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Are Natural Disasters Good for Economic Growth?

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Abstract

Natural disasters plague the populations of many countries, and the international community often seeks to alleviate the human suffering by means of humanitarian aid. Do natural disasters also have negative effects on aggregate economic growth? This paper shows that natural disasters on average have a positive association with subsequent economic performance. This overall positive association is driven by the experience of democratic developing countries that receive humanitarian aid.

Keywords: natural disasters, economic growth, humanitarian aid

JEL-codes: O11, Q54, H84

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1 Introduction

In the early afternoon of May 12, 2008, a powerful earthquake caused mayhem in Chengdu, the capital of the Chinese province of Sichuan. The epicenter of this Richter's scale magnitude 8.0 earthquake (henceforth M8.0), was 80 kilometers west-northwest of the city. Tremors were reported as far away as Shanghai, at a distance of 1,700 kilometers. 15 million people lived in the affected area, and 70,000 was killed. In stark contrast to the human suffering, the Chinese GDP was expected to grow by an additional 0.3 percentage points as a consequence of the earthquake, according to official estimates made by the State Information Center of China, a Chinese government policy think tank.

Natural disasters are events such as floods, windstorms, extreme temperatures, wildfires, droughts, earthquakes, tsunamis, and volcanic eruptions. The main common feature of these events, that separates them from other forms of disasters, is that they are triggered by hazardous natural events. Natural disasters are often equated with heavy losses and human suffering. From that perspective, the possibility of positive growth effects seems counterintuitive. There are, however, good reasons not to expect all natural disasters to cause macro-economic losses. Disasters can give a boost by attracting new resources to a country, incentivize increased efforts in unaffected areas, or by allowing a more rational infrastructure to be built.

The existing literature on the economic effects of natural disasters is not conclusive - some studies find that growth after natural disasters is slower, others the exact opposite. There is even disagreement about whether the emerging consesus in the literature is that the effects are on average positive (Crespo Cuaresma et al. 2008), or negative (Cavallo and Noy 2010). This disagreement may be partly explained by inadequate attention to the apparent endogenous nature of natural disaster losses.

This paper investigates the effects of natural disasters on aggregate economic growth from 1965 to the present. We first provide a brief informal analysis of key methodological issues in previous studies, and how these may have biased the results. In the subsequent empirical analysis, we take particular care to maintain a representative sample, to control for unobserved heterogeneity, and to address endogeneity.

This paper contributes to the literature by showing that there is a positive association between natural disasters and subsequent economic performance, in the short run, in the medium run, and in the long run . A significant methodological contribution is that we identify instruments that can be used to address potential endogeneity in analyses using reported natural disasters data from sources such as EM-DAT (2010). This approach allows us to conclude that the positive long-term effects of natural disasters are *causal*. We propose that the overall positive association is driven by the dynamics in democratic developing countries, and that the inflow of humanitarian aid is a key factor in determining when natural disasters can result in such positive effects. The effect in developed countries is neutral.

The rest of the paper is organized as follows. Section 2 presents the findings, theory, and empirical methods used in previous research, and outlines the empirical framework later used in the present paper. After a discussion about what natural disaster are in Section 3, Section 4 further describes the empirical strategy, the data, and presents the empirical results. Section 5 concludes the paper.

2 Previous research

2.1 Findings

At present, there is no agreement in the literature on neither the size or the sign of the effects of natural disasters.[1] The modern literature on the economic effects of natural disasters started with Albala-Bertrand (1993). Using a small sample of countries that had experienced natural disasters, he found a mild positive effect, but only in the short run. More recently, Skidmore and Toya (2002) also find positive effects, but now on long-run growth. They argued that the cause of these positive effects was gains from Schumpeterian creative destruction, a mechanism which is explicitly examined, and refuted, by Crespo Cuaresma et al. (2008). The most solid of the recent slate of studies is Loayza et al. (2009), and they find no significant medium-run effects of disasters in general. Depending on economic sector and disaster type, the effects can even range from positive to negative, and while moderate disasters may have a positive effect on some economic sectors, severe disasters generally do not. Exactly how, or why, this is the case is left unexplained. A study strongly advocating that the growth effects of natural disasters really is negative is Noy (2009). He finds that natural disasters hurt growth in the short term but have almost no effect in the long run. The negative effects of disaster damages apply only to developing countries, while the effects in the OECD sample are positive. The idea that developing countries may be more sensitive is supported by findings in Loayza et al. (2009).

A strand of the literature is focused on extreme events, and here the finding is typically that natural disasters have negative effects on the aggregate economy. Looking at the effects of very large natural disasters in low-income economies, Raddatz (2007) finds that climatic and 'humanitarian' disasters have diverse effects but that geological disasters do not. However, using a similar method, Melecky and Raddatz (2011) find no average effects on output, even from large natural disasters. Cavallo et al. (2010) study the impact of a limited set of very severe disasters and compare them with similar country-years where no disaster occurred. Only extremely large disasters have negative output effects, and then only when followed by political turmoil. The results in Cavallo et al. (2010) and Melecky and Raddatz (2011) are interesting in that they find that even the negative effect of very serious disasters lacks robustness, thus questioning the results in Loayza et al. (2009).

2.2 Mechanisms

Several possible mechanism behind these contradicting empirical patterns have been discussed in the literature. The treatment is mostly informal, with a notable exception in Loayza et al. (2009). On one hand, disasters are in their model hypothesized to have negative effects due to adverse effects on total factor productivity and the supply of inputs. On the other hand, when more capital than labor is destroyed, implying a lower capital to labor ratio, countries are shifted further from their steady states. Short-term growth should result as the return to

[1] The present lack of agreement on both size and sign of the growth effects of natural disasters is well reflected in the following quotes. "Most of the research [on the short-run response to natural disasters] tends to find that gross domestic product (GDP) increases after the occurrence of a natural disaster" (Crespo Cuaresma et al., 2008). "[...] the emerging consensus in the literature is that natural disasters have, on average, a negative impact on short-term economic growth" (Cavallo and Noy, 2010).

capital is higher.

In a like-minded, but informal discussion, Melecky and Raddatz (2011) agree that a destruction of capital reduces the amount of output that can be produced given the amount of labor. They add that there can be positive effects on the incentive to work as people are intertemporally poorer. If there is an increase in government spending, and the multiplier is large enough, the overall effect on output can be positive.

Cavallo et al. (2010) discuss possible effects using a wider set of standard growth theories. In traditional neoclassical models, similar to the one in Loayza et al. (2009), technology is independent of capital. Disasters that destroy physical or human capital push countries further from their steady-states and can for that reason positively affect growth. The results are more complex in endogenous growth models. When these incorporate increasing returns to technology in production, the destruction of capital can have lasting negative effects. If constant returns to scale are assumed, the effect is no change to the growth rate. Further, in models with Schumpeterian creative destruction, the effects can be positive as disasters force upgrading and allow for re-optimization of capital and infrastructure.

