THE SHOCKING ORIGINS OF POLITICAL TRANSITIONS? EVIDENCE FROM EARTHQUAKES*

Muhammad Habibur Rahman, Nejat Anbarci, Prasad Bhattacharya, and Mehmet Ulubaşoğlu[**]

Deakin University

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Abstract

Do earthquakes trigger political transitions? Using a rich panel dataset of 160 countries observed over 1950 to 2007, we find that earthquake shocks, measured in terms of the effect of ground-motion amplitude on death toll, have two contradicting effects on political change. On the one hand, earthquakes drive transitions into democracy due to a direct effect, which we interpret to be the reaction of voters to earthquakes by which they hold the incumbent government responsible for many human lives lost. On the other hand, earthquakes can indirectly hasten transitions into a less democratic regime if they increase the income level through 'creative destruction', and thus, make it costlier to contest the incumbent government. Overall, our findings show that, while not leading to a full-fledged regime change, earthquake shocks open a new democratic window of opportunity, but this window is narrowed by improved economic conditions.

Keywords: Earthquake shocks, political transitions, autocracy, democracy

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[**] Corresponding author: Deakin University, School of Accounting, Economics and Finance, 70 Elgar Road, Burwood, VIC 3125, Australia; email: maulubas@deakin.edu.au; tel: (+61 3) 9244 6592; fax: (+61 3) 9244 6283.

1. Introduction

Do earthquakes trigger political transitions? History portrays numerous tragic earthquakes that not only reshaped geographical settings, but also realigned the political powers within countries. Many ancient cities, including Herculaneum and Pompeii in Italy, Sodom and Gomorrah in modern-day Jordan, Bura and Helice in Greece, Lima in Peru, Copiapo in Chili, among others, faced catastrophic destruction by earthquakes that in turn changed the political balances of the then period (Boscowitz and Pitman, 1890).[1]

In the modern era, earthquakes have occurred frequently without changing the topographic structure (e.g., Peru in 1970, China in 1976, Mexico in 1985, Armenia in 1988, the United States in 1989, Iran in 1990, Japan in 1995, Turkey in 1999, Indonesia in 2004 and Haiti in 2010), but causing massive human as well as economic losses in a greater proportion than that of ancient times. On average, approximately 1.4 million earthquakes occur in a year around the world (USGS, 2011). Between 1950 and 2009, the earth quaked *catastrophically* around 570 times, not only killing over two million people but also affecting over 300 million people in total[2] (EM-DAT, 2011). In the last two decades, earthquakes have caused an average of 27,000 human deaths a year (Guha-Sapir and Vos, 2010). Figure 1 illustrates an important increasing trend of earthquakes on human mortality and economic losses from 1950 to 2009.[3]

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[1] Sometimes earthquakes also remap the earth as a benefactor to human civilisation. For instance, an earthquake that resulted in a long rampart in 1819 at the mouth of the Indus still serves as an embankment protecting its adjacent population from inundation of the sea (Boscowitz and Pitman 1890).

[2] The number of total affected people is the sum of the number of people injured, the number of people rendered homeless and the number of people accessing emergency response services.

[3] This trend can be affected by the unavailability of natural disasters data in earlier periods, and hence, needs to be taken with a caveat. Note, however, that most of the seismic observatory stations to measure earthquakes were installed prior to 1950, i.e., before our sample coverage.

Incumbent regimes may face severely negative outcomes as a result of collateral destruction caused by earthquakes. Drastic changes in economic conditions triggered by earthquakes, such as altered income levels, investment, and the distribution of resources in the rehabilitation and renovation process, may affect the fate of the governing authority. Such a possibility of political change has been strongly indicated by a meteoric rise in the number of studies exploring political transitions sparked by drastic changes in economic conditions (*see* Lipset, 1959; Muller, 1995; Acemoglu and Robinson, 2001; and Rodrik and Wacziarg, 2005).

In a similar vein, a burgeoning literature has explored the influence of climatic, topographic, and more generally, geographic, conditions on political transitions. For instance, Brückner and Ciccone (2011) found that lack of rainfall in Sub-Saharan Africa, through causing an economic downturn, led to transitions towards democracy. Further, this effect is unidirectional, since economic booms due to high rainfall do not result in transitions from democracy to autocracy. The theoretical background of these findings is rooted in the work of Acemoglu and Robinson (2001), who predict that, in times of turmoil, pro-democratic masses may revolt against the incumbent autocratic regimes (which are typically supported by the elite) if the opportunity cost of doing so is sufficiently low. Facilitated by the underlying imbalance in political and economic power and due to reduced incomes (at least in the short run), such turmoil may, consequently, lead to political change.

