Economic Development and the Impacts of Natural Disasters

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Abstract

We use disaster impact data over time to examine the degree to which the human and economic losses from natural disasters are reduced as economies develop. We find that countries with higher income, higher educational attainment, greater openness, more complete financial systems and smaller government experience fewer losses.

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1. Introduction

It is generally understood that as a country develops, it devotes greater resources to safety, including implementing precautionary measures designed to reduce the impacts of natural disasters. With the recent devastating human and economic impact of the tsunami in Southeast Asia and Hurricane Katrina, interest among economists in disaster impacts is heightened. In this study, we use data on total deaths and economic damages caused by natural disasters for many countries over forty-three years to estimate the relationships between measures of social/economic development and the effects of natural disasters.

Our analysis shows that as economies develop there are fewer disaster-related deaths and damages/GDP. What is more interesting is that controlling for income, we also find that other measures of social/economic infrastructure are important in determining the impact of natural disasters. Specifically, we show that human and/or economic losses are less in countries with higher levels of education, more open/competitive economies, more complete financial systems and smaller governments. The following section provides a brief review of some of the most relevant research on disaster mitigation, the demand for safety and the limited research on relationship between development and disaster impacts. Imbedded in this section is a brief theoretical discussion that guides our econometric analysis. In section three we present the empirical analysis, and section four concludes.

2. Literature Review and Theoretical Framework

In a study of the Japanese response to the Kobe earthquake in 1995, Horwich (2000) argues that a critical underlying factor in any economy's response to a natural disaster is its level of wealth. Similarly, Wildavsky (1988) interprets the degree of safety enjoyed by citizens of a country as a natural product of a growing market economy. In this framework, since demand for safety rises with income, a nation's per capita income is a good initial indication of its degree of safety. Increases in income provide not only improvements in general safety, but also additional protection against natural disasters.

A several researchers have noted the importance of economic development in reducing vulnerability. Tol and Leek (1993) and Burton, *et al*, (1993) discuss the potential for reduced exposure to natural disasters as income increases. Burton, *et al*, (1993) show a modest inverse relationship between deaths due to natural disasters and income for twenty countries for years 1973 and 1986. Albala-Bertrand (1999) also argues that the people most affected by direct disaster impacts are primarily those who have weaker economic and political bases. In a recent study that utilizes disaster data from OFDA/CRED, Kahn (2003) shows that the number of deaths, injured and homeless are reduced as income rises. He also shows that more democratic countries experience fewer human losses than do less democratic countries. We extend this line of work by examining the role of several other measures of social/economic fabric in the disaster-safety-development relationship. We also examine the relationship between the level of development and economic damages/GDP.

We suggest that there are two components of the disaster-income-safety relationship. First, increases in income increases the private demand for safety. Higher income enables individuals respond to the risks around them by employing additional costly precautionary measures. In aggregate some countries are wealthier than others, suggesting that greater precautionary measures will be taken on privately by individuals. However, distinct from this private disaster-income-safety relationship is the existence of an underlying social/economic fabric that increases safety for all of society. We examine several measures of social/economic infrastructure that may determine the degree of exposure for society as a whole: Educational attainment, openness, financial development, and size of government. While these factors are correlated with income, we note that independent of income these factors are shown to play a role in the determining the degree of safety from natural disaster events. We use the following measures in our empirical analysis: Per capita GDP, total years of schooling attainment, (exports + imports)/GDP, M3/GDP and government consumption/GDP. We also control for other factors such as population, land area and a series of dummy variables indicating disaster type.

3. Empirical Analysis

Data on natural disasters come from the OFDA/CRED International Data Base (2004), and macroeconomic data that is available from several sources (Barro and Lee, 1996; International Financial

Statistics Web page, Heston, Summers and Aten, 2002; World Development Indicators, 2003).[1] Using this merged data set we conduct an empirical analysis to determine the relationship between various indicators of economic development and disaster-related deaths and economic damages/GDP. OFDA/CRED uses specific criteria in classifying a natural disaster (ten or more people killed, 100 or more people were affected/injured/homeless, significant damages were incurred, a declaration of a state of emergency and/or an appeal for international assistance was made (http://www.cred.be/emdat)).[2] Summary statistics, a list of countries and data sources in presented in the Appendix Tables A, B, and C.[3] **(These tables are included for the editor/referees but are not intended for final publication)**

