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Earthquake Propensity and the Politics of Mortality Prevention

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Earthquake Propensity and the Politics of Mortality Prevention

Abstract

Governments can significantly reduce earthquake mortality by enforcing quake-proof construction regulation. We examine why many governments do not. First, mortality is lower in countries with higher earthquake propensity, where the payoffs to investments in mortality prevention are greater. Second, the opportunity costs of these investments are higher in poorer countries; mortality is correspondingly less responsive to propensity in poor countries. Third, mortality is higher at any level of quake propensity when governments have fewer incentives to provide public goods, such as in autocracies with less institutionalized ruling parties or in more corrupt countries.

Keywords: disaster, mortality, political economy, democracy, risk, public goods

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1. INTRODUCTION

No government can prevent earthquakes, but all governments can optimize the regulations that reduce mortality when disaster strikes. Yet, earthquake mortality varies widely and systematically across countries. We argue that a set of inter-related factors is responsible for these differences. One is that the propensity for experiencing a strong earthquake varies greatly across different parts of the world. Governments in countries with a higher earthquake propensity have stronger incentives to implement effective earthquake mortality prevention measures. As a consequence, a seeming paradox arises: earthquake mortality is *lower* in areas with *higher* quake propensity, controlling for the strength of an actually occurring quake.

This relationship, however, is contingent on additional economic and political factors that influence government incentives to undertake *ex ante* preventive measures that reduce earthquake mortality. First, the opportunity costs of earthquake mortality prevention policies tend to be higher at low levels of per capita income. Earthquake-proof construction is expensive; in poorer countries, households and governments have more effective ways to spend scarce resources than to invest in earthquake-proof construction. Second, political incentives to implement and enforce earthquake-proof construction standards vary with the level of democracy and governments' ability to credibly commit to enforcement. These political regime characteristics therefore also condition the inverse relationship between earthquake propensity and earthquake mortality.

Our analysis moves beyond earlier research showing links between institutions and earthquake mortality. Kahn (2005) finds that democracy reduces disaster mortality in specifications where all disaster types are pooled and neither disaster magnitude nor the likelihood of disasters are taken into account. Anbarci et al. (2005) argue that inequality reduces the probability that citizens collectively agree to finance construction regulation and show that disaster mortality rises with inequality and with corruption (Escaleras et al. 2007). Our analysis augments and advances on this important prior research in four ways.

First, we argue that an important channel through which political incentives matter is by conditioning the responsiveness of governments to disaster propensity (and vice versa). Second, while we argue that elected governments are more sensitive to an elevated quake propensity than non-elected governments, both democracies and non-democracies exhibit considerable heterogeneity in political incentives to provide public goods and to make credible commitments to enforcing regulation. We explicitly take this heterogeneity into account, showing that democracies, more institutionalized autocracies and non-corrupt regimes respond more to a higher level of earthquake propensity than less institutionalized autocracies and corrupt regimes. Third, we argue that income also conditions the effect of disaster propensity: richer countries respond more to an elevated quake propensity than poorer countries. Fourth, we improve on previous research designs. In contrast to Kahn, we are able to take disaster propensity into account. And in contrast to Anbarci et al. (2005) and Escaleras et al. (2007), who also show an inverse relationship between earthquake propensity and mortality, we use more accurate measures of the magnitude and location of earthquakes and of quake propensity that take into account the exponential nature of the Richter scale. We also offer a different explanation for the result: while these papers claim that higher earthquake propensity improves the response to earthquakes because it offers more opportunities for "learning-by-doing", we argue that earthquake propensity affects the opportunity costs of investing in earthquake mortality reduction and, therefore, the incentives of political decision makers to respond to the threat of earthquakes.

In the next section, we discuss why government intervention is necessary for the prevention of earthquake mortality despite the fact that most buildings are privately owned. We then develop our theory in several steps, first explaining why there is an inverse relationship between earthquake propensity and mortality and then demonstrating how income and political incentives condition this effect. After a detailed description of our research design, we present our main estimation results in section 5 and summarize the findings from an extensive set of robustness tests in section 6. Consistent with our predictions, empirical analysis of earthquake mortality over the period 1962 to 2005 demonstrates that not only is earthquake mortality lower in democracies, in high quake propensity countries, and in rich countries; the conditional political and income effects predicted by the theory are also significant and large.

2. EARTHQUAKE MORTALITY: THE NEED FOR GOVERNMENT INTERVENTION

Government policies have a substantial influence on disaster mortality through their influence on private risk reduction measures and through post-disaster aid (Neumayer and Plümper 2007; Plümper and Neumayer 2009). Although building collapse is the main cause of mortality in earthquakes (Osaki and Minowa 2001) and buildings are often privately owned, government decisions have a large effect on earthquake mortality. On the one hand, government decisions entirely dictate the safety of key public buildings, such as schools and hospitals. On the other hand, governments can mitigate three potentially large market failures.

One is imperfect information. Earthquake-resistant features are costly to verify after construction is complete. Blondet, et al. (no date) point to the clay and straw content of adobe bricks as being central to the earthquake resistance of adobe homes. Steel reinforcement bars make a well-known contribution to earthquake resistance in concrete buildings. However, not only is the steel itself invisible (encased, as it is, in concrete), but the durability of the steel depends on the quality and quantity of concrete around it. Since these features cannot easily be verified at reasonable cost, buyers are less willing to pay a higher price for quality construction and construction companies have weaker incentives to provide it. Escaleras, et al. (2007) emphasize this information asymmetry in assuming that it is impossible for private parties to contract for high quality construction. In the absence of regulation, they argue, earthquake mortality is high.

However, even if construction quality were observable (for example by individuals who make daily visits to their home construction site), seismic design requirements are specialized and may not be well-understood by buyers or by building constructors themselves. In this case, information about how to design earthquake-resistant buildings is a public good that the market may under-supply. Building codes provide a way in which governments can provide information about appropriate earthquake-proof construction.

A second market failure in construction is the difficulty of using reputational mechanisms when construction failures are revealed only after low probability events such as earthquakes. Government enforcement of private contracts can obviate the need to rely on reputation. Finally, third, behavioral distortions are a pervasive phenomenon in the face of low-probability, high-loss events, when individuals frequently make decisions that lower their utility (Kahneman, et al., 1982). Even if fully informed about building quality, buyers may care too little about the benefits of building attributes that protect them against low probability events. One study in the US shows that if the probability of a disaster is sufficiently low, individuals simply stop thinking about it (Camerer and Kunreuther 1989). A laboratory experiment in the US concluded that individuals are unwilling to pay *anything* for insurance against low probability events, even if the cost of the event is high (McClelland et al., 1993). Private individuals tend to be reluctant to purchase construction quality, even when doing so leaves buyers better off, and government intervention can overcome such reluctance.[1]

Whether governments actually take actions to correct market imperfections or to construct earthquake-proof public buildings depends on their political incentives. Where those incentives are weak, earthquake mortality is likely to be higher. Escaleras, et al. (2007), emphasize corrupt payments as the main reason that building codes are not enforced. However, the problem may not be an adequate number of building inspectors who take bribes, but rather weak political incentives to enforce the codes, which can also be manifested in an insufficient number of inspectors. Following the severe 2009 earthquake in Sumatra, the *Wall Street Journal* quoted the mayor of the hard-hit port city of Padang, with a population of 750,000 as saying that "Most of the buildings that collapsed were those that didn't follow updated building codes (…). The local government lacks resources to check all buildings (…) with only four staff members to check building licenses." (Wall Street Journal October 6, 2009, p. A11). In contrast, the budget for building and residential inspections and construction compliance in Washington, DC, a city with a population of approximately 600,000, amounted to 118 full-time equivalent positions.[2]

3. THE POLITICS OF EARTHQUAKE MORTALITY PREVENTION

The argument we develop here and test below is that higher earthquake propensity reduces the opportunity costs of transferring resources to the construction of more quake-proof buildings that decrease quake mortality. However, the effects of propensity are heterogeneous and differ for countries at different levels of economic development and with different political incentives. The opportunity costs of expenditures to limit earthquake mortality are higher in poor countries, so that rich countries should respond more strongly than poor countries to higher earthquake propensity. And in countries where citizens or members of the ruling party can more easily sanction leaders for poor performance, leaders should respond more strongly to higher earthquake propensity.

