Estimating the direct economic damage of the Earthquake in Haiti[1]

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Abstract

We use simple regression techniques to make a first assessment of the monetary damages caused by January 12, 2010 earthquake the struck Haiti. Damages are estimated for a disaster with both 200,000 and 250,000 total deaths plus missing (i.e., the range of mortality that is estimated to have caused the earthquake) and using Haiti's economic and demographic data. Our base estimate is US$8.1bn for a 250,000 death toll. We suspect that this is a lower bound estimate for various reasons and an estimate of US$13.9bn for the same death toll is within statistical error. While the results are subject to many caveats, the implications of such an estimate are significant. Raising such a figure will require many donors, bilateral, multilateral and private. Hence excellent coordination of funding and of execution will be the key to ensuring the efficient use of funds.

Keywords: Natural disasters, direct economic damages, Haiti, earthquake, reconstruction, aid and development.

JEL Classification: O11, O19, O54, Q54, F35.

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1. Introduction

We use simple regression techniques to assess the estimated direct cost of the catastrophic earthquake that struck Haiti on January 12 2010. The earthquake, which hit about 15km (10 miles) south-west of the capital city Port-au-Prince, was followed by several strong aftershocks and has caused significant loss of human life, hundreds of thousands of people displaced and severe damage to the economic infrastructure of the country.

In order to estimate the monetary damages caused by this event, we combine worldwide data from about 2000 natural catastrophic events between 1970 and 2008. We model the dollar amount of damage of each event as a function of the number of deaths or missing, the level of economic development (real GDP per capita), country size (alternatively measured as population size, real GDP or land area), regional dummies, and a linear trend. Using these regression results we make out-of-sample predictions regarding the estimated dollar amount of damages that can be expected for a country with Haiti's economic and demographic characteristics in the aftermath of the catastrophic earthquake of January 12th.

The unit of observation is an event as recorded in the Emergency Events Database (EM-DAT) maintained by the Center for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Louvain, Belgium (http://www.emdat.be/). The database is compiled from various sources, including various UN agencies, non-governmental organizations, insurance companies, research institutions, and press agencies. Disasters can be hydro-meteorological, including floods, wave surges, storms, droughts, landslides and avalanches; geophysical, including earthquakes, tsunamis and volcanic eruptions; and biological, covering epidemics and insect infestations (these are much more infrequent in this database). There are approximately 2000 such events recorded in the dataset over the timeframe 1970 – 2008 for which we also have all the necessary information to conduct the empirical analysis.[2]

The direct damage reported in EM-DAT is the damage to fixed assets and capital (including inventories), damages to raw materials and extractable natural resources, and mortality and morbidity that are a direct consequence of the natural phenomenon.

The nature of the exercise we perform is simple. It uses historical data on catastrophic events and econometric techniques to answer the following question: what can we expect to be the costs of reconstructing Haiti's infrastructure?[3] Damages are estimated for a disaster with both 200,000 and 250,000 total deaths plus missing (i.e., the range of mortality that is estimated to have caused the earthquake) and using Haiti's economic and demographic data. The bottom line is for a disaster with 200,000 total deaths and missing, in a country with Haiti's observable characteristics, damages are expected to be about US$7.2bn (2009 dollars). For a death toll of 250,000 the estimate would be US$8.1bn. Intermediate numbers give intermediate results. Unfortunately recent estimates place the

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[2] We focus primarily on the three types of disasters which are more common and for which there is more reliable data available in the dataset: earthquakes –including tsunamis—, floods and windstorms.

[3] Note that this assumes infrastructure is rebuilt, this is not then a Needs Assessment which may contemplate building different infrastructure or infrastructure in different places according to a revised development strategy, we focus here on the more traditional damage assessment.

actual death toll at the top of this range. However, the errors attached to these estimates (obtained via bootstrapping) remain quite large, in part as there are relatively few disasters of this size: while the base-estimate may be as high as US$8.1bn, for 250,000 deaths, an estimate of US$13.9bn is within statistical error.