In addition to these arguments, which are standard in the literature, a distinction that deserves attention is the relative effect on the disaster zone and on other areas in the country. The disaster zone can experience a costly disruption of economic activities. In contrast, the need for assistance and reconstruction can lead to increased economic activity in areas outside the disaster zone. The sign on the net effect on the national level can be either negative or positive. A related mechanism is that idle capacity in unaffected areas can substitute for production in the disaster zone to at least limit the negative effects on the national level.[2]

Insights can be drawn from the literature on natural disasters and conflict. Most empirical studies find that natural disasters make violent conflict more likely (Nel and Righarts 2008). This would suggest mostly negative effects on economic performance. However, according to another prevalent view, some natural disasters contribute to defuse tensions. They do so by binding people to a common fate. When everyone share a goal of successful reconstruction, previous disagreements may seem relatively unimportant (Schubert et al. 2007). If natural disasters can unite societies and allow the social and political system to focus on what is good for society as a whole, then overall economic performance could improve as well.

To sum up, the potential mechanisms pointing to a negative effect include the destruction of factors of production, which lowers productive capacity, the destruction of supporting infrastructure, which lowers returns to remaining factors of production, and political instability, which reduces the incentives to invest and produce. Positive effects are to expect from the local demand for assistance and reconstruction, whereby production in surrounding areas increases, a process of unification or reconciliation, which increases investment and production via reduced uncertainty and a more positive outlook, an inflow of international aid and increased attention, and, finally, creative destruction. The last of these point to the possibility of building a more rational infrastructure or industrial structure. The fact that destruction precedes construction has lead to expectations that natural disasters should be associated with recessions in the short-run

[2] In a study of the economic consequences of the 1995 earthquake in Kobe, Japan, Horwich (2000) finds such effects at work. Part of the reason that the effect on Japan's economy was modest was that there were other regions with idle capacity.

but positive effects later on.

A growing literature focuses on what determines the direct losses in natural disasters. It has been found that rich countries report fewer deaths and lower economic and human losses, even if they do not experience fewer or weaker natural disasters (Kahn 2004, Strömberg 2007, Toya and Skidmore 2007). The reason is that they can afford better housing, warning systems, medical care, and evacuation plans (Strömberg 2007).

It is less clear whether losses are lower in countries with more solid democratic systems, even if that is what one would expect *a priori*. On the one hand, Kahn (2004) and Toya and Skidmore (2007) find that losses are lower in countries that are more democratic and have better institutions. On the other hand, Strömberg (2007) finds that the number of killed is actually higher in more democratic countries, once government effectiveness is held constant. He suggests that this can be explained by more complete reporting by democracies.

2.3 Empirical Frameworks in the Literature

The great variation in results in the studies of the growth effects of natural disasters can be explained by particular choices of empirical methods, samples, and natural disaster indicators.

An important distinction is that between what we can call *event* indicators and *loss* indicators. Event indicators capture the number, or the incidence, of natural disasters. These indicators are sometimes normalized by country size (area). Loss indicators capture the number of affected or killed, or the direct economic damages. These are typically normalized by country size (population or GDP). The loss indicators are heavily skewed, a problem that is sometimes addressed by including them in log form. In some cases, loss data is used to construct new event indicators, e.g., by counting the number of disasters over some threshold level of severity.[3] Studies that use loss indicators or indicators of severe disasters more often tend to find negative effects of natural disasters than studies that use event indicators.[4] This could reflect non-linearities in the true effects, or that endogeneity is a more serious problem when loss indicators are used. I return to this topic below.

There is clearly a lack of consensus also about the most appropriate econometric method. The techniques range from standard cross-sectional ordinary least squares (Skidmore and Toya 2002), to panel vector autoregression (Raddatz 2007, 2009, Melecky and Raddatz 2011), Hausman-Taylor random effects (Noy 2009), system-GMM (Loayza 2009), and "comparative case studies"

[3] Noy (2009) uses loss indicators, mainly damages, as a fraction of GDP, and finds negative effects on growth. Ramcharan (2007) uses a dummy for if a windstorm occurred, and the value of the magnitude if an earthquake occurred. Raddatz (2007, 2009), on the other hand, uses the number of very large natural disasters weighted by area. Toya and Skidmore (2002) use the frequency of natural disasters over the period from 1960 to 1990. Anbarci et al. (2005) have a limited list of earthquake that caused a disaster, and use magnitude as their indicator. Loayza et al. (2009) use combinations of event and loss indicators, where events are disasters in which the number of killed plus 0.3 times the number affected amounts to more than 0.01 percent of the population. As 'severe' they code "the top 10% of natural disasters according to intensity" (Loayza et al. 2009:24). What intensity refers to, or if '10%' refers to the full sample, the sample of recorded disasters, or the sample of distasters where data on severity is actually available is not specified.

[4] It is not uncommon that the sample is constrained along the key independent variable, see, e.g., Raddatz (2009) and Hochrainer (2009). Different methods are used, but they all imply that countries in which, for whatever reason, there are no hazardous natural events, or where the society is capable of limiting the effects to be below the threshold used by the author, are systematically dropped from the sample. The validity of this approach rests on the strong assumption that the macroeconomic effects are orthogonal to the incidence of natural hazards, to disaster preparedness, and to the response capacity of the society in which the event takes place.

(Cavallo et al. 2010). These techniques are similar in only one important aspect – their validity rest on the assumption that natural disasters are exogenous to economic development.[5]

Sometimes the argument is first made that natural disasters can be viewed as exogenous events, and then the empirical analysis employs a large set of control variables that effectively limit the potential sample, see, e.g., Loayza et al. (2009) and Noy (2009).[6] If these smaller samples are representative, and under the exogeneity assumption, the reduction in sample size only leads to unnecessarily imprecise estimates. However, if the inclusion of these control variables, that mostly capture macroeconomic characteristics, systematically discriminate against certain types of countries, or countries temporarily under certain forms of stress, the estimates can be severely biased. Though rarely explicitly stated, a high number of control variables is motivated by concerns about an omitted variables bias. If natural disasters were truly exogenous events there would be no omitted variables bias in the estimate for natural disasters. As that assumption is generally made, implicitly or explicitly, the controls could be dropped. The analysis could instead be made on a more representative sample.

2.4 Empirical Framework

The empirical framework used in this paper was chosen to address a few key methodological problems in previous studies. First, since there are more severe disasters in poor countries, standard OLS estimates will have a negative bias. As a partial solution, the time-invariant component of this effect is removed.

Second, a standard assumption is that natural disasters can be treated as exogenous. The event indicators are clearly less problematic in this respect than are the loss indicators. For instance, high magnitude earthquakes become reported natural disasters in most inhabited areas, but they have severe effects, with high values on the loss indicators, only in *vulnerable* societies. This motivates the use of event indicators, and when these are used the omitted variables bias will be less serious than if loss indicators were used. When the potential omitted variables bias is less of a problem, there is less need to include a wide set of sample size-limiting control variables. For this reason, and in order to maintain a sample that is as representative as is possible, most specifications will include only a limited number of key control variables.

To address endogeneity directly, one can use in instrumental variables estimations. The main difficulty with that approach is always to find instruments that are informative and valid. The analysis in this paper uses data on seismic events, the natural shocks that trigger earthquakes and other geophysical disasters.[7]

[5] Some studies, such as Hochrainer (2009) and Cavallo et al. (2010), attempt to solve the identification problem by constructing artificial counterfactuals. Yet, since 'synthetic control groups' are just that, synthetic, it does not matter how inventive the empirical technique is. The analyses rely on real world data in which no true control group exists.

