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## NATURAL DISASTER IMPACTS AND FISCAL DECENTRALIZATION

HIDEKI TOYA\* AND  
MARK SKIDMORE\*\*

### 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. The recent onslaught of hurricanes/typhoons and earthquakes in the Caribbean and Asia along with the accompanying devastating human and economic impacts has spurred interest in the factors that determine the patterns and types of resulting losses. Previous research (Anbarci, Escalaras and Register 2005; Kahn 2005; Toya and Skidmore 2007; Kellenberg and Mobarak 2008) demonstrates that there is a distinguishable and predictable pattern between losses from natural disaster events and economic development. Paralleling efforts to spur development around the world has been a growing interest among policymakers and economists in fiscal decentralization.<sup>1</sup> While the existing research on the impacts of decentralization are generally positive in terms of public service delivery, as pointed out by Bardham (2002) existing studies are 'largely descriptive, not analytical, and often suggest correlations rather than causal processes'. Because government plays such vital roles in both the preparation for and response to disaster events, and because naturally occurring disaster events are not systematically related to levels of development (Kahn 2005), natural disasters may provide an opportunity to evaluate the effectiveness of governmental structure in protecting human life. In this study, we merge fiscal, economic, demographic and geographic data with information on total deaths

caused by natural disasters for many countries for years 1972 through 2005. Extensive information on disasters that has been underutilized by economists is available from the Office of US Foreign Disaster Assistance/Center for Research on the Epidemiology of Disasters (OFDA/CRED). We use these data to estimate the relationship between fiscal decentralization and the effects of natural disasters, while controlling for a range of other factors found to be important determinants of disaster-induced human fatalities.

To preview the main finding, our analysis shows that while controlling for a variety of factors, nations with governments that are more decentralized experience fewer disaster-related deaths. However, we also document important interrelationships between decentralization, educational attainment and disaster impacts. Places with more decentralized government systems also tend to have higher average educational attainment. The analysis suggests that the one route by which decentralization reduces disaster-induced deaths is through human capital. Generally, our findings suggest that decentralized governments are more effective in disaster preparations and/or responses relative to more centralized governmental systems.

The following section provides a review of the literature and a discussion of fiscal decentralization and disaster mitigation. This section also offers a theoretical discussion of the effects of fiscal decentralization on disaster mitigation decisions. In sections three and four we present the empirical framework and analysis, respectively. Section five concludes.

### Literature review and theoretical discussion

We review two relevant strands of literature: the research on fiscal decentralization and the economics of natural disasters. In these contexts, we further limit our review to those studies that examine the performance of fiscal decentralization and research on the role of economic development in mitigating disaster-related fatalities.



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<sup>1</sup> See Bardham (2002) for a review of the extensive literature on fiscal federalism in developing countries.

*Fiscal decentralization*

Of the substantial literature on fiscal decentralization there is a strand that focuses on assessing the effectiveness of fiscal decentralization efforts in transition and developing economies. As discussed in Bardham (2002), even though decentralization efforts are occurring in a number of countries around the world, quantitative evidence of effectiveness is limited. Studies that do exist utilize several methodologies, but generally attempt to evaluate government service delivery in a 'before-after' framework. For example, Santos (1998) evaluated the decentralization initiative in Bolivia, finding that access to basic sanitation services (water and sewage) and utilization of elementary and secondary schools increased two-fold following decentralization. Alderman (1998) utilized household survey data to evaluate a social assistance program in Albania that was decentralized in 1995. He finds evidence of modest gains in efficiency and cost-effectiveness as a result of decentralization. Azfar, Kähnkönen and Meagher (2000) surveyed households and government officials in the Philippines to ascertain the matching of public investment priorities between government officials and local residents. They find that the stated priorities of municipal authorities more closely matched those of local residents than did provincial authorities, suggesting that decentralization may improve public investment decision-making. The 1994 World Development Report on Infrastructure cited cases of cost savings as well as quality improvement in public infrastructure projects following the transfer of management responsibility to local authorities. The study, which included data from 42 countries, cited numerous cases in which decentralized governments were more effective in providing infrastructure such as roads and water supply at a lower cost.

These and a number of other studies suggest that decentralized governmental systems provide public services more efficiently and at a lower cost than more centralized systems. However, Bardham (2002) asserts that many of the studies are unable to identify causal processes. Further, in our review of this literature we found no studies that utilized cross-country data to evaluate the effectiveness of decentralization. The lack of cross-country analysis is largely due the unavailability of comparable data on costs and effectiveness of government activity.