These estimates are useful to put this event into perspective and to inform the international community of the enormity of the challenge that lies ahead in the task of reconstructing Haiti. However, several caveats are in order. Given the nature of the exercise results should be interpreted with caution. First, there are conceivably measurement errors in the data, the model we postulate may be incorrectly specified and there may be other problems with the empirics. Second, we cannot know if the experience with past episodes around the world will be relevant for Haiti. Every event is different and although we control for country and regional specific characteristics' in the regressions, we could have missed something. This is compounded by the fact that the characteristics of this particular event are quite special: it is the most destructive event a country has ever experienced when measured in terms of the number of people killed as a share of the country's population[4] (see Table 1) and affected the capital city of the country: the center of commerce, Government and communication. Moreover, many priceless buildings were destroyed or severely damaged including the Presidential Palace, the National Cathedral, churches and Government Buildings, but it has not been possible to control for this in the estimation. Finally, as with any empirical exercise of this nature the estimates are subject to the statistical uncertainty and as detailed there are few events of such ferocity as the Haiti 2010 earthquake.

Table 1: Large Natural Disasters

Rank	Country	Year	Description	Killed	Deaths per million inhabitants	Damages (US Millions, 2009)
	Haiti	**2010**	**Earthquake**	**200,000 - 250,000**	**20,000 - 25,000**	**7,200 - 8,100**
1	Nicaragua	1972	Earthquake	10,000	4,046	4,325
2	Guatemala	1976	Earthquake	23,000	3,707	3,725
3	Myanmar	2008	Cyclone Nargis	138,366	2,836	4,113
4	Honduras	1974	Cyclone Fifi	8,000	2,733	2,263
5	Honduras	1998	Cyclone Mitch	14,600	2,506	5,020
6	Sri Lanka	2004	Tsunami*	35,405	1,839	1,494
7	Venezuela	1999	Flood	30,005	1,282	4,072
8	Bangladesh	1991	Cyclone Gorki	139,252	1,232	3,038
9	Solomon Is	1975	Tsunami	200	1,076	n.a.
10	Indonesia	2004	Tsunami*	165,825	772	5,197

*Indian Ocean Tsunami caused a total of 226,000 deaths over 12 countries.
n.a. Not available
Source: Authors' calculations based on EM-DAT and WDI databases.

The structure of this paper is as follows: the next section discusses the empirical model and other methodological issues. Section 3 presents the regression results and section 4 the out of sample predictions for Haiti. Section 5 has some policy discussion and section 6 concludes.

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[4] For example, while the ballpark estimates of the number of people killed or missing are similar to the 2004 Tsunami in Indonesia, the population of Haiti is only a small fraction of the one of the Asian country, making this particular event more damaging than that infamous tsunami.

2. Model Specification and Methodology

Following the literature[5] we estimate a model of the form:

$$DIS_{it} = \alpha + \beta \mathbf{X}_{it} + \varepsilon_{it} \quad (1)$$

Where DIS_{it} is a measure of dollar amount of direct damages caused by the immediate impact of a disaster in country *i* and time *t*. For comparability purposes, all the data is converted into 2009 US dollars using the United States' Consumer Price Index (CPI). $\mathbf{X}_{it}$ is a vector of control variables of interest that capture the "vulnerability" of the country to disasters (i.e., the conditions which increase the susceptibility of a country to the impact of natural hazards), and countries' demographic characteristics. ε_{it} is an independent and identically distributed (iid) error term.

We first estimate the model for the full sample of events available in the dataset over the timeframe 1970-2008. Next, we use the coefficient estimates $\hat{\alpha}$ and $\hat{\beta}$ to predict out of sample the dollar amount of direct damages for the recent earthquake in Haiti. In other words, we replace $\mathbf{X_{it}}$ in (1) with $\mathbf{X_{Haiti,2010}}$ and use the coefficient estimates from the model to provide an estimate for $\mathbf{DIS_{Haiti,2010}}$. Finally, we use bootstrapping simulation methods to determine the confidence intervals around these predictions.

We initially pool all types of events (approximately 2000 events with full data) and compute pooled regressions. However, we alternatively compute the model for three different types of events separately: (a) earthquakes, (b) windstorms, and (c) floods. When we do so, we augment the set of controls to include measures of the physical intensities of events (i.e., Richter scale for earthquakes or wind speed for hurricanes).