[6] In the case of Loayza et al. (2009), to less than half of the economies in the world. The effect on Noy's (2009) sample is more unclear, but it is evident that a majority of the possible country-years are excluded.

[7] Note that this strategy is completely different from the use of alternative indicators, such as the windspeeds or the Richter scale magnitudes of listed natural disasters, as it is done in, e.g., Anbarci et al. (2005) and Noy (2009). The fundamental problem with these indicators is that they are only included when a natural disaster is reported. High windspeeds or seismic events that did not result in a disaster are not included.

3 Natural Disasters

The popular preconception that natural disasters *must* have a negative effect on growth is perhaps a consequence of the character of the few natural disasters that make international headlines. Those disasters are unusually destructive. They are rare and atypical events. Yet natural disasters are not rare phenomena. In any given year between 1990 and 2008, two-thirds of all countries experienced at least one natural disaster, as defined by EM-DAT (2010). The average number of natural disasters reported was 2.3 per year. The average number of people that required immediate assistance was 1,5 million people per country and year or, as a share of the population, 1.6 percent.

To see why the *number* of natural disasters, in general, and the number of geophysical disasters, in particular, are appropriate indicators for natural disasters, the data must be described in more detail.

3.1 Reported Natural Disasters

The widest collection of data about natural disasters is the EM-DAT (2010) database. An absolute majority of the studies in the field use this as their primary source of data. To be included, events must meet at least one of following criteria: 10 or more reported killed; 100 people reported affected (in need of immediate assistance); a declaration of a state of emergency; or there is a call for international assistance. The sources are mainly United Nations agencies, non-governmental organizations, insurance companies, research institutions, and press agencies.

Natural hazards, that can become natural disasters in vulnerable environments, are in the EM-DAT (2010) database divided into five main categories. In order of decreasing frequency, these are hydrological (floods, wet massmovements), meteorological (windstorms), biological (epidemics, insect infestations), climatological (extreme temperatures, wildfires, droughts), and geophysical (earthquakes, including tsunamis, volcanic eruptions, dry massmovements).[8]

Data from EM-DAT cannot be used investigate the economic effects of natural disasters without problems. Strömberg (2007:201) finds systematic differences in reporting "across time, level of income, and political regimes." He correctly notes that this complicates assessments of what role such societal characteristics play for the direct natural disaster losses. Furthermore, there is a clear risk that governments exaggerate damages in order to attract more humanitarian aid. Section 4.3 expands on the issue of possible over- and underreporting in EM-DAT.

3.2 Seismicity

The instrumental variables used in this study build on seismic data. Seismic activity cause earthquakes, whose location and timing still cannot be predicted. It is also the primary natural cause of secondary event, such as tsunami, and it can trigger both volcanic eruptions and dry massmovements.

[8] A natural disaster is "a severe disruption in the functioning of a society, with far-reaching humanitarian, material, economic or environmental damage that exceeds the coping capacity of the society in question" (Schubert et al. 2007:236).

4 Empirical Analysis

The sample consists of 157 countries and covers the period from 1965 to 2008.

4.1 Natural Disaster Indicators

The main *event* indicator, *Natural disasters*, reflects the number of reported events of all types of natural disasters. The other event indicator used, *Geophysical disasters*, captures the number of geophysical disasters, which includes earthquakes, tsunamis, volcanic eruptions, and dry massmovements. Both indicators are drawn from EM-DAT (2010). The *loss* indicators *Natural disasters: Affected* and *Natural disasters: Killed* indicate the reported number of affected or killed as a fraction of total population. *Natural disasters: Damages*, also a loss indicator, captures disaster damages as a fraction of total GDP. All loss data for these variables are drawn from EM-DAT (2010). In the following discussion, I have coded cases where no losses were reported as zero losses.

The loss indicators are, at best, noisy indicators of actual losses. They can even be directly misleading, as there are indications of systematic under- and overreporting. Underreporting is an obvious problem in the EM-DAT data. Between 1965 and 2008, the number of people killed as a percentage of population was *zero* in 21 percent of the observations where a natural disaster is reported. The number of people affected in percent of the population is zero for 16 percent, and economic damages in percent of GDP is zero for 52 percent of the observations with a positive amount of disasters reported. This as an indication, not that there are natural disaster with zero damages, but that there is a lot of missing information. That is, many if not most of the zeros that any study using these indicators would bring into the empirical analysis would be instances of missing data, rather than true zeros.

Data can be missing for the simple reason that no one really knows the number of dead or the amount of damages. Another issue is deliberate *over*reporting. The 2010 Haitian earthquake can serve as an example. News agencies have reported about a draft report commissioned by the US government concluding that there may have been gross overreporting of losses. This is not disputing the fact that many lives and much property was lost, but it illustrates how official estimates can be seriously misleading.[9]

4.2 Indicators of Seismicity

Data on the timing, magnitude, and location for seismic events with a magnitude of 5.5 or more comes from Allen et al. (2009), a comprehensive list of global seismic events. The most well-known measure of an earthquake's size is its magnitude on Richter's magnitude scale. This scale can be used to order earthquakes of different sizes, but it is not a measure of their destructive potential. The indicator of seismic events used in this paper is designed to capture the potential damages to man-made structures. This variable, TNT, is an estimate of the seismic

[9] The conclusions in this report was that "Reported casualties and economic damages may be greatly exaggerated," that the "death toll [is] between 46,000 and 85,000 while Haiti's government says about 316,000," that "many of those still living in tent cities did not lose their homes in the disaster, " and that there was "significantly less rubble around the country's capital than previously thought" (BBC 2011).

energy released by all seismic events in TNT equivalents.[10] It should be noted that TNT is an approximation that does not take local surface and subsurface conditions into account.

4.3 Event vs. Loss Indicators

The loss indicators most relevant from a resource perspective are *Natural disasters: Killed* and *Natural disasters: Damages*. The number of killed directly affects human capital. Damages directly affects the capital stock. The distributions of these indicators are shown in Figure I, where the 5,243 observations in the yearly sample used to estimate the specification in Column 1, Table III, are ordered horizontally in order of increasing severity or frequency. These variables are heavily skewed, and the loss indicators more so than the event indicator.

A relatively small number of very serious disasters drag the means on the loss variables up to well above the medians. How extreme these rare events are in relation to median losses becomes apparent in a comparison of maximum values and values at the 99th percentile. As reported in Table I, the maximum share of the population killed is *40 times* higher than the share killed at the 99th percentile.

[Figure I about here]

The median values in subsamples limited to observations with positive values reported in EM-DAT are listed in Table II. A good majority of all natural disasters cause relatively few deaths, and result in relatively limited damages. Among countries that report a natural disaster, less than a tenth of a percent of the population is affected, a share of 0.0001 percent of the population is killed, and damages are zero percent of GDP (all figures are sample medians). This is in countries that *have* a natural disaster. The numbers are somewhat higher for countries where positive losses are reported. For instance, median economic damages in countries where damages are reported is 0.05 percent of GDP. An obvious question to ask is what effect on the aggregate economy one should expect from such losses. Is it reasonable to expect relatively moderate losses to have strong effects on aggregate economic performance?