This paper contributes to the above line of research by investigating the impacts of earthquakes on political transitions. The principal link between this study and the afore-mentioned papers is that the turmoil ignited by earthquakes may alter the income levels *and* trigger political change. We differ from the extant work above in two respects. First, we focus on earthquakes, which are catastrophes that result in deaths and various types of destructions, with potential long-lasting consequences through economic and political turmoil that might follow. In this way, we also contribute to the scarce literature on the political economy of earthquakes studying their consequences on different outcomes (see, notably, Kahn 2005, Anbarci *et al.* 2005, Brancati 2007, and Keefer *et al.* 2011). Second, we distinguish between the 'direct' and 'indirect' effects of earthquakes on political transitions. That is, we not only study the income (i.e., indirect) channel of earthquakes in line with other studies mentioned above, but also consider the direct effect of earthquakes. We interpret the direct effect as the affective shock experienced by citizens due to the catastrophe. This sort of reaction may originate from sudden and unanticipated nature of earthquakes, which, unlike other catastrophes, come without early warning. They may thus instigate enormous anxiety due to imminent death that has just bypassed, which may lead, in turn, to a voter behavior that punishes the incumbent regime under psychological trauma. This reaction also parallels a number of historical accounts and anecdotal evidence in which countries face drastic political transitions ensuing a disaster whereby such affective shock drives political changes on their own right. This paper offers an empirical test of this affective shock effect, ignoring of which is likely to underestimate the true impact of earthquakes on political transitions. Together the direct and indirect effects that we consider in this paper cover the two major groups of incumbent regime responsibilities in the aftermath of a disaster. That is, people's affective behavior is a function of emergency response and relief activities, and income is a function of the rehabilitation and recovery efforts.

Using the ground-motion amplitude derived from the Richter magnitude scale as an instrumental variable for earthquake death toll, we empirically verify the affective shock effect. Specifically, we find that it leads to a democratic improvement along the Polity spectrum. Several falsification exercises indicate that our interpretation of the direct impact as the affective shock effect is plausible. Moreover, we document evidence for two situations in which such affective shock becomes instrumental for improvement in democratic conditions; when there are national elections in proximity, and when the extent of insured disaster risk in the country is low. We also find that earthquakes increase income through a creative destruction effect, which in turn deteriorates democracy. This finding is consistent with Acemoglu and Robinson (2001) who argue that contesting the incumbent regime becomes costlier when income increases. Again we document two mechanisms through which the creative destruction outcome can arise after earthquakes; investment stimulus due to post-disaster expenditure on reconstruction and rehabilitation, and transfer of technology to the affected country following disaster. The net finding in our analysis is that, while not leading to a full-fledged political transition, earthquakes improve the democratic conditions. Numerically, this effect corresponds to an improved democracy score of 1.2 points in the Polity scale of [–10, 10] for one thousand deaths in every one million. Our main result is robust to alternative approaches to econometric investigation.

Before proceeding, we briefly illustrate the connection between earthquakes and political regimes graphically. Figure 2 portrays a significant association between earthquake death toll and democratic conditions. Higher death toll is mostly associated with 'partially democratic'[4] nations

[4] Partially democratic countries are those with a Polity2 score between 0 and 7, see Epstein *et al.* (2006).

with comparatively lower GDP per capita, while democratic countries with a higher GDP per capita seldom face deaths from earthquakes. This pattern suggests that earthquakes' channels of impact and the way in which these channels alter political landscape are a fruitful question.

The rest of the paper is structured as follows. Section 2 provides a brief overview of the relevant literature. Section 3 describes the data and some measurement issues related to earthquakes. Section 4 presents the estimation methodology. Section 5 discusses the results and presents several robustness checks. Section 6 identifies the mechanism of evidencing income and affective effects of earthquakes. Finally, section 7 concludes.

