0 \text{ (no effect of disasters on the convergence rate)}$$

One can also recover the magnitude of the effects, and test for the structural specification in several ways.

As before, we also control for foreign aid flows as a form of investment, but in this case the aid must show up twice on the right hand side, once alone and once interacted with the cumulative measures of disaster. We report these estimates in Table D1, using only one of the disaster measures in each column. We do not include them simultaneously because the interactions generate too many regressors.

The results are in line with those of the specification with constant convergence rates in all cases.

Dep var: Log of per capita GDP growth

MEASURE:	**COUNTER**	**DAMAGES**	**KILLED**	**TOTAL AFFECTED**
	(1)	**(2)**	**(3)**	**(4)**
	dln_ypc	dln_ypc	dln_ypc	dln_ypc
cumulative measure	-0.000	23.618	0.039	0.011
	(1.84)	(0.44)	(0.03)	(2.00)*
current measure	0.001	119.431	8.831	-0.017
	(2.06)*	(0.77)	(1.29)	(0.56)
lag of measure	0.002	44.880	-1.373	-0.006
	(2.42)*	(0.35)	(0.37)	(0.27)
Ypc growth [t-1]	0.023	0.038	0.036	0.020
	(0.84)	(1.43)	(1.36)	(0.74)
___ * cumulative measure	0.002	253.123	28.249	0.238
	(3.08)**	(0.32)	(1.07)	(2.36)*
% change in savings rate	0.185	0.258	0.236	0.258
	(1.85)	(2.56)*	(2.40)*	(2.58)**
____ * cumulative measure	0.015	5,260.059	254.194	0.708
	(6.85)**	(1.61)	(3.10)**	(1.80)
% change in population growth	-0.309	-0.473	-0.438	-0.547
	(1.03)	(1.67)	(1.57)	(2.03)*
___ * cumulative measure	-0.006	5,477.822	402.681	1.596
	(1.20)	(1.10)	(0.77)	(2.30)*
% change in aid	-0.668	-0.795	-0.713	-0.793
	(3.21)**	(3.74)**	(3.70)**	(3.71)**
___ * cumulative measure	-0.003	3,841.618	37.770	0.676
	(0.19)	(1.95)	(0.53)	(1.56)
open [t-1]	0.000	0.000	0.000	0.000
	(2.60)**	(2.58)**	(2.58)**	(2.55)*
Observations	4055	4055	4055	4055
Number of isogrp	113	113	113	113
R-squared	0.09	0.08	0.09	0.09

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

TABLE D1: Structural specification with varying convergence rates
All regressions have country and year fixed effects. [t-1] indicates the one-period lag of the variable.