[Table I about here]
[Table II about here]

Suppose natural disasters could be understood from a purely fiscal perspective, where deaths only affected human capital (population size), and damages only affected physical capital. First, consider physical capital. Under the assumption that the capital stock in our sample is on average twice that of annual GDP, simply divide the damage indicators, presented in Table I and II, by two to get a rough estimate of the effect on the capital stock.

[10] The rule of thumb is that an M4.0 earthquake releases seismic energy corresponding to the energy released by the underground explosion of a thermonuclear bomb with a power equivalent to 1 kiloton of the conventional explosive material TNT (trinitrotoluene). According to the *Gutenberg-Richter magnitude-energy relation*, each unit higher magnitude is associated with 32 times more seismic energy being radiated. Hence, the energy radiated by an M6.0 (M8.0) earthquake corresponds to 1 million (1,000 million) kilograms of TNT.

At the 99th percentile, with 52 country-years with more serious damages, the damages add up to slightly less than one percent of the capital stock. This could affect aggregate growth, but a country needs a only a one-year boost of two percentage points in the investment rate to completely offset such damages. Second, human capital. The average annual population growth in the sample is 1.9 percent. The median loss in life in countries that experience a natural disaster is 0.0001 percent, and at the 99th percentile in the full sample the loss is 0.022 percent of the population. These figures represent considerable human suffering, but would not make more than a tiny bump on the growth of the human capital stock.

One should not without further justification expect these costs, in terms of human life and damages to capital and buildings, to drastically weigh down aggregate economic performance. If one nevertheless finds significant effects, one should consider understanding natural disasters as discrete social and political events that affect economic performance through social and political mechanisms.

In this paper, the main indicators of natural disasters are the number of events. This have several advantages. First, the number of events is a less skewed variable than are indicators that relate losses to the size of the population or total production. As such they will give more precise estimates. Second, the number of reported events is probably a less noisy indicator of the actual number of events, than, say, the reported number of killed is of the actual number of killed.

Third, endogeneity will be a smaller problem with event indicators. Losses are greater in poorly functioning countries. When economic growth is regressed on a loss indicator, the estimate will therefore suffer from a negative bias. This source of bias, which may explain some of the strong negative results in the literature, can here be avoided with the use of event indicators.[11] Fourth, there are exogenous instruments for the number of events, based on seismic data, that can be used to infer a *causal* link from natural disasters to growth.

The final argument in support of using event variables for this study is that one of the main argument in favour of the loss variables is not a very good argument. The argument in favor is that loss indicators separate more serious events from less serious events. Given that losses are typically in the order of mere fractions of a percent of the population or national income, there is no obvious reason why they should be linearly related to aggregate economic growth.

4.4 Regression Analysis

The multivariate analysis starts with an estimation of the following dynamic econometric model,

$$y_{it} - y_{it-1} = \alpha y_{t-1} + \gamma D_{it} + \mathbf{x}'_{i,t-1}\boldsymbol{\beta} + \nu_t + \mu_i + \epsilon_{it},$$

where y_{it} is log income per capita in country i in period t. Since this makes the model dynamic, fixed effects OLS results would suffer from a dynamic panel bias. In longer panels, as the one we have in the yearly sample with 43 periods, this problem is limited. In shorter panels, which we have when we estimate this model using 2-year and 5-year panel data samples, it can be more problematic. For this reason, we check the robustness of the results with

[11] As already mentioned, there are less losses in rich countries, even if they do not experience fewer natural disasters. A full investigation of the distribution of events and losses is beyond the scope of this paper.

two consistent estimators, an Anderson-Hsiao IV estimator (Anderson and Hsiao, 1982) and a difference-GMM estimator (Arellano and Bond, 1991). Our main interest lies in the estimate of D_{it}, the number of natural disasters during t. The other key covariates are included in the vector $\mathbf{x}$; international trade as a fraction of GDP (*Openness*), government expenditures as a fraction of GDP (*Government Size*), and Polity IV's main combined democracy indicator (*Polity2*). ν_t represents time fixed effects, μ_i country fixed effects, and ϵ_{it} is an error term.[12] More detailed variable descriptions can be found in the Appendix.

In Table III, we use yearly data. Disasters in the present year have no effect on the aggregate income level. The coefficient for natural disasters becomes significant only in the year after the disasters have taken place, and it is then positive, not negative. Though this is not the first finding of a positive association between economic growth and natural disasters, the results are remarkable as they are visible already in the short-run, and among a representative group of countries.

Natural disasters are neither unpredictable nor random events, even if countries differ greatly in their natural vulnerability. The fixed effects results in Columns 1 to 3 estimate the role of within-country variation in the number of disasters, so the results should not be driven by between-country differences in disaster exposure and preparedness. What they show is not that exposed countries always grow faster, but that they grow faster at times when they experience natural disasters. A relevant question is whether we would find the same association when we included both within and between-country variation. The last column estimates a model where the country fixed effects, μ_i, have been dropped. The pooled OLS estimate is weaker than the fixed effects effect, but it nevertheless shows that on average, one can expect a significant positive association between economic growth and lagged natural disasters.

[Table III here]

Given that natural disaster in the present year neither have a significantly negative or significantly positive association with present income, while lagged disasters have a positive one, it is natural to ask whether the total short-run association over these two years also is positive. Table IV answers that question. *Natural disasters*$_t$ still captures the number of reported natural disaster events during period t, with the difference compared to Table III being that t is a two-year period. *Log GDP per capita*$_t$ is the end of the 2-year period income level. The positive association is significant both in fixed effects and pooled OLS. Since the number of periods is lower than in the yearly sample, it becomes necessary to address the dynamic panel bias. Column 3 does this with an Anderson-Hsiao IV estimator and Column 4 uses the more efficient Arellano-Bond difference-GMM estimator. In both cases, I find that the estimates are slightly lower than the fixed effects result, but they are still positive and statistically significant. Based on the findings presented in Tables III and IV, we believe one must accept that the short-run association between natural disasters and economic growth is positive on average.

[12] In the pooled and fixed effects OLS estimations, two-way clustered standard errors are used when possible, and then serial autocorrelation adjusted for when found. The Anderson-Hsiao and dynamic-GMM estimates use robust standard errors, in the latter case with Windmeijer correction.

[Table IV here]

[Table V here]

In Table V, the specifications in Table IV are reestimated on a 5-year sample, thus capturing the medium-term association between natural disasters and economic growth. *Natural disasters*$_t$ is the number of disasters during the present 5-year period, and *Log GDP per capita*$_t$ is the end of the five-year period income level. . The results are quite similar to those presented in Table III, with the execption of the pooled OLS estimate that is considerably lower. The fixed effects OLS, the Anderson-Hsiao IV estimate and the difference-GMM estimate are slightly stronger in the 5-year sample than in the 2-year sample, which suggests that the positive mechanisms dominate the negative mechanisms even more when we move to longer time horizons. The longest time horizon possible is the full 43 year period from 1965 to 2008. Table VI presents cross-sectional results for the 80 to 87 countries for which we can track all key variables over the whole period. Naturally, these results cannot address unobserved heterogeneity between countries.[13] With this caveat, we observe that the association between natural disaster events and economic growth is here even stronger than in both the short- and the medium-run. Over time, it appears that countries that suffer from more natural disasters actually do better than countries that suffer from less natural disasters. This is not disputing that natural disasters have many negative outcomes, it merely shows that the average effect on economic growth does not seem to be one of them.

