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Fiscal decentralization and natural hazard risks

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Abstract At least to some extent due to pressure from international donors, many countries have become more fiscally decentralized the underlying premise being that greater decentralization might improve the provision of local public goods and services. We test this proposition by determining whether relatively more decentralized countries fare better when natural disasters strike in terms of its effects on the population. Overall, we find evidence supporting our maintained hypothesis, though the effect appears much more robust in developing countries.

Keywords Governmental decentralization · Management of natural hazard risks

JEL Classification H11 · H41 · H73 · H77 · Q54

1 Introduction

Over the past several decades countries from all parts of the world have moved toward some form of decentralization of central government actions in an attempt to improve overall government performance. Some have taken these steps unilaterally while others have been persuaded to do so by bilateral donor countries or international organizations, such as the World Bank, who have included decentralization requirements in their development assistance programs. As an example, of all completed World Bank projects in the early part of the 1990s, 12% had some decentralization requirement built into them (Litvak 1998: 1). These policies all grew, to one degree or another, from the simple Tieboutian notion that decentralization can improve the provision of local public and semipublic goods and services. This notion would especially seem to hold for those goods and services that target unique local or regional (that is, sub-national) needs. The reasons for this belief are numerous but center

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around the idea of bringing decision makers closer to those affected by their decisions. Examples include local governmental officials having greater knowledge and understanding of unique local needs and enhanced accountability on the part of local government officials to their constituents than would be the case if those officials were appointed from higher levels of government (Treisman 2002).

Of course, as is often the case, there are countervailing arguments about the assumed benefits of decentralization. First in this regard is the redundancy costs involved in setting up multiple layers of government. Further, it is often argued that local governments are more susceptible to corruption that lessens their ability to provide local public goods and services (Tanzi 1995). Finally, an old but still intuitively appealing criticism of decentralization is that of John Stuart Mill (1977: 422) who noted that in a relatively decentralized state, "the local representative bodies and their officers are almost certain to be of a much lower grade of intelligence and knowledge, than Parliament and the national executive." That is, the most competent administrators likely target the highest office possible given the relatively greater prestige and compensation that accompany more prestigious positions.

Given the competing beliefs as to the effectiveness of decentralization it is not surprising that a great deal of empirical research has been devoted to the subject. Authors have, using various notions of decentralization, alternative methods, and data from a variety of countries and time periods, considered decentralization's effect on factors as varied as local investment and economic growth (Sole-Olle and Esteller-More 2005; Thiessen 2003; and Strumpf and Oberholzer-Gee 2002), foreign direct investment (Kessing et al. 2005), public sector corruption (Treisman 2002; and Fisman and Gatti 2002), provision of health and educational services (Cantarera Prieto and Sanchez 2006; Barankay and Lockwood 2006; and Inchauste 2009), public happiness (Bjornskov et al. 2008), and adherence to the rule of law and the costs of opening a new business (Dreher 2006).[1]

While the question of decentralization's effectiveness has spawned a great deal of research, that body of literature's results are far from consistent. As an example, while Fisman and Gatti (2002) report that decentralization is associated with less public sector corruption Treisman (2002) reached the opposite conclusion. Similarly, when the focus is on aspects of education, Inchauste (2009) concludes that decentralization does not lead to substantial positive results, while Barankay and Lockwood (2006) do find evidence of increased educational attainment related to decentralization.

This lack of consistency across studies may simply result from differing samples, differing definitions of decentralization, differing outcome measures, differing empirical procedures, or some similar factor. Further, and closer to the present paper, decentralization may simply be more effective in dealing with some issues than others. This final prospect is implicitly suggested in Sole-Olle and Esteller-More (2005), who consider local investment in schools in 44 Spanish provinces during that country's move from a unitary to a quasi-federal state and find decentralization to be associated with regional allocation of resources that is more responsive to local needs. A similar outcome is found by Clark (2009) in his analysis of a schools reform program in Brittan which allowed public high schools to opt out of local governmental control and re-establish themselves as autonomous though publicly funded institutions. The latter's results suggest significant achievement gains for those schools where voters supported the opt-out opportunity—that is, there are significantly positive effects for the relatively more decentralized schools. In this situation, the positive effect of decentralization found by the authors is an example of Hayek's (1984: 217) logic that only through

[1] For a thorough and current overview of the various decentralization programs and their effectiveness, see Ahmed and Brosio (2009).

decentralization "can we insure that the knowledge of the particular circumstances of time and place will be promptly used."

The examples of Sole-Olle and Esteller-More (2005) and Clark (2009) provide the potential nexus between decentralization and improved management of natural hazard risks that we wish to pursue in this paper. Natural disasters, while capable of striking entire nations, more typically strike a local or regional part of a country. Taken one step further, within a large country such as the United States practically no area is free from some type of natural hazard risk. Rather than facing the threat of the same type of disaster, the differing regions of the country tend to be subject to unique disasters (windstorms in the southeast and Gulf states, earthquakes along the western coast, and volcanoes in the northwest and Hawaii, as examples). This understanding of disasters leads Bollin et al. (2003) to conclude "In general terms a consensus exists that the majority of risks are formed at the local level by an inappropriate interaction between human activity and the environment. This suggests the need for the elevated involvement of local actors in risk reduction."