Another related line of research has focused on the role of decentralization in promoting economic growth. The limited number of existing studies on this topic provides mixed evidence. Davoodi and Zou (1998) use a panel data set of 46 countries over the 1970-1989 period to examine the relationship between fiscal decentralization and growth, reporting evidence of a negative relationship between decentralization and growth for developing countries. They attribute this finding to the potential inefficient use of resources at the local level in developing countries. Xie, Zou and Davoodi (1999) look at again at this same issue only in the context of the United States. This analysis suggests that existing spending shares of state and local governments are consistent with growth maximization, and that further efforts at decentralization in the United States might be counterproductive. Akai and Sakata (2002) use data for the 50 US states over the 1992 through 1996 period to determine the relationship between several measures of decentralization and growth. In contrast to previous work, they report some evidence that decentralization may encourage economic growth. Thornton (2007) uses data from OECD countries to reexamine this issue, finding decentralization has no statistically significant impact on growth. In terms of theory, Brueckner (2006) develops an endogenous growth model to more carefully explore the connection between decentralization and economic growth. The model offers a formal analysis to show that more units of government allows for differing levels of public goods across jurisdictions in order to better meet differing community demands for public services. This creates an incentive to increase savings and investment in human capital, and this in turn generates a higher rate of economic growth. Of special relevance to the present study is the recent work of Arze del Granado, Martinez-Vasquez and McNab (2005), which provides empirical support for Brueckner's conjecture by showing that decentralization may increase public education spending. This line of research is relevant to the issue of the role of decentralization in protecting human life for two reasons. First, it demonstrates that there is an important interconnection between decentralization and economic well-being. This suggests that if we are to isolate the effect of decentralization on preserving human life, we will want to control for measures of economic development. Second, there may important interactions between decentralization and educational attainment that require consideration in assessing the determinants of disaster-induced fatalities.

In the context of the even more specific literature on disaster management and response, Wildasin (2008) points out that the particular institutional structures within fiscal federalism may create incentives for local governments to limit financial and policy preparations. In the United States, for example, much of the incidence of local disasters is shifted to the rest of society through intergovernmental transfers. Wildasin argues that it may be necessary for central government to implement new forms of federal control of subnational governments, including requirements for the creation of 'rainy day' funds targeted at disaster management/recovery. Effective public-sector *ex ante* avoidance measures as well as *ex post* disaster response requires coordination and sharing of financial costs between national and subnational governments. Subnational governments are perceived to have a comparative advantage over national governments in the management of land use, economic development, safety and other regionally-based policies that affect disaster risk. On the other hand, there is a role for national governments in setting certain disaster-management policies. This suggests that there may be an optimal mix of responsibility between national and subnational governments in disaster management activity, and more generally in the devolution of public responsibilities.

#### *Economics of natural disasters*

A critical underlying factor in any economy's response to disaster events is its level of wealth. Horwich (2000) argues that increased income translates to a general increase in the level of safety. Wildavsky (1988) interprets the degree of safety enjoyed by citizens of a country as a natural product of a growing market economy. Wildavsky broadly defines as protection against hazardous things and circumstances (e.g. less dangerous machinery, improved construction quality, more reliable automobile braking and steering mechanisms, and more reliable means of transportation and communication). He describes a learning-process by which individual buyers weigh the cost of each technically feasible increment of safety against the expected benefit. 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. An increase in income provides not only leads to improvements in general safety, but also additional protection against natural disasters. As a society becomes more developed it sequentially implements policies

designed to reduce the risk of the most hazardous factors in the environment.

The decision as to which of the existing hazards should be mitigated depends on the marginal benefit and marginal cost of hazard reduction for each of the potential hazards. For example, in the United States reducing malaria, measles and small pox were high priority issues in the early to mid twentieth century because they were prime killers at the time. As these diseases were mitigated via vaccines and other means, other lower priority hazards came to the forefront: cancer and heart disease became high priority research issues much later. The implementation of seat-belt laws, child seats and other improvements in automobile safety also occurred much later. This sequence of hazard reducing policy implementation is closely related the level of economic development. As income rises, it becomes possible to reduce risks, and of course the most dangerous hazards ought to be mitigated first. We can place risk from natural events within this continuum. The implementation of warning systems, building codes, emergency response plans, etc. will only occur when income levels are high enough to support them and when other more hazardous factors have first been addressed.

While both developed and developing countries have some degree of disaster protection initiated by the public sector, the degree to which economic agents benefit from and are able to comply with and employ their own established safety standards depends on the level of income. For example, whether or not new construction complies with code depends on the costs of compliance relative to income. In addition, at some threshold level of income private disaster protection emerges (Horwich 2000) – e.g. emergency and risk management departments in commercial and other enterprises, private disaster consultants, disaster property insurances, including self-insurance through private saving (Skidmore 2001).

Tol and Leek (1999) and Burton *et al.* (1993) also discuss the potential for reduced vulnerability 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. As noted by Tol and Leek (1999), there is probably a rapid transition between relatively vulnerable and invulnerable that occurs somewhere in the modernization process. According

to Albala-Bertrand (1999), the people most affected by direct disaster events are primarily those who have weaker economic and political bases. While disasters occur in both industrialized and developing countries, about 95 percent of the deaths occur in the developing world (Alexander 1993). This discussion suggests that income and wealth are highly correlated with the number of deaths caused by natural disasters. As an illustration, the United States seems to have made such a transition during the 20th century. The annual average number of deaths caused by hurricanes on the Atlantic coast during the 1900–1940 period was 327. However, over the 1972–2005 there was only an average of about 58 deaths annually, including the 1,319 deaths caused by hurricane Katrina.