[Table VI here]

4.5 Instrumental variables results

We have argued that loss indicators are endogenous, which makes results using such indicators unreliable, but also that endogeneity is less of a problem when one uses event indicators. To use event indicators does not completely remove the threat to identification posed by reversed causality (simultaneity). There is good reason to expect some endogeneity in all indicators of reported natural disasters as hazardous natural events are more likely to become natural disasters in vulnerable environments with, e.g., a lack of democracy, poor institutions, or low income levels. These are all factors that affect income via channels other than natural disasters. If more natural disasters occur in countries with low levels on factors that are good for growth, then also fixed effects estimates will have a negative bias. Problems with over- and underreporting tells us that *Natural disasters* is an imperfect indicator of all relevant natural events. The logical next step is to instrument for disaster events, which we can do for a subset of *Natural disasters*, namely *Geophysical disaster*.[14] The instrumental variables procedure used here involves using seismic

[13] I add the additional control variables *Log area*, the log of the physical size of the country, and *Latitude*, the distance from the equator, to the cross-section specifications to somewhat reduce this problem.

[14] For a general critique on the use of instruments, see Deaton (2010).

data to instrument for reported geophysical natural disasters.[15] At a first approximation, seismic events are most closely tied to the number of earthquakes, yet they can cause also tsunami, dry massmovements, and can trigger volcanic eruptions. Together these disasters make up the category geophysical natural disasters.

[Table VII here]

[Table VIII here]

The instrumental variables results are presented in Tables VII, which uses two-year data, and VIII, which uses cross-sectional data. The results are mixed. When not instrumented for, *Geophysical disasters* have a positive association with income in the two-year panel. This relationship completely disappears when we use our indicator of destructive potential of seismic events (*TNT*) to instrument for reported *Geophysical disasters*. In principle, this could be because the effect is not identified, in the sense that the first stage fails due to weak instruments, or because there is no short-run effect of geophysical natural disasters on income per capita, once endogeneity is properly addressed. The fact that *TNT* is highly significant in the first stage and the first stage F-value is decent is, albeit not conclusive, evidence in favor of the latter interpretation. That is, on average there really is no, positive or negative, short-run effect of geophysical natural disasters. Since the results using (not instrumented) *Natural disasters*, see Table IV, indicated a positive association with income, we conclude that the average effect of natural disasters probably lies in the range of positive to none. Importantly, we find no evidence of a negative short-run effect.

The cross-sectional IV results in Table VIII, tell us that the long-run the effects are positive, and stronger than what standard cross-sectional OLS would suggest. In Column 3 of Table VIII, we remove all countries that had no seismic activity between 1965 and 2008 to ensure that the instrument does not simply capture differences between countries with and countries without seismic activity. We add the indicator of destructive potential (*TNT*) directly in Column 4, and find that countries with more seismic activity gained economically during this period. In contrast to the results from the two-year panel, the cross-section IV results fully support the standard cross-section results - countries that experience more natural disasters grow faster in the long run.

4.6 Mechanisms

The emprical framework prevents us from separating out the effects of disasters that have more severe consequences in terms of direct losses. The results reflect the *average* effect of disasters over the full range of disaster destruction, from truly devastating wide-ranging disasters to disasters with limited consequences.[16] Although a full analysis of the potential mechanisms

[15] The key difference between the number of geophysical disasters listed in the EM-DAT, and indicators of seismic events, is that the former is an endogenous variable while the latter is not.

[16] Under the assumption that some disasters may have a negative effect on economic growth, the positive effects of other disasters must be even stronger than the estimated coefficients suggest.

behind these averages is beyond the scope of this paper, we propose that a key explanation can be a positive interaction with the inflow of emergency and distress relief from international donors. The definition of the key variable *Humanitarian aid* is, following OECD-DAC (2010), the per capita amount of "emergency and distress relief in cash or in kind, including emergency response, relief food aid, short-term reconstruction relief and rehabilitation, disaster prevention and preparedness."

Earlier studies using loss indicators tend to find that the *negative* effect is stronger among developing countries (Noy 2009). We argue that the endogeneity introduced by loss indicators may explain such findings. Here, where an econometrically less problematic event indicator is used, it appears that the *positive* association between natural disasters and economic performance is only found among developing countries. In Column 1, only industrialized (OECD) countries are included in the sample, and there is no significant relationship between natural disasters and income. In Column 2, only developing countries (non-OECD) are included, and then the effect is much stronger than in the full sample (compare with Column 4, Table V).

The lack of significant results in OECD countries may be because industrialized countries also tend to have more solid democracies, a factor known to be associated with, e.g., more investments in disaster prevention. In results not shown, the full sample was split into observations with democracy (a lagged Polity2 greater than or equal to zero) and observations without democracy. The estimates for *Natural disasters* was insignificant in both samples. A reason for this could be that the democracy sample contains both industrialized democracies and democratic developing countries, and the effect of natural disasters is not homogenous over this division. This becomes apparent when we make a further split of the non-OECD sample in Columns 3 and 4 along the same democracy dimension. The positive association is limited to democratic developing countries.

[Table IX here]

The potential mechanism most clearly in the hands of the international community is that of humanitarian aid. More disaster relief (in absolute terms) goes to poorer countries that are hit by disasters with a higher number of people affected or killed (Strömberg 2007). Democracies are more open in general, more available for an inflow of international aid and assistance, and also receive humanitarian aid more often than non-democracies. It is also likely that a larger fraction of the inflow goes to the right things in democracies, rather than disappears in the form of corruption. We propose that the inflow of humanitarian aid, and the associated international attention, is a key factor to understand why the natural disasters are positively associated with subsequent economic performance only in democratic developing countries.[17]

Before we add humanitarian aid directly in Columns 5 and 6, we separate countries not receiving humanitarian aid in the previous period from countries receiving humanitarian aid. All else equal, countries that recieved aid in the previous period should be more likely to do so

[17] For insightful discussions on the components of humanitarian aid, see Strömberg (2007) and Fearon (2006).

also in this period when they suffer from a natural disaster.[18] Donors are more likely to have a functioning system for providing assistance already in place, and political obstacles to providing aid are arguably less of a problem for these countries. To split the sample on past rather than present aid inflow is a way to reduce potential endogeneity caused by such a sample split. The result is clear - only if there was an inflow of humanitarian aid in the last period is the estimate significant. This is an indication that the positive association between natural disasters and economic performance in democratic developing countries is because they are more likely to receive humanitarian aid. It could be this inflow of humanitarian aid that makes the net effect positive.