(a) Earthquake Propensity and Opportunity Costs

It is well-understood that there are few technical obstacles to constructing buildings that have a fair chance of surviving even the strongest quake. However, the returns to an investment in earthquake-proofing a building vary sharply across regions and countries according to their earthquake propensity. Governments rationally abstain from passing and enforcing strict construction standards in areas with relatively low earthquake propensity, where the opportunity costs of investments in earthquake mortality prevention are high. We therefore expect mortality to be higher when a strong earthquake occurs in a country in which earthquake propensity is low.

The contrast between earthquake experience in Italy, on the one hand, and California and Japan, on the other, illustrates this. Italy lies at the very end of a zone where the African plate is submerged under the European plate, tectonic conditions that are not conducive to earthquakes. Correspondingly, including the April 6, 2009 earthquake in the town of L'Aquila in Central Italy, the country had experienced only four earthquakes above 6.0 on the Richter scale since World War II. None of these quakes reached a 7.0 on the Richter scale. California, by contrast, is located in one of the world's most geologically active zones. In the post-war period, it experienced 19 earthquakes above 6.0, of which six were stronger than 7.0.[3] Japan is also in a seismically active area. It experienced 31 quakes above 6.0, eight of which were stronger than 7.0 on the Richter scale. The seismic energy of all earthquakes that occurred in Italy over the last 60 years (approximately the equivalent of 50-70 megatons TNT), fell far short of the seismic energy of Japan's strongest single earthquake (which had the equivalent of roughly 2000 megatons TNT). In fact, each of the seven strongest Japanese earthquakes unleashed more seismic energy than all Italian quakes combined.

Given vast differences in propensity, we would expect earthquakes in Italy to have much larger mortality effects. In fact, the L'Aquila earthquake, with a magnitude of 6.3 on the Richter scale, left almost 300 people dead and an estimated 28,000 homeless.[4] In contrast, similar earthquakes in Japan and California have caused many fewer deaths. One earthquake in California offers a particularly useful comparison: the 1994 earthquake in Northridge, California, in a densely populated area of southern California, had a larger magnitude of 6.7, but killed only 72 people. In sum, controlling for the magnitude and the exposure of a country's population to an actually occurring earthquake, mortality should be significantly higher in areas of *low* earthquake propensity, where the *ex ante* opportunity costs of mortality prevention are high.

(b) Group heterogeneity in the effect of quake propensity: the level of economic development

For numerous reasons, poor developing countries should respond less to earthquake propensity than rich developed countries. First, citizens of richer countries generally consume higher quality housing that is incidentally more resistant to earthquakes. Second, richer countries simply have larger budgets to reduce mortality risk in all areas, ranging from disease control to traffic safety to earthquake mortality prevention. Third, however, under plausible conditions, sensitivity to earthquake propensity increases in income, because the marginal benefit of those expenditures is higher in the poor than the rich country.

To see this, assume earthquake mortality risk is a function of earthquake propensity ρ and mortality prevention, q, $q(\rho)$. Larger investments in mortality prevention, q, reduce mortality risk, but the effects on mortality risk are lower at lower levels of propensity, ρ: if earthquakes never occur, investments in mortality prevention have no effect on risk. Utility is a function of mortality risk and other goods, y. The benevolent social planner therefore finds the optimal quantity of mortality prevention by, as usual, maximizing a concave utility function $U = U(q(\rho), y)$ subject to a budget constraint $M = p_q q + p_y y$. Our argument is that, since poorer countries generally consume less of y, their marginal utility of y is correspondingly higher than that of richer countries. Consequently, their marginal loss in utility of switching expenditures away from y to q is higher than for richer countries at every level of propensity ρ. In general, then, poorer countries should be less sensitive to propensity.

This is, for example, true for a straightforward Cobb-Douglas utility function. Let mortality risk be given by q^{ρ}: expenditures have a smaller effect on mortality risk when earthquake risk is low and a large effect when the probability of an earthquake is very large. Then $U(q(\rho), y) = (q^{\rho})^{\alpha} y^{1-\alpha}$. Choosing q and y to maximize social welfare and substituting into the budget constraint yields an expression for the demand for mortality prevention, $q(\rho, M, p_q, p_y) = M\,[p_q(\rho(\alpha - 1) + 1)(\rho\alpha)^{-1}]^{-1}$. The derivative of this expression with respect to propensity, ρ, is positive, as the previous section predicts (less mortality prevention is consumed when earthquake risk is lower). Differentiating again with respect to income M yields an expression that is again greater than zero: the sensitivity of mortality prevention to propensity increases in income. We therefore expect that, other things equal, mortality is not only lower the higher a country's earthquake propensity, but particularly so if the country is relatively rich.

One would not expect the effects of quake propensity to vary across countries grouped by income if it were very cheap to make buildings earthquake-proof. This is not the case, however. Kenny (2009), for example, summarizes evidence on the costs and benefits of retrofitting schools for earthquake mortality prevention and finds that even the most optimistic estimates put the costs of retrofitting at eight percent of total construction costs. In most cases, the costs of reducing child mortality risk through retrofitting are much higher than the costs of reducing child mortality risk through interventions in other areas, such as health.

(c) Group heterogeneity in the effect of quake propensity: political incentives

A large literature identifies conditions under which governments have incentives to provide public goods such as disaster risk mitigation. Bueno de Mesquita, et al. (2003), for example, argue that the larger is the "selectorate", the group of people who select the government, the more difficult it is for the government to use targeted payoffs to remain in power and the more likely the government will rely on public goods instead (see also Plümper and Martin 2003). The larger the selectorate, the more it encompasses non-elite members of society.

Competitive elections increase the size of the selectorate. Policies implemented by democratic governments should therefore, in principle, target a broader population than policies implemented by autocracies. They are more likely to provide public goods, benefiting all citizens, including policies that reduce the risks to all citizens in the event of an earthquake. Moreover, since earthquakes are more likely to kill poor people living in sub-standard housing, and since an expansion of the selectorate generally serves to expand the enfranchisement of the poor, a larger selectorate should increase government incentives to enforce building standards (Plümper and Neumayer 2009).

However, the effects of competitive elections on political incentives diminish in the presence of "political market imperfections" (Keefer and Khemani 2005) that undercut the ability of voters to hold incumbents accountable. Ideally, citizens accurately observe incumbent performance and, in the event that performance is poor, can expel the incumbent in favor of a challenger who can credibly commit to perform at a higher level. As the comparisons of regime types in Persson and Tabellini (2000) make clear, under these circumstances, incumbents have strong incentives to provide public goods and to avoid rent-seeking, corrupt behavior.