One problem with the disaster's data in the EM-DAT database is that as the threshold used to assess what events constitute a natural disaster is quite lenient, there are many events recorded in the dataset that are not conceivably catastrophic.[6] To avoid overrepresentation of small events in the sample (which may not be relevant for the case of Haiti) and to obtain a parsimonious representation, we exclude approximately 250 very small events, defined as those that have less than 10 people reported dead or missing and for which reported damages are less than US$10 million.[7]

3. Regression Results

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[5] See, for example, Kahn (2005) and Skidmore and Toya (2007), Cavallo and Noy (2009) and references therein.

[6] EM-DAT defines a disaster as a natural situation or event which overwhelms local capacity and/or necessitates a request for external assistance. For a disaster to be entered into the EM-DAT database, at least one of the following criteria must be met: (1) 10 or more people are reported killed; (2) 100 people are reported affected; (3) a state of emergency is declared; or (4) a call for international assistance is issued. See Cavallo and Noy (2009) for a discussion.

[7] Including these events we obtain even higher estimates of the damage.

The regression results for the pooled model are presented in Table 2. The estimation method is OLS and the preferred regression is in logarithms. The dependent variable is direct damage in US$ of 2009. The baseline specification includes a control for the intensity of the event in terms of mortality (number of people killed or missing), the stage of economic development (lagged real GDP per capita), and country size. For the latter we use either population size (column 1), land area in Km^2 (column 2) or lagged real GDP (column 3).[8] All regressions include a linear trend as some of the increases in reported damages overtime may be due to improvements in the recording capacity or data availability, and also regional dummies (not reported) to account for the possible heterogeneity across regions in the incidence of the various events. Finally in column 4 we also include a dummy for the type of event (earthquakes is the excluded variable).[9]

Table 2: Baseline Regressions

Disasters regression model. Dependent variable: Log of Damages (2009 US$, bn)
Sample: 1971 - 2008

Variables	Model			
	(1.1)	**(1.2)**	**(1.3)**	**(1.4)**
Number of killed people (in logs)	0.529	0.537	0.533	0.526
	[20.36]***	[21.08]***	[20.93]***	[20.22]***
Real GDP per capita (first lag, in logs)	0.501	0.499	0.356	0.485
	[11.58]***	[11.54]***	[6.72]***	[11.19]***
Population (in logs)	0.147			0.155
	[5.08]***			[5.35]***
Land area (in logs)		0.0855		
		[3.93]***		
Lag of real GDP level (in logs)			0.146	
			[5.08]***	
Storm dummy				0.0455
				[0.32]
Flood dummy				-0.268
				[-1.93]*
linear trend	0.003	0.006	0.003	0.005
	[0.68]	[1.29]	[0.72]	[0.98]
Constant	-11.050	-9.823	-11.070	-10.980
	[-19.49]***	[-21.95]***	[-19.65]***	[-18.74]***
R-squared	0.388	0.388	0.394	0.392
Adjusted R-squared	0.383	0.383	0.389	0.387
Observations	1760	1774	1773	1760

Notes: For all regressions, regional dummies were included (not shown). t statistics in brackets. * p<0.10, ** p<0.05, *** p<0.01
Source: Authors' calculations based on EM-DAT and WDI datasets.

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[8] GDP measures are lagged to reduce possible endogeneity problems.

[9] The inclusion of additional control variables, such as the level of educational attainment, openness to trade, financial development and the size of government do not significantly change the baseline results (details available upon request). The most likely reason is that some of these variables are known to be highly correlated to economic development.

The fit of the regressions is good with an adjusted R-squared of approximately 0.4. The estimated damages increase significantly with the intensity of the event, with the level of economic development (in richer countries there is more wealth exposed to the disasters) and with country size (bigger countries also have more wealth exposed). In terms of the type of events (column 4), earthquakes appear to be more destructive than floods, but not more destructive than storms. The linear trend is not statistically significant.[10] The results are intuitive except perhaps for the positive sign of real GDP per capita which appears to be at odds with previous results by Khan (2005) and Skidmore and Toya (2007). Both of these papers use similar methods to examine the relationship between human and economic losses from natural disasters and economic development and find that countries with higher income per capita experience fewer losses. This in turn is interpreted as meaning that economic development provides implicit insurance against natural disasters. However the results are not directly comparable as unlike the cited papers, we use the number of people killed as a right-hand side (explanatory) variable. In other words, in this paper, rather than focusing on the relationship between human mortality with economic development, we look at the relationship between mortality and economic development with monetary losses.