2. Earthquakes, Income and Political Transitions

Although several studies highlight the nexus between earthquakes and economic conditions (Ramcharan, 2007; Kellenberg and Mobarak, 2008; and Cavallo *et al.*, 2010), only a few studies mention the link between earthquakes and political change (*see* Kubicek, 2002; Anbarci *et al.*, 2005; and Keefer *et al.*, 2011). No study, to our knowledge, has hitherto pursued the relationship between earthquakes and political change in a systematic fashion. This section spells out the two potential avenues that could connect earthquakes and political change: i) affective shock of the citizens that may arise just after the disaster, and ii) changed economic conditions.

2.1. *The Emergency Response Channel: The Direct Effect of Earthquakes on Political Change*

This paper hypothesizes the first leading channel through which earthquakes may affect political regimes to be the human mind; people's affective behaviour towards the incumbent regimes may be affected by earthquakes. Earthquakes, unlike many other catastrophes, come without early warnings. Consequently, their psychological impacts turn out to be enormous. Underlying the psychological impact is necrophobia, that is, the fear of death, which is inherent in most adult individuals. Earthquakes represent a sudden and unexpected arrival of the probability of death. Although one may escape death in an earthquake incident, anxiety triggered by the incident might remain at extremely high levels given that people might have seen numerous others dying or in torment. Thus, sudden and unanticipated feature of earthquakes has direct and important implications for the citizenry, especially when individuals perceive the incumbent regime as responsible for deaths. Further, individuals hold the incumbent regime accountable not only for providing a short-run emergency response, but also for leading long-run recovery and reconstruction. If the government fails to address the emergency situation to the degree expected by the majority, people's confidence on the current political regime may drop drastically. We argue that the direct impact of earthquakes provides an opportunity to test the voter reaction under the influence of major psychological trauma as directed towards the incumbent regime. This argument parallels a recent evidence which shows that voters may punish incumbent regimes for events beyond their control (e.g., Achen and Bartels, 2004; Coles et al., 2012) (see also below).

The political change ensuing such shocks can occur either toward a more democratic or a more autocratic regime. For example, depending on where the regime initially lies in the autocracy-democracy spectrum, a prolonged democratic process, a post-disaster conflict to share the basic resources, or a corrupt bureaucratic machinery observed in the emergency response phase may tempt citizens to elect an autocrat as a consequence. Alternatively, citizens might also expect the democratic regimes to ensure more equitable allocation of post-disaster relief, and their regime choice might be shaped by this expectation. In this regard, Cole *et al.* (2012) show using public relief data from India that fewer voters punish the ruling party when the party responds vigorously to the emergency crisis, and that democratic regimes respond better to salient emergencies than to less conspicuous ones.

History also supports these arguments. Drury and Olson (1998) document three anecdotes that portray the direct effect of earthquakes on political change. First, the autocratic regime of Guatemala failed to conduct emergency response and recovery activities after the catastrophic earthquake in 1976, and this initiated a process of democratisation leading to change in the leadership of the regime. Second, the *twin* earthquakes of Mexico in 1985 shook the one-party authoritarian regime, and the resulting legitimacy crisis triggered the emergence of a multi-party system. At the other extreme, natural disasters may lead to autocracies. The destructive Hurricane San Zenon, which struck the Dominican Republic in 1931, gave an opportunity to Rafael Trujillo to take advantage of the disaster by accelerating the emergency response as well as recovery and reconstruction activities. Later on, Trujillo capitalised on people's sentiments and established an autocratic regime that ultimately became one of the worst and longest-lasting dictatorships in the Western Hemisphere (Crassweller, 1966).

The political outcomes of earthquakes may also rest on the deep divisions in the populace. According to Cuny (1983, p. 54), "A disaster makes it very evident that the poor are vulnerable because they are poor, and this can lead to profound political and social changes within a society: many governments destabilize in the years immediately following a disaster." Along these lines, Libaridian (1989) observed that the rescue and relief efforts for Armenian earthquake in 1988 were highly politicised, leading him to argue that this politicisation was one of the passive catalysts for the collapse of the Soviet Union in 1991. Similarly, the Marmara earthquake in Turkey in 1999 fostered political turmoil (Kubicek, 2002), which, in turn, led to a new election in 2002, toppling the then coalition government.[5] Recently, the Haiti earthquake in 2010 claimed over 222,500 human lives while affecting a total of around 3,700,000 people (EM-DAT, 2011), marking several failures of the Haitian government in post-disaster response. Consequently, people elected the pop-star Michel Martelly as the president.