An important difference among democracies stems from the ability of political competitors to make broadly credible commitments to citizens. Democracies in which this is not the case are less likely to provide public goods (Keefer and Vlaicu 2008). Keefer (2007) argues that credibility differences between democracies with more and fewer years of continuous competitive elections explain the distinct policy choices of these two groups: younger democracies provide a lower level of public goods than older, more established democracies. Consequently, politicians in democracies with more continuous years of competitive elections should provide higher levels of regulation for making buildings earthquake-proof than those in democracies with fewer continuous years of competitive elections.[5]

Compared to democracies, autocracies of all kinds tend to discourage collective action by citizens. Consequently, even though it may be easier for citizens to coordinate a collective response after a disaster than after other policy failures, it is difficult to coordinate any collective response against autocratic rulers. Autocracies vary, however, in the degree to which leaders allow ruling party members to organize collectively (that is, allow ruling-party institutionalization). Autocrats who do not permit collective organization by ruling party members are less able to make credible commitments to those members, making it difficult for leaders to promise rewards to party members who successfully implement leader policy initiatives (Gehlbach and Keefer 2009). Regulations to reduce earthquake mortality are therefore less likely to be introduced or effectively enforced in settings where party members cannot collectively organize.

Lastly, both democracies and autocracies exhibit large within-regime type differences in corruption, which is also associated with weak incentives to provide public goods. Where political incentives to restrain corruption are low, incentives to provide public goods are generally (though not always) lower. Even when they are not lower, the inability of governments to restrain corruption by public officials reduces political incentives to implement policies that are sensitive to corruption, such as building regulations. Finally, in corrupt regimes costly regulation – and earthquake-proof building regulations are costly for construction companies – can be circumvented by bribing government officials.

Following this line of reasoning, we expect corrupt regimes to provide less regulation for preventing quake mortality than non-corrupt regimes and also to fail in the enforcement of such regulations. For example, in addition to exhibiting low earthquake propensity, Italy also exhibits much worse scores than other OECD countries on cross-country measures of corruption.[6] This presumably underlies the conclusions of observers, such as Franco Barberi, a geologist, who argued that the L'Aquila quake could have occurred "without causing a single death (…) if [it had] happened in California or in Japan or some other country where for some time they have been practicing anti-seismic protection."[7] It is unclear, however, whether the implication that government malfeasance was responsible for the large number of deaths is warranted; Italy's low propensity can also explain the difference in mortality. The empirical tests below distinguish these multiple explanations.

The effects of political incentives also imply group heterogeneity in the effect of earthquake propensity on mortality. The higher the probability that a strong earthquake will occur, the higher the probability that citizens will hold current policy-makers accountable for failing to act. That is, the greater is the probability of a strong earthquake, the greater the role for political incentives to reduce earthquake mortality. For example, since democracies are more responsive than autocracies, they should also respond more to a higher earthquake propensity than autocracies. They should enact more and better earthquake safety regulations relative to autocracies the higher the earthquake propensity of the country. We thus expect earthquakes of the same magnitude not only to kill fewer people the higher is earthquake propensity, but particularly so if the country is democratic. Similarly, older democracies should respond more to a higher earthquake propensity and thus have lower mortality at each level of propensity than younger democracies; autocracies with more institutionalized ruling parties should respond more relative to those with less institutionalized ruling parties, as should less corrupt relative to more corrupt regimes.

(d) Hypotheses

The empirical tests below examine six hypotheses that emerge from this discussion. First, quake mortality is lower in countries with a higher earthquake propensity. Second, higher quake propensity lowers mortality more in richer countries. Third, higher propensity also lowers mortality more in democratic than in autocratic countries. Fourth, politicians in older democracies have stronger incentives to provide public goods than those in younger democracies and an elevated quake propensity thus lowers mortality more in the former than in the latter. Fifth, autocracies with more institutionalized ruling parties are better able to commit to providing public goods and, especially, to implement construction regulations, and thus experience lower mortality at higher quake propensity than less institutionalized autocracies. Finally, the differences in political incentives that distinguish corrupt and non-corrupt regimes should yield greater public good provision (mortality prevention efforts) and stronger enforcement of appropriate regulations than in non-corrupt regimes. As a consequence, a higher quake propensity should lower mortality more in non-corrupt than in corrupt regimes.

These hypotheses are helpful in clarifying whether the effects of earthquake propensity reflect the opportunity costs of investing in risk mitigation or reflect learning-by-doing. If learning-by-doing is solely the product of experience with earthquakes and does not reflect the opportunity costs of investing in lower earthquake mortality, then income and political characteristics should have no effect on the relationship between propensity and mortality. Only if learning-by-doing requires costly investments should we expect countries grouped by income or political characteristics to exhibit different effects of quake propensity. In that case, however, one is immediately in the world of opportunity costs: countries with the greatest incentives to invest in learning-by-doing, and in preventing earthquake mortality generally, are those in which the opportunity costs of making these investments are low, and in which political incentives to make them are high.

4. RESEARCH DESIGN

To test these hypotheses, we analyze the determinants of earthquake mortality over the period 1962 to 2005. In this section, we describe our research design in detail.

(a) Data sources and operationalization

Our dependent variable is the annual sum of earthquake deaths in a country, with data taken from EM-DAT (2008).[8] We take the sum of fatalities in a country year rather than fatalities from individual earthquakes as the unit of analysis, since practically all of our control variables are measured at the country year level. Aggregation is unlikely to affect the estimates, however, since in the vast majority of country years no more than one large earthquake occurs (smaller follow-on quakes after a major quake notwithstanding).

Similar to Kahn (2005), we limit the estimation sample to observations where earthquake fatalities were possible. This is important because country-years in which no one could have possibly been killed by an earthquake are irrelevant; their inclusion injects unnecessary noise into the estimation. We therefore restrict the sample to country years in which at least one quake of magnitude 5 on the Richter scale happened. In the robustness section, we further restrict the sample to country years in which stronger quakes of magnitude 6 or above occurred.

Mortality should be higher, all else equal, the greater the magnitude of an earthquake and the larger the number of people exposed to it. Mortality should be lower, all else equal, the larger the distance between the hypocenter (the point within the earth where an earthquake rupture starts) and the epicenter (the point directly above it at the surface of the Earth), i.e. the larger is the so-called focal depth of the quake. We therefore construct two magnitude variables, one capturing magnitude itself, and one capturing magnitude weighted by the number of people in the area affected by the earthquake. We also include the minimum focal depth observed in a country year.

The measures of magnitude begin with each earthquake's measure on the Richter scale. The Richter scale is on a base-10 logarithmic scale: small increases on the scale imply large increases in disaster magnitude. To ensure that disaster exposure properly reflects the much larger impact of earthquakes with a larger Richter score, we transform the Richter scale magnitude according to the formula 10exp(magnitude-5). We compare all the earthquakes in a country-year and select the one with the highest transformed magnitude value, *max_magnitude*. The second variable (*magnitude_popdensity*) additionally takes into account that earthquakes in more densely populated areas kill more people, *ceteris paribus*. This variable weights each transformed quake magnitude value by the average population density within 15 kilometers of the earthquake's epicenter, though results are robust to extending this boundary to 30 or to 50 kilometers. It then sums up all population density-weighted transformed quakes in a country year.[9] The earthquake data have been taken from the United States Geological Survey Advanced National Seismic System (ANSS) Composite Earthquake Catalogue. Population density data are sourced from Gridded Population of the World, Version 3.[10]

Earthquake propensity, though not directly observable, can be indirectly inferred from historical earthquake records. Earthquakes are unevenly distributed around the world and are far more likely to occur in regions where different tectonic plates border each other. Most earthquakes occur at the various borders of the Pacific plate, the Western border of the Latin American plate, and the boundaries between the African, the Arabic and the Indian plates and the Eurasian plate. It is in countries located in these regions that the opportunity costs of earthquake safety regulation are lowest. However, it is inappropriate to use a country's location along these boundaries to measure its earthquake propensity, since relevant geological features (the speed of tectonic movements, the degree to which the lower plate bends the upper plate) can vary substantially along the boundary.

