WPS5182

Policy Research Working Paper 5182

Earthquake Propensity and the Politics of Mortality Prevention

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January 2010

Policy Research Working Paper 5182

Abstract

Governments can significantly reduce earthquake mortality by implementing and enforcing quake-proof construction regulation. The authors examine why many governments do not. Contrary to intuition, controlling for the strength and location of actual earthquakes, mortality is lower in countries with higher earthquake propensity, where the payoffs to mortality prevention are higher. Importantly, however, the government response to earthquake propensity depends on country income and the political incentives of governments to provide public goods to citizens. The opportunity costs of earthquake mortality prevention are higher in poorer countries; rich countries invest more in mortality prevention than poor countries in response to a higher earthquake propensity. Similarly, governments that have fewer incentives to provide public goods, such as younger democracies, autocracies with less institutionalized ruling parties and countries with corrupt regimes, respond less to an elevated quake propensity. They therefore have higher mortality at any level of quake propensity compared to older democracies, autocracies with highly institutionalized parties and non-corrupt regimes, respectively. The authors find robust evidence for these predictions in our analysis of earthquake mortality over the period 1960 to 2005.

This paper—a product of the Macroeconomics and Growth Team, Development Research Group and the Global Facility for Disaster Reduction and Recovery Department—is part of a larger effort in the departments to study the main sources of vulnerability and to disseminate the emerging findings of the forthcoming joint World Bank-UN Assessment of the Economics of Disaster Risk Reduction.. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at Pkeefer@worldbank.org.

Earthquake Propensity and the Politics of Mortality Prevention

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

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Acknowledgements: We are grateful to Apurva Sanghi, S. Ramachandran and seminar participants at the World Bank for valuable comments. This paper was commissioned by the joint World Bank – UN Project on the Economics of Disaster Risk Reduction. Partial funding of this work by the Global Facility for Disaster Reduction and Recovery is gratefully acknowledged. The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the International Bank for Reconstruction and Development/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent.

1. Introduction

No government can prevent earthquakes. All governments, though, can optimize the regulations that reduce mortality when disaster strikes. Yet, earthquake mortality varies widely and systematically across countries. For example, in Japan and California, earthquake prone areas known for their strict regulations and enforcement, even large quakes cause few fatalities. In other countries and regions, however, much less powerful earthquakes at times kill large numbers of people.

We argue that a set of inter-related factors is responsible for these vast differences in mortality. One is that the propensity for experiencing a strong earthquake varies greatly across different parts of the world. Since most earthquakes result from sudden movements of tectonic plates, most earthquakes occur at the intersection of those plates. However, this does not imply that areas where quakes are strongest and most frequent necessarily experience the highest quake mortality. Governments in countries with a higher earthquake propensity implement more effective earthquake mortality prevention measures. As a consequence, a seeming paradox occurs: earthquake mortality is *lower* in areas with *higher* quake propensity, controlling for the strength of an actually occurring quake.

This relationship, however, is not unconditional and depends on additional economic and political factors that influence governments' ex ante preventive measures and condition the effect of earthquake propensity on earthquake mortality. We identify two sets of intervening factors. First, the wealth of countries matters because the opportunity costs of earthquake mortality prevention policies tend to be higher at lower levels of per capita income. Earthquake-proof construction significantly increases the construction cost of houses and infrastructure and in poorer countries households and governments have more effective ways to spend scarce resources at their disposal than to invest in earthquake proof construction. And second, political incentives such as the level of democracy and governments' ability (or lack thereof) to credibly commit themselves to enforcing effective earthquake mortality prevention policies condition the inverse relationship between earthquake propensity and earthquake mortality. We discuss the underlying causal mechanisms in greater detail in section 3.

In providing a political economy explanation for the variation in earthquake mortality, our paper contributes to the literature on the politics of disaster mortality prevention. In an influential paper, Kahn (2005) argues that democracy reduces disaster mortality, but he finds this result only 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) suggest that inequality reduces the probability that citizens collectively agree to finance construction regulation. Empirically, they 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 agree with Kahn, Anbarci et al. and Escaleras et al. that failure to reduce avoidable disaster mortality is most accurately attributed to weak political incentives. However, while these authors argue that political incentives reduce disaster mortality directly, we argue that an important channel through which political incentives matter is by conditioning the responsiveness of governments to disaster propensity (and vice versa). Thus, for example, elected governments are more sensitive than unelected governments to an elevated propensity. Second, 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 older democracies, more institutionalized autocracies and non-corrupt regimes respond more to a higher level of earthquake propensity than younger democracies, less institutionalized autocracies and corrupt regimes. Third, we argue that income also conditions the effect of disaster propensity (and vice versa): richer countries respond more to an elevated quake propensity than poorer countries. Fourth, while Anbarci, et al. (2005) and Escaleras, et al.

(2007) also show a strong inverse relationship between earthquake propensity and mortality, we are able to improve on previous research designs by constructing 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: propensity not only affects learning by doing, as they argue, but it also affects the opportunity costs of investing in earthquake mortality reduction.