2.1. *Income Channel: The Indirect Effect of Earthquakes on Political Transitions*

At least four considerations suggest the income channel as the second leading mechanism for earthquakes' impact on political transitions. First, earthquakes may affect capital stock by destroying the physical infrastructure. Second, they restructure economic activities in many sectors, especially the secondary and tertiary sectors, eventually affecting employment opportunities. Third, earthquakes may attract external assistance and affect the fiscal capacity of the regime. Finally, all these may alter income levels by influencing the government policy, resource allocation, and power imbalance in the society. In what follows, we provide a brief overview of the income channel.

I. *Creative destruction vs. broken window hypothesis*

There is an extensive debate in the literature as to how natural disasters impact on the economy. One school of thought, relying on the celebrated Schumpeter's (1942) 'creative destruction'

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[5] A related effect of the Turkish earthquake in 1999 in regard to influencing public perception has been observed in a different sphere: the improved diplomatic relations between Turkey and Greece, a neighbouring country that was rocked by another earthquake shortly after Turkey. International aid exchange between the two countries following these earthquakes is widely considered to be the turning point in decades-long strained public and diplomatic sentiments and animosities between the two nations.

hypothesis, argues that the rebuilding effect of natural disasters has a positive impact on long-run economic growth and development. Reviewing the literature from the 1960s, Tol and Leek (1999) reiterate that natural disasters facilitate upgrading of the capital stock via adoption of more productive technologies, which may, consequently, improve economic performance. Later on, Skidmore and Toya (2002), Cuaresma *et al.* (2008), and Loayza *et al.* (2012) have all presented various evidence in favour of the 'creative destruction' hypothesis.

A different school of thought, namely, Bastiat's popularly-named 'broken window' hypothesis, presents a contrasting view about the effect of natural disasters. Bastiat (1995) considers the potential costs and benefits of a broken pane of glass in a window, and argue that opportunity costs of funds spent to cover the losses due to destruction are unlikely to exceed the gains. Hallegatte and Dumas (2009) and Felbermayr and Gröschl (2014) provide some empirical support for this hypothesis.

II. *Income and political change: Autocratic vs. democratic transitions*

As with disasters and income, the link between income and political transitions is inconclusive. Lipset (1959), Moore (1966) and Przeworski and Limongi (1997) show a positive connection between income and democracy, which is termed as 'modernisation theory'. Epstein *et al.* (2006) observe that economic growth enhances the likelihood of democratic regimes. There is also evidence of feedback from political transitions to economic freedom and growth (see, in particular, Rodrik and Wacziarg, 2005). However, challenging the modernisation theory, Muller (1995) and Przeworski *et al.* (2000) report that a rise in per capita income does not necessarily result in a democratic transition. Acemoglu *et al.* (2008, 2009) find that the positive association between income and democracy is absent when one takes into account the country fixed effects. Brückner and Ciccone (2011) test Acemoglu and Robinson's (2001) theory of political transitions in the context of sub-Saharan Africa using rainfall as an instrumental variable, and find that transitory negative economic shocks open a window of opportunity for citizens to contest power, as the cost of fighting ruling autocratic regimes in that situation is relatively low.

3. Data and Measurement

We employ the Emergency Disasters Database (EM-DAT) in our analysis (*see*, for instance, Skidmore and Toya, 2002; Kahn, 2005; Neumayer and Plümper, 2007; Ramcharan, 2007; Stromberg, 2007; Cuaresma *et al.*, 2008; Cavallo *et al*,. 2010; Keefer *et al.*, 2011; and Loayza *et al.*, 2012). EM-DAT defines *natural disaster* as a 'serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses that exceed the ability of the affected community or society to cope using its own resources'. The database makes an entry if a disaster event satisfies any one of the following conditions: (i) 10 or more reported killed; (ii) 100 people reported affected; (iii) a call for international assistance; (iv) a declaration of a state of emergency. These low thresholds guarantee that most natural disasters, including earthquakes, are recorded (Ramcharan, 2007). Given these criteria, EM-DAT provides data on the disruptive effect of earthquakes, such as total death toll, injured, homeless, and affected people. Further, information on the physical dimension is provided with the Richter scale.