Instead, we use as a proxy for earthquake propensity the sum of earthquake strengths of quakes above magnitude 6 over the period 1960 to 2008, transformed according to the above mentioned formula. Results are robust to counting the sum of earthquakes above magnitude 5 or 6.5 instead. They are equally robust to using instead the strongest earthquake over the period 1960 to 2008. This is not surprising, since the total number of earthquakes a country experiences is strongly correlated with the magnitude of its single most powerful earthquake. We do not take into account earthquake activity before 1960 in our measure of earthquake propensity; data on earthquakes are much less complete and reliable before 1960. However, because geologic variables are unchanging over long periods of time, the choice of period is largely irrelevant. Countries that experience no or very few earthquakes before 1960 will also experience no or very few earthquakes from 1960 onwards. Given this, reliance on more complete post-1960 data to construct a propensity measure does not give rise to any bias in our estimations. It accurately depicts what politicians could have been expected to know about earthquake risk in their countries and the measure is (nearly) the same as if we had had adequate pre-1960 data available to us. In any case, we also show that our results are largely robust to using a pre-1960 data measure of quake propensity.[11]

The other main explanatory variables are country income and political characteristics. Data on income per capita (*ln gdppc*) are taken from World Bank (2009). Democracy is measured by the *polity2* variable taken from the Polity project (Marshall, Jaggers and Gurr 2006). Despite being coded on a 21-point scale from -10 to 10, *polity2* is not truly a continuous variable and observations are heavily clustered toward the lower and upper end of the scale. In line with much of the political science literature, we therefore dichotomize the democracy variable and classify a country as a democracy if it has a *polity2* score of 5 or above, which holds true for roughly 40 per cent of country years. The age of democracy is measured by the number of years since a country has become a democracy, defined as 5 or above on the Polity scale (as in Gerring, et al. 2005). The institutionalization of the ruling party in non-democracies is calculated as the age of the largest government party less the years in office of the current leader, with both variables taken from the Database of Political Institutions (Beck, et al. 2001), which starts in 1975, thus restricting the relevant sample to the 1976 to 2005 period (as in Gehlbach and Keefer 2009). Except for the earthquake magnitude variables, we lag all explanatory variables by one year to mitigate endogeneity bias.

The last variable that captures the political incentives of governments is corruption. Corruption measures are subjective and available only for recent periods. We use the source that provides the earliest time coverage, the corruption index of the International Country Risk Guide from Political Risk Services (www.prsgroup.com). They report corruption data from 1982 onwards and the estimation model which includes corruption as an explanatory variable is therefore restricted to the period 1983 to 2005. As a further control variable we use the log of population size (*ln pop*) from World Bank (2009). This is a standard control in analyses of public goods provision, capturing both possible economies of scale in public good provision (the costs per citizen of developing government construction standards falls with population size); and possibly greater heterogeneity in citizen preferences over public goods in see, for example, Keefer 2007 and the references therein).

To capture whether the effect of earthquake propensity on earthquake mortality differs across countries grouped according to income or political characteristics, we estimate separate earthquake propensity coefficients for country groups, giving us separate implicit response functions for these distinct groups. The estimated coefficients across the different groups are directly comparable; tests along the lines suggested by Chow (1960) can then be applied to analyze whether any differences are statistically significant.

For example, in contrasting the effects of propensity in democracies and autocracies, we create two variables: propensity times a dummy variable that equals one if a country is a democracy and zero otherwise; and propensity times a dummy variable that equals one if a country is an autocracy, and zero otherwise. Both of these variables enter the estimations. One represents the effect of quake propensity on mortality in democracies, the other the effect of quake propensity in autocracies. The estimated coefficients for quake propensity in democracies versus quake propensity in autocracies thus indicate how mortality changes with increases in earthquake propensity in democracies on the one hand versus increases in earthquake propensity in autocracies on the other.

In addition to separate quake propensity coefficients for democracies and autocracies, we estimate, in separate model specifications, separate propensity coefficients for high-income and low-income (or, to be precise, "not high-income") countries, using the World Bank (2009) classification.[12] About 25 per cent of countries are classified as having high income. Earthquake propensity coefficients are also estimated, in a separate estimation model, for democracies with above median continuous years of democracy (old democracies) and below median continuous years of democracy (young democracies) and for autocracies with above and below median values of the age of the ruling party at the time the current leader took office, thus separating high institutionalization from low institutionalization autocracies. Finally, we estimate separate quake propensity coefficients for corrupt and non-corrupt regimes, where a country is non-corrupt if it scores 4 or above on the scale that runs from 0 (most corrupt) to 6 (free of corruption). Roughly 35 per cent of country years fall into the 'not corrupt' category.

(b) Estimation strategy

The dependent variable, earthquake mortality, is a strictly non-negative count variable for which ordinary least squares (OLS) is inappropriate as it violates the underlying OLS assumptions of linearity of the estimation model and of normally distributed errors. There are two main estimation models for count data – Poisson and negative binomial. Since the sample variance significantly exceeds the sample mean, we have opted for the negative binomial model. The zero-inflated negative binomial model is sometimes employed to deal with the presence of many observations in which no disaster deaths occur. Although others have estimated disaster mortality determinants using this model (Kahn 2005), we do not. First, we already restrict the estimation sample to *relevant* country years, i.e. to country years with at least one quake of a magnitude large enough to potentially cause mortality. As a consequence, the share of observations with zero mortality is not excessively large (roughly 24 per cent of observations exhibit positive mortality). Second, the zero-inflated negative binomial model assumes that some observations take on a value of zero with probability of one (Long & Freese, 2006). This is not a reasonable assumption, however, given that the sample is intentionally restricted to country years at risk of earthquake mortality.

5. RESULTS

Table 1 presents the main estimation results. In the baseline model 1, we do not test for group heterogeneity in quake propensity. As one would expect, quakes of higher magnitude on the transformed Richter scale and quakes of higher magnitude in more densely populated areas kill more people, while, other things equal, the greater the focal depth of quakes, the lower is mortality. Controlling for the strength and focal depth of actually occurring earthquakes in this way, we find that a higher quake propensity is associated with *lower* mortality, as our theory predicts and as Anbaci, et al. (2005) first documented with a much different sample and propensity measure. Countries with higher per capita income and democracies have lower fatalities, whereas a larger population leads to higher mortality.

In model 2, we estimate separate quake propensity coefficients for high-income and low-income countries. Both rich and poor countries respond to increasing earthquake propensity: mortality falls significantly with higher quake propensities in both groups of countries. However, the effects are significantly larger for rich countries. The difference between the two estimated coefficients is statistically significant at $p<.002$.

Figure 1 provides an illustration of the difference in sensitivity to increasing quake propensity in the two groups of countries. It plots expected mortality as a function of increasing quake propensity in the two groups of countries, where the two quake magnitude variables are fixed at the 95th percentile of quake magnitudes, focal depth is fixed at the 5th percentile and all other variables are set at mean values (this convention is followed for the remaining figures, as well). Consistent with our predictions, expected fatalities drop much more rapidly in developed as opposed to developing countries as quake propensity increases to the maximum in the sample (Indonesia has the highest quake propensity).[13]

Model 3 estimates separate quake propensity coefficients for democracies and autocracies. Consistent with the argument that the prospect of elections should make democratic rulers more sensitive to earthquake propensity, the estimated coefficient for quake propensity in democracies is roughly 2/3 larger than the respective estimated coefficient in autocracies (-.00605 versus -.00372), although the difference between the two estimated coefficients is not statistically significant. Figure 2 plots expected fatalities on quake propensity in democracies and autocracies; expected mortality falls more rapidly in democracies than in autocracies.[14]

Model 4 further distinguishes among both democratic and non-democratic regimes. The specification distinguishes among autocracies according to whether the age of the ruling party at the time the current leader came to power – ruling-party institutionalization – is above or below the median for that variable. Democracies are distinguished according to whether they are above or below the median years of continuous democratic experience.[15] Since the Database of Political Institutions starts in 1975, and is required for the ruling-party institutionalization variable, the sample in this estimation is smaller than for the other models. The democracy dummy variable is dropped from this model since we now measure democracy as years of continuous democratic experience.