In our empirical analysis of earthquake mortality over the period 1960 to 2005, we find ample support for the hypotheses generated from our theory. 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. For example, both income and political incentive effects are contingent on the level of earthquake propensity (or, equivalently, country responses to earthquake propensity depend on income and political incentives). Thus, we find that an elevated quake propensity lowers mortality more in relatively rich than in relatively poor countries. Likewise, democracies in which political competitors have greater incentives to provide public goods – older democracies – respond more to an elevated quake propensity and thus experience significantly less earthquake mortality than other democracies or autocracies. Autocracies in which leaders can make credible commitments to party members – autocracies with more institutionalized ruling parties – are better able to implement policies such as building regulations, are therefore better able to respond to an elevated quake risk and thus also experience lower earthquake mortality. The same applies to non-corrupt countries.

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.

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). The necessity of government intervention in the specific case of earthquakes is not entirely obvious, however, since building collapse is the main cause of mortality in earthquakes (Osaki and Minowa 2001) and most buildings are privately owned. Certainly, government decisions are entirely relevant to the safety of public buildings, such as schools and hospitals. However, the assumption that government performance should have a large effect on mortality from the collapse of privately constructed and owned buildings is less obvious and requires some explanation.

Three potential market failures might call for government intervention. The most common is simply that 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, but not only is the steel itself not visible (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 (unless an earthquake occurs), buyers do not wish to pay for them and, in turn, they will not be provided. 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, earthquake mortality is high.

Information asymmetry, in and of itself, is not a satisfactory explanation for mortality, however. Private markets are replete with transactions that entail significant information asymmetries about product quality. A key feature of these markets is the enforceability of contracts to provide quality. Government typically plays a key role here. If governments fail to support the enforcement of contracts, private markets are forced to rely on reputational mechanisms. These are difficult to implement when construction failures are revealed with low probability, following an earthquake. The enforcement of building codes is also likely to be weak in environments where contract enforcement is weak. The failure of contract enforcement, however, is symptomatic of broader government failures to provide public goods.

Government intervention might also be necessary even if construction quality is observable (e.g., 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. Governments that are responsive to citizen needs can increase knowledge of seismic design principles; government-instituted building codes are one way in which they can do this.

Finally, 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 falls too 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 are often reluctant to purchase construction quality, even when doing so leaves buyers better off, and government intervention can overcome such reluctance. The evidence that higher earthquake propensity has a large and negative effect on earthquake mortality is an indication that, at least at the societal level, behavioral distortions are muted: higher risk appears to be associated with significantly greater mortality prevention efforts.

These arguments predict that earthquake mortality is lower when governments have stronger incentives to provide public goods in the form of enforcement of construction contracts and building codes, facilitating the provision of construction quality in private markets. Escaleras, et al. (2007), emphasize corrupt payments as the main reason that building codes are not enforced. However, if this were true, high mortality countries would be overrun with inspectors who fail to do their job in exchange for bribes. This appears not to be the case, however. Suggestive cases indicate, instead, that inspectors are few and far between, consistent with political disinterest in public good provision. For example, 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 "'[Construction companies] are only thinking about costs, not the safety of the people. . .' 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.[1] Income alone is unlikely to account for this large difference, particularly since Washington confronts a much smaller quake propensity than Padang.

[1] 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. The Politics of Earthquake Mortality Prevention

In this section, we develop our theory. As already mentioned in the introduction, we argue, first, that the opportunity costs of mortality reduction policies depend on a country's earthquake propensity. Higher propensity leads to lower opportunity costs of transferring resources to the construction of more quake-proof buildings and thus to lower quake mortality. We focus on deaths from building collapse because these are by far the most important source of mortality from earthquake disasters (in contrast to other disasters, such as flooding, where disease can have a large mortality effect). Second, income conditions opportunity costs. Specifically, the opportunity costs of expenditures to limit earthquake mortality differ across rich and poor countries and rich countries should respond more strongly than poor countries to an elevated earthquake propensity. And third, political incentives also condition the effect of earthquake propensity on mortality. In countries where citizens or members of the ruling party can more easily sanction leaders for poor performance, leaders are more likely to take – and to enforce – measures to prevent disaster mortality. In such countries, governments should respond more strongly to a higher earthquake propensity. In the remainder of this section, we elaborate on these arguments.

3.1. Earthquake Propensity and Opportunity Costs

That "earthquakes don't kill people, (bad) buildings do" may easily be the most common cliché in popular discussions of earthquake mortality. 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. It is therefore not the case that significant earthquake mortality is necessarily the product of negligence by households or governments.

The recent earthquake in Italy provides a case in point. On April 6 2009, an earthquake of magnitude 6.3 on the Richter scale struck close to the town of L'Aquila in Central Italy, leaving almost 300 people dead and an estimated 28,000 homeless.[2] In contrast, 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. Aware of these differences in mortality across developed countries, many put the blame on the Italian government. For example, Franco Barberi, a geologist, argues that a quake of the scale of the L'Aquila quake may have occurred "without causing a single death (…) if this happened in California or in Japan or some other country where for some time they have been practicing anti-seismic protection."[3] Implicit in these criticisms are beliefs regarding malfeasance by government officials. Consistent with these beliefs, Italy exhibits much worse scores on cross-country measures of corruption than other OECD countries: 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.