There are two commonly used metrics of fiscal decentralization: devolution of national government expenditures and intergovernmental revenues to local and regional governments. To evaluate the relation, if any, between decentralization and natural hazard risks we focus on the former, measured as the percentage of total government expenditures controlled by sub-national governments.[2] While this is a commonly used measure of decentralization we recognize that ideally we would like to have this variable based on disaster-related spending at the national and sub-national levels as opposed to total spending. Unfortunately such data are not available for more than a very few wealthy countries. Regardless, the lack of this disaggregated data rightly should cause some caution in interpreting our empirical results. With respect to natural disasters, we take information from the EM-DAT archive collected and maintained by the non-profit institution Centre for Research on the Epidemiology of Disasters (CRED) on five natural disasters (earthquakes, floods, volcanoes, land slides, and windstorms) occurring during the period 1972–2000. CRED uses specific criteria for determining whether an event is classified as a natural disaster. These include ten or more people killed; 100 or more people affected, injured or left homeless; significant damages incurred; and, whether a declaration of a state of emergency and/or an appeal for international assistance was issued.[3] As the CRED data clearly point out, the number of deaths and the portion of the population affected from natural disasters has risen sharply over the past decades (Kahn 2005). While many of these events are merely part of longer run natural cycles, it cannot be denied that humankind has played a role in some, if not many, by increasingly locating housing and production facilities in hazard zones, and the altering of the natural flow of rivers and streams. Put differently, while the CRED data show a dramatic increase in the ill effects of disasters over time, it must be recognized that this could be due to an actual spike in events or, for example, simply greater development in hazard zones. Given that our interest is on managing hazard risks, whether of humankind's making or of nature's, the distinction is of little concern to the analysis.

Prior to turning to the empirical analysis, it is worth expanding on the role that international organizations have played in our understanding of the relationship between natural

[2]There are other approaches to decentralization, including the notion of political decentralization which is often measured by either a dummy variable reflecting whether a country has a federal structure or by the number of layers of government that exist (Treisman 2002 and Fisman and Gatti 2002). We opt for fiscal decentralization as a proxy for natural hazard risk management. If that activity is delegated to sub-national governments, it necessarily requires devolving of expenditures which is not necessarily the case with political decentralization.

[3]http://www.cred.be/emdat/.

disasters and decentralization. As an outgrowth of the United Nations International Decade for Natural Disaster Reduction (1990–1999), a better understanding of disaster risk and how that risk might be best managed was developed. Specifically, it was recognized that overall disaster risk is the product of the hazard itself and a locality's vulnerability to it. This leads to a three-part risk management cycle with the first being the pre-event stage. Hazard mitigation elements of the pre-event stage might include disaster-sensitive building codes and land zoning, pre-positioning of medical supplies and the resources necessary to protect the public from Mother Nature's wrath, and emergency nutritional support, not to mention physical infrastructure items such as hospitals/clinics and search and rescue facilities. And above all, plans must be developed and clearly understood to effectively integrate and deploy all of the elements of the pre-event stage. There must be a chain of command in place for coordinating the responses to natural disasters of central and state/local governments.

The second stage is the disaster itself. The key to the event stage is that it tends to be rather brief in duration. Considering earthquakes, for example, while aftershocks might occur for weeks, the actual initial quake takes at most minutes and often less. While other types of disasters might take a bit longer to fully unfold the actual event is typically measured in hours to days or perhaps a week or two at most (volcanoes are often the obvious exception to this view). During the event stage mitigation efforts involve almost exclusively search and rescue services, medical treatment facilities, nutritional support, and protection from the elements for the affected population.

The final stage of the disaster is the recovery/rebuilding stage. This stage begins only after the event has fully run its course and can take years to complete as it involves reproducing all of the elements of the pre-event stage, especially those items related to physical construction of lost or damaged infrastructure.

While governmental efforts at each of the three stages of the disaster could be undertaken in a centralized fashion, once again we turn to Hayek's (1984: 217) statement noted above that only through decentralization "can we insure that the knowledge of the particular circumstances of time and place will be promptly used." In each stage, it would seem that local knowledge combined with delegated spending authority may prove particularly useful in managing natural hazard risks and thus reducing deaths and injuries from disasters. Consistent with this perspective, we find two outcomes of particular interest from our empirical analysis. First, overall there is a negative and consistently statistically significant relation between a country's degree of fiscal decentralization and its death rate from natural disasters that holds across various specifications. The same is true when we broaden the analysis to include those negatively affected by disasters, not just those killed. Second, while we find negative relations between federalism and the number of disaster-related causalities for developed and developing countries alike, the link is statistically significant only for the latter group of nations.

In the following section we present the data and primary empirical analysis. In Sect. 3 we undertake a number of robustness checks and in the final section we offer a summary conclusion.