These results are also robust to the exclusion of events in industrialized countries. This is shown in Table 3 that has the same regressions excluding industrial countries. The coefficient estimates remain virtually unchanged, with the only exception of the dummy for Floods in column (4), suggesting that for the sample of developing countries only there is no statistically significant difference in the damage caused by earthquakes and floods.

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[10] Its exclusion from the regressions does not change the results.

Table 3: Baseline Regressions with developing countries only

Disasters regression model. Dependent variable: Log of Damages (2009 US$, bn)
Sample: 1971 - 2008

Variables	Model			
	(2.1)	(2.2)	(2.3)	(2.4)
Number of killed people (in logs)	0.493	0.503	0.501	0.495
	[16.79]***	[17.54]***	[17.42]***	[16.76]***
Real GDP per capita (first lag, in logs)	0.444	0.441	0.280	0.436
	[7.74]***	[7.75]***	[4.22]***	[7.59]***
Population (in logs)	0.167			0.173
	[4.74]***			[4.89]***
Land area (in logs)		0.107		
		[4.05]***		
Lag of real GDP level (in logs)			0.166	
			[4.76]***	
Storm dummy				0.162
				[0.97]
Flood dummy				-0.0689
				[-0.43]
linear trend	-0.003	0.001	-0.002	-0.001
	[-0.46]	[0.22]	[-0.41]	[-0.25]
Constant	-10.720	-9.457	-10.740	-10.830
	[-15.35]***	[-17.41]***	[-15.65]***	[-15.01]***
R-squared	0.323	0.329	0.333	0.326
Adjusted R-squared	0.317	0.322	0.327	0.318
Observations	1344	1357	1357	1344

Notes: For all regressions, regional dummies were included (not shown). t statistics in brackets. * p<0.10, ** p<0.05, *** p<0.01
Source: Authors' calculations based on EM-DAT and WDI datasets.

Next, we recomputed the regressions separating by event types. When doing so, we can also control in the regressions for the physical intensity of earthquakes (Richter scale) and windstorms (wind speed). The results are in table 4.

Table 4: Baseline regressions by event type

Disasters regression model. Dependent variable: Log of Damages (2009 US$, bn)
Sample: 1971 - 2008

Variables	Model			
	Baseline	Earthquakes	Storms	Floods
Richter magnitude scale		-0.104		
		[-0.54]		
Windspeed (in logs)			0.759	
			[2.10]**	
Number of killed people (in logs)	0.529	0.657	0.473	0.597
	[20.36]***	[11.27]***	[6.74]***	[11.98]***
Real GDP per capita (first lag, in logs)	0.501	0.572	0.493	0.527
	[11.58]***	[3.95]***	[4.36]***	[5.99]***
Population (in logs)	0.147	-0.143	0.150	0.279
	[5.08]***	[-0.95]	[2.47]**	[4.95]***
linear trend	0.003	0.043	-0.032	0.003
	[0.68]	[2.62]***	[-1.90]*	[0.43]
Constant	-11.050	-5.673	-13.210	-14.450
	[-19.49]***	[-1.84]*	[-5.71]***	[-12.89]***
R-squared	0.388	0.569	0.521	0.339
Adjusted R-squared	0.383	0.531	0.485	0.327
Observations	1760	171	201	753

Notes: For all regressions, regional dummies were included (not shown). t statistics in brackets. * p<0.10, ** p<0.05, *** p<0.01
Source: Authors' calculations based on EM-DAT and WDI datasets.

The results are also consistent with the baseline. The only exceptions are that the linear trend is positive and significant in the case of earthquakes (suggesting that earthquakes have become more damaging over time) and negative and significant for storms (suggesting that storms have become less damaging). These results may not be surprising as by their nature, earthquakes are less predictable and the exact location where they may strike is usually unknowable. Therefore, while it is possible to implement building codes and standards that prepare infrastructure better to resist possible earthquakes, it is not easy to locate the wealth in "safer" areas. Instead, climatologic events like hurricanes affect disproportionally more certain regions; in particular costal locations in tropical areas, so vulnerable countries may chose to locate its wealth away of the most exposed areas.[11]

Interestingly, the results in Table 4 suggest that the physical intensity of earthquakes do not affected by the amount of damages (controlling for the number of people killed), while in the case of storms, wind