Such a conclusion, however, does not take into account the role of earthquake propensity. Anbaci, et al. (2005) and Escalantes, et al. (2007) control for the frequency of earthquakes in a country in their analysis of earthquake mortality, arguing that countries with more experience with earthquakes become better at confronting earthquake risks – they have greater opportunity to "learn by doing". Yet, much more than a "learning by doing" effect is likely to be critical. Even in societies that are fully informed about how to mitigate mortality risks, governments rationally abstain from passing and enforcing strict construction standards in areas with relatively low earthquake propensity, where the opportunity costs of earthquake mortality prevention are high. Small reductions in expected mortality demand large transfers

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

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

of resources from other uses (health infrastructure, medication, sanitation or, for a household, food or education) that yield more than offsetting mortality increases. In the unfortunate event that a strong earthquake does occur in a country in which earthquake propensity is low, we would therefore expect mortality to be higher. *Ex ante*, however, this outcome does not necessarily imply sub-optimal policy.

The L'Aquila earthquake illustrates the importance of propensity since, in fact, earthquake propensity in Italy is much lower than in California and Japan, which are located on two of the world's geologically most active zones. Italy, in comparison, lies at the very end of a zone where the African plate is submerged under the European plate. The L'Aquila quake was only the 4th earthquake above 6.0 on the Richter scale in Italy's postwar history – and none of these quakes reached a 7.0 on the Richter scale. Japan, on the other hand, experienced 31 quakes above 6.0, eight of which were stronger than 7.0 on the Richter scale. Similarly, while Ellwood and Ellwood (1998, cited in Kenny 2009) observe that a previously unknown fault triggered the Northridge earthquake, California as a whole experienced 19 earthquakes above 6.0, of which six were stronger than 7.0. This comparison understates the true difference because of the strong exponential logic of the Richter scale.[4] 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. A comparison with Californian earthquakes yields similar conclusions.

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.

[4] See appendix 1.

Further below, we will argue that corruption also plays a role and, in fact, conditions the effect of earthquake propensity on quake mortality. Bad governance in Italy is therefore likely to also have played an important role in the relatively high mortality following the L'Aquila earthquake. However, while a quake similar to that in L'Aquila would have cost far fewer lives had it happened in Japan or California, Italy would have arguably wasted resources if its construction standards had been as strict as those in these areas of high earthquake propensity.

3.2. The Conditioning Effect of Income

With identical earthquake propensities, poor countries face higher mortality than rich countries when an earthquake strikes. One reason is that buildings are likely to be better built in richer countries for other reasons. Moreover, richer countries can afford more measures to reduce mortality in all areas, ranging from disease control to traffic safety to earthquake mortality prevention. For any given earthquake propensity, social welfare maximizing governments in both rich and poor countries would invest in mortality reduction, but the rich country's budget for mortality reduction is exhausted at a higher level of expenditure that results in lower mortality from all causes.

However, richer and poorer countries should also respond to differences in earthquake propensity differently. Under plausible conditions, sensitivity to earthquake propensity increases in income. A straightforward way to see this is to compare two cases. In the first case, a rich and a poor country with otherwise identical incentives of political leaders to serve citizen interests face very low earthquake propensity; neither spends any money on earthquake mortality prevention. However, both countries face mortality threats from other sources. The poor country, with a tighter budget constraint, spends less to reduce mortality from these threats than the rich. This means that the marginal benefit of those expenditures is correspondingly higher in the poor than the rich country: the last dollar of expenditure on the prevention of, say, infectious diseases prevents more mortality in the poor than in the rich country. In the second case, the two countries face high earthquake propensity, but with the opportunity costs to the poor country of transferring resources away from infectious disease prevention to earthquake mortality prevention being higher than they are for the rich country, the rich country invests much more in quake-proofing constructions than the poor country in response to this higher earthquake propensity.

There are two conditions under which our argument that income conditions the negative effect of earthquake propensity on quake mortality would not hold. We believe neither condition is realistic and our empirical results support this contention. The first condition would be if it were very cheap to make buildings earthquake-proof, such that opportunity costs were not to play a major role. This condition clearly does not hold in reality. Kenny (2009), for example, summarizes three scenarios for the retrofitting of schools for earthquake mortality prevention, each including assumptions that are within ranges viewed as plausible by experts and taking into account the losses incurred by a society if fewer schools are built to accommodate the higher costs of retrofitting existing schools. The cost per student death averted by retrofitting ranges from $40 to $213,333. The latter figure is orders of magnitude larger than the cost of other government interventions that would reduce child mortality in many, particularly poorer countries. Although the costs of making buildings earthquake-proof at the time of construction are less than retrofitting buildings afterwards, these figures nevertheless make it clear that the opportunity costs for earthquake mortality reduction are substantial and can be prohibitive.

Second, our argument would not hold if the marginal costs of reducing earthquake deaths were so much lower as to fully cancel out the opportunity cost consideration. However, even if it were the case that rich countries, with better buildings independently of earthquake propensity, confronted a somewhat higher marginal cost of reducing earthquake mortality, which is not clear, the marginal benefits of the last dollar spent on public health or sanitation are still likely to be far less than those in poor countries and are therefore better spent on preventing earthquake mortality. In sum, therefore, we expect that, all other things equal, mortality is not only lower the higher a country's earthquake propensity, but particularly so if the country is relatively rich.