Consistent with our prediction, autocracies with low institutionalization are unresponsive to increases in earthquake propensity, while increasing propensity significantly reduces mortality in autocracies with high institutionalization. Increasing propensity reduces mortality even more in democracies. Contrary to our expectation, young democracies respond somewhat more strongly to increasing earthquake propensity than old democracies. However, the estimated coefficients for earthquake propensity in the two groups of countries are not statistically significant from each other. Moreover, the period of continuous democratic experience has an additional, unconditional and significant negative effect on quake mortality. In other words, older and more established democracies experience lower mortality, all other things equal, independent of quake propensity, such that, in total, older democracies tend to have lower mortality than younger democracies. Figure 3 shows how expected mortality decreases with increasing earthquake propensity for old and young democracies as well as for autocracies with high institutionalization.

In the final model 5, we test whether corrupt regimes differ from non-corrupt regimes in their response to an elevated quake propensity. Since the corruption variable is available only since 1982, the sample size is further reduced. Consistent with the notion that a non-corrupt political regime is indicative of stronger political incentives to provide earthquake-proof construction regulation, we find that corrupt regimes are totally unresponsive to an increase in earthquake propensity. Figure 4 shows how expected mortality falls rapidly with increasing quake propensity in non-corrupt countries, but not in corrupt countries.

6. ROBUSTNESS

These results are robust to a number of potential alternative specifications of the estimation model, displayed in table 2.[16] First, the results could be driven by the specific cut-off that we employ for measuring earthquake propensity. However results are largely similar when we substitute into all of the models of table 1 a propensity measure that uses, instead of a threshold of 6 on the Richter scale, a threshold of 5 (column 1) or 6.5 (column 2), or simply the largest earthquake that the country experienced over the period 1960-2008 (column 3).[17]

Anbaci et al. (2005) limit their sample to observations in which earthquakes of magnitude six and above on the Richter scale, although smaller earthquakes can also have fatal consequences, and which caused at least ten fatalities or approximately $1 million in property damages. This implies selecting on the dependent variable, since very successful earthquake fatality and damage prevention measures can lead to the exclusion of observations that should be properly included in the sample. Nevertheless, if we include only earthquakes above 6 (column 4), instead of above 5, results are fully robust. They also demonstrate that their findings are robust to the inclusion of several continent dummies; our results are similarly robust to the inclusion of these dummies (not shown).

Our measure of quake propensity covers the period 1960 to 2008, for which more accurate data are available. However, results are not sensitive to the choice of long-run period over which one sums up earthquake activity to construct earthquake propensity. Estimation results reported in column 5 are based on a quake propensity measure exclusively based on earthquake activity before 1960. With the exception only of quake propensity in poor countries and young democracies (model 4), and despite the much noisier data from the earlier period, results are in line with the ones from the quake propensity variable based on the period 1960 to 2008.

The political incentives of leaders who have been in office for longer periods of time could differ from those who have newly taken office and this could be correlated with the political measures we include, yielding spurious estimates. However, when we include the number of years the chief executive has been in office then all effects remain essentially the same (column 6). Mortality is significantly lower the more years leaders are in office, suggesting that longer-serving leaders are more likely to internalize the future political costs of neglecting earthquake preparedness. Earthquake mortality might be affected by the degree to which people live in urban areas, but results are unchanged if we include the percentage of population living in cities in the estimations (results not shown).

The exact number of quake victims is often estimated and not known exactly, injecting noise into the data. Measurement error could be random, in which case there would be attenuation bias of the estimated coefficients toward zero. But measurement error could also be non-random. Estimates could be noisier, if still unbiased, in poorer countries, where there is less capacity to accurately register deaths. In autocracies, authorities might have an incentive to downplay the actual number of deaths, but foreign observers might well over-estimate fatalities, knowing that domestic sources tend to under-estimate them. We therefore conducted a Monte Carlo study, similar to what Plümper and Neumayer (2009) do for mortality from famines, to explore the effect of measurement error on the estimates.

Specifically, we re-estimated all models 100 times. In each re-estimation, we multiplied the value of the dependent variable of approximately 15 percent of observations by a uniform random number. For high-income countries and democracies, the number was drawn from the interval [0.5, 1.5], which mirrors measurement errors of up to 50 percent. For low-income countries and autocracies, it was drawn from the interval [0.25, 2] to reflect the larger degree of measurement error in these countries.[18] Table 3 reports the full range of coefficients from the Monte Carlo study (minimum to maximum), taking each single iteration into consideration. Results are fully robust. This suggests that potential measurement error is unlikely to have a significant impact on our results.

7. CONCLUSION

The politics of disaster mortality prevention exert a large influence on actual disaster mortality rates. We argue that governments face different incentives to implement and enforce effective quake-proof construction regulations. If earthquake propensity is low, governments are unlikely to implement an effective earthquake mortality prevention system because this is costly in the absence of major earthquakes. In the rare event of a major earthquake, however, the lack of ex ante incentives to implement preventive measures leads to higher actual mortality. Such an earthquake might also lead to a burst of activity that lowers mortality in future earthquakes; dynamic effects such as this raise distinct theoretical issues and have different empirical requirements than the questions we examine here, which we would like to tackle in future research.

Even if earthquakes are relatively frequent and potentially strong, governments may opt against effective earthquake mortality prevention regulation when the country is relatively poor. Under this condition, the ex ante opportunity costs of such regulation can be prohibitively high if the government can save many more expected lives at lower cost in other areas of social or health spending.

Finally, political institutions directly and indirectly influence government efforts to reduce disaster mortality. Directly, they affect government willingness and ability to credibly commit to provide the public good of earthquake morality prevention. Indirectly, political institutions also impact on the extent to which governments will respond to higher earthquake propensity. The January 2010 earthquake in Haiti, which killed around 230,000 people, provides a telling illustration of our theory. The combination of low earthquake propensity (since 1860, there had been no major quake prior to this one), extreme poverty (Haiti is the poorest country in the Western hemisphere), a history of notoriously corrupt regimes together with a relatively young and fragile democracy make it unsurprising that the disaster resulted in one of the highest number of people killed for an earthquake of size 7 on the Richter scale. International aid may help to rebuild a more quake-resistant Haiti. Yet, given low earthquake propensity, quake-resistance is unlikely to be the highest value use of these resources. Instead, what Haitians need most urgently is a more accountable government and sustained economic development.

In sum, this article explains why earthquake mortality varies widely even after controlling for the seismic energy and the location of actually occurring quakes. First, countries vary in their propensity to experience earthquakes, and so have different opportunity costs to investing in earthquake preparedness. Second, propensity has a systematically different effect across countries with different incomes or political incentives. Such group heterogeneity suggests that, independent of the degree to which higher earthquake propensity reduces mortality because of learning-by-doing, propensity has a significant impact on the opportunity costs of mitigating risks. If learning-by-doing were costless, and were the only reason that propensity affected mortality, then the effects of propensity would be independent of the income and political characteristics of countries.

Critics have been quick to put the blame on politicians and their apparent failure to prevent or at least reduce mortality from earthquakes. Yet, our theory suggests that in countries with low quake propensity, failing to enact and enforce regulations for earthquake-proof construction is not necessarily a failure, but may be perfectly rational. Our empirical results corroborate this view. We thus find that mortality and earthquake propensity are related in precisely the way one would expect if governments were welfare-maximizing: where propensity is higher, mortality is significantly lower and poor countries respond less to higher quake propensity, precisely as expected, given the higher opportunity costs for poor countries of investing in earthquake mortality prevention. At the same time, we have also argued and demonstrated empirically that the presence of political market imperfections (lack of elections or of credible politicians) has a large effect on how countries react to earthquake propensity. In the extreme cases, higher quake propensity has no significant effect on mortality in autocracies that lack institutionalized ruling parties or in corrupt regimes. Our results thus suggest that policy advice to countries regarding disaster preparedness should strongly depend on the political characteristics of these countries.