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[11] However, this does is not always the case. For example, Kellenberg and Mobarak (2008) suggest a nuanced, nonlinear relationship between economic development and vulnerability to natural disasters, with risk initially increasing with higher incomes as a result of changing behaviors, such as residents locating to more desirable but more dangerous sites near coasts and floodplains. Sadowski and Sutter (2005) provide some confirmation for this view by examining hurricanes in the United States and the ways in which better preparedness leads to higher residential coastal concentrations (where the risk from hurricane-associated wave surges is higher).

speed has a significant independent effect on damages. This suggests that people killed in earthquakes may be more correlated to the physical intensity of the event than in the case of windstorms.

4. Out-of-sample prediction for Haiti

The next step is to use the regression results to predict the damages caused by the devastating earthquake that hit in Haiti on January 12, 2010. The earthquake of scale 7.0 in the Ritcher scale struck very close to the capital city of Port-au-Prince causing extensive casualties and huge damages to private and public assets. Haiti is the poorest country in the Latin America and the Caribbean region and ranks in the bottom quartile of the United Nations Development Program Human Development Index.

To estimate the overall damages caused by the earthquake in a country with Haiti's economic and demographic characteristics, we use the coefficient estimates from the baseline regressions replacing matrix $\mathbf{X}_{\mathbf{it}}$ in (1) with $\mathbf{X}_{\mathbf{Haiti},\mathbf{2010}}$. Table 5 summarizes the elements of $\mathbf{X}_{\mathbf{Haiti},\mathbf{2010}}$ that are relevant for the estimation:

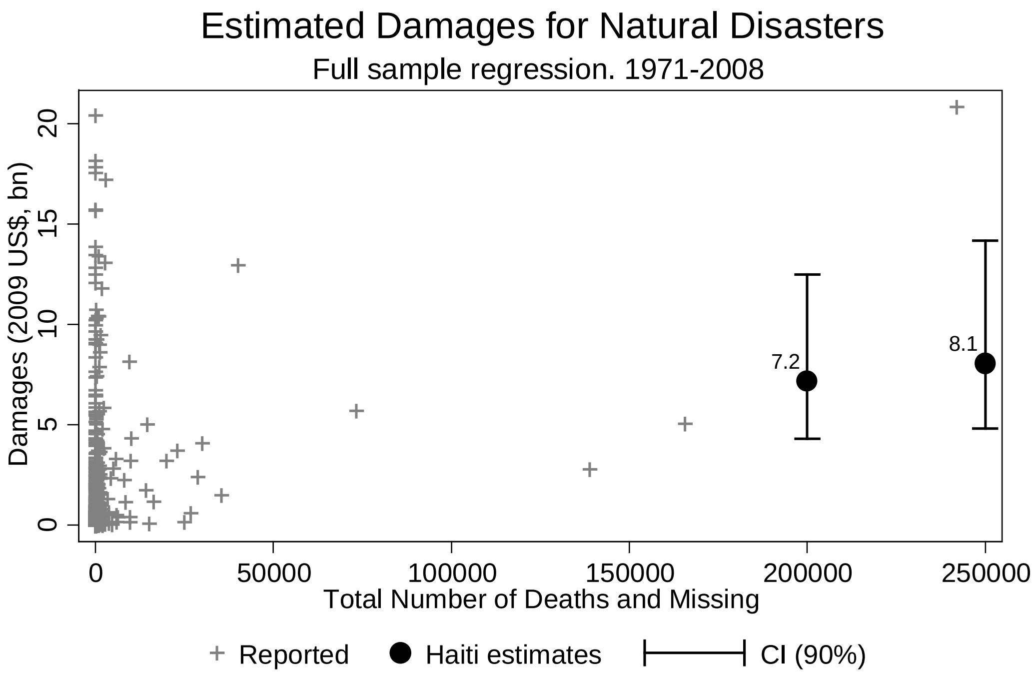
Table 5: Haiti's data matrix

Explanatory variable	Value
Richter scale measure	7.0
Number of killed people	200,000
	250,000
GDP per capita (2000 US$, 2008)	410.29
Population (2009)	9,951,529
Land Area (sq km)	27,560
GDP level (2000 US$, 2008)	4,012,627,061
Source: Authors' calculations and WDI dataset.	