3.3. The Conditioning Effect of Political Incentives

Effective government regulation to improve building standards is likely to reduce earthquake mortality because the three conditions cited in section 2 undermine private efforts to mitigate risk: citizens are myopic when confronted with low-probability, high-risk events; they are uninformed about specific seismic design options and their value; and seismic design features are only observable at high cost in finished buildings. These government interventions – contract enforcement and the elaboration and enforcement of building regulations – have public good characteristics and their provision should therefore be subject to the same political conditions as the provision of public goods more generally.

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 effective 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 to die 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. Whenever natural disasters have a strong distributive effect and the elite is significantly less affected than the broader population, an effect of democracy on disaster mortality is likely (Plümper and Neumayer 2009), because government survival in autocratic regimes depends less on the population and more on the elite than the re-election of government in democracies.

While the theory is clear, democratic institutions, by themselves, are often not associated with policy outcomes aligned with the interests of citizens, poor or otherwise. 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 favour 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 behaviour. Yet, for many policy areas citizens are uninformed about government performance and political challengers cannot credibly commit to do better.

Disaster mortality prevention exhibits some of these imperfections. Because disaster prevention is difficult for citizens to observe (prior to a disaster occurring) and because disasters are rare events, such prevention is a low priority for governments.[5] At the same time,

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[5] Healy and Malhotra (2008) present direct evidence of political biases against disaster risk prevention. They document that US federal government spending favors post-disaster relief spending by a large margin over spending to prevent damage from disaster: per capita spending on relief was $34.50 in 2000, compared to $1.59 on prevention, though their calculations suggest that an extra one million dollars in damage prevention was associated with a reduction in the present value of future disaster damage of approximately 15 million dollars.

however, politicians cannot completely offset the political consequences of *ex ante* failures to prevent mortality with *ex post* relief. In India, for example, following rain-related disasters citizens tend to vote against politicians from the incumbent ruling party, even if the government provides large amounts of *ex post* assistance to farmers. Average relief spending reduces the probability of expulsion by only one-seventh relative to no spending at all (Cole, Healy and Werker 2008). Moreover, and more importantly, with the vast majority of earthquake victims dying at the time of or shortly after building collapse (Osaki and Minowa 2001), *ex post* disaster relief can only play a relatively minor role in the prevention of quake mortality. Why, then, would the mere fact of competitive elections lead politicians to invest in pre-disaster risk mitigation?

As Ferejohn (1986) and Persson and Tabellini (2000) demonstrate, even when politicians are not credible, voters can still hold incumbents accountable as long as they can coordinate on a standard against which to judge incumbent performance. Incumbents who meet this standard are re-elected; incumbents who do not are expelled, regardless of challenger characteristics. While, in general, *ex post* performance standards hold governments only weakly accountable, this is less so in policy areas for which crisis clearly exposes the scope of government failure, as earthquakes do.[6] In contrast to other policy areas where performance failure is difficult to detect, such as education, once an earthquake occurs, government policy failures are obvious and coordination around a performance standard faces few obstacles: citizens all observe the same effects, and the scale of policy failure ensures that citizens will jointly regard the failure as particularly salient in judging performance. Democracies, where citizens can more easily enforce *ex post* performance standards, should therefore exhibit lower earthquake mortality.

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[6] Keefer (2007) finds, for example, that the fiscal costs of banking crises are as much as 22 percentage points of GDP lower in countries with competitive elections.

Nevertheless, even among democracies variation in incentives of governments to provide public goods or to engage in rent-seeking at the expense of public good provision should also matter for earthquake mortality. A large 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, even if all politicians have stronger incentives to provide ex post disaster relief than ex ante measures to mitigate mortality, 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.

Compared to democracies, autocracies of all kinds tend to actively 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 sufficiently difficult to coordinate any collective response against the autocratic rulers. Autocracies do vary, however, in the degree to which leaders allow ruling party members to organize collectively (that is, the extent to which they 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 the degree of corruption, which is also associated with weak incentives to pursue the broad public interest and 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.

The effects of political incentives are not only direct. They also condition the effects of earthquake propensity and, conversely, their effects will be conditioned by earthquake propensity. Political incentives to undertake ex ante measures to limit mortality, driven by the threat of ex post accountability analyzed by Ferejohn, rise with the level of earthquake propensity, since the higher the probability that a strong earthquake occurs in this period, 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. However, since democracies are more responsive than autocracies, they should also respond more to a higher earthquake propensity than autocracies. In other words, democratic governments are likely to enact more and better earthquake safety regulations relative to autocracies the higher the earthquake propensity of the country and we expect that quakes of the same magnitude not only kill fewer people the higher earthquake propensity, but particularly so if the country is democratic.

This reasoning is analogous to the earlier discussion of the conditioning effect of income on propensity. When propensity is very low, neither autocracies nor democracies have an incentive to take precautionary measures. When it is high, democracies have a greater incentive than autocracies. The difference in precautionary measures between high and low propensity democracies must, therefore, be greater than between high and low propensity autocracies. Similar arguments apply for the remaining political incentives identified in our discussion above. Older democracies should respond more to a higher earthquake propensity and thus have lower mortality at each level of propensity than younger democracies. The same holds true for autocracies with more institutionalized ruling parties relative to those with less institutionalized ruling parties and for less corrupt relative to more corrupt regimes.