ENDNOTES

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[1] For disaster types such as riverine flooding, where mortality risks are low relative to economic damages, the potential for a fourth market failure, moral hazard, is also large; individuals forego investment in prevention in the expectation of government relief after the disaster has occurred. Moral hazard is less relevant for mortality-intensive disasters, such as earthquakes, since disaster relief only helps the living.

[2] Government of the District of Columbia, Proposed Budget and Financial Plan FY 2010, Volume 2, Agency Budget Chapters – Part I, p. B-91, http://cfo.dc.gov/cfo/frames.asp?doc=/cfo/lib/cfo/budget/2010_9_29/volume_2_agency_chapters_part_i_web.pdf)

[3] This comparison understates the true difference because of the strong exponential logic of the Richter scale. See appendix 1.

[4] http://news.bbc.co.uk/1/hi/world/europe/7992936.stm

[5] Some research has shown that voters reward mitigation expenditures (post-disaster relief) more than prevention expenditures. Healy and Malhotra (2009) show that voters reward the incumbent presidential party for delivering disaster relief spending (ineffective in reducing earthquake mortality) but not for investing in disaster preparedness spending (more effective). Our argument is not, however, that elected governments set policy optimally with respect to mortality prevention; only that they are more likely than unelected governments to respond to higher earthquake propensity with greater preparedness spending.

[6] In 2007, the *International Country Risk Guide* measure of lack of corruption rates Italy at 2.5, compared to an average of 4.5 for the other 22 members of the OECD for which these data are available.

[7] http://news.bbc.co.uk/1/hi/world/europe/7987772.stm

[8] See Neumayer and Plümper (2007) for a discussion of the weaknesses of this dataset, which is, however, the only publicly accessible source of disaster type-specific mortality data.

[9] Minor quakes are unlikely to cause major damage, let alone kill people, so we drop all quakes with a magnitude below five on the Richter scale for constructing this variable.

[10] Since the population density data are only available for four distinct years, values are taken from the closest (prior) year available. This introduces some measurement error. Our measure of the population at risk, based on the population living within a circle drawn around the epicenter, introduces additional measurement error, since ground shaking does not expand uniformly from the epicenter, but rather follows the fault line Fortunately, this measurement error should not be systematically correlated with our main explanatory variables such that it does not bias our results. Allen et al. (2009) provide more precise estimates of the number of people exposed to

earthquakes, but the dataset, which is available at http://earthquake.usgs.gov/research/data/pager/expocat.php, only covers the period from 1973 onwards. Since our estimations start in 1962, we prefer our own measure of exposed population, but we recommend that any future research that focuses on the period since the 1970s use these alternative and superior estimates of exposed population.

[11] The pre-1960 data are taken from http://earthquake.usgs.gov/earthquakes/world/historical_country.php.

[12] Our results are fully robust to using dummy variables for OECD countries and non-OECD countries instead, also following World Bank (2009) classification.

[13] Given the strong correlation of high income with good governance, it is difficult to exclude an alternative explanation for this finding, namely that poor countries are also generally governed by rulers who are less sensitive to the broad public interest and, therefore, less responsive to increases in earthquake risk. However, this interpretation of the risk-income interaction is also consistent with our theoretical arguments.

[14] Note that although this difference is not statistically significant, the total difference between democracies and autocracies *is* statistically significant at all levels of propensity, because of the magnitude and significance of the democracy variable.

[15] Note that since we use two different operationalizations for democracies on the one hand and autocracies on the other, there is no single variable which could be added to the estimation model to capture the direct effects of within-regime type heterogeneity on mortality. We have therefore added two variables, namely the number of years of continuous democratic experience (set to zero for autocracies) and the number of years in office of the largest government party minus the number of years in office of the current leader.

[16] Full results will be made available in a replication dataset and do-file upon publication of the article.

[17] All measures exponentially transformed as before.

[18] To determine the ‘subsample with measurement error’ we drew a second continuous uniform random variable of the interval (0..1) and changed only those observations for which the randomly drawn parameter exceeded 0.85. Thus, on average, we changed the dependent variable of about 15 percent of the ‘nonzeros’ in each iteration of the Monte Carlo analyses.

REFERENCES

Ai, C. and E.C. Norton (2003). “Interaction Terms in Logit and Probit Models.” *Economics Letters*, 80, 123-129.

Allen, T.I., Wald, D.J., Hotovec, A.J., Lin, K., Earle, P.S. and Marano, K.D. (2009) “An Atlas of ShakeMaps and population exposure catalog for earthquake loss modeling.” *Bulletin of Earthquake Engineering*, 7(3), 701-718.

Anbarci, N., Escaleras, M. and Register, C. A. (2005). “Earthquake fatalities: the interaction of nature and political economy.” *Journal of Public Economics*, 89 (9-10), 1907-1933.

Beck, T., Clarke, G., Groff, A., Keefer, P., and Walsh, P. (2001). “New Tools in Comparative Political Economy: The Database of Political Institutions.” *World Bank Economic Review*, 15 (1), 165–76.

Blondet, M., Villa Garcia, G., and Brzev, S. (no date). “Earthquake-Resistant Construction of Adobe Buildings: A Tutorial.” EERI/IAEE World Housing Encyclopedia, http://www.world-housing.net/.

Bueno de Mesquita, B., Smith, A., Siverson, R. M., and Morrow, J. D. (2003). *The Logic of Political Survival*. Cambridge, MA: MIT Press.

Camerer, C. and Kunreuther, H. (1989). “Decision Processes for Low Probability Events: Policy Implications.” *Journal of Policy Analysis and Management*, 8, 565-592.

Chow, G. C. (1960) “Tests of Equality Between Sets of Coefficients in Two Linear Regressions.” *Econometrica*, 28, 591–605.

Ellwood, J. and Ellwood, L. (1998) Political Engineering for Earthquakes paper presented at the PEER Workshop, Berkeley, May 14-15 1998

Escaleras, M., Anbarci, N, and Register, C. A. (2007). “Public sector corruption and major earthquakes: A potentially deadly interaction.” *Public Choice*,132, 209-230.

Ferejohn, J. (1986). “Incumbent performance and electoral control.” *Public Choice*, 50, 5-26.

Gehlbach, S. and Keefer, P. (2009). “Private Investment and the Institutionalization of Collective Action in Autocracies: Ruling Parties, Militaries, and Bureaucracies.” Working Paper, Department of Political Science, University of Wisconsin, Madison.

Gerring, J., Bond, P., Barndt, W., and Moreno, C. (2005). “Democracy and Economic Growth: A Historical Perspective.” *World Politics*, 57(3), 323-364.

Healy, A. and Malhotra, N. (2009). “Citizen Competence and Government Accountability: Voter Responses to Natural Disaster Relief and Preparedness Spending.” Working Paper, Loyola Marymount University.

Kahn, M. E. (2005). “The death toll from natural disasters: the role of income, geography, and institutions.” *Review of Economics and Statistics*, 87 (2), 271-284.

Kahnemann, D., Slovic, P. and Tversky, A. (1982). *Judgement under Uncertainty: Heuristics and Biases*. New York: Cambridge University Press.

Keefer, P. (2007). “Clientelism, credibility and the policy choices of young democracies.” *American Journal of Political Science,* 51:4, 804-821 (October).