The estimates of the number of people killed are still subject to a lot of discussion and revisions. At the time of writing, estimates range anywhere between 200,000 and 250,000 including missing people. The official estimate of the government of Haiti as of February 10th 2010 was a total of 230,000 people dead (not including missing).

Figure 1 shows the estimated damage (y-axis) plotted against the death toll (x-axis) with its confidence intervals computed using bootstrapping (1000 replications).

Figure 1



Source: Authors' calculations based on EM-DAT and WDI datasets.

The results are that for an earthquake that causes 200,000 deaths striking in a country with Haiti's observable characteristics, the estimated damage is US$7.2bn, with 90% confidence intervals between US$4.1bn and US$12.2bn. If the death toll were up to 250,000 the estimated damage is US$8.1bn with 90% confidence intervals between US$4.6 and US$13.9. Intermediate numbers give intermediate results. For example, using the official death toll as of February 10th of 230,000 people, the estimated damage is US$7.7bn with 90% confidence intervals between US$4.4bn and US$13.2bn.

These estimates are based on the regression results using model (1.1) in table 2. Table 6 below summarizes the results we obtain using the regressions (1.2) and (1.3) in that table.

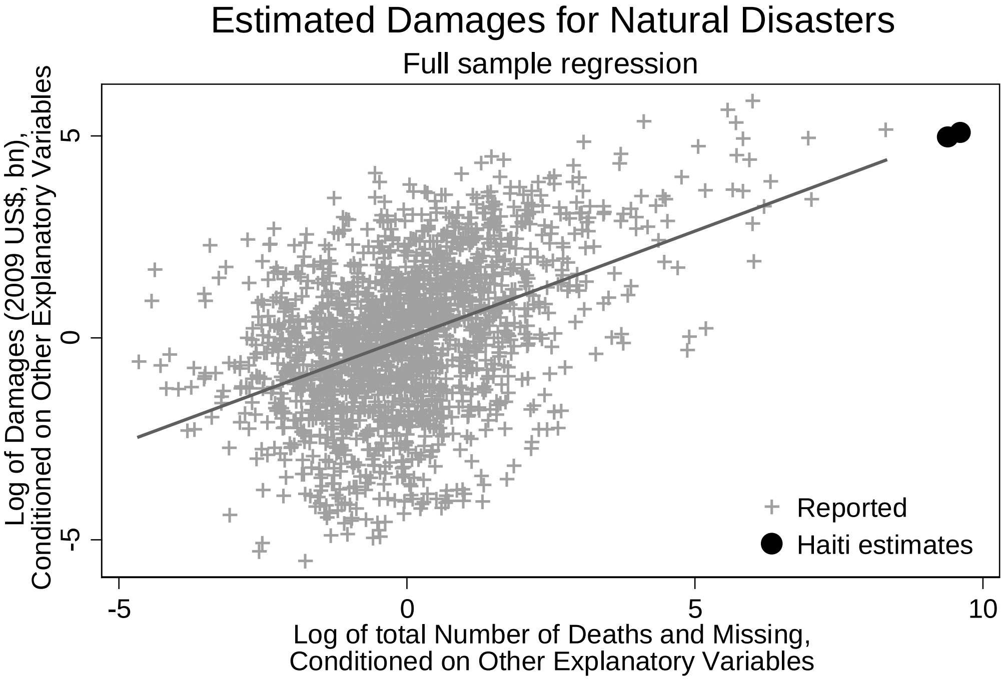
Table 6: Confidence Intervals

Model	Estimated of killed people in Haiti					
	200,000			250,000		
	Point estimate	Lower CI	Upper CI	Point estimate	Lower CI	Upper CI
Regression (1.1)	7.2	4.1	12.2	8.1	4.6	13.9
Regression (1.2)	7.7	4.3	13.2	8.6	4.8	14.7
Regression (1.3)	7.5	4.3	12.2	8.4	4.8	13.9

Note: The confidence intervals (90%) were computed by bootstrapping (1000 replications)
Source: Authors' calculations based on EM-DAT and WDI datasets.

Figure 2 shows the *partial* correlation scatter plot between the log of US$ damages (Y-axis) and the log of total number of people killed (x-axis). This figure (based on model 1.1 in table 2) illustrates the strength of the relationship between the two variables after conditioning on the other explanatory variables included in the regression. Furthermore, it shows that the event in Haiti in very big after accounting for the observable characteristics we control for in the regressions but that the results do not appear to be driven by outliers. [12]

Figure 2



Source: Authors' calculations based on EM-DAT and WDI datasets.