When an earthquake strikes more than once in the same year, we take the annual sum of death toll and total affected at the country level. As noted by Keefer *et al.* (2011), this aggregation strategy is unlikely to affect our estimates. However, the same aggregation process is not appropriate for the Richter measure, which is based on a logarithmic scale of base 10, where a small increase in the scale implies a large increase in its impact magnitude. To ensure comparability, we transform the Richter magnitude scale into ground-motion amplitude by applying the formula $\sum_{i=1}^{n} A_i = \sum_{i=1}^{n} 10^{(RichterScaleMagnitude-3)}$, where A stands for ground-motion amplitude from zero (i.e., epicentre) to peak (i.e., earth surface) and i for each earthquake incidence. See Richter (1935 and 1958).[6] Moreover, following Keefer *et al.* (2011), we drop all earthquakes with a magnitude below 5.

We adopt the Polity2 index to measure the quality of democracy. We utilize it in continuous form to gauge the extent of the change in democratic conditions since a regime transition can be inferred through the magnitude of change in the continuous metric, whereas an aggregate indicator which can be otherwise used would mask useful information.

Appendix A1 provides the sources and definitions of other data, while Table 1 presents the summary statistics of variables used. Appendix A2 lists the countries included in the sample.

4. Empirical Analysis

4.1. *Econometric Framework*

To track the direct and the indirect income effect between earthquakes and political transitions, we formulate a three-equation system in our econometric analysis. The principal advantage of the system estimation is that it explicitly allows for modelling the channels hypothesised in this paper. Specifically, using Three-Stages-Least Squares (3SLS), we estimate:

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6 Keefer *et al*. (2011) used the same formula (i.e., 10exp[magnitude–3]) with the exception that they subtracted 5 instead of 3 from the Richter magnitude scale. However, Richter (1935) originally used 3 in the formula (see Richter, 1958).

$$(1)\quad Death_{i,t} = \alpha_i + \rho_i t + \emptyset_t + \beta_1 logGM_{i,t} + \beta_2\, logy_{i,t} + \beta_3\, logy_{i,t}^2 + \varepsilon_{i,t}$$

$$(2)\quad logy_{i,t} = \partial_i + \varphi_i t + \theta_t + \gamma_1 Death_{i,t} + \gamma_2 logNY_{i,t} + \vartheta_{i,t}$$

$$(3)\quad Polity2_{i,t} = \complement_i + \omega_i t + \delta_t + \lambda_1 logy_{i,t} + \lambda_2 Death_{i,t} + \lambda_3 NP_{i,t} + \upsilon_{i,t}$$

where *i* stands for country and *t* for time, with country-specific fixed effects ($\alpha, \partial, and\ \complement$), country-specific time trend ($\rho_i t, \varphi_i t\ and\ \omega_i t$), and common time-varying shocks that affect all countries ($\emptyset, \theta\ and\ \delta$); all are controlled in three equations of the system. In Equation (1), we explain number of earthquake mortality normalised by population ($Death$) by log ground motion amplitude of the earthquake ($logGM$) along with the quadratic forms of log income per capita ($logy$ & $logy^2$). Log of ground motion is completely exogenous in this setting. We control for log income per capita and its quadratic in order to capture the differential effects of earthquakes in developing and developed countries. The impacts of natural disasters largely depend on preparedness levels and risk-mitigation plans within countries, and the quadratic income specification is expected to capture this differential (*see* Kellenberg and Mobarak, 2008; and Noy, 2009).

To measure the effect of earthquakes on income, Equation (2) utilises $Death$ as the explanatory variable, together with the log average income of neighbouring countries ($logNY$) as the exogenous shifter for system identification. A voluminous literature suggests that countries with open, large and developed neighbours grow faster than those with closed, smaller and less developed neighbours (see Ramon and Trehan, 1997; Ades and Chua, 1997; and Kenny, 1999). We provide detailed explanations for exogeneity conditions of this shifter below. It is important to note that there can be Keynesian multiplier-type mechanisms that raise the expenditure and income levels following an earthquake. Our specification captures the final outcome of this type of mechanism. Meanwhile, we explored the lagged effects of earthquake shocks on income up to three lags, and all the lagged terms are estimated to be insignificant.