We estimate two sets of regressions to determine the relationship between the level of development and disaster impacts. The first set of regressions is characterized by the following equation:

$$deaths_{jit} = \beta_1(pcgdp_{it}) + \beta_2(hc_{it}) + \beta_3(open_{it}) + \beta_4(fin_{it}) + \beta_5(gov_{it}) + \beta_n(y_{jit})$$

where $deaths_{jit}$ is the natural logarithm of the total number of deaths caused by natural disaster event j in country i during period t, $pcgdp_{it}$ is the natural logarithm of real per capita gross domestic product, hc_{it} is total years of schooling attainment in the population aged 15 and over, $open_{it}$ is (exports+imports)/GDP, fin_{it} represents M3/GDP, and gov_{it} is government consumption/GDP, and y_{jit} represents a vector of additional variables that determine the deaths caused by the natural disaster (e.g., population, land area, disaster type). We hypothesize that controlling for income countries with a higher level of educational attainment, greater openness and a more highly developed financial sector will experience fewer deaths.

[1] The OFDA/CRED database is a result of collaboration between the Office of U.S. Foreign Disaster Assistance and the Center for Research on the Epidemiology of Disasters. Efforts to establish better preparedness for and the prevention of disasters have been a primary concern for donor agencies, implementing agencies, and affected countries. For this reason, demand for complete and verified data on disasters and their human and economic impact, by country and type of disasters has been growing. The OFDA/CRED initiative to develop a validated database on disaster impacts is a response to this need.

[2] Although the data set provides information on a number of natural disaster types, we restrict or analysis to earthquakes, floods, slides, volcanic eruptions, extreme winds[2] and waves. A key advantage of the earthquake, flood and wind data is that information is available on the magnitude of the event (Richter scale readings, square kilometers of flooding, and wind speeds).

[3] The OFDA/CRED disaster data include a large number of observations in which a zero is recorded. It may be the case that there are zero deaths caused by a natural event. However, sometimes the data set indicates that a positive number of deaths occurred but there were no injuries or there was a zero recorded for the number of people affected. It is unlikely that a disaster would cause deaths but not any other human injury. As another example, in some cases a positive number of deaths is recorded but a zero is recorded for economic damages. A zero in such cases is likely the result of missing information. For this reason, we omit all zero observations, treating them as missing data.

Higher educational attainment may enable citizens to make a series of choices ranging from engaging in safe construction practices to assessing potential risk that result in fewer deaths when a disaster strikes. Greater openness of an economy serves as a proxy for the degree of competition[4] and the transferal of technological knowledge from abroad that reduces environmental risk.[5] A more highly developed financial sector may reduce disaster impacts because an efficient financial system that provides accurate information and risk assessment is less likely to finance projects in inherently risky locations.[6] Informed investors may also require more stringent safety standards. The expected effect of size of government is *a priori* ambiguous. On the one hand, a larger government may translate into greater public assistance and stronger social response to disaster risk and risk management. On the other hand, government may be less responsive and less efficient at handling disaster response initiatives.[7]

The second set of disaster impact regressions focus on economic damages ($damages/GDP_{it}$) in which damages are the registered figure that corresponds to the damage value in real US$ at the moment of the event.[8] These data again come from OFDA/CRED, but there are several limitations that warrant discussion. First, this measure of economic damages only includes direct costs and not indirect costs (lost future income for example) of the disaster. Second, developing countries have an incentive to exaggerate the scale of damages in order to secure international assistance. Third, obtaining damage estimates in developing countries is challenging because the poor are often without insurance, bookkeeping and formal markets (Tol and Leek, 1999).[9] Nevertheless, the OFDA/CRED data are best data on economic damages available, and the analysis should provide an initial indication of the relationship between the level of development and economic damages from disasters. We hypothesize that as income rises,