In a recent study that utilizes disaster data from OFDA/CRED, Kahn (2005) shows that income and institutional quality are important determinants of human casualties from natural disasters. Of special note, Kahn (2005) also shows that, while the probability of disaster occurrence is not related to the level of development, the number of deaths, injured and homeless are reduced as income rises. His work also suggests that more democratic countries experience fewer human losses than do less democratic countries. Using data similar to that of Kahn (2005), Anbarci and Escaleras (2005) examine the relationship between earthquake fatalities and income inequality, finding that countries with greater inequality experience greater losses. Toya and Skidmore (2007) extend the research on the development-disaster relationship by examining additional factors such as human capital accumulation and the degree of openness, finding that both greater human capital and openness reduce losses from natural disaster events. Toya and Skidmore (2007) suggest that distinct from the private disaster-income-safety relationship is the existence of an underlying social/economic fabric that increases safety for all of society. Even more recently, Kellenberg and Mobarak (2008) demonstrate that there may be important nonlinearities between the level of development and disaster impacts.

As highlighted by Horwich (2000), disaster mitigation efforts (*ex ante* and *ex post*) are sometimes most effectively implemented by the private sector. For example, Horwich (2000) found that the most responsive organization following the 1995 earthquake in Kobe was the Japanese mafia. This market-oriented group was especially effective at distribut-

ing resources when and where they were most needed. In contrast, government officials suffered from paralysis immediately following the quake, taking days to mobilize and provide meaningful assistance. Free market economists have used the term ‘decentralization’ as a synonym for privatization (Bardham 2002), arguing for the benefits of reducing the power of a strong centralized government.

In recent years governments have been criticized for lack of preparation and inability in response to extreme large magnitude disaster events. For example, in the aftermath of hurricane Katrina both state and local officials in Louisiana were criticized for not enhancing the flood control infrastructure, which ultimately led to massive flooding. Public responsibilities regarding safety, land use and economic development decisions, etc. play important roles in limiting the impacts of natural catastrophes. The first level of assistance in response to a disaster event will come from police and fire authorities. Such services account for a significant portion of public service expenditures regardless of fiscal structure. Within a decentralized governmental system, public safety services are typically provided by more autonomous subnational authorities. Importantly, the *ex ante* public sector preparations (establishing and enforcing land use and building code regulations, maintaining infrastructure, etc.) as well as *ex post* response (public safety) is crucial in terms of protecting human life. It would then seem that data on deaths from natural disaster events provides a good test case for examining the role of government structure on public service delivery as it relates to protecting the populace from the potentially devastating impacts of catastrophic events. Further, given evidence suggests that decentralized fiscal systems increase educational attainment, and education enables citizens to better prepare for and respond emergency circumstances.

Wildasin (2008) identifies another important consideration: intergovernmental transfer mechanisms may weaken the incentives for subnational governments to engage in *ex ante* disaster preparations. Under the current US federal government emergency management policy, assistance has effectively shifted much of the burden of disaster losses (particularly floods) to the rest of society. While such a policy relieves the financial stress on the affected region, it also reduces the incentive for subnational governments to invest in costly but effective disaster avoidance activities. Wildasin (2008) suggests another

er approach to strengthen sub-national incentives: mandate subnational governments to build disaster reserve funds.

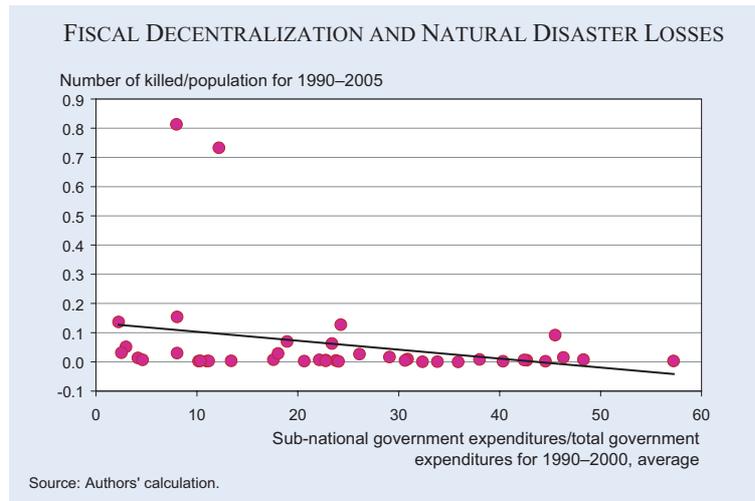
This discussion outlines two opposing forces in decentralization with regard to disaster management and response. First, the literature on the effectiveness of decentralization efforts in the developing world suggests that subnational governments may provide many public services more efficiently, including education, and may be more responsive to heterogeneous local

needs. An opposing view is the certain institutional structures within fiscal federalism may weaken the incentives for subnational units of government in terms of *ex ante* preparation as well as *ex post* recovery from disaster events.