3.4. Hypotheses

In sum, our theory generates six testable hypotheses. First, all other things equal and controlling for the strength and location of earthquakes in particular, quake mortality is lower in countries with a higher earthquake propensity. Second, a higher quake propensity lowers mortality more in relatively rich than in relatively poor countries. Third, a 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 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, non-corrupt regimes not only face higher incentives to provide public goods, but are also in a better position to enforce appropriate regulation than corrupt regimes. In contrast, in corrupt regimes earthquake-proof construction regulation is not only less likely, but if existent is unlikely to be enforced. 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 costs nothing (that is, if propensity does not at all reflect opportunity costs of investing in lower earthquake mortality, including learning about how to respond best to quake risks), 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 such contingent effects to emerge. 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. In other words, if we find evidence for our hypotheses that the effects of quake propensity on mortality are contingent on factors such as the income and political characteristics of countries, then this supports the conclusion that opportunity cost plays a large role, whether or not there is learning by doing.

4. Research Design

To test these hypotheses, we analyze the determinants of earthquake mortality over the period 1960 to 2005. In this section, we describe our research design in detail.

4.1. Data Sources and Operationalization

Our dependent variable is the annual sum of earthquake deaths in a country, with data taken from EM-DAT (2008).[7] 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

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[7] 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.

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 at risk of mortality. This is important because country years in which no major earthquakes happened are not at risk; no one could have possibly been killed by an earthquake. They are irrelevant and their inclusion would therefore inject 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.

A key challenge in assessing the effect of earthquake propensity, economic constraints and political incentives on mortality is to control for the magnitude of earthquakes. Mortality is higher, all else equal, the greater the magnitude of an earthquake and the larger the number of people exposed to it. We therefore construct, and control for, two magnitude variables, one capturing magnitude itself, and one capturing magnitude weighted by the number of people in the area affected by the earthquake.

The measure of magnitude begins 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 epicentre, 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.[8] 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.

Earthquake propensity, the first variable of main interest, 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. Figure 1 shows the global distribution of earthquakes and the borders of tectonic plates. 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.

[8] 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.

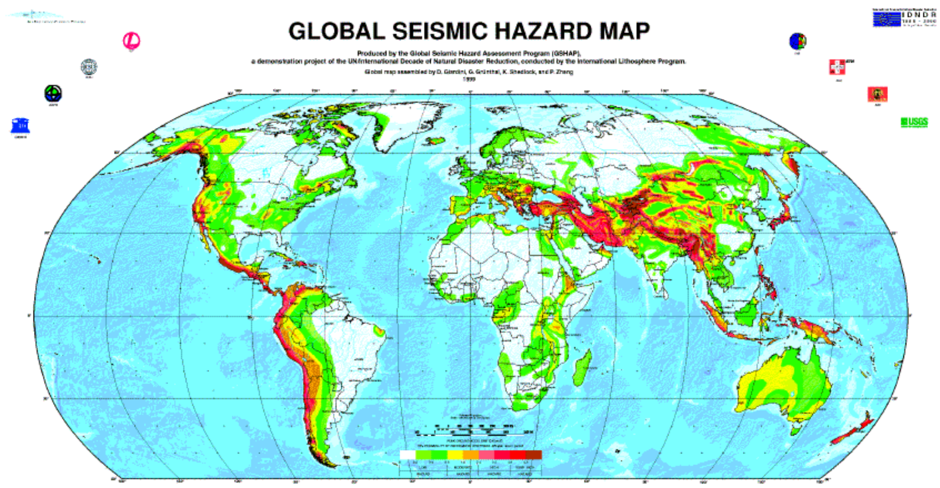

Figure 1: Tectonic Plates and Earthquake Activity (Source: ETH Zürich, Global Seismic Hazard Assessment Program).

We use as a simple 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.[9] It may seem strange to use a variable that contains information up to 2008 for estimations that start in 1960. However, this variable is meant to proxy for latent earthquake propensity.

[9] We take 1960 as the start year because our dataset on earthquakes starts in this year. Our results are fully robust to using the highest observed earthquake magnitude experienced since 1900 instead, derived from data collected by the United States Geological Survey (http://earthquake.usgs.gov/earthquakes/world/historical.php).

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. 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 1975 to 2005 period. 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 1982 to 2005. As a further control variable we use the log of population size (*ln pop*) from World Bank (2009) since more populous countries will face larger mortality, all other things equal.

Our hypotheses postulate that income and political incentives condition the effect of earthquake propensity to pursue policies that reduce earthquake mortality. Such conditional effects are typically estimated in a model in which two or more variables are interacted. Unfortunately, the interpretation of interacted terms of two or more continuous variables is problematic in non-linear models. As Ai and Norton (2003: 129) have shown, in nonlinear models "the interaction effect (…) cannot be evaluated simply by looking at the sign, magnitude, or statistical significance of the coefficient of the interaction term." Instead, the interpretation of the interaction term requires computing the cross derivative of the expected value of the dependent variable, which depends on all the covariates in the model and their values. Testing the significance of interaction terms in non-linear models with two or more continuous variables is thus an extremely complex task.