_____ and Khemani, S. (2005). "Democracy, Public Expenditures and the Poor." *World Bank Research Observer*, 20:1, 1-28 (Spring).

_____ and Razvan, V. (2008). “Democracy, Credibility and Clientelism.” *Journal of Law, Economics and Organization*, 24:2, 371-406.

Kenny, C. (2009). “Why Do People Die in Earthquakes? The Costs, Benefits and Institutions of Disaster Risk Reduction in Developing Countries.” World Bank Policy Research Working Paper 4823 (January).

Long, J.S., and Freese, J. (2006). *Regression Models for Categorical Dependent Variables Using Stata*. College Station, TX: Stata Press Publication.

Marshall, M. G., Jaggers, K. and Gurr, T. R. (2006). Polity IV data sets (University of Maryland, Center for International Development and Conflict Management).

McClelland, G., Schulze, W., and Coursey, D. (1993). "Insurance for Low-Probability Hazards: A Bimodal Response to Unlikely Events." *Journal of Risk and Uncertainty*, 7, 95-116.

Neumayer, E. and Plümper, T. (2007). "The Gendered Nature of Natural Disasters: The Impact of Catastrophic Events on the Gender Gap in Life Expectancy, 1981-2002." *Annals of the American Association of Geographers*, 97 (3), 551-566.

Osaki, R. and Minowa, M. (2001). "Factors Associated with Earthquake Deaths in the Great Hanshin-Awaji Earthquake, 1995." *American Journal of Epidemiology*, 153 (2), 153-156

Persson, T. and Tabellini, G. (2000). *Political Economics: Explaining Public Policy*. Cambridge, MA: The MIT Press.

Plümper, T. and Martin, C. W. (2003). "Democracy, Government Spending, and Economic Growth. A Political-economic Explanation of the Barro-Effect" *Public Choice*, 117, 27-50.

Plümper, T. and Neumayer, E. (2009). "Famine Mortality and Rational Political Inactivity." *World Development*, 37 (1), 50-61.

Schirber, M. (2009). Large California quake possible within 30 years, http://www.msnbc.msn.com/id/7832219/

World Bank (2009). *World Development Indicators*. Washington, DC: World Bank.

Table 1. Main estimation results.

Dep. variable: earthquake mortality	model 1	model 2	model 3	model 4	model 5
max_magnitude	0.0175***	0.0163***	0.0180***	0.0173***	0.00577
	(0.00643)	(0.00584)	(0.00643)	(0.00636)	(0.00489)
magnitude_popdensity*1,000	0.0257**	0.0371**	0.0317**	0.0465**	0.0368**
	(0.0124)	(0.0161)	(0.0151)	(0.0203)	(0.0172)
min_focaldepth	-0.00688*	-0.00685*	-0.00724**	0.00183	-0.00106
	(0.00366)	(0.00381)	(0.00337)	(0.00924)	(0.00727)
quake propensity	-0.00476***				
	(0.00114)				
quake propensity in developing countries		-0.00430***			
		(0.00106)			
quake propensity in developed countries		-0.00885***			
		(0.00135)			
quake propensity in autocracies			-0.00372**		
			(0.00166)		
quake propensity in democracies			-0.00605***		
			(0.00124)		
quake propensity in autocracies				-0.00262***	
w. high institutionalization				(0.000591)	
quake propensity in autocracies				0.00114	
w. low institutionalization				(0.00210)	
quake propensity in old democracies				-0.00409**	
				(0.00189)	
quake propensity in young democracies				-0.00531***	
				(0.000891)	
quake propensity in corrupt countries					-0.00318
					(0.00195)
quake propensity in non-corrupt countries					-0.00770***
					(0.00164)
ln gdppc	-0.588**	-0.397	-0.603**	-0.372	-0.595***
	(0.252)	(0.260)	(0.242)	(0.228)	(0.218)
Democracy	-1.871***	-1.767***	-1.489*		-2.369***
	(0.602)	(0.633)	(0.795)		(0.770)
ln pop	0.613***	0.638***	0.575**	0.608***	0.547**
	(0.226)	(0.230)	(0.233)	(0.174)	(0.235)
years continuous democratic experience				-0.0185***	
				(0.00697)	
years in office largest party in autocracy				0.00311	
– years in office autocratic leader				(0.00363)	
lack of corruption					-0.173
					(0.290)
Constant	-0.466	-2.392	0.0196	-7.371*	1.760
	(3.834)	(4.272)	(3.752)	(3.776)	(4.814)
Observations	1,288	1,288	1,288	803	698
Countries	73	73	73	65	59
Period of study	1962-2005	1962-2005	1962-2005	1976-2005	1983-2005

Note: Coefficients from a negative binomial model. Standard errors clustered on countries. * significant at p<.1 ** at p<.05 *** at p<.01.

Table 2. Robustness tests.

	Propensity: ≥_5 (Richter)	Propensity: ≥ 6.5 (Richter)	Propensity: largest quake	Only quakes ≥ 6 (Richter)	Propensity ≥ 6 (pre-1960 quakes)	Executive years in office incl.
Model 1						
quake propensity	-0.000345***	-0.0173***	-0.00122***	-0.00484***	-0.000106***	-0.00463***
	(0.0000775)	(0.00424)	(0.000299)	(0.000728)	(0.0000258)	(0.00158)
Model 2						
propensity in developing countries	-0.000314***	-0.0157***	-0.00111***	-0.00577***	-0.0000634	-0.00410**
	(0.0000655)	(0.00402)	(0.000290)	(0.000823)	(0.0000449)	(0.00160)
propensity in developed countries	-0.000739***	-0.0314***	-0.00162***	-0.00873***	-0.000182***	-0.00920***
	(0.0000991)	(0.00518)	(0.000334)	(0.00163)	(0.0000311)	(0.00181)
Model 3						
propensity in autocracies	-0.000279***	-0.0138**	-0.00111***	-0.00528***	-0.000153***	-0.00187
	(0.000103)	(0.00581)	(0.000290)	(0.00117)	(0.0000421)	(0.00388)
propensity in democracies	-0.000419***	-0.0222***	-0.00143***	-0.00443***	-0.0000830**	-0.00760***
	(0.0000892)	(0.00475)	(0.000343)	(0.00130)	(0.0000404)	(0.00178)
Model 4						
propensity in autocracies	-0.000185***	-0.00947***	-0.000562***	-0.00325***	-0.000339***	-0.00218***
w. high institutionalization	(0.0000411)	(0.00215)	(0.000141)	(0.000577)	(0.0000950)	(0.000708)
propensity in autocracies	0.0000683	0.00441	0.000779	-0.000519	0.0000424	0.000895
w. low institutionalization	(0.000184)	(0.00760)	(0.000890)	(0.00237)	(0.000124)	(0.00220)
propensity in old democracies	-0.000329***	-0.0145**	-0.000632	-0.00462**	-0.000119**	-0.00396**
	(0.000107)	(0.00701)	(0.000528)	(0.00204)	(0.0000478)	(0.00196)
propensity in young democracies	-0.000355***	-0.0207***	-0.00143***	-0.00717***	0.000142	-0.00537***
	(0.0000649)	(0.00307)	(0.000273)	(0.000906)	(0.000150)	(0.000920)
Model 5						
propensity in corrupt countries	-0.000276***	-0.0116	-0.00109***	-0.00488***	0.0000742	-0.00123
	(0.0000945)	(0.00716)	(0.000349)	(0.00107)	(0.000147)	(0.00209)
propensity in non-corrupt countries	-0.000641***	-0.0274***	-0.00138***	-0.0107***	-0.000140***	-0.00686***
	(0.000113)	(0.00596)	(0.000282)	(0.00186)	(0.0000321)	(0.00180)

Notes: Table 2 reports estimated coefficients, identified in the first column, using the indicated models in Table 1, modified according to the sample or specification change indicated in columns 2-7. Standard errors clustered on countries. * significant at p<.1 ** at p<.05 *** at p<.01.