We add to both of these lines of research by examining the relationships between fatalities induced by natural disaster events, education and decentralization while controlling for a number of other variables that characterize the level of economic development. Our analysis adds new insight to the research the effectiveness of fiscal decentralization as well as to the research on disaster mitigation. We acknowledge that our empirical analysis provides a more general evaluation: clearly, more focused country-specific analyses such as that of Wilsdasi (2008), Chernick and Haughwout (2006) and Horwich (2000) also yield important insights.

We present some initial evidence regarding the relationship between disasters and economic growth in Figure 1. This figure shows the simple linear relationship between the natural logarithm of the number of annual disaster-induced deaths and the ratio of subnational to total government expenditures for 61 countries over the 1990–2005 period. The vertical axis represents the natural logarithm of natural disaster-induced deaths. Along the horizontal axis is the ratio of subnational to total government spending. The disaster data illustrated in Figure 1 represents current and detailed information on natural disaster fatalities from the Center for Research on the Epidemiology of Disasters (CRED) (EMDAT 2004). The figure indicates a clear negative and statistically significant

**Figure 1**



association between disaster-related fatalities and decentralization. While this slope coefficient is generated without controlling for other factors that may affect the degree to which natural disasters lead to death, the figure motivates a more carefully examine of the issue.

In order to rigorously evaluate the impact of decentralization on mitigating disaster losses, we control for other factors found to be important in previous studies (Kahn 2005; Anbarci, Escaleras and Register 2005; Toya and Skidmore 2007) such as income, human capital, openness and size of government. We examine these issues by including per capita GDP, average years of secondary and higher schooling completed, openness ((exports + imports)/GDP), government size (government expenditure/GDP) into our empirical analysis. We also control for other factors such as a time indicator variables, population, land area, OECD dummy, disaster type that determine human fatalities induced by catastrophic events.

To provide a more formal framework for our empirical analysis, consider the following Cobb-Douglas production function which maps the relationship between the production of safety that society enjoys and the factors that determine safety:

$$(1) \quad S_i = A_{ji} K_i^{\alpha} L_i^{\beta}$$

where  $S$  measures the quantity of ‘safety’ produced by society  $i$ ,  $K$  is capital and  $L$  represents labor and is equal to  $\psi^h N$  where  $h$  is average schooling years and  $N$  is population. Following Topel (1999), we specify human capital as an exponential function of schooling in the production function. This implies

that schooling will enter the ‘safety’ production function linearly.<sup>2</sup> Last,  $A_{jt}$  is a productivity parameter specific to disaster type  $j$  (e.g. climatic or geologic). Dividing both sides by population  $N$  yields:

$$(2) \left(\frac{S}{N}\right)_t = A_{jt} \left(\frac{K}{N}\right)_t^{\hat{a}} \left(\psi e^h \frac{N}{N}\right)_t^{\hat{a}} N_t^{\hat{a}+\hat{a}-1}$$

Simplifying equation (2) results in:

$$(3) \left(\frac{S}{N}\right)_t = A_{jt} k_t^{\hat{a}} (\psi e^h)^{\beta} N_t^{\alpha+\beta-1}$$

where  $k$  is equal to physical capital per capita. To convert the notion of ‘safety’ into a more tangible measure, deaths ( $D$ ) resulting from natural disasters, consider the following relationship:

$$(4) D = f(S)N = \frac{N}{S}$$

where  $f$  is the probability of disaster induced death,  $f' < 0$

Substituting  $D$  for  $\frac{N}{S}$  and simplifying further yields:

$$(5) D_t = A_{jt}^{-1} k_t^{-\hat{a}} \psi e^{-h\beta} N_t^{\alpha+\beta}$$

Finally, taking the natural logarithm of both sides and combining  $\ln A$  and  $\ln \psi$  together into  $Z$ , an overall ‘technology’ parameter, produces an equation that is the basis for our empirical analysis:

$$(6) \ln(D)_t = -Z_{jt} - \hat{a} \ln(k)_t - \beta h_t + (\hat{a} + \hat{a}) \ln(N)_t$$

The productivity parameter,  $Z_j$ , is then a function of decentralization, government size (government expenditure/GDP), as well as factors such as openness ((exports + imports)/GDP), fertility and a measure of inequality. We also control for other factors such as land area, OECD dummy, time indicator variables and disaster type that determine human fatalities induced by catastrophic events. Given that GDP is highly correlated with  $k$ , we use GDP per capita as a proxy for  $(k)$ . Consistent with the model, we also include popu-

lation as a control variable. From this model we expect higher levels of GDP per capita and educational attainment to reduce death tolls, and higher levels of population to increase death tolls. The degree of trade openness is expected to reduce deaths as well (Toya and Skidmore 2007). However, greater fertility and inequality are expected to increase disaster-induced fatalities. We test these notions in the empirical analysis which is presented next.