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[4] For example, Horwich (2000) notes that property insurance markets in Japan are hampered by government restrictions.
[5] For example, the Maldives was spared from severe damage that might have resulted from the Southeast Asian tsunami because Japan provided the technology and assistance to construct a massive sea wall around the capital of Male.
[6] Not unless the potential returns are high enough to offset the risk.
[7] Horwich (2000) argues that government was the slowest to respond to the Kobe earthquake. In contrast, the most effective organization in terms of developing distribution networks and getting badly needed resources to victims was the very market-oriented Japanese mafia.
[8] We convert these figures to real US$.
[9] A CRED consultant also indicated that damages "were estimated by people without much knowledge of economics, without being assisted by any guidelines."

economic damages/GDP will fall. It is important that we control for population and land area because disaster events may only affect a particular region of a larger country, but for a smaller nation a disaster may affect the entire country. The regressions are estimated using an ordinary least squares procedure with a correction ensure heteroskedasticity-consistent standard errors (White, 1980).

Table 1 presents regression estimates for the number of deaths and economic damages/GDP equations using the entire sample. In Table 2 we restrict our analysis to OECD countries, and in Table 3 we present estimates using non OECD (developing) countries. The explanatory power of the regressions is somewhat limited, with the adjusted R^2 ranging from 9 to 35 percent depending on the specification and sample.[10] The best fit appears to be with the OECD sample, whereas the less of the variation in deaths and damages is explained in the developing country sample.

Consider first the results found in Table 1. Columns 1 and 3 show that per capita income is inversely correlated with both disaster deaths and damages/GDP. In columns 2 and 4 we add a series of social/economic infrastructure variables. The coefficient on income is still negative and significant in the deaths regression but the magnitude of the coefficient is greatly reduced, and in column 4 the income variable is not significant. From column 2, controlling for income we see that a higher level of educational attainment is associated with fewer deaths, as is greater openness and a stronger financial sector. Interestingly, the coefficient on size of government is positive and marginally significant, indicating that a larger public sector is associated with more deaths. Results in column 4 are consistent those found in column 2: The schooling and openness variables are negative correlated with damages/GDP, but the coefficients on the financial sector[11] and government size variables are not significant.

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[10] In separate regressions not reported here but are available upon request, we also include a set of interaction terms between the wind, earthquake and flood indicator variables and measures of magnitude (wind speed, Richter scale reading, and square kilometers of flooding). These regressions capture more of the variation in human and economic damages but are otherwise quite similar to the regression presented here. We do not include these estimates because many recorded events lack data on magnitude.

[11] The financial sector variable is positive and is almost significant at the 10 percent level. A possible explanation for the positive coefficient on this variable is that a more highly developed financial sector may also mean more complete insurance markets. Insurance mechanisms may serve as an incentive to rebuild in inherently risky areas.

The results from the OECD sample, as presented in Table 2, are largely consistent with the full sample estimates but there are some notable differences. First, the coefficient on income is roughly four times larger than in the full sample: Higher income levels have translated into significant improvements in safety over time. According to column 2, a 10 percent increase in income reduces deaths by about 15 percent. Note, however, that the only other significant variable is size of government: A larger public sector is correlated with more deaths.

In Table 3 we present our estimates from the developing country sample. Income is still a statistically significant factor but its magnitude is smaller than the estimates generated from the OECD sample. Of greater importance are the other measures of social/economic infrastructure. In particular, column 2 shows that educational attainment, openness and the financial sector are all inversely correlated with deaths caused by natural disasters but size of government is not significant. The estimates found in column 4 show a similar pattern: Educational attainment and openness are both negatively correlated with damages/GDP.

4. Conclusion

Private entities, governmental and not-for-profit organizations engage in a variety of actions to reduce the impacts of natural disasters. For example, in areas where seismic activity is present building codes (and compliance) are likely to be more stringent. In hurricane prone areas, certain measures may be undertaken to protect life and property (forecasting, warning systems, planning, building codes, etc…). However, for many low-income persons (and by extension nations) the costs of employing precautionary measures may be prohibitive. To illustrate, it may not be feasible for the poor to construct of a home with appropriate and costly engineering standards. For those living in poverty, the additional costs of implementing safety measures out weigh the expected benefits so that the available knowledge and technology is not utilized. However, some countries have made significant strides in economic development, which has led to increased overall safety. It is natural that as a country transitions into a more developed state, death tolls and damages/GDP will be reduced.