5. Implications of the Results

There are significant implications of our results for Haiti and for the international community. While a detailed assessment of needs will come from the so-called Post Disaster Needs Assessment that will be conducted in the coming months, the estimates above indicate that Haiti's needs will run into several billions of dollars. This sum will be beyond the scope of one agency or one bilateral donor and so donor coordination will be key in any reconstruction effort. Bobba and Powell (2006) argue that aid is more effective and when fewer donors are present and multilateral organizations may be seen as a coordinating tool. One extreme is a one all-encompassing general multi-donor trust fund managed by a

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[12] Moreover, it can be observed from figure 2 that once we condition on the other explanatory variables included in the regressions, the relationship between economic damages and the number of people killed is much more parsimonious that what can be inferred from the unconditioned correlation (figure 1).

single agency. It may be more feasible to have several “aggregator” funds perhaps organized on thematic lines. However the coordination of the funding is achieved it will be critical to ensure donors are coordinated on the ground. A single executing agency with appropriate powers, transparency and accountability to the Haitian Government and donors would be helpful in this regard. One view is that aid will be constrained by the capacity of institutions in Haiti to manage and execute the projects to be financed. An alternative opinion is that this constraint is endogenous to the architecture of funding and execution that donors and the Haitian Government find acceptable. Moreover, coordination and execution structures may also serve to ensure that aid is used most efficiently for Haiti rather than favoring particular projects favored by donors or tied in any way, such as conditions to employ firms from any particular donor country.

Academic work suggests that the impact of such disasters is very persistent. Cavallo et al (2010) estimate that even ten years after a major disaster, the affected country’ growth may be some 30% below what growth would have been – relative to an estimated counterfactual. This is the case even given significant increases in aid flows that tend to occur after a major disaster. Of course this does not necessarily mean that aid does not work, perhaps the negative growth effect would have been even worse if aid had not increased. However, this does underline the challenge ahead for Haiti and for the international community attempting to support the country.

One concern is that large aid inflows may provoke cost rises, real appreciation and a Dutch Disease increasing aid-dependence and damaging private sector activity not directly related to reconstruction including the export sector. In the case of Haiti exports are small (some 10% of GDP) but were growing (at 12% in 2009) and are highly concentrated in assembly industries including garments (some 90% of exports are assembly goods). The US Hope II legislation gives Haiti unparalleled access to US markets with generous “origin rules” for garments and other selected activities and there was increasing interest from foreign firms in employing workers in Haiti for assembly and other activities. Given the growth effects of natural disasters and the macroeconomic management issues of large aid flows, it appears important to ensure the potential for job creation and growth in these sectors is not put at risk. Other potential growth areas for exports include high value agricultural goods including mangos (also useful for reforestation to resist soli degradation) and tourism. These sectors are also important ones to consider supporting.

6. Conclusions

In this short note we have attempted to give a preliminary estimate of the potential damages resulting from the tragedy of the January 12th Haiti earthquake. Our estimate derives from simple regression techniques employing data on past natural disasters and their damages estimates. Our base estimate is US$8.1bn for a 250,000 death toll. We suspect that this is a lower bound estimate for various reasons and an estimate of US$13.9bn for the same death toll is within statistical error.

The implications of such an estimate are significant. Raising such a figure will require many donors, bilateral, multilateral and private. Hence excellent coordination of funding and of execution will be the key to ensuring the efficient use of funds. This is likely to imply that individual donors will have to relinquish control of their donations in terms of which projects they fund and the precise execution conditions, which in turn implies that appropriate mechanisms of transparency and accountability will be very important. Unfortunately past experience suggests despite higher aid inflows after disasters, the growth impact of major disasters remains highly persistent. Apart from potential inefficiencies of the management of aid flows, microeconomic bottlenecks and a macroeconomic Dutch Disease type phenomenon may hurt private activity not directly related to reconstruction. While Haiti’s export sector is very small, it does have significant growth potential. The international community will need to consider how best to support private activities to ensure the negative growth impact is minimized and to ensure sustainable growth once reconstruction activities start to diminish.

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