### Empirical analysis

Data on natural disasters come from the OFDA/CRED International Data Base (2006), and macroeconomic data are available from several sources (Barro and Lee 1996; International Financial Statistics website; Heston, Summers and Aten 2002; World Development Indicators 2003). Government fiscal data are taken from the World Bank website. The OFDA/CRED database is a result of collaboration between the Office of US 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 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.

Using this merged data set we conduct empirical analyses to determine the relationship between decentralization and disaster-induced fatalities, while controlling for a range of other factors. 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>). Although the data set provides information on a number of natural disaster types, we restrict our analysis to earthquakes, floods, slides, volcanic eruptions and extreme winds.<sup>3</sup> Summary statistics and data sources are in presented in the Appendix (Tables A1 and A2).

<sup>2</sup> For example, consider a standard Cobb-Douglas production function:  $y = Ak^{\alpha}h^{1-\alpha}$ , where  $y$  is per capita GDP,  $A$  is the level of technology,  $k$  is per capita capital stock, and  $h$  is per capita human capital. Transforming this function into log form yields:  $\ln y = \ln A + \alpha \ln k + (1-\alpha) \ln h$ . With a Mincer-type model,  $h$  equals  $\Psi e^s$  with  $s$  = average years of schooling. Taking the log yields:  $\ln y_t = (\ln A_t) + \alpha (\ln k_t) + (1-\alpha) (\ln h_t)$ . Substituting in for  $h$  yields:  $\ln y_t = \ln A_t + \alpha (\ln k_t) + (1-\alpha) (\ln \Psi + s_t)$ .

<sup>3</sup> Hurricanes, tornadoes, typhoons, etc. are included in this category.

An average 193 deaths resulted from each recorded disaster events over the 1970–2005 period.<sup>4</sup> In our sample, the most common types of disasters were floods and extreme wind, accounting for 39 and 38 percent of the total, respectively. Seven percent of the total resulted from slides, 12 percent were earthquakes, and volcanic eruptions accounted for just three percent of the total.

It is also important to provide a careful definition of our key independent variable, the subnational share of total government expenditures. First, expenditure data include intergovernmental transfers in addition to functional expenditures. Thus, caution is warranted in making comparisons across government tiers. Second, these data only provide a proxy for expenditure autonomy because a large portion of subnational expenditures may be mandated by the central government. Despite these limitations, this is probably the best and most utilized measure of decentralization available. It includes the following expenditure categories: general public services; defense; public order and safety; education; health; social security and welfare; housing and community amenities; recreational, cultural, and religious affairs and services; fuel and energy; agriculture, forestry, fishing, and hunting; mining and mineral resources, manufacturing and construction; transportation and communication; other economic affairs and services; and other expenditures. Expenditures related to disaster preparation and management occurs in a number of functional categories. Clearly, the public order and safety category is critical, but other functional areas like health, transportation and communication, and economic affairs are likely to also play important roles. We also include a measure of vertical imbalance, which is the ratio of intergovernmental transfers from national government to subnational government expenditures. Our analysis estimates effects of the government structure in terms of spending at the subnational level while controlling for the degree subnational reliance on national authorities for financial resources. In some specifications, we also interact decentralization with educational attainment to determine how human capital alters government productivity in providing safety.

We estimate a series of regressions to determine the relationship between disaster-induced fatalities and decentralization. Our basic regression is characterized by the following equation:

$$(7) \quad \ln(\text{deaths}_{jit}) = \beta_1(\text{decent}_{it}) + \beta_2(vi_{it}) + \beta_n(y_{jit}) + t_i + e_{jit}$$

where  $\text{deaths}_{jit}$  is the total number of deaths<sup>5</sup> caused by natural disaster type  $j$  (hurricane, earthquake, flood, etc.) in country  $i$  during period  $t$ ;  $\text{decent}_{it}$  is defined as sub-national own source expenditures/total government expenditures;  $vi_{it}$  is the ratio of national intergovernmental transfers to subnational expenditures;  $y_{jit}$  represents a vector of  $j$  variables that may determine the deaths caused by the natural disaster (e.g. natural logarithm of per capita GDP in real US dollars, a measure of human capital (years of secondary and higher education schooling), openness ((exports+imports)/GDP), population, land area, OECD dummy, a series of indicator variables characterizing the type of disaster); and  $t$  represents a series of time indicator variables. In addition to controlling for various aspects of development, it is critical to control for the size of government to isolate the impact of government structure. We therefore include the ratio of government spending to GDP as an additional control.

As shown in Figure 2, roughly one-third of our observed disaster events record zero deaths. Our dependent variable is therefore truncated at zero:

$$(8) \quad \ln(\text{deaths}_{jit}) = \max(0, \ln(\text{deaths}_{jit}))$$

We therefore use a Tobit random effects specification to properly treat the censored variable within a panel data framework.<sup>6</sup>

One last potentially important econometric issue warrants our attention: it is possible that the likelihood of a disaster event being recorded depends, in part, on the level of development. However, in a careful analysis Kahn (2005) demonstrates that the probability of a disaster event occurring and being recorded is not dependent on the level of development: with the exception of floods, high and low income countries are equally likely to experience a naturally occurring disaster event. Relying on Kahn's result, we move directly to an analysis of the determinants of disaster-related fatalities.