The primary contribution of this paper is to show that income is not the only important measure of development in reducing disaster deaths and damages/GDP. Rather, there is an underlying social/economic fabric that can improve the level of safety: Higher educational attainment, greater openness, a well-developed financial sector and smaller government are also important. Policymakers and field agencies engaged in preparedness and assessment of future needs may find it useful to know the number of lives that are likely to be saved as a result of development. Importantly, some economic development factors are, to some degree, within the control of policymakers. In addition to more direct disaster mitigation efforts, long-run disaster reduction policies might to include efforts to improve education, increase the openness and further develop financial markets.

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World Development Indicators (2003)

Table1: Natural Disaster Losses and Economic Development: All Countries

Dependent variables	Log (Number of killed)		Log (Damage/GDP)	
Log (GDP per capita)	-0.514	-0.152	-0.501	-0.115
	(-18.92)	(-2.216)	(-9.831)	(-0.806)
Total schooling years		-0.092		-0.170
		(-4.276)		(-3.948)
Size of government		0.978		0.772
		(1.882)		(0.654)
Openness		-0.820		-1.230
		(-6.275)		(-4.879)
M3/GDP		-0.364		0.323
		(-3.497)		(1.645)
No. of Obs.	3893	3210	2000	1655
Adjusted R^2	0.139	0.154	0.305	0.301

Numbers in parentheses are t-values based on the White (1980) heteroscedasticity-consistent covariance matrix. Other independent variables not reported here are Log (Population), Log (Area), and a series of dummy variables to indicate disaster type (Earthquake, Flood, Volcano, Wind, and Wave).

Table 2: Natural Disaster Losses and Economic Development: OECD Countries

Dependent variables	Log (Number of killed)		Log (Damage/GDP)	
Log (GDP per capita)	-2.118	-1.533	-2.103	-2.326
	(-16.05)	(-5.370)	(-6.703)	(-3.540)
Total schooling years		0.002		-0.258
		(0.033)		(-2.304)
Size of government		6.825		-3.140
		(4.094)		(-1.005)
Openness		-0.830		1.178
		(-1.502)		(1.278)
M3/GDP		0.260		-0.191
		(1.123)		(-0.467)
No. of Obs.	752	588	685	588
Adjusted R^2	0.313	0.334	0.335	0.346

Numbers in parentheses are t-values based on the White (1980) heteroscedasticity-consistent covariance matrix. Other independent variables not reported here are Log (Population), Log (Area), and a series of dummy variables to indicate disaster type (Earthquake, Flood, Volcano, Wind, and Wave).

Table 3: Natural Disaster Losses and Economic Development: Developing Countries

Dependent variables	Log (Number of killed)		Log (Damage/GDP)	
Log (GDP per capita)	-0.482	-0.166	-0.678	-0.227
	(-11.11)	(-2.156)	(-7.294)	(-1.254)
Total schooling years		-0.079		-0.150
		(-3.060)		(-2.648)
Size of government		0.319		0.341
		(0.575)		(0.260)
Openness		-0.611		-1.106
		(-3.529)		(-3.433)
M3/GDP		-0.456		0.385
		(-3.049)		(1.281)
No. of Obs.	3141	2622	1315	1067
Adjusted R^2	0.098	0.112	0.275	0.247

Numbers in parentheses are t-values based on the White (1980) heteroscedasticity-consistent covariance matrix. Other independent variables not reported here are Log (Population), Log (Area), and a series of dummy variables to indicate disaster type (Earthquake, Flood, Volcano, Wind, and Wave).

Appendix A: Summary of Statistics Variables Used in the Analysis

	Mean	Standard Deviation	Number of Observations
Log (Number of killed)	3.213	1.821	3893
Log (Damage/GDP)	-1.900	2.638	2000
Log (GDP per capita)	8.335	1.023	3893
Total schooling years	5.783	2.781	3210
Size of government	0.186	0.073	3210
Openness	0.419	0.297	3210
M3/GDP	0.531	0.375	3210
Earthquake	0.122	0.328	3893
Flood	0.397	0.489	3893
Volcano	0.012	0.108	3893
Wind	0.369	0.483	3893
Wave	0.004	0.064	3893
Log (Population)	10.96	1.749	3893
Log (Area)	13.51	1.950	3893