2 Data and primary empirical analysis

The unit of observation is a country-year for each of 79 countries during the period 1972–2000. The panel is rather unbalanced since, for inclusion, a country-year must have experienced a disaster satisfying one or more of the CRED criteria and must have data available on all variables discussed below. These limiters leave us with 21 countries appearing in the

Table 1 Summary statistics, cross country data 1972–2000

	Average	St. Deviation	Minimum	Maximum
Deaths (per 100,000 persons)	1.34	12.18	0	265.44
Sub-national expenditure	23.12	15.43	1.49	58.24
GDP per capita	8,253.30	8,760.50	118.23	36,837.44
GDP growth (%)	3.26	4.41	−16.23	17.73
Population	8.25e+07	1.81e+08	212,000	1.24e+09
Elevation	302.49	416.50	30.13	1,871.13
Democracy	6.42	3.95	0	10
Ethnic fractionalization	0.40	0.23	0	0.88
Frequency of disasters	0.06	0.12	0.03	1.10

sample fewer than three times. Appendix 1 lists the countries, by continent. Given the possibility of unobserved, unique local characteristics or institutions which tend to be relatively constant over time for a given region and thus might influence outcomes, all but one model is estimated with continental fixed effects. In order to narrow the regions as much as is reasonably possible we have identified nine continents rather than the typical four or five. Of course we would like to estimate the models with country fixed effects, this is not possible, however, since such a large share on the 79 countries in the sample appear only once and thus would be dropped from the sample—12 countries amounting to 15% of the overall sample. This problem is common to all of the literature on disaster's, as can be seen in Kahn (2005), Escaleras and Register (2007), and Skidmore and Toya (2002), each of which control for fixed effects at the continent level, though none divide the world into nine continents as we do.

Table 1 provides descriptive statistics for all variables used in the primary analysis while descriptions of the variables and their sources are given in Appendix 2. It should be noted that for ease of interpretation, the variables which will be logged in the models to follow are presented in Table 1 without being logged.

The essential variables in the analysis relate to deaths due to natural disasters and the degree of fiscal decentralization within a country. Table 1 reports the number of deaths per 100,000 persons, *Deaths*, a country endures from earthquakes, floods, landslides, volcanoes, and windstorms during a given year. The primary dependent variable is the *Death rate*, which represents the ratio of the total number of deaths due to these natural disasters within a country during a year in which a disaster struck to the country's population, with the following adjustments. First, since the ratio is naturally extremely small, it is then multiplied by 100,000 to ease interpretation. Second, note the wide variation in the observations on *Deaths* in our sample; thus we take the log of this variable in the models to follow. Finally, since some disasters in the sample resulted in no deaths, we add one death to each observation. Thus, the primary dependent variable, *Death rate* is the log of ((deaths + 1)/population)∗100,000). The number of deaths is taken from the CRED dataset discussed in the introduction while population comes from the World Bank's *World Development Indicators*. The key independent variable relates to decentralization. As discussed above, we focus on the expenditures of local/regional governments relative to the total of spending within a country by all levels of government, *Sub-national expenditure*. This is a common proxy for fiscal decentralization, as can be seen in Oates (1972), Panizzi (1999), and Fisman and Gatti (2002). If decentralization is effective in mitigating the negative effects of natural disasters, we expect to find a negative relation between this variable and the disaster death rate. We prefer focusing on fiscal decentralization rather than other notions of decentralization such as political decentralization as the latter may not carry with it the devolution of expenditures for sub-national governments to undertake the aspects of disaster risk management discussed in the introduction—especially those associated with the critical pre-event and event stages of the disaster.

Before discussing the remaining variables used in the analysis, one might reasonably question whether correlating overall sub-national expenditure shares with deaths from natural disasters might lead to a spurious correlation in that, especially in wealthier countries, it is not uncommon for what are relatively decentralized countries to nevertheless *centralize* their responses to natural disasters. The U.S. response to Hurricane Katrina is an excellent example of this tendency (for insightful treatments of this see Shughart 2006; Leeson and Sobel 2008; Sobel and Leeson 2006, 2007; and Boettke et al. 2007). However, since spending on natural disasters typically accounts for an extremely small share of national or sub-national spending, such *re*-centralizing would likely not be large enough to noticeably change the country's degree of overall centralization (and the resulting measure of sub-national expenditure shares). In such a case, if a centralized disaster response proves unusually effective in mitigating deaths, that success would be inappropriately attributed to the country's overall fiscal decentralization. Given this, and as discussed in the introduction, ideally we would like to have national and sub-national expenditure data that reflect only spending on disasters. This is possible, in some cases, when the unit of observation is a given country. However there is no source for such a break-down of spending internationally; we are thus left with this point as a caveat for our results.

This caveat is rather weak, however, if mitigation of natural disasters is viewed in the three-part process presented in the introduction. Specifically, spending on resources in the pre-event stage, whether controlled at the national level or transferred to the sub-national level, must occur months or even years in advance of a disaster to be fully developed and in place for use when the disaster strikes. At the opposite extreme, the recovery/rebuilding stage begins only after the event has fully run its course and can take years to complete as it involves reproducing all of the elements of the pre-event stage, especially those items related to physical reconstruction of lost or damaged infrastructure. This leaves only the event stage of the disaster itself, which as discussed above, tends to be rather brief in duration.

This three-part view of disaster mitigation serves to minimize, in our opinion, the caveat discussed above of a relatively decentralized country centralizing its response to a natural disaster and thus clouding the estimated correlation between decentralization and disaster mitigation over time. The reason for this is that the notion of mitigation we are considering is the number of lives lost and as is well-known, for nearly all natural disasters, the vast majority of those killed lose their lives either during the event itself or very shortly thereafter. Thus, the only *re*-centralizing of national spending that would be fully picked up by the sub-national spending variable would be that occurring in the recovery/rebuilding stage, with some of it potentially being captured in the latter part of the typically very brief event stage. That is, the vast majority of the deaths that we consider would pre-date any *re*-centralization, negating the caveat. Regardless, given that some of the *re*-centralization spending might occur prior to the end of the time in which deaths from the disaster occur, it is appropriate to keep this potential caveat in mind as we interpret our results.