## Results

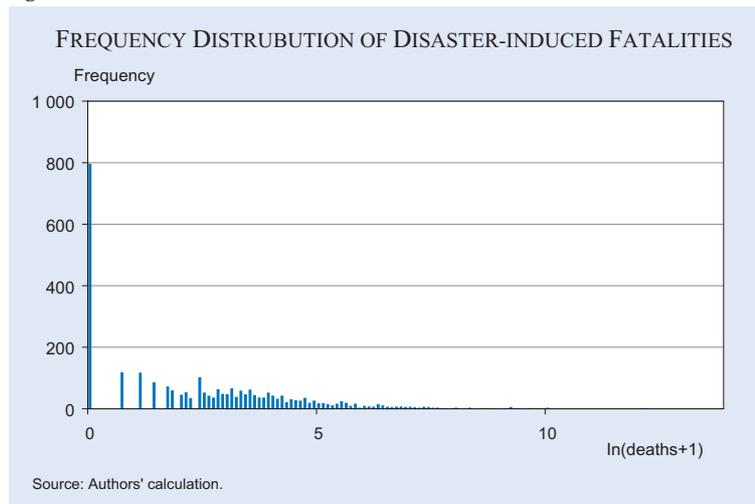
Table 1 presents a series of regressions using data for all natural disasters recorded for all countries over

<sup>4</sup> The average is pulled up by the catastrophic tsunami that occurred in Asia in 2004. Omitting this event reduces the average number of deaths to 124.

<sup>5</sup> Since we use the natural logarithm of deaths, to avoid arithmetic error we use  $\ln(\text{deaths}+1)$  as our dependent variable.

<sup>6</sup> The Tobit model within the fixed effects framework could potentially be used, but this econometric approach generates biased parameter estimates.

Figure 2



the 1970–2005 period. In column 1, we present a base regression in which measures of decentralization are excluded from the analysis. Column 2 presents a regression that includes a primary measure of decentralization (*decent*), but excludes educational attainment. The column 3 regression includes both educational attainment and decentralization measures together simultaneously. A key purpose in presenting these first three regressions is to demonstrate important interrelationships between decentralization, education and death tolls from disasters. Column 1 results show negative relationship between educational attainment and death tolls, although the coefficient is only significant at the 90 percent level of confidence. In column 2, we see that the coefficient on decentralization is negative and highly significant. Now consider the regression presented in column 3. Here, we include both educational attainment and decentralization together in a single regression. The coefficient on educational attainment is smaller than in column 1 and it is now insignificant. Also, the coefficient on decentralization is smaller than in column 2, but its statistical significance is maintained. These three regressions demonstrate an important relationship between decentralization and educational attainment

in reducing disaster-induced deaths. One possible interpretation is that a route by which decentralization leads to fewer deaths is through providing a more educated population that is better able to prepare for and respond to catastrophic events. Another possibility is a more highly educated population enhances the effectiveness of a decentralized government structure. Consider also the coefficients on government size and the degree of vertical imbalance. The coefficients on government size and vertical imbalance are never significant in the regressions.

Before turning to additional regressions in Table 2, consider the coefficients on the other control variables. The coefficient on GDP per capita is negative, but only statistically significant in three of the five regressions. As expected, greater trade openness reduces disaster-induced fatalities. Openness is thought to enhance commodity distribution networks so that international assistance can be allocated to

Table 1

**Fiscal decentralization and natural disaster losses**  
Dependent variable:  $\text{Log}(1 + \text{Number of killed})$

	1	2	3
Log (GDP per capita)	-0.474 (-1.905)	-0.441 (-2.468)	-0.515 (-2.249)
Secondary and higher schooling years	-0.392 (-2.757)		-0.119 (-0.938)
Log (Openness)	-0.499 (-2.600)	-0.647 (-4.188)	-0.688 (-4.202)
Fertility	0.006 (0.060)	0.020 (0.237)	0.012 (0.121)
Gini coefficients	0.002 (0.157)	0.008 (0.928)	0.004 (0.431)
Log (Size of government)	0.324 (1.087)	0.091 (0.421)	-0.002 (-0.006)
<i>Local Gov<sub>total</sub> / Total Gov<sub>total</sub></i>		-2.057 (-2.967)	-1.837 (-2.324)
Vertical imbalance		-0.171 (-0.483)	-0.300 (-0.787)
No. of countries	59	69	55
No. of observations	2761	2712	2581
Log-likelihood	-4956.1	-4858.2	-4632.9

Notes: Numbers in parentheses are z-values. Other independent variables not reported here are Constant, Log (Population), Log (Area), OECD, Earthquake, Flood, Volcano, Wind, Wave and a series of year indicator variables.