Instead, we interact dummy variables for our main variables of interest with the continuous earthquake propensity variable. This is easiest done for our measure of regime type, which is already captured by a dummy variable for democracy. We thus interact dummy variables for democracies and autocracies with earthquake propensity. These estimated coefficients are not subject to the difficulty identified by Ai and Norton (2003). They 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. This formulation is equivalent to, but easier to interpret than interacting a single democracy dummy variable, equal to one for democratic and zero for non-democratic countries, with propensity.[10]

We similarly interact, in separate estimations, the continuous propensity variable with dummy variables for high-income versus low-income (or, to be precise, "not high-income") countries, using the World Bank (2009) classification, to estimate different earthquake

[10] To see this, imagine an estimation model of the form $y = b_1x+b_2z+b_3xz$, with x a continuous and z a dummy variable. The marginal effect of x on y is given by b_1 for z=0 and by (b_1+b_3) for z=1. Now consider instead an estimation model of the form $y = b_4x$ (for z=0) + b_5x (for z=1) + b_6z. b_4 is the same as b_1, while b_5 is the same as (b_1+b_3). In the first model, the interaction effect is statistically significant if b_3 is statistically significantly different from zero. In the second model, it is significant if b_4 and b_5 are statistically significantly different from each other.

propensity coefficients for these two groups of countries.[11] About 25 per cent of countries are classified as having high-income. The earthquake propensity variable is also interacted with a dummy variable for democracies with below median continuous years of democracy and above median continuous years of democracy; while for autocracies the propensity variable is interacted with a dummy variable for, respectively, below and above median age of the ruling party, relative to the leader's years in office. The final interaction specification is between earthquake propensity and dummy variables for corrupt and non-corrupt regimes, where we classify a country as 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.

4.2 Estimation Strategy

The earthquake mortality dependent variable 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 decided against the zero-inflated model for two reasons. 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

[11] Our results are fully robust to interacting the earthquake propensity variable with dummy variables for OECD countries and non-OECD countries instead, also following World Bank (2009) classification.

mortality is not excessively large (roughly 20 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, quake propensity is not interacted with any dummy variable. 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. Controlling for the strength 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 interact the quake propensity variable with dummy variables for high-income and low-income countries, thus in effect estimating separate quake propensity coefficients for these two groups of countries. Both rich and poor countries respond to increasing earthquake propensity: mortality falls significantly with higher quake propensities in both sets of countries. However, the effects are significantly larger for rich countries. The difference between the two estimated coefficients is statistically significant at $p<.001$. In substantive terms, keeping all other variables at mean values, a one standard deviation increase in quake propensity lowers the expected count of quake fatalities by 62.8 per cent in rich countries and by 46.5 per cent in poor countries. This supports the earlier opportunity cost argument: poor countries face a larger opportunity cost of transferring resources to earthquake mortality prevention than rich countries such that they respond less to an elevated earthquake propensity than rich countries.[12]

Model 3 interacts the quake propensity variable with dummy variables 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 2/3 larger than the respective estimated coefficient in autocracies (-.0044 versus -.0029), although the difference between the two estimated coefficients is not statistically significant. A one standard deviation increase in quake propensity is estimated to decrease expected mortality by 49.4 per cent in democracies and by 42.2 per cent in autocracies, if other variables are held at mean values. The statistically significant coefficient of the linear democracy term indicates that democratic governments suffer significantly fewer earthquake deaths at all levels of quake risk.

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 (see Gehlbach and Keefer 2009). Democracies are distinguished according to whether they are above or below the median years of continuous democratic experience.[13] Since the Database of Political Institutions starts in 1975, and is

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[12] 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.

[13] 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. Results, though, are substantively similar, with all variables statistically significant as before, if we re-estimate the model with two additional variables, namely the number

required for the ruling-party institutionalization variable, the sample in this estimation is smaller than for the other models. Consistent with our prediction, autocracies with low institutionalization are non-responsive to increases in earthquake propensity, whereas increasing propensity significantly reduces mortality in autocracies with high institutionalization. Increasing propensity reduces mortality even more in democracies and particularly so in older democracies, which react more to increasing propensity than young democracies (difference statistically significant at p<.002), which in turn react more than autocracies with high institutionalization, even if the difference is not statistically significant at conventional levels. A one standard deviation increase in quake propensity decreases the expected count of quake deaths by 64.4 per cent in old democracies, by 42.9 per cent in young democracies and by 35.7 per cent in autocracies with high institutionalization (all other variables at mean values).