The remaining control variables relate to a country's income, population, geography, social and political institutions, and the frequency of disasters striking a country during the entire period of study, each of which are common in the literature on disasters (Kahn 2005; Anbarci et al. 2005; and Escaleras and Register 2007). We use two measures of income, each taken from the World Bank's *World Development Indicators*. They are a country's *GDP per* *capita*, which is entered in log form and its percentage growth in GDP, *GDP growth* (%). While per capita GDP has regularly been shown to be of value in mitigating the effects of natural disasters (see, for example, Escaleras and Register 2008), the relation between the growth rate of GDP and deaths is more difficult to predict, especially if rapid growth comes at the expense of weak or ignored building codes, poor land zoning controls, and the like. To control for the size of a country's population, we take from the World Bank's *World Development Indicators* each country's population, *Population,* which given its broad range enters the models in log form. Geography can also play an important role in determining the severity of a natural disaster though the expected sign is ambiguous. For example, for disasters such as floods and landslides, elevation is likely to be negatively related to death rates while the opposite is likely for volcanoes and earthquakes. As such, we include a country's mean elevation, *Elevation*, taken from the Sachs Center of International Development. In addition, we include two measures of institutional quality. The first, *Democracy*, is a zero-12 scale with higher values indicating more thoroughgoing democratic institutions, taken from Polity IV. We also consider the extent of *Ethnic fractionalization* taken from Alesina et al. (2003). To the extent that democratic institutions signal good governance, this variable should be negatively related to deaths from natural disasters while ethnic fractionalization likely makes it more difficult for a country to agree on and develop public goods such as disaster mitigation leading to a positive expected relation with the disaster's death rate. Finally, as it seems plausible that country's which suffer more regularly from disasters learn from and are thus more prepared for future events we include the ratio of the total number of events to the 29 years in the sample, *Frequency of disasters,* taken from CRED.

Thus the primary model of the relation between fiscal decentralization and the death rate from natural disasters is:

$$\begin{aligned} \textit{Death rate}_i &= \alpha_0 + \alpha_1\ \textit{Fiscal decentralization}_i + \alpha_2\ (\log)\ \textit{GDP per capita}_i \\ &\quad + \alpha_3\ \textit{GDP growth}\ (\%)_i + \alpha_4\ (\log)\ \textit{Population}_i + \alpha_5\ \textit{Elevation}_i \\ &\quad + \alpha_6\ \textit{Democracy}_i + \alpha_7\ \textit{Ethnic fractionalization}_i \\ &\quad + \alpha_8\ \textit{Frequency of disasters} + \varepsilon_i \end{aligned} \tag{1}$$

where each variable is defined as above.

Column 1 of Table 2 reports the baseline results of the primary model (disregard Columns 2 and 3 for now). Prior to discussing individual outcomes it should be noted that while the continent dummy variables are omitted to save space, the model offers a reasonable R-square value suggestive of a reasonable fit, and that the standard errors were corrected for heteroscedasticity using the Huber-White approach. The key result of this baseline model is the negative coefficient on the decentralization variable, *Sub-national expenditure*, and the *Death rate* which is statistically significant at the 0.1 level.

For the remaining independent variables, we find that while (*log*) *GDP per capita* is negative and statistically significant, as expected, *GDP growth* (%) is not a significant determinant of the *Death rate*. The per capita GDP outcome no doubt reflects factors such as public desire for enhanced building codes, the existence of early warning systems, and more disaster-sensitive land zoning and use decisions. *Population* (logged) is positive and statistically significant suggesting that the more people who are at risk from a given disaster, the higher is the resulting *Death rate* likely to be. *Elevation* is positive and significant. As discussed above, this variable is likely positively correlated with deaths from some types of disasters and negatively correlated with others with, in this sample, the positive effect outweighing the negative. We would like to pursue this outcome further by estimating the

Table 2 Correlates of natural disasters death rate

	(1)	(2)	(3)
Sub-national expenditure	−0.011[a]	−0.013[b]	−0.010[a]
	(0.006)	(0.006)	(0.006)
(log) *GDP per capita*	−0.452[c]	−0.420[c]	−0.430[c]
	(0.075)	(0.072)	(0.077)
GDP growth (%)	−0.005	−0.001	0.008
	(0.022)	(0.016)	(0.018)
(log) *Population*	0.161[b]	0.111[a]	0.099
	(0.064)	(0.068)	(0.072)
Elevation	0.001[c]	0.001[c]	0.001[c]
	(2.14e−04)	(1.87e−04)	(1.99e−04)
Democracy	0.034	0.050[b]	0.057[b]
	(0.025)	(0.023)	(0.024)
Ethnic fractionalization	−0.932[b]	−0.920[b]	−0.933[b]
	(0.441)	(0.393)	(0.417)
Frequency of disasters	0.129[c]	0.122[b]	0.094
	(0.038)	(0.056)	(0.059)
Constant	4.194[c]	2.959[b]	2.682[b]
	(1.398)	(1.288)	(1.365)
Method	Ordinary Least Square	Robust Regression	Quantile Regression
Number of Observations	566	566	566
Continent Dummies	Yes	No	No
R^2	0.24		
F-test		16.11	
Pseudo R^2			0.15