Source: Authors' calculation.

areas in need more effectively. In addition, countries with greater openness may have access to technologies and practices that improve safety. Countries with higher rates of fertility and greater income disparities tend to have more disaster-induced deaths, although the coefficients on these variables are only sometimes significant. These findings are generally consistent with Kahn (2005), and Toya and Skidmore (2007).

In Table 2, we present additional regressions to examine robustness of our key finding to the inclusion of government ‘quality’ measures, and to further explore the decentralization-educational attainment relationship. In column 1 we repeat the estimates presented in column 3 of Table 1, except we include a measure of the degree of political freedom and a measure of civil liberty. Note that our core result remains: the coefficient on the overall measure of decentralization maintains its statistical significance. Civil liberty and political rights are not significant determinants of disaster deaths.

In columns 2 and 3, we examine whether decentralization enhances the degree to which education reduces safety by including an interaction between educational attainment and decentralization. Consider column 2, which repeats the column 2 regression in Table 1 except that the decentralization measure is now replaced with the interaction variable. The coefficient on the interaction variable is negative and highly significant. Once we include educational attainment as in column 3, the coefficient on the interaction term is smaller but it maintains its statistical significance. One interpretation of this finding is that the productivity of an educated population in terms of protecting life is enhanced by greater autonomy at the local level. An alternative interpretation is that the ability of local government to operate effectively and thus produce a safer environment is greatly enhanced by

having an educated work force from which to hire capable public employees.

How many lives are likely to be saved as a result of decentralization? From column 2 of Table 1, an increase in subnational government expenditures relative to total government expenditures of 0.2 reduces lives lost by about 30 percent. Thus, if a very centralized government with a small ratio of subnational to national expenditures of, say, 0.1 were to decentralize such that this ratio increased to about the average (0.3), the number of disaster-induced fatalities would fall by 40 percent. If we control for educational attainment as in column 3, direct decentralization effect indicates that fatalities would fall by 36 percent. One should, however, be careful not to extend such calculations to hyperbole: countries that are already decentralized are not likely to save more lives as a result of further decentralization.

**Table 2**  
**Fiscal decentralization, human capital and natural disaster losses**  
Dependent variable: Log (1+Number of killed)

	1	2	3
Log (GDP per capita)	-0.590 (-2.941)	-0.420 (-2.322)	-0.497 (-2.645)
Secondary and higher schooling years	-0.075 (-1.043)		0.184 (1.498)
Log (Openness)	-0.712 (-4.987)	-0.589 (-4.820)	-0.581 (-4.747)
Fertility	0.093 (1.171)	0.111 (1.517)	0.092 (1.239)
Gini coefficients	0.011 (1.399)	0.013 (1.720)	0.011 (1.503)
Log (Size of government)	-0.129 (-0.530)	-0.308 (-1.553)	-0.192 (-0.900)
<i>Local Gov<sub>total</sub> / Total Gov<sub>total</sub></i>	-1.575 (-2.661)		
<i>(Local Gov<sub>total</sub> / Total Gov<sub>total</sub>) × Secondary and higher schooling years</i>		-0.357 (-3.283)	-0.620 (-2.996)
Vertical imbalance	-0.276 (-0.941)	-0.133 (-0.476)	-0.194 (-0.686)
Political right	0.057 (0.862)		
Civil liberty	-0.037 (-0.420)		
No. of countries	54	55	55
No. of observations	2527	2581	2581
Log-likelihood	-4518.3	-4479.6	-4475.3

Notes: Numbers in parentheses are z-values. Other independent variables not reported here are Constant, Log (Population), Log (Area), OECD, Earthquake, Flood, Volcano, Wind, Wave and a series of year indicator variables.

Source: Authors' calculation.

## Robustness

We have also estimated these regressions using the pooled Tobit<sup>7</sup> econometric technique.<sup>8</sup> Results from this alternative specification yields qualitatively similar results. We also estimated a series of regression using the fixed effects estimation procedure. However, a word of caution in interpreting these findings is in order. The parameter estimates from the fixed effects estimates are generate from the within country variation in the independent variables. It therefore seems prudent to identify which countries experienced significant changes in the ratio of subnational to national spending over the period of analysis. While many countries experience relatively minor changes in the degree of decentralization, we identified eight countries (Argentina, Bolivia, Brazil, Italy, Mexico, Spain, Peru and South Africa) that had both a significant number of recorded disaster events as well as significant changes over time in fiscal federalism. The fixed effects parameter estimate on the decentralization variable is largely driven by the experiences of these eight countries. Thus, one should interpret the fixed effects results with this in mind. The coefficient on our key decentralization variable is again negative and highly significant: countries that have become more decentralized over time have experienced fewer disaster-induced deaths.<sup>9</sup>

## Conclusion

Private entities, governments 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.). Further, the public sector preparations and response to natural disasters are critical. Lack of proper preparation and delayed and/or ineffective response may result in lives lost. The primary objective of this study is to determine whether government fiscal structure is important in disaster-induced fatality prevention.

<sup>7</sup> A likelihood ratio test indicates that the panel-level variance component is important, and therefore the random effects estimator is more appropriate than that pooled Tobit estimator. Nevertheless, we examine the pooled Tobit estimator.