Equation (3) estimates the effect of $Death$ and $logy$ on democracy ($Polity2$). $Death$ represents the direct, i.e., the ‘shock’, effect of earthquakes on political change, specifically, the citizens’ reaction to the incumbent regime following the disaster. This interpretation is predicated on the notion that a shocked state of the human mind that may emerge after the catastrophe and that may result from either the government’s failure to address the preparedness phase prior to the disaster or its poor intervention strategies in the emergency response stage following the earthquake, or both, can drive a drastic political change. The historical anecdotes illustrated above regarding successful/failed governments in both preparedness and emergency response phases fits to this reasoning. Our interpretation of this effect as the ‘shock’ effect is also facilitated by the related instrumental variable: the greater the ground-motion amplitude, the greater is the affective shock, and the greater reaction to the concomitant death toll. Several robustness checks and falsification tests presented below yield strong evidence that interpreting this direct effect as the shock effect is plausible.

On the other hand, in equation (3) $logy$ is the indirect effect (i.e., income channel) of earthquakes on political change. The weighted average Polity2 score of neighbouring countries (NP) acts as the shifter. [7] The relevance of this variable for $Polity2$ is well established in the

[7] Our neighbors’ size measure is GDP. Alternative size measures such as surface area and population yield quite similar results.

literature of democratic domino theory[8] (Starr, 1991; Leeson and Dean, 2009; Teorell, 2010; Zhukov and Stewart, 2011). See below for exogeneity conditions of this shifter.

Our specification jointly controls for the country-specific fixed effects, country-specific time trends and common time effects (*see* Brückner and Ciccone, 2011). Such a restrictive specification is unlikely to pick up spurious effects. In addition, with the use of fixed effects and country-specific time trends, our models capture not only the deviations 'from within-country means', but also deviations of 'relationships outside their country-specific long-run path'. Recent history demonstrates what may be an extreme but a highly illustrious example of this sort of relationship: the recent Arab Spring represents such deviations from the long-run political trajectories of the Middle Eastern countries, as initiated by Tunisia, later followed by Egypt, Libya and Syria. Indeed a recent line of research also takes advantage of regional democratization movements in explaining a country's own democratic performance (see Acemoglu et al. 2014). Our neighbours-oriented shifter variables capture exactly this kind of spurts.

4.2. *Potential Caveats against Identification*

I. *Ground Motion Amplitude*

While it is intuitively plausible that ground motion amplitude as an instrumental variable for earthquake fatalities is exogenous, it must also satisfy the exclusion restriction. Our assumption is that ground motion intensity affects income and polity2 only through the number of human

[8] During the Cold War, 'domino theory' concerned the expansion of communism, whereas in recent times it refers to the spread of democracy. Persson and Tabellini (2009) ascertained that democratic capital (i.e., countries' historical experience with democracy, and the incidence of democracy in their neighbouring nations) not only reduces exit rates from democracy but also raises exit rates from autocratic regimes.

casualties it provokes. One may argue that ground motion intensity could not only strike population but also destroy physical capital, which is likely to have an independent effect on income and polity2. We explore such possibility by estimating the impact of ground motion on the extent of gross capital formation, and we did not observe a statistically significant relationship (not reported).

Another possibility is that the effect of earthquake fatalities on income tends to be influenced by the level of urbanization: the larger population density implied in urbanization is likely to increase the reported fatalities from earthquakes in the last decades (as shown in Figure 1). We control for income and its quadratic term when we estimate the impact of ground motion amplitude on earthquake casualties assuming that the level of development may play role in determining earthquake casualties (*see* Section 4.1).

One may argue that a catastrophic earthquake produces a large loss of lives disregarding government's preventive efforts towards disaster risk mitigation and emergency responses. Under such scenario, the signal of regime incompetence to its citizens tends to be unclear. Rather, it is "excess" fatalities—the death toll beyond what can be expected from the physical intensity of earthquakes—that provide the strongest signal to the population. Unfortunately we do not have reliable cross-country data on the extent of regime's efforts towards disaster risk reduction. We, however, take an alternative strategy to estimate our benchmark model by restricting our sample to countries that are less susceptible to experience major earthquakes, and find qualitatively similar results compared to the global sample.