Appendix B: List of Countries

1	Albania	39	Denmark	77	Kyrgyzstan	115	Rwanda
2	Algeria	40	Dominica	78	Lao P Dem Rep	116	Saudi Arabia
3	Angola	41	Dominican Rep	79	Lebanon	117	Senegal
4	Antigua and Barbuda	42	Ecuador	80	Lesotho	118	Seychelles
5	Argentina	43	Egypt	81	Lithuania	119	Sierra Leone
6	Armenia	44	El Salvador	82	Macau	120	Slovenia
7	Australia	45	Ethiopia	83	Macedonia FRY	121	South Africa
8	Austria	46	Fiji	84	Madagascar	122	Spain
9	Azerbaijan	47	France	85	Malawi	123	Sri Lanka
10	Bangladesh	48	Gabon	86	Malaysia	124	St Kitts and Nevis
11	Barbados	49	Gambia The	87	Mali	125	St Lucia
12	Belarus	50	Georgia	88	Mauritania	126	St Vincent and The Grenadines
13	Belgium	51	Germany	89	Mauritius		
14	Belize	52	Ghana	90	Mexico	127	Sudan
15	Benin	53	Greece	91	Moldova Rep	128	Swaziland
16	Bolivia	54	Grenada	92	Mongolia	129	Sweden
17	Botswana	55	Guatemala	93	Morocco	130	Switzerland
18	Brazil	56	Guinea	94	Mozambique	131	Syrian Arab Rep
19	Bulgaria	57	Guinea Bissau	95	Namibia	132	Taiwan (China)
20	Burkina Faso	58	Guyana	96	Nepal	133	Tajikistan
21	Burundi	59	Haiti	97	Netherlands	134	Tanzania Uni Rep
22	Cambodia	60	Honduras	98	New Zealand	135	Thailand
23	Cameroon	61	Hong Kong (China)	99	Nicaragua	136	Togo
24	Canada	62	Hungary	100	Niger	137	Trinidad and Tobago
25	Cape Verde Is	63	Iceland	101	Nigeria	138	Tunisia
26	Central African Rep	64	India	102	Norway	139	Turkey
27	Chad	65	Indonesia	103	Oman	140	Uganda
28	Chile	66	Iran Islam Rep	104	Pakistan	141	Ukraine
29	China P Rep	67	Ireland	105	Panama	142	United Kingdom
30	Colombia	68	Israel	106	Papua New Guinea	143	United States
31	Comoros	69	Italy	107	Paraguay	144	Uruguay
32	Congo	70	Jamaica	108	Peru	145	Uzbekistan
33	Costa Rica	71	Japan	109	Philippines	146	Venezuela
34	Cote d'Ivoire	72	Jordan	110	Poland	147	Viet Nam
35	Croatia	73	Kazakhstan	111	Portugal	148	Yemen
36	Cuba	74	Kenya	112	Puerto Rico	149	Zaire/Congo Dem Rep
37	Cyprus	75	Korea Rep	113	Romania	150	Zambia
38	Czech Rep	76	Kuwait	114	Russia	151	Zimbabwe

Appendix Table C : Definitions and Sources of Variables

Variables	Definition	Source
Log (Number of killed)	Logarithm of number of Persons confirmed as dead and persons missing and presumed dead	EMDAT
Log (Damage/GDP)	Logarithm of the ratio of estimated damage in real US$ to GDP	EMDAT IFS, HSA
Log (GDP per capita)	Logarithm of real GDP per capita	HSA
Total schooling years	Years of schooling in the total population aged 15 and over	BL
Size of government	Ratio of government consumption to GDP	HSA
Openness	Ratio of exports plus imports to GDP	HSA
M3/GDP	Ratio of M3 to GDP	WDI
Earthquake	Dummy for earthquake	EMDAT
Flood	Dummy for flood	EMDAT
Volcano	Dummy for volcano	EMDAT
Wind	Dummy for wind	EMDAT
Wave	Dummy for wave	EMDAT
Log (Population)	Logarithm of population	HSA
Log (Area)	Logarithm of land area	WDI

Sources:

EMDAT:"EM-DAT: The OFDA/CRED International Disaster Database - www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium" (2004), Data version: v09.04

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