When we add humanitarian aid as well as an interaction term directly to the sample of democratic developing countries, only the interaction between *Natural disasters* and *Humanitarian aid per capita* is significantly positive. With the caveat that this does not settle causality, this illustrates that perhaps neither disasters nor aid inflows have a positive effects on income on their own, but jointly they do. Natural disasters appear to boost economic performance if followed by more aid, or, perhaps, natural disaster are good for the overall economy only because they attract foreign aid. If either of these interpretations are correct, countries shocked by natural disasters can improve their economic performance when they are assisted by the international community. It is worth emphasizing that this result holds in the the sample of democratic developing countries, but that it cannot be generalized to the full sample.

To sum up, the positive association between natural disasters and income per capita is stronger among non-OECD members and especially among democratic non-OECD members. The positive association is *only* found among countries that received humanitarian aid, while there is neither a positive nor a negative association when there is zero inflow of humanitarian aid.

[Table V about here]

5 Concluding Remarks

Natural disasters can be terrible events. In already poor countries, thousands die each year in natural disasters, and considerable amounts of physical capital are destroyed. The international community often seeks to help disaster victims by sending humanitarian aid. It is worth asking whether more aid can be motivated also with reference to the negative growth effects of natural disasters. In this paper, we provide evidence to the contrary. The focus is on keeping the sample as representative as possible, to avoid including too many control variables, and to embrace endogeneity rather than assume exogeneity.

Natural disasters in general, and geophysical disasters in particular, are not associated with poor economic performance. In fact, countries hit by natural disasters tend to have higher incomes, both in the short-, medium, and long-run. The long-run effects are both stronger and

[18] Since the specifications are estimated with difference-GMM, the results are not driven by systematic time-invariant differences between countries. Also, in the sample used here, there is no indication that the inflow of humanitarian aid (in relative terms) is determined by the severity of disasters. The five-year sample correlations between *Humanitarian aid per capita* and all three loss indicators (*Affected*, *Killed*, *Damages*) are practically zero and far from significant. I conjecture that *Humanitarian aid per capita* captures something else than the seriousness of the disaster.

causal. Economic and political development matters. Positive effects in democratic developing countries that have recieved humanitarian aid appears to be driving the overall positive association between natural disaster events and economic performance.

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Appendix

Variable Descriptions

Democracy$_{t-1}$. Indicates a Polity2-score of zero or higher in previous period.

Geophysical disasters. Number of geophysical disasters (earthquake including tsunami, volcanic eruption, dry massmovement) reported. Source: EM-DAT (2010).

Government Size. The government share of real GDP per capita. Source: Heston, Summers, and Aten (2009).

Humanitarian aid per capita. The inflow of humanitarian aid divided by population size lagged once. OECD (2010) defines this as "emergency and distress relief in cash or in kind, including emergency response, relief food aid, short-term reconstruction relief and rehabilitation, disaster prevention and preparedness. Excludes aid to refugees in donor countries." Countries for which no aid inflow is listed are assumed to have received no aid in that year. Source: OECD (2010) and Heston, Summers, and Aten (2009).

Latitude. Absolute latitude of capital (divided by 90). Source: La Porta et al. (1999).

Log area. The natural log of physical area. Source: Cepii (2010).

Log GDP per capita. The natural log of the real GDP per capita, in constant USD (2000). Source: World Development Indicators.

Natural disasters. Number of natural disaster events reported. The main natural disaster categories are hydrological, meteorological, biological, climatological, and geophysical natural disasters. Source: EM-DAT (2010).

Natural disasters: Affected. Number of persons affected by a natural disaster as a fraction of (lagged) population size. Source: EM-DAT (2010) and Heston, Summers, and Aten (2009).

Natural disasters: Damages. Estimated damages due to natural disasters as a fraction of (lagged) GDP. Source: EM-DAT (2010) and Heston, Summers, and Aten (2009).

Natural disasters: Killed. Number of killed by natural disasters as a fraction of (lagged) population size. Source: EM-DAT (2010) and Heston, Summers, and Aten (2009).

OECD$_{1970}$. Indicates that a country was a member of OECD in 1970.

Openness. Total trade (imports plus exports) as a percentage of GDP (real). Source: Heston, Summers, and Aten (2009).

Polity2. The revised combined Polity2-score. Source: Marshall and Jaggers (2002).

TNT. Annual destructive potential of seismic events during t. To avoid the influence of extreme outliers, magnitudes are capped at M8.0. Estimations are made with TNT first replaced by TNT divided by 10^9 and then included in log form. Set to -13 if $TNT = 0$ before logging, in order to retain a representative sample. Source: Allen et al. (2009).

Graphs

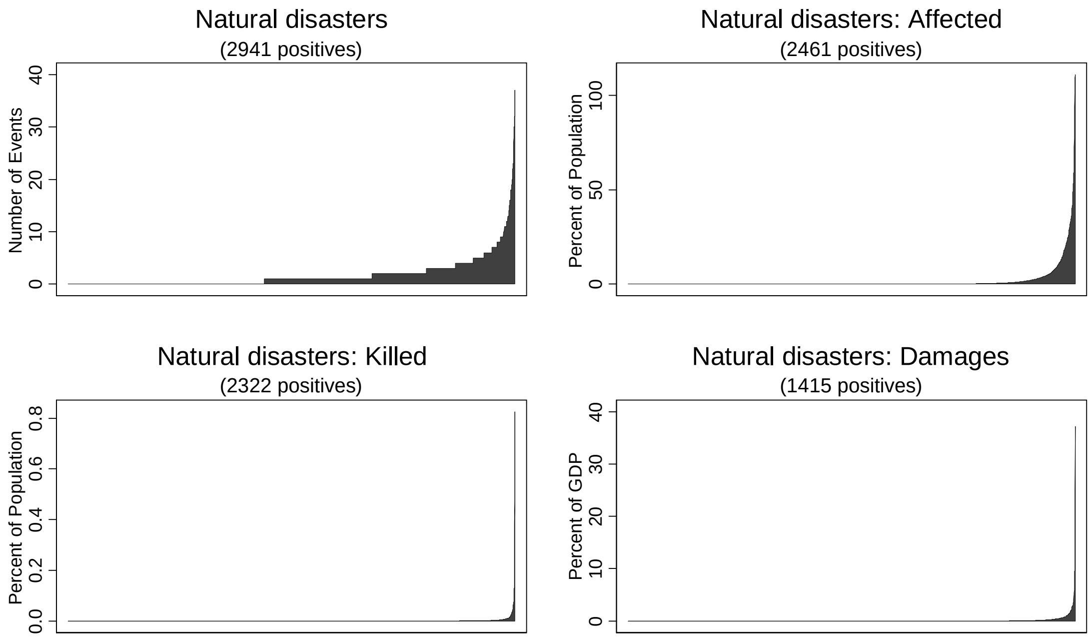

Figure I. Comparison of Natural Disaster Indicators
(The observations are ordered horizontally with increasing severity or frequency to the right)

Tables

TABLE I
DESCRIPTIVE STATISTICS
Annual data

	N	MEAN	ST.DEV.	MIN	P50	P99	MAX
Log GDP per capita	5243	7.414	1.585	4.131	7.278	10.462	10.769
Geophysical disasters	5243	0.183	0.658	0	0	3	11
Government size	5089	18.028	9.658	1.438	15.584	57.320	83.350
Latitude	5240	0.275	0.187	0	0.233	0.689	0.711
Natural disasters	5243	1.704	3.221	0	1	17	37
Natural disasters: Affected	5243	1.514	7.057	0	0	33.780	111.008
Natural disasters: Damages	5243	0.097	0.831	0	0	1.945	37.197
Natural disasters: Killed	5243	0.002	0.024	0	0	0.021	0.826
Openness	5089	71.045	46.235	7.008	59.702	215.684	456.561
Polity2	5239	1.339	7.410	-10	3	10	10
TNT	5243	-10.773	3.611	-13	-13	-0.918	0.890

Notes:

Descriptive statistics for the sample used to estimate the specification in Table III, Column 1.