II. Neighbour-weighted Instruments for Income and Polity

Using neighbour-weighted characteristics as sources of exogenous variations is not rare in comparative economic growth (e.g., Ramon and Trehan, 1997; Ades and Chua, 1997; and Kenny, 1999) and political economy literature (for instance, see Starr, 1991; Leeson and Dean, 2009; Persson and Tabellini, 2009; Teorell, 2010; Zhukov and Stewart, 2011). These arguments are based on the fact that countries with open, large, developed and democratic neighbours grow and democratise faster than those with closed, smaller, less developed, and nondemocratic neighbours.

Notwithstanding our very restrictive specification that controls for country-fixed effects and country-specific time trends, hence capturing only out-of-long-run-trajectory relationships, one may argue that income of neighbouring countries $(logNY)$ may influence $Polity2$ in Equation (3) through channels other than the country's own income. These mechanisms typically concern time-*variant* channels. The main possibility in this case is trade and other bilateral relationships: a spurt in trade with bordering countries is associated with a similar spurt in the income and democracy of a country. We empirically test this possibility by including the share of trade with neighbours in equations (2) and (3), but this does not make any difference to the results (not reported). This is consistent with Teorell (2010) who provides evidences that democracy diffuses between neighbours; this diffusion effect does not seem to be influenced by factors such as neighbour's economic outcomes, economic shocks, political mobilization, or country's membership in regional organizations. In our context, we control for whether a country is a member of a trading bloc, including the European Union, Commonwealth of Independent States, North American Free Trade Agreement, Association of South East Asian Nations, and Gulf

Cooperation Council. We find that membership of such unions does not make a change to income and polity, nor suggest a channel of concern for identification (the result is available upon request).

An additional check is in line with Acemoglu *et al.* (2008, pp. 825) who test, using a large panel of world countries analogous to ours, for the relationship between trade-weighted world democracy and democracy at home. For instance, whether the US decreases its quotas for Bangladeshi garment exports if Bangladesh improves its polity score epitomizes the basic idea of this test. We symmetrically check this possibility by including trade-weighted income and trade-weighted polity in income and polity equations respectively, both in separate and joint models as additional shifters, in the presence of log of neighbours' average GDP and neighbours' average polity score, but we find qualitatively similar results (*see* Appendix A3). This indicates that trade-related bilateral effects are unlikely to contaminate our findings.

Using neighbouring countries' conditions as sources of exogenous variations may raise doubts from a conceptual perspective: if the performances of neighbouring countries affect domestic country's income and polity2, by the same reasons, the country should have reverse effects on its neighbours. This argument may seem a serious violation of our identification conditions. In our dataset, 143 of 160 countries have more than one neighbour. This suggests that on average, a country is less likely to affect its adjacent (multiple) neighbours to the same extent that the neighbouring countries collectively do to it.

Despite all these caveats, we may still be unable to entirely rule out the possible endogeneities that may occur through other time-variant political, social and cultural factors associated with our neighbour-weighted instruments. However, it should further be iterated that our restrictive empirical design and a wide array of robustness checks along with pining down possible mechanisms support the view that other channels through which neighbours may affect a country are likely to be minor in our context.

5. Results and Discussion

5.1. *Main Findings*

Covering the entire 1950–2007 period, Model 2.1 in Table 2 indicates that earthquake shocks, measured in terms of ground-motion amplitude and death toll, have two opposite effects on the level of democracy. Our estimates show that, after controlling for country-specific heterogeneity, common time shocks and country-specific long-term associations in related variables, the occurrence of one thousand deaths in every one million members in the population as a result of earthquakes in a given year increases per capita GDP by 0.374 per cent in that year, which then decreases the Polity2 score by 0.59 point, that is, 0.374 × (–1.567), in the scale of [–10, 10]. Both effects are statistically significant at the 1% level. This positive relationship between death toll in earthquakes and per capita GDP is consistent with the creative destruction hypothesis. On the other hand, the inverse relationship between per capita GDP and *Polity2* score (i.e., –1.567) indicates that earthquake-driven increases in income levels reduce the level of democracy. In terms of the *direct* effect of earthquakes, our estimates in Model 2.1 strikingly indicate that one thousand deaths in every one million people improve the Polity2 score in a country by around 1.78 points, an effect that is statistically significant at the 1% level. The net effect of earthquakes, therefore, is that the occurrence of one thousand earthquake-related deaths in every one million in a given year leads to an improvement of 1.19 points (i.e., 1.78 – 0.59) in the Polity2 score. Given the [–10, 10] range of

Polity2, a 1.19 point increase corresponds to an improvement of 5.95 percentage points, that is, (1.19/20)×100.