Table 3. Summary Statistics of the Monte Carlo Analysis testing the Importance of Measurement Error (based on 100 iterations)

	Mean	Std. Dev.	Mininum	Maximum
Model 1				
quake propensity	-0.00479	0.00024	-0.00548	-0.00430
	0.00115	0.00005	0.00101	0.00132
Model 2				
propensity in developing countries	-0.00432	0.00024	-0.00499	-0.00382
	0.00106	0.00006	0.00092	0.00132
propensity in developed countries	-0.00886	0.00028	-0.00949	-0.00814
	0.00135	0.00005	0.00124	0.00151
Model 3				
propensity in autocracies	-0.00378	0.00035	-0.00470	-0.00302
	0.00164	0.00016	0.00129	0.00217
propensity in democracies	-0.00605	0.00024	-0.00659	-0.00541
	0.00126	0.00007	0.00114	0.00146
Model 4				
propensity in autocracies	-0.00262	0.00017	-0.00329	-0.00220
w. high institutionalization	0.00059	0.00002	0.00055	0.00067
propensity in autocracies	0.00097	0.00054	-0.00150	0.00182
w. low institutionalization	0.00210	0.00003	0.00198	0.00218
propensity in old democracies	-0.00410	0.00034	-0.00500	-0.00298
	0.00190	0.00017	0.00153	0.00255
propensity in young democracies	-0.00527	0.00029	-0.00584	-0.00435
	0.00096	0.00012	0.00074	0.00143
Model 5				
propensity in corrupt countries	-0.00322	0.00038	-0.00444	-0.00254
	0.00192	0.00022	0.00130	0.00243
propensity in non-corrupt countries	-0.00771	0.00032	-0.00855	-0.00678
	0.00165	0.00008	0.00140	0.00184

Note: first row shows coefficient, second row standard error.

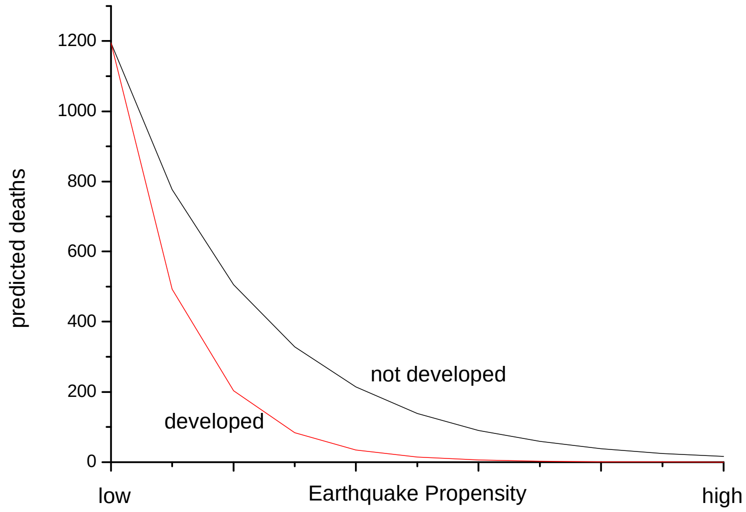

Figure 1. The effect of increasing quake propensity in developed versus non-developed countries.

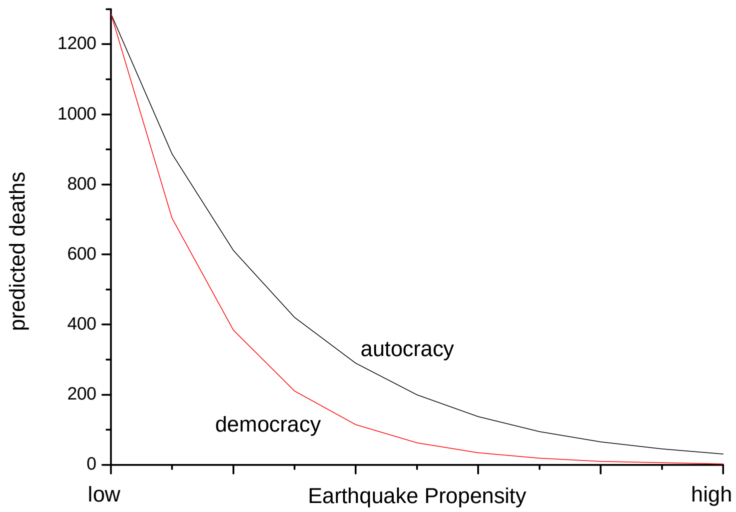

Figure 2. The effect of increasing quake propensity in democracies versus autocracies.

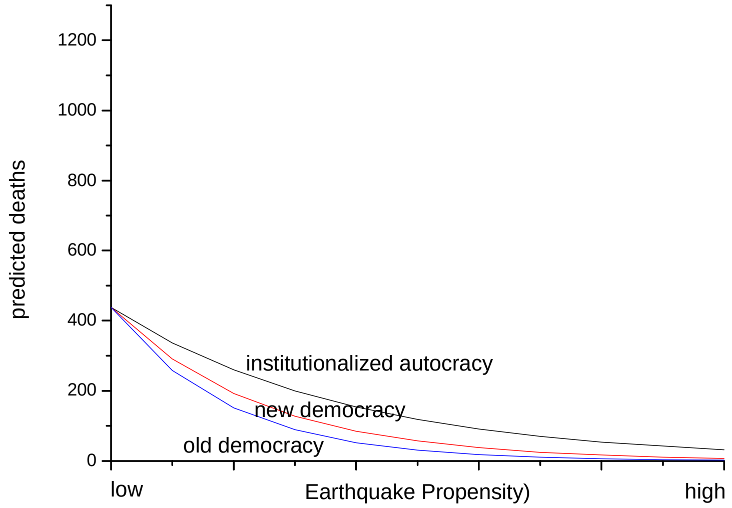

Figure 3. The effect of increasing quake propensity in institutionalized autocracies, young democracies and old democracies.

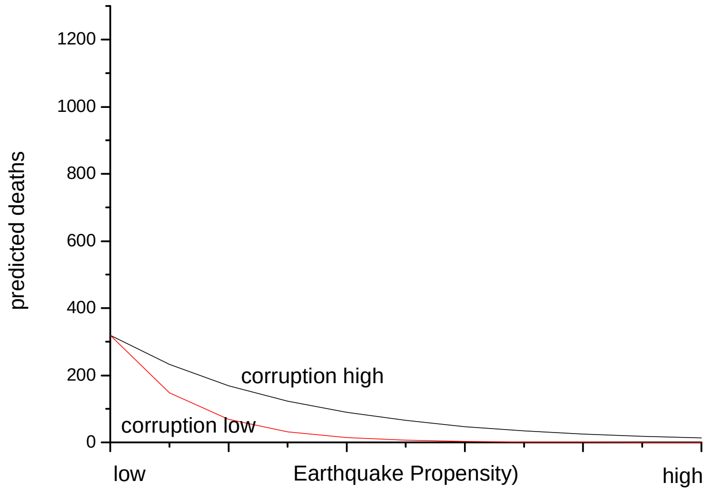

Figure 4. The effect of increasing quake propensity in corrupt versus non-corrupt countries.

Appendix 1. The exponential nature of the Richter scale in terms of explosive equivalent.

Richter scale	1000 Tons TNT equivalent
5.0	32
5.5	178
6.0	1,000
6.5	5,600
7.0	32,000
7.5	178,000
8.0	1,000,000
8.5	5,600,000
9.0	32,000,000