TABLE II

NATURAL DISASTER INDICATORS: MEDIAN VALUES

Annual data

	Full Sample	Natural disasters >0	Natural disasters Affected>0	Natural disasters: Killed>0	Natural disasters: Damages>0
Natural disasters	1	2	2	2	3
Natural disasters: Affected	0	0.0804	0.1755	0.1037	0.2087
Natural disasters: Damages	0	0.0001	0.0002	0.0002	0.0002
Natural disasters: Killed	0	0	0.0001	0.0007	0.0473
Observations	5243	2941	2461	2322.	1415
Fraction with positive values reported when disaster(s) reported.			84%	79%	48%

Notes:

The loss indicators are expressed in percentage of the population (Natural disasters: Affected and Natural disasters: Killed) or GDP (Natural disasters: Damages).

TABLE III
NATURAL DISASTERS AND ECONOMIC GROWTH
Annual data 1965-2008

Dependent Variable	Log GDP per capita$_t$			
	(1) Fixed effects OLS	(2) Fixed effects OLS	(3) Fixed effects OLS	(4) Pooled OLS
Log GDP per capita$_{t-1\ or\ t-2}$	0.970***	0.927***	0.927***	1.002***
	(0.006)	(0.012)	(0.012)	(0.001)
Natural disasters$_t$	1.066		1.265	-0.029
	(0.728)		(1.026)	(0.511)
Natural disasters$_{t-1}$		3.105**	2.447**	1.382***
		(1.427)	(0.968)	(0.451)
Additional controls	Yes	Yes	Yes	Yes
Observations	5,240	5,237	5,237	5,276

Notes:
In parentheses are two-way (country and year) clustered standard errors, robust to arbitrary autocorrelation. *** / ** / * indicate p-values below 0.01 / 0.05 / 0.1. Unreported constants, time fixed effects, and lagged levels of Openness, Government size, and Polity2, are included in all specifications. Specifications in Columns 1-3 (C1-C3) estimated with (linear) Fixed Effects, and C4 estimated with Ordinary Least Squares. The control variables are lagged once in C1 and twice in Columns 2-4. Coefficients and standard errors for the natural disaster variables are scaled up by a factor of 1000. Subscript t means that data represent time period t, here a one year period.

TABLE IV

NATURAL DISASTERS AND ECONOMIC GROWTH

2-year data 1966-2008

Dependent Variable	Log GDP per capita$_t$			
	(1) Fixed effects OLS	(2) Pooled OLS	(3) Anderson–Hsiao IV	(4) Arellano-Bond difference-GMM
Log GDP per capita$_{t-1}$	0.926***	1.003***	0.542***	0.593***
	(0.014)	(0.002)	(0.150)	(0.080)
Natural disasters$_t$	2.183**	1.344**	1.512*	1.812**
	(0.852)	(0.680)	(0.819)	(0.854)
Additional controls	Yes	Yes	Yes	Yes
AR (2) test				0.523
Hansen J test				0.385
Observations	2,563	2,565	2,409	2,409

Notes:

In parentheses are standard errors. In Columns 1-2 (C1-C2), two-way (country and year) clustered standard errors, robust to arbitrary autocorrelation. In C3, standard errors clustered on country. In C4, standard errors are Windmeijer-corrected appropriate for small samples. *** / ** / * indicate p-values below 0.01 / 0.05 / 0.1. Unreported constants, time fixed effects, and lagged levels of Openness, Government size, and Polity2, are included in all specifications. C1 estimated with Fixed effects OLS and C2 estimated with Pooled OLS. C3 is estimated with an Anderson-Hsiao IV estimator. C4 is estimated with Arellano-Bond's difference-GMM estimator where the first 5 appropriate lags are used as internal instruments for the lagged values of Log GDP per capita, Openness, Government size, and Polity2, while Natural disasters and the time fixed effects are is treated as exogenous variables. The instrument matrix is collapsed, as recommended by Roodman (2006).The p-value for the Arellano-Bond test for autocorrelation of the second order is reported under AR (2) test. The p-value for an over-identification test is reported under Hansen J test. If rejected, this test indicates that the instruments as a group are invalid. Coefficients and standard errors for the natural disaster variable are scaled up by a factor of 1000. Subscript t means that data represent time period t, here a two year period.

TABLE V
NATURAL DISASTERS AND ECONOMIC GROWTH
5-year data 1965-2005

Dependent Variable	Log GDP per capita$_t$			
	(1) Fixed effects OLS	(2) Pooled OLS	(3) Anderson–Hsiao IV	(4) Arellano-Bond difference-GMM
Log GDP per capita$_{t-1}$	0.795***	1.003***	0.415*	0.561***
	(0.033)	(0.001)	(0.246)	(0.119)
Natural disasters$_t$	2.543**	0.269**	2.009*	2.112*
	(1.036)	(0.135)	(1.113)	(1.126)
Additional controls	Yes	Yes	Yes	Yes
AR (2) test				0.468
Hansen J test				0.364
Observations	932	951	783	783

Notes:
In parentheses are standard errors. In Columns 1-2 (C1-C2), two-way (country and year) clustered standard errors, robust to arbitrary autocorrelation. In C3, standard errors clustered on country. In C4, standard errors are Windmeijer-corrected appropriate for small samples. *** / ** / * indicate p-values below 0.01 / 0.05 / 0.1. Unreported constants, time fixed effects, and lagged levels of Openness, Government size, and Polity2, are included in all specifications. C1 estimated with Fixed effects OLS and C2 estimated with Pooled OLS. C3 is estimated with an Anderson-Hsiao IV estimator. C4 is estimated with Arellano-Bond's difference-GMM estimator where the first 5 appropriate lags are used as internal instruments for the lagged values of Log GDP per capita, Openness, Government size, and Polity2, while Natural disasters and the time fixed effects are is treated as exogenous variables. The instrument matrix is collapsed, as recommended by Roodman (2006). The p-value for the Arellano-Bond test for autocorrelation of the second order is reported under AR (2) test. The p-value for an over-identification test is reported under Hansen J test. If rejected, this test indicates that the instruments as a group are invalid. Coefficients and standard errors for the natural disaster variable are scaled up by a factor of 1000. Subscript t means that data represent time period t, here a five year period.