Notes: Standard errors corrected for heteroskedasticity using Huber/White correction in parentheses for the OLS model

[a]denotes significance beyond the 0.10 level

[b]denotes significance beyond the 0.05 level, and

[c]denotes significance beyond the 0.01 level

model for individual disaster types but this is not possible as an unacceptably large portion of the already small sample would have to be dropped since a number of countries experienced no disasters of a given type during the estimation period. *Democracy* has an unexpectedly positive but insignificant relation with the *Death rate*. This may just be an artifact of the data or methods employed. Alternatively, if *Democracy* is primarily a measure of transparency, this result may simply point out that relatively more democratic countries are less likely to underestimate and underreport deaths due to disasters for political reasons. Regardless, it should be noted that this is the same result reported by Stromberg (2007) in his treatment of natural disasters and economic development though in his case *Democracy* was statistically significant. *Ethnic fractionalization* enters the model positively and statistically significantly as expected, perhaps due to the tendency of heightened ethnic tensions making it more difficult for a country to agree on and develop public goods such as disaster mitigation. An alternative but consistent explanation of this outcome is offered in Kimenyi and Shughart (2010) who note in their analysis of the 2005 Kenyan constitutional referendum that many country's with heightened ethnic tensions are also autocratic in nature resulting in public goods disproportionately being provided to those in the ethnic groups who control power. Finally and unexpectedly, the *Frequency of disasters* is statistically significantly associated with an increase in the *Death rate*. Possible explanations for this might be that, contrary to Anbarci et al. (2005) who focus only on earthquakes, the current approach uses the sum of earthquakes, floods, landslides, volcanoes, and windstorms. The hypothesized negative relation assumes that learning and thus better preparedness likely takes place the greater the number of events that a country endures. Consequently, the outcome we find may result from different types of disasters entailing differing degrees of learning and that the learning from one type of disaster may lead to preparedness measures that are in no way related to the learning that might result from another.

3 Robustness checks

To further evaluate the stability of our results, a variety of alternative estimations of the primary model were undertaken. First, given the broad range of the dependent variable, we consider the possibility of outliers driving the results presented above. We take two approaches here, as presented in Columns 2 and 3 of Table 2. Column 2 replicates the baseline model above through estimation by robust regression, which, in general terms, is an iterative technique that starts with OLS estimates, calculates case weights based on absolute residuals, and then iteratively re-estimates the model using those case weights until a pre-set tolerance level is reached. Observations for which the absolute residual is small are assigned case weights that approach unity. Observations with a case weight of unity indicate no detectable outlier problem and thus enter the regression as they would in the simple OLS case. Case weights decline from unity as the absolute residual increases in size. In the extreme, a case weight of zero is assigned to those observations that have very large absolute residuals. So long as an observation has a case weight greater than zero, it is included in the final iterated estimation, in a weighted fashion. Those observations, if any, having case weights equal to zero are essentially dropped from the model. In this way, robust regression provides stable results in the presence of outliers.[4] Overall, the robust regression confirms the results of the baseline model where the potential effects of outliers are ignored. All coefficients remain of the same sign and most maintain their qualitative level of statistical significance.[5] Exceptions include the slightly less significant results for the population and frequency of disasters variables (0.05 to 0.1) and the now statistically significant result for *Democracy*. Of greater importance, however, is the fact that in the robust regression model, *Sub-national expenditure* increases in significance from 0.1 to 0.05.

An alternative to robust regression for handling the possibility of outliers is quantile regression, as presented in Column 3 of Table 2. We use the most common form of quantile regression in which the regression line minimizes the sum of the absolute residuals rather than the OLS model's minimizing of the sum of the squares of the residuals, known as median regression. Here, all results and qualitative levels of significance mimic those of the baseline model with the exception of, as with robust regression, we now have a significant coefficient on *Democracy* and an unexpected insignificant result for *Frequency of disasters*. Most importantly, however, the *Sub-national expenditure* variable remains negative and statistically significant.[6] Thus, while it is no doubt important to take note of the potentially misleading effects of outliers in the sample, the negative and statistically significant results for the baseline model's relation between fiscal decentralization and deaths due to natural

[4] The specific method we use begins with OLS, then switches to Huber (1973) weights, and finally, for all of the non-zero case weights, finishes the estimation using the biweight function of Beaton and Tukey (1974).

[5] Further, note the model's relatively good fit, based on the highly significant reported F-test.

[6] Again note the model's reasonable fit, as given by the Pseudo R-square value.

disasters remain the same when either robust or quantile regression is used as a treatment for potential outliers.