In the final model 5, we test whether corruption conditions the effect of earthquake propensity on quake mortality. Since the corruption variable is available only since 1982, the sample size is further reduced. Consistent with the notion that political incentives to provide earthquake-proof construction regulation require a non-corrupt political regime, we find that corrupt regimes are totally unresponsive to an increase in earthquake propensity, while non-corrupt regimes are responsive to elevated earthquake risk with a standard deviation increase in quake propensity estimated as decreasing the expected count of quake fatalities by 50.3 per

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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. The only exception is that, while quake propensity continues to have the highest effect on mortality in older democracies, followed by younger democracies and then by autocracies with high intstitutionalization, the difference in the effect of quake propensity between older and younger democracies is no longer statistically significant, while the difference between younger democracies and autocracies with high institutionalization now becomes significant.

cent (all other variables at mean values). Beyond this conditioning effect on earthquake propensity, corruption has no independent effect on quake mortality.

6. Robustness

The results reported in table 1 are robust to a number of potential mis-specifications of the estimation model – see table 2.[14] First, it could be argued that the results are driven by the specific cut-off that we employ for measuring earthquake propensity. However, in all but two cases, results are similar in terms of coefficient signs and statistical significance 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 1960-2005 (column 3).[15]

Anbaci et al. (2005) limit their sample to observations in which earthquakes of magnitude six and above on the Richter scale 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 from the relevant population that should be in the sample. Moreover, smaller earthquakes can also have fatal consequences. Nevertheless, if we follow their lead and only include earthquakes above 6 (column 4), instead of above 5, on the Richter scale in the sample, results are fully robust.

The political incentives of leaders who have been in office for longer periods of time could differ from those newly in office and this could be correlated to 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 5).

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

15 All measures exponentially transformed as before.

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. Results reported in column 5 of table 2 also demonstrate that the results in models 1-3 are robust to the post-1975 sample. In fact, in this sample, which is restricted to the post-1975 period since the variable measuring the tenure length of the chief executive is only available from 1975 onwards, not only is the magnitude of the democratic response to increased propensity greater than that of the autocratic response, as in model 3, but the difference becomes statistically significant if the sample is restricted to the post-1975 period.

The exact death toll of earthquakes is typically unobserved. Therefore, no one actually *knows* the exact number of quake victims, which is instead estimated. There can thus be no doubt that the estimation results we have reported in the previous section are based on the analysis of noisy data. We therefore conducted a Monte Carlo study, similar to what Plümper and Neumayer (2009) do for mortality from famines, which aims at exploring 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 of the interval [0.5..1.5], which mirrors measurement errors of up to 50 percent.[16] By drawing the measurement error from a uniform distribution, it is *on average* unlikely to be correlated with the explanatory variables. However, the actually drawn measurement error *in each iteration* may well be correlated with some of the regressors even if the average correlation over infinite iterations is zero. By

[16] 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 MC.

reporting the full range of coefficients from the Monte Carlo study (minimum to maximum) in table 3, we take each single iteration into consideration and thus account not only for random measurement error, which would simply render estimates less efficient, but also for some systematic measurement error as well. Results are fully robust. The same is true if we impose larger measurement error on stronger earthquakes and lower measurement error on smaller earthquakes (results not shown), rather than the same proportional extent of measurement error on all quakes as in table 3. This suggests that potential measurement error is unlikely to have a significant impact on our results.

7. Conclusion

The politics of disaster mortality prevention exerts a large influence on actual disaster mortality rates. We have argued here that governments face very different incentives to implement and enforce an effective system of quake-proof construction regulations. One main influence on government policies comes from earthquake propensity. If earthquakes tend to be rare and – if they do occur – tend to be moderate, governments are unlikely to implement an effective earthquake mortality prevention system, because this regulation 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.

Even if earthquakes are relatively frequent and potentially strong, governments may opt against implementation of 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 influence governments' response to earthquake propensity. Political institutions not only exert an influence on the extent to which governments are willing to provide, and can credibly commit themselves to providing, the public good of earthquake morality prevention. Political institutions also condition the extent to which governments will respond to higher earthquake propensity. In sum, earthquake propensity together with economic and political incentives explain why earthquake mortality varies widely even after controlling for the seismic energy and the location of actually occurring quakes. These interaction effects indicate 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, failure to enact and enforce regulations for earthquake-proof construction is not necessarily a failure, but may be perfectly rational, following opportunity cost considerations. 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, a 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.

Table 1. Main estimation Results.

Dependent variable: annual sum of earthquake deaths	model 1	model 2	model 3	model 4	model 5
max_magnitude	0.0000222*	0.0000367**	0.0000234*	0.0000450**	0.0000374*
	(0.0000115)	(0.0000177)	(0.0000124)	(0.0000210)	(0.0000225)
magnitude_popdensity	0.0209**	0.0193**	0.0209***	0.0221***	0.0123
	(0.00854)	(0.00772)	(0.00809)	(0.00700)	(0.0151)
quake propensity	-0.00366***				
	(0.00103)				
quake propensity in developing countries		-0.00304***			
		(0.00104)			
quake propensity in developed countries		-0.00885***			
		(0.00143)			
quake propensity in autocracies			-0.00293*		
			(0.00165)		
quake propensity in democracies			-0.00445***		
			(0.00153)		
quake propensity in autocracies				0.00256	
w. low institutionalization				(0.00259)	
quake propensity in autocracies				-0.00277***	
w. high institutionalization				(0.00103)	
quake propensity in young democracies				-0.00457***	
				(0.00158)	
quake propensity in old democracies				-0.00813***	
				(0.00107)	
quake propensity in corrupt countries					-0.00189
					(0.00262)
quake propensity in non-corrupt countries					-0.00639***
					(0.00210)
ln gdppc	-0.513*	-0.331	-0.521*	-0.649**	-0.780***
	(0.267)	(0.268)	(0.268)	(0.325)	(0.285)
democracy	-1.558***	-1.512**	-1.348*	0.531	-1.916**
	(0.595)	(0.616)	(0.774)	(0.930)	(0.932)
ln pop	0.657***	0.675***	0.625***	0.994***	0.641***
	(0.216)	(0.218)	(0.227)	(0.279)	(0.248)
lack of corruption					-0.177
					(0.292)
Constant	-2.524	-4.245	-2.057	-9.444**	0.650
	(3.957)	(4.278)	(4.109)	(4.141)	(4.777)
Observations	1696	1692	1696	1065	867
Period of study	1960-2005	1960-2005	1960-2005	1975-2005	1982-2005