TABLE VI

NATURAL DISASTERS AND ECONOMIC GROWTH

Cross-section 1965-2008

Dependent Variable	Log GDP per capita$_{2008}$		
	(1)	(2)	(3)
Log GDP per capita$_{1965}$	1.156***	1.010***	1.018***
	(0.036)	(0.050)	(0.064)
Natural disasters$_{1965-2008}$	2.885***	3.940***	4.070***
	(0.998)	(1.056)	(1.143)
Log area & Latitude	No	Yes	Yes
Additional controls	No	No	Yes
Observations	87	87	80

Notes:

In parentheses are robust standard errors. *** / ** / * indicate p-values below 0.01 / 0.05 / 0.1. Unreported constants included in all specifications. The Additional controls included in Column 3 are initial level of Openness, Government size, and Polity2. Estimated with OLS. Coefficients and standard errors for the natural disaster variables are scaled up by a factor of 1000.

TABLE VII

GEOPHYSICAL DISASTERS AND ECONOMIC GROWTH

2-year data 1966-2008, *Instrumental variables*

Dependent Variable	Log GDP per capita$_t$		
	(1)	(2)	(3)
	Fixed effects OLS	Fixed effects IV	Fixed effects OLS
		A. Fixed Effects / Second stage results	
Log GDP per capita$_{t-1}$	0.928***	0.940***	0.932***
	(0.015)	(0.021)	(0.016)
Geophysical disasters$_t$	5.542*	-12.215	
	(2.903)	(9.422)	
TNT$_t$			-1.106
			(0.853)
		B. First stage results	
TNT$_t$		0.091***	
		(0.014)	
F (excluded instrument)		43.88	
Anderson-Rubin test		0.195	
Additional controls	Yes	Yes	Yes
Observations	2,563	2,563	2,563

Notes:

In parentheses are robust standard errors. *** / ** / * indicate p-values below 0.01 / 0.05 / 0.1. Unreported constants, time fixed effects, and lagged levels of Openness, Government size, and Polity2, are included in all specifications. The specifications in Columns 1 and 3 (C1 and C3) are estimated with Fixed Effects OLS. C2 is estimated with two-step GMM with fixed effects. The Anderson-Rubin test is a weak-instrument robust test of whether the endogenous variable has a significant effect on the dependent variable. The reported figure is the p-value for that test. Coefficients and standard errors for the Geophysical disasters are in Panel A scaled up by a factor of 1000. Subscript t means that data represent time period t, here a two-year period. Geophysical disasters$_t$ is the sum of Geophysical disastersysical natural disasters per country and two-year period. TNT$_t$ is the logged sum of TNT per country and two-year period. When the sum is zero before being logged, we substitute the missing logged value with -13.

TABLE VIII
GEOPHYSICAL NATURAL DISASTERS AND ECONOMIC GROWTH
Cross-section 1965-2008, *Instrumental variables*

Dependent Variable	Log GDP per capita$_{2008}$			
	(1)	(2)	(3)	(4)
	OLS	IV	IV	OLS
		A. Fixed Effects / Second stage results		
Log GDP per capita$_{1965}$	0.950***	0.968***	0.920***	0.856***
	(0.074)	(0.073)	(0.069)	(0.099)
Geophysical disasters$_{1965-2008}$	13.823***	18.698***	14.706***	
	(3.658)	(5.359)	(4.920)	
TNT$_{1965-2008}$				43.938***
				(14.215)
		B. First stage results		
TNT$_{1965-2008}$		2.235***	3.162***	
		(0.565)	(0.766)	
F (excluded instrument)		17.27	17.05	
Anderson-Rubin test		0.002	0.006	
Additional controls	Yes	Yes	Yes	Yes
Seismic activity 1965-2008 Only	No	No	Yes	No
Observations	80	80	68	80

Notes:
In parentheses are robust standard errors. *** / ** / * indicate p-values below 0.01 / 0.05 / 0.1. Unreported constants, Log Area, Latitude, and initial level of Openness, Government size, and Polity2 are included in all specifications. The specifications in Columns 1 and 4 (C1 and C4) are estimated with OLS. C2 and C3 are estimated with two-step GMM. The Anderson-Rubin test is a weak-instrument robust test of whether the endogenous variable has a significant effect on the dependent variable. The reported figures are the p-values for that test. Coefficients and standard errors for the Geophysical disasters are in Panel A scaled up by a factor of 1000. Geophysical disasters$_{1965-2008}$ is the sum of Geophysical disastersysical natural disasters per country between 1965 and 2008. TNT$_{1965-2008}$ is the logged sum of the annual TNT per country between 1965 and 2008. When the sum is zero before being logged, we substitute the missing logged value with -13

TABLE IX
NATURAL DISASTERS AND ECONOMIC GROWTH
MECHANISMS
5-year data 1965-2005

Dependent Variable	Log GDP per capita$_t$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Arrelano-Bond difference-GMM							
Log GDP per capita$_{t-1}$	0.679***	0.565***	0.607	0.470**	0.639	0.579**	0.739***	0.642***
	(0.164)	(0.166)	(0.409)	(0.207)	(0.427)	(0.245)	(0.268)	(0.195)
Natural disasters$_t$	3.088	15.900**	9.367	14.369**	-0.117	16.645**	6.715	0.977
	(5.407)	(6.658)	(22.075)	(7.115)	(4.527)	(8.234)	(7.452)	(0.947)
Humanitarian aid per capita$_t$							381.496	160.246
							(493.915)	(325.066)
Natural disasters$_t$ × Humanitarian aid per capita$_t$							578.445**	77.314
							(286.745)	(55.609)
OECD$_{1970}$	Yes	No	No	No	-	-	No	-
Democracy$_{t-1}$	-	-	No	Yes	-	-	Yes	-
Humanitarian aid inflow$_{t-1}$	-	-	-	-	No	Yes	-	-
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(2) test	0.976	0.382	0.409	0.344	0.890	0.233	0.490	0.956
Hansen J test	0.137	0.482	0.447	0.348	0.773	0.264	0.818	0.493
Observations	138	645	354	291	339	444	291	783

Notes:
In parentheses are Windmeijer-corrected standard errors appropriate for small samples. *** / ** / * indicate p-values below 0.01 / 0.05 / 0.1. Unreported constants, time fixed effects, and lagged levels of Openness, Government size, and Polity2, are included in all specifications. Estimated with Arellano-Bond's difference-GMM estimator. In the specifications in Columns 2 to 7 (C2-C7), the first 3 appropriate lags are used as internal instruments for the lagged values of Log GDP per capita, Openness, Government size, and Polity2, while Natural disasters, Humanitarian aid per capita, the interaction between Natural disasters and Humanitarian aid per capita, and the time fixed effects are is treated as exogenous variables. In C1, only 2 lags are used to keep the instrument count below the number of countries in the sample used. The instrument matrix is collapsed, as recommended by Roodman (2006). The p-value for the Arellano-Bond test for autocorrelation of the second order is reported under AR (2) test. The p-value for an over-identification test is reported under Hansen J test. If rejected, this test indicates that the instruments as a group are invalid. Coefficients and standard errors for natural disasters and humanitarian aid are scaled up by a factor of 1000. Subscript t means that data represent time period t, here a 5-year period. OECD$_{1970}$ indicates that the country was a member of OECD in 1970. Democracy$_{t-1}$ indicates a Polity2-score of zero or more in the previous period. Humanitarian aid inflow$_{t-1}$ indicates positive inflow of humanitarian aid in the previous period.