A second robustness check involves instrumental variables estimation to deal with any endogeneity that might be present. This could potentially arise from at least two possible sources. First, as discussed in the introduction, international development donor organizations have for the past few decades been including demands for greater decentralization in their development transfers. That is, relatively high levels of deaths due to disasters typically lead to larger donations into which decentralization requirements are built. Alternatively, even with the variables added above, we may still have a problem with omitted variables that are correlated with the measures of decentralization and which tend to vary over time thus negating the ability of the fixed effects modeling to control for them. As such, we add a two-stage, instrumental variable estimation process with the first stage having the decentralization variable, *Sub-national expenditure,* as the dependent variable. Potentially effective instruments should have a high correlation with, in this case, the decentralization variable but a relatively low correlation with the error term of the second stage model where the *Death rate* is the dependent variable—that is, the instruments' influence on the *Death rate* is transmitted uniquely through their effect on decentralization. Fisman and Gatti (2002) have shown that a country's legal origin can serve as effective instruments for decentralization in their analysis of the relation between decentralization and public sector corruption. The data on a country's legal origin are taken from La Porta et al. (1999) who identify five possible legal origins: English, Socialist, French, German, and Scandinavian.[7] Legal origin is likely a good source of instruments for decentralization as has been noted by legal scholars (see, for example, Glos 1978) since countries evolving from civil legal codes (such as those with French origins) tend to be much more centralized in the present than those evolving from common law (such as those with British foundations). Further, we see no plausible linkage between long pre-existing legal origins and deaths due to natural disasters in modern times, other than through their impact on contemporary government structure. When we formally test for the validity of legal origin as instruments for decentralization, Appendix 3 offers some insight by showing the simple correlations among the *Death rate*, *Sub-national expenditure*, and the five possible legal origins noted above. Of most importance here is the fact that in every case, the simple correlation between legal origin and decentralization is far stronger than it is with the *Death rate*.

Table 3 presents four variants of the instrumental variables approach. Consider first the model reported in Column 1 which simply replicates the baseline model (Table 2, Column 1) with the exception of the *Sub-national expenditure* being instrumented.[8] Clearly the results support the notion of a negative and statistically significant relation between decentralization and deaths due to natural disasters. In fact, the relation is both larger in size and of greater statistical significance when the instrumented value of *Sub-national expenditure* is used and the results for the remaining variables mimic those of the baseline model. Further, the Sargan test p-value indicates that we cannot reject the hypothesis of no correlation between the instruments and the error terms of the second regression. But what of the underlying model which generates the predicted values of *Sub-national expenditure* and the validity of our instruments? This model is given in Appendix 4. Note first that three of the four included sources of legal origin are strongly correlated with the decentralization variable. More formally, consider the three test statistics related to the instruments included, the F-test of the

[7]Legal origin is a commonly used instrument in the decentralization literature. See, for examples, Fisman and Gatti (2002), Dreher (2006), and Ranjan and Zingales (1999).

[8]As is appropriate, since we are using STATA's ivreg2 command, no constants are reported.

Table 3 Correlates of natural disasters death rate (IV estimation)

	(1)	(2)	(3)
Sub-national expenditure	−0.023[b]	−0.022[b]	−0.020[a]
	(0.009)	(0.009)	(0.011)
(log) *GDP per capita*	−0.320[c]	−0.120	−0.247
	(0.119)	(0.380)	(0.151)
GDP growth (%)	−0.018	−0.016	−0.042[a]
	(0.017)	(0.022)	(0.023)
(log) *Population*	−0.089	0.057	−0.111
	(0.083)	(0.342)	(0.090)
Elevation	8.54e−04[c]	7.76e−04[c]	9.98e−04[c]
	(2.07e−04)	(2.33e−04)	(2.44e−04)
Democracy	0.053[b]	0.053[a]	0.076[b]
	(0.026)	(0.028)	(0.034)
Ethnic fractionalization	−0.746[a]	−1.065[b]	−0.584
	(0.437)	(0.495)	(0.536)
Frequency of disasters	0.123[b]	0.103[a]	0.163[c]
	(0.058)	(0.059)	(0.064)
(log) *Government expenditure*		−0.162	
		(0.327)	
Socioeconomic conditions			−0.044
			(0.069)
Number of Observations	552	523	364
Continent Fixed Effects	Yes	Yes	Yes
Sargan Test (p-value)	0.14	0.19	0.43

Notes: Standard errors corrected for heteroskedasticity using Huber/White correction in parentheses

[a]denotes significance beyond the 0.10 level

[b]denotes significance beyond the 0.05 level, and

[c]denotes significance beyond the 0.01 level

joint significance of the instruments, the Shea Partial R-square value of the explanatory power of the instruments, and the Anderson-Rubin Wald test of weak instruments. In each case we find relatively strong support for the validity of the instruments.

While the instrumental variables approach is a valid way to treat omitted variables, Table 3 presents two additional variants of the model of Column 1, each with an additional control variable added. Each of these models is instrumented in the same way as in the model of Column 1, with the exception of the added control variable being included in the underlying first regression. Given that the addition of these variables in the first equation had no significant impact on the instruments or test statistics of the first equation, these models are not reported.[9] The two additional variables included are the log of overall government expenditure, (log) *Government expenditure*, taken from the World Bank's *World Development Indicators*, and a measure of social and economic stability, *Socioeconomic conditions*, taken from the International Country Risk Guide published by Political Risk Services Group. While the first of these is self-explanatory, we should note that the latter ranges from zero to 12 with lower values reflecting greater risk.[10] Given that many aspects of disaster mitigation programs are semi-collectively or collectively consumed, we expect the overall government

[9]Each unreported model is available upon request.