Notes: Standard errors clustered on countries. * significant at p<.1 ** at p<.05 *** at p<.01.

Table 2. Robustness tests.

Dependent variable: annual sum of earthquake deaths	Propensity: ≥5 (Richter)	Propensity: ≥6.5 (Richter)	Propensity: largest quake	Only quakes > 6 (Richter)	Executive years in office incl.
Model 1					
quake propensity	-0.000248***	-0.0139***	-0.00114***	-0.00387***	-0.00343**
	(0.0000688)	(0.00382)	(0.000273)	(0.000981)	(0.00166)
Model 2					
propensity in developing countries	-0.000207***	-0.0118***	-0.000997***	-0.00332***	-0.00275*
	(0.0000698)	(0.00378)	(0.000240)	(0.000908)	(0.00160)
propensity in developed countries	-0.000740***	-0.0316***	-0.00172***	-0.00940***	-0.0103***
	(0.000116)	(0.00527)	(0.000333)	(0.00154)	(0.00187)
Model 3					
propensity in autocracies	-0.000202*	-0.0114**	-0.00104***	-0.00311**	-0.000981
	(0.000121)	(0.00556)	(0.000267)	(0.00150)	(0.00230)
propensity in democracies	-0.000286***	-0.0173***	-0.00134***	-0.00472***	-0.00752***
	(0.000109)	(0.00541)	(0.000313)	(0.00141)	(0.00161)
Model 4					
propensity in autocracies	0.000213	0.00920	0.00245**	0.00201	0.00143
w. low institutionalization	(0.000220)	(0.00935)	(0.00122)	(0.00254)	(0.00303)
propensity in autocracies	-0.000184**	-0.0104***	-0.000548**	-0.00254**	-0.00207**
w. high institutionalization	(0.0000724)	(0.00375)	(0.000232)	(0.00101)	(0.000985)
propensity in young democracies	-0.000295***	-0.0188***	-0.00110***	-0.00476***	-0.00440**
	(0.000103)	(0.00594)	(0.000404)	(0.00119)	(0.00175)
propensity in old democracies	-0.000568***	-0.0300***	-0.00173***	-0.00800***	-0.00809***
	(0.0000870)	(0.00418)	(0.000303)	(0.00110)	(0.00103)
Model 5					
propensity in corrupt countries	-0.000173	-0.00596	-0.000949**	-0.00225	0.00303**
	(0.000205)	(0.0100)	(0.000415)	(0.00242)	(0.00149)
propensity in non-corrupt countries	-0.000564***	-0.0243***	-0.00133***	-0.00718***	-0.00381*
	(0.000169)	(0.00749)	(0.000301)	(0.00190)	(0.00216)

Notes: 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	-0.00365	0.00011	-0.00397	-0.00339
	0.00104	0.00002	0.00096	0.00109
Model 2				
propensity in developing countries	-0.00302	0.00010	-0.00330	-0.00268
	0.00105	0.00003	0.00098	0.00116
propensity in developed countries	-0.00886	0.00015	-0.00938	-0.00853
	0.00143	0.00002	0.00139	0.00149
Model 3				
propensity in autocracies	-0.00293	0.00015	-0.00351	-0.00257
	0.00165	0.00010	0.00132	0.00205
propensity in democracies	-0.00445	0.00014	-0.00490	-0.00384
	0.00152	0.00005	0.00135	0.00177
Model 4				
propensity in autocracies	0.00699	0.00055	0.00512	0.00887
w. low institutionalization	0.00669	0.00037	0.00492	0.00748
propensity in autocracies	-0.00353	0.00011	-0.00380	-0.00322
w. high institutionalization	0.00116	0.00004	0.00102	0.00125
propensity in young democracies	-0.00630	0.00018	-0.00697	-0.00561
	0.00171	0.00003	0.00161	0.00177
propensity in old democracies	-0.00905	0.00011	-0.00933	-0.00878
	0.00097	0.00002	0.00093	0.00102
Model 5				
propensity in corrupt countries	-0.00143	0.00025	-0.00214	-0.00082
	0.00290	0.00010	0.00261	0.00317
propensity in non-corrupt countries	-0.00675	0.00023	-0.00747	-0.00603
	0.00216	0.00006	0.00200	0.00230

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

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