<sup>8</sup> The number of recorded fatalities can be thought of count data with over-dispersion. The negative binomial is therefore potentially an appropriate alternative estimation technique.

<sup>9</sup> These additional estimates are available from the authors upon request.

Previous research that has sought to assess the effectiveness of fiscal decentralization is limited in terms of identifying causal relationships, and more systematic analysis has been hampered by the lack of consistent cross-country data on government costs and effectiveness (Bardham 2002). Despite the tragic nature of catastrophic events, they in fact provide a good opportunity to assess the role of government structure in limiting the fatalities resulting from such events: death tolls provide a clear and consistent time varying cross-country measure of effectiveness.

Our analysis provides evidence that more decentralized countries as measured by the ratio of subnational expenditures to national expenditures experience fewer deaths. Our findings also suggest that one route by which a decentralized system reduces disaster-induced deaths is through educational attainment. This finding is consistent with the work of Brueckner (2006), and Arze del Granado, Martinez-Vasquez and McNab (2005) who provide arguments and evidence for the notion that decentralized systems increase human capital. More generally, these findings are robust to the inclusion (or exclusion) of a variety of other factors that have been found to be important determinants of disaster-related deaths in previous studies. The results are also robust to alternative econometric methods. The research presented here increases our understanding of the role of government in disaster management and response. Disaster death toll data has enabled us to conduct the first time-varying cross-country evaluation of the effectiveness of decentralization efforts, and therefore this research contributes to both the literatures on the fiscal decentralization and the economics of natural disasters.

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## Appendix: Tables A1 and A2

## Appendix

**Table A1**  
**Summary of statistics variables used in the analysis**

	Mean	Standard deviation	Number of observations
Log (1+Number of killed)	2.248	1.985	2761
Log (GDP per capita)	8.940	1.003	2761
Secondary and higher schooling years	2.742	1.822	2761
Log (Openness)	3.601	0.678	2761
Fertility	2.792	1.250	2761
Gini coefficients	37.65	9.446	2761
Log (Size of government)	-1.218	0.417	2761
Local Gov <sub>total</sub> / Total Gov <sub>total</sub>	0.315	0.169	2712
Vertical imbalance	0.405	0.184	2712
(Local Gov <sub>total</sub> / Total Gov <sub>total</sub> ) × <i>Secondary and higher schooling years</i>	1.031	0.998	2581
Log(Population)	11.49	1.671	2761
Log(Area)	14.32	1.711	2761
OECD	0.376	0.484	2761
Earthquake	0.106	0.309	2761
Slides	0.071	0.257	2761
Volcano	0.024	0.154	2761
Wave	0.005	0.068	2761
Wind	0.408	0.492	2761
Flood	0.386	0.487	2761
Political right	2.676	2.076	2527
Civil liberty	2.916	1.857	2527

Source: Authors' calculation.

Table A2

## Definitions and sources of variables

Variables	Definition	Source
Number of killed	The number of persons confirmed as dead and persons missing and presumed dead	EMDAT
GDP per capita	Real GDP per capita	HSA
Secondary and higher schooling years	Years of secondary and higher schooling in the total population aged 15 and over	BL
Openness	Ratio of exports plus imports to GDP	HSA
Fertility	Total fertility rate	WDI
Gini coefficients	Gini coefficients	WIID
Size of government	The ratio of total government expenditures to GDP	GDN
Local Gov <sub>total</sub> / Total Gov <sub>total</sub>	The ratio of total sub-national government expenditures to total government expenditures	WB_FDI
Vertical imbalance	The ratio of intergovernmental transfers to sub-national expenditures	WB_FDI
Population	Logarithm of population	HSA
Area	Logarithm of land area	WDI
OECD	Dummy for OECD countries	
Wind	Dummy for wind	EMDAT
Flood	Dummy for flood	EMDAT
Earthquake	Dummy for earthquake	EMDAT
Slides	Dummy for slides	EMDAT
Volcano	Dummy for volcano eruption	EMDAT
Wave	Dummy for wave	EMDAT
Political right	Political right (range from 1(good) – 7(bad))	FH
Civil liberty	Civil Liberty (range from 1(good) – 7(bad))	FH

Sources: BL = Barro and Lee (1996); EMDAT = EMDAT (2004); FH = Freedom in the World from <http://www.freedomhouse.org/template.cfm?page=15>; GDN = Global Development Network Growth Database from <http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:20701055~pagePK:64214825~piPK:64214943~theSitePK:469382,00.html>; HAS = Heston, Summer and Aten (2002); WB\_FDI = Fiscal Decentralization Indicators from <http://www1.worldbank.org/publicsector/decentralization/fiscalindicators.htm>; WDI = World Development Indicators 2006 from <http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2006>; WIID = World Income Inequality Database from [http://www.wider.unu.edu/research/Database/en\\_GB/wiid/](http://www.wider.unu.edu/research/Database/en_GB/wiid/).