[10]A more complete discussion of the *Socioeconomic conditions* variable can be found in Knack and Keefer (1995).

spending variable to be negatively correlated with deaths. And since higher values of the social and economic stability variable point to stronger institutions, it should also be found to be negatively correlated with deaths. The results here are supportive of the notion that decentralization is negatively and significantly correlated with deaths. However, even though both added control variables have the expected signs, neither of them is found to be statistically significant. Further, it should be noted that the addition of these variables not only leaves the coefficients on *Sub-national expenditure* negative and significant, their ceteris paribus impact on the sizes of these coefficients is extremely small. Finally, as was true for the instrumented version of the baseline model, in each of these models the Hansen J test p-value again indicates that the hypothesis of no correlation between the instruments and the error terms of the second regressions can not be rejected.

While the case for a negative and statistically significant relation between decentralization and deaths due to natural disasters appears robust, we also wish to exploit the fact that the CRED dataset includes information not only on those killed but more broadly on those negatively affected by a natural disaster. The total number of people affected includes those who were killed, those who suffered physical injuries requiring medical attention, those who were left homeless, and those requiring immediate assistance during the emergency period. This number is then transformed in the same way as the number of deaths (log of ((total affected + 1)/population∗100,000)) and referred to as the *Total affected rate*. We then replicate the models of Table 3 and the underlying model of Appendix 4.[11] The results for the second stage regression are presented in Table 4. Given the similarities with the models that use the *Death rate*, these models can be summarized as supporting the *Death rate* findings, that is, there is a negative and statistically significant correlation between decentralization and the number of people negatively affected by natural disasters and that all test statistics support the validity of legal origins as instruments.

Finally, we wish to consider whether fiscal decentralization influences the *Death rate* and *Total affected rate* from natural disasters differently for developed versus developing countries, using the World Bank's definition of development. We do so by estimating the instrumented baseline model separately for developing and developed countries.[12] The results for the decentralization variable in the second stage regressions are given in Table 5.[13] Here we do find a result of some interest. Specifically, while negative in all cases, the decentralization variables are statistically significant only for the developing countries. Developed countries, on average, have substantially higher levels of decentralization than do developing countries. Given this, it might be the case that the marginal impact of decentralization declines as the level of development increases, at least beyond some threshold level. Particular care must be taken in drawing this conclusion, however, as other possible explanations exist, the models do not include continent fixed effects, and the developed/developing sub-samples are comparatively small.

[11] Again we omit all but the first stage regression for the baseline model though the remaining first stage regressions are available upon request.

[12] Given the limited number of country-year observations, once the sample is broken into developed and developing countries, these models do not include continent fixed effects.

[13] The remaining variables in the second stage models are not illuminating and are thus omitted, as are the underlying first stage models though all are available upon request.

Table 4 Correlates of natural disasters total affected rate (IV estimation)

	(1)	(2)	(3)
Sub-national expenditure	−0.059[c]	−0.054[c]	−0.062[b]
	(0.019)	(0.019)	(0.028)
(log) *GDP per capita*	−1.174[c]	−1.597[b]	−0.400
	(0.258)	(0.734)	(0.318)
GDP growth (%)	−0.086[b]	−0.077[a]	−0.069
	(0.039)	(0.040)	(0.047)
(log) *Population*	0.091	−0.234	0.465[a]
	(0.191)	(0.696)	(0.263)
Elevation	3.93E−04	7.50E−04[a]	1.05E−03[b]
	(4.54E−04)	(4.40E−04)	(5.05E−04)
Democracy	0.046	0.109[a]	0.117
	(0.057)	(0.057)	(0.079)
Ethnic fractionalization	−4.203[c]	−4.278[c]	−3.857[c]
	(0.937)	(0.920)	(1.017)
Frequency of disasters	0.590[c]	0.575[c]	0.356[c]
	(0.096)	(0.095)	(0.109)
(log) *Government expenditure*		0.085	
		(0.663)	
Socioeconomic conditions			−0.370[b]
			(0.155)
Number of Observations	551	522	363
Continent Fixed Effects	Yes	Yes	Yes
Hansen J Test	0.39	0.23	0.95

Notes: Standard errors corrected for heteroskedasticity using Huber/White correction in parentheses

[a]denotes significance beyond the 0.10 level

[b]denotes significance beyond the 0.05 level, and

[c]denotes significance beyond the 0.01 level

Table 5 Determinants of natural disasters death rate/total affected rate: developing and developed countries (IV estimation)

	Death rate		Total affected rate	
	Developing	Developed	Developing	Developed
Sub-national expenditure	−0.125[c]	−0.006	−0.223[c]	−0.053
	(0.031)	(0.013)	(0.066)	(0.034)
Number of Observations	347	205	347	204
Continent Fixed Effects	No	No	No	No
Hansen J Test (p-value)	0.40	0.28	0.32	0.40

Notes: Standard errors corrected for heteroskedasticity using Huber/White correction in parentheses

[a]denotes significance beyond the 0.10 level

[b]denotes significance beyond the 0.05 level, and

[c]denotes significance beyond the 0.01 level

4 Conclusion

This paper offers the first assessment to our knowledge of the relation between governmental decentralization and death rates from natural disasters. If the Tieboutian notion that decentralization can improve the provision of local public and semi-public goods and services is accepted, we would expect that greater decentralization would be associated with lower death rates from natural disasters. We test this proposition by focusing on fiscal decentralization, that is, the percentage of total government expenditures controlled by sub-national governments. The outcomes are consistent. For the overall sample, no matter the estimation technique or variables employed, we do find fiscal decentralization to be associated with lower natural disaster death rates. Interestingly, however, there is some evidence that this relation is robust only for developing countries. Since the existing data do not allow us to definitively explain this latter result, it would seem to be an interesting and potentially fruitful area for further study. Further, the negative relation between natural disasters and deaths is supported when the number killed is broadened to include the number of persons affected by disasters. Regardless, these results are supportive of international donor agencies growing trend in coupling their development assistance to increasing decentralization, at least with respect to natural hazard risk management.

Appendix 1: List of countries by continent

Asia	**Western Europe**	**North America**
China	Austria	Canada
India	Belgium	Mexico
Indonesia	Denmark	United States
Japan	Finland	
Korea, Rep.	France	**Central America and Caribbean**
Malaysia	Germany	Costa Rica
Mongolia	Greece	Dominican Republic
Philippines	Iceland	Guatemala
Sri Lanka	Ireland	Honduras
Thailand	Italy	Nicaragua
	Luxembourg	Panama
Middle East and North Africa	Netherlands	Trinidad and Tobago
Azerbaijan	Norway	
Iran, Islamic Rep.	Portugal	**South America**
Israel	Spain	Argentina
Pakistan	Sweden	Bolivia
Tunisia	Switzerland	Brazil
Turkey	United Kingdom	Chile
		Colombia
Eastern Europe	**Africa**	Ecuador
Albania	Burkina Faso	Paraguay
Belarus	Ethiopia	Peru
Bulgaria	Kenya	Uruguay
Croatia	Madagascar	
Czech Republic	Malawi	**Australia and Oceania**
Hungary	Mauritius	Australia
Latvia	South Africa	Fiji
Lithuania	Swaziland	New Zealand
Moldova	Zambia	
Poland		
Romania		
Russian Federation		
Slovak Republic		
Slovenia		

Appendix 2: Data description and sources

Variable	Description	Source
Deaths	Deaths from natural disasters, per 100,000 persons.	Center for Research on the Epidemiology of Disasters (CRED)
Sub-national expenditure	Share of sub-national (state and local) expenditures (% of total expenditures)	*IMF's Government Finance Statistics (GFS)*
GDP per capita (Constant 2000 US $)	Gross domestic product divided by midyear population.	*World Development Indicators*
GDP growth (Annual %)	Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2000 US dollars.	*World Development Indicators*
Population	The de facto definition of population, which counts all residents regardless of legal status.	*World Development Indicators*
Elevation	Mean elevation (meters above sea level)	*Sachs Center of International Development*
Democracy (Scale zero–12)	Higher values indicate more thoroughgoing democratic institutions.	*Polity IV database*
Ethnic fractionalization	This index measures the probability that two randomly selected persons from a given country will not belong to the same ethno-linguistic group.	Alesina et al. (2003)
Frequency of disasters	Total number of events a given country endured during the period 1972–2000 scaled by the 29 years of the sample period.	Center for Research on the Epidemiology of Disasters (CRED)

Appendix 3: Correlates of instruments with sub-national expenditure and death rate

	Sub-national expenditures	*Death rate*	*English*	*Socialist*	*French*	*German*	*Scandinavian*
Sub-national expenditure	1						
Death rate	−0.451	1					
English	0.347	−0.006	1				
Socialist	0.144	−0.085	−0.220	1			
French	−0.435	0.039	−0.676	−0.302	1		
German	0.301	−0.194	−0.162	−0.072	−0.223	1	
Scandinavian	0.218	0.003	−0.156	−0.070	−0.215	−0.051	1

Appendix 4: First stage regression results of Table 3 column 1

English	−23.742***
	(2.326)
Socialist	0.051
	(3.529)
French	−34.727***
	(2.151)
German	−13.115***
	(2.442)
(log) *GDP per capita*	0.021
	(0.613)
GDP growth (%)	−0.064
	(0.087)
(log) *Population*	6.001***
	(0.369)
Elevation	−0.002*
	(0.001)
Democracy	0.738***
	(0.134)
Ethnic fractionalization	2.674
	(2.321)
Frequency of disasters	−0.204
	(0.298)
Number of Observations	552
F-test	111.78
Shea Partial R^2	0.46
Anderson-Rubin Wald test	12.42

Appendix 5: First stage regression results of table 4 column 1

English	−23.742***
	(2.326)
Socialist	0.051
	(3.529)
French	−34.727***
	(2.151)
German	−13.115***
	(2.442)
(log) *GDP per capita*	0.021
	(0.569)
GDP growth (%)	−0.064
	(0.087)
(log) *Population*	6.001***
	(0.324)
Elevation	−0.001
	(0.001)
Democracy	0.738***
	(0.145)
Ethnic fractionalization	2.672
	(2.444)
Frequency of disasters	−0.204
	(0.211)
Number of Observations	551
F-test	179.91
Shea Partial R^2	0.45
Anderson-Rubin Wald test	11.68

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