Overall, our estimates show that earthquakes *indirectly* (i.e., through increasing income) deteriorate the democratic conditions. This result is consistent with Acemoglu and Robinson (2001) in that the post-disaster expenditure on reconstruction and rehabilitation activities increases economic incentives in the economy leading ultimately to an increase in the opportunity cost of contesting the incumbent regime. Conversely, the *direct* effect of earthquakes is a democratic improvement. Earthquake shocks are likely to cause the voters to release their wrath against the incumbent regime because of the failure to save many human lives. Besides, empathetic citizens are likely to provide more charitable giving to the distressed victims if the regime fails to act effectively during emergency response period. This additional charity burden may incentivise empathetic individuals to support victims to contest against incumbent the political power (for instance, *see* Eckel, Grossman and Milano (2007)). Taken together, these results suggest that earthquake shocks open a democratic window of opportunity, but this window is narrowed by improved economic conditions.

In Table 2, Model 2.2, we use the total number of affected people instead of death toll in earthquakes. The estimates indicate that earthquake shocks have only an indirect effect on the level of democracy and, somewhat expectedly, a zero direct effect. In particular, the occurrence of one thousand people in every one million people affected by earthquake leads to a 0.003 point lower Polity2 score through the income channel. While statistically significant, this effect is numerically low. The statistical insignificance of the direct effect, on the other hand, indicates that, when people survive in earthquakes, they are unlikely to punish the incumbent regime. Therefore, this finding suggests that it is the death toll that triggers the nature of being shocked rather than being affected, which is ultimately reflected to the incumbent regime. What is common between the effects of death toll and total affected people in earthquakes, though, is that both affect the Polity2 score negatively through raising income (i.e., the indirect effect).

In Table 3, Model 3.1 includes only the observations for developing countries and Model 3.2 includes those for developed countries, both using death toll information. In Model 3.1, both direct and indirect effects of death toll in earthquakes qualitatively remain similar to that in Model 2.1. Moreover, the direct shock effect of earthquakes on the Polity2 score becomes statistically more significant (i.e., at the 5% level). In particular, the occurrence of one thousand deaths in every one million people *directly* improves democracy by 2.33 points in the Polity2 scale of [–10, 10]. Similarly, the indirect effect (i.e., through the income channel) of death toll in developing countries on the Polity2 score is negative, which is 0.97 points. In sum, the net effect of earthquake death toll in developing countries is a movement into democracy (i.e., approximately 1.36 points in the Polity2 scale).

However, in Model 3.2, the direct effect of earthquake death toll on the Polity2 score in developed countries is insignificant. This finding, unsurprisingly, suggests that governments in developed countries tend to be more effective at reducing earthquake risks compared to developing countries (e.g., in terms of formulation and implementation of appropriate building codes, earthquake contingency plans, Standing Orders on Disaster (SoD) and disaster management acts).[9] Consequently, post-earthquake affective shocks and the scope for the incumbent regime being held responsible for failure are minimised. In terms of the indirect effect of death toll, developed countries again exhibit insignificant effects on income levels, and subsequently on political change. In summary, the results in Model 3.2 intuitively indicate that developed countries exhibit neither a direct nor an indirect effect of earthquakes on political change. It is noteworthy that the shifter variables in all regressions in Table 3 are strongly significant, rendering the system estimates reliable.

Model 3.3 tests the finding of Przeworski *et al.* (2000) that countries with per capita GDP over US$4,000 are more likely to stay in a democratic regime even after confronting any exogenous shocks. We find that the income effect of earthquakes on the Polity2 score is insignificant in this set of countries. That is, earthquakes neither increase per capita GDP nor facilitate autocratic change. In addition, the direct shock effect of earthquakes in countries with per capita GDP over US$4,000 fosters democratic improvements (i.e., around 2.76 points in the Polity2 score), and this effect is statistically significant at the 1% level. Taken together, our result is consistent with the findings of Przeworski *et al.* (2000).[10]

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[9] For instance, according to Keen and Pakko (2011), in the immediate aftermath of Hurricane Katrina the Federal Reserve Bank of USA has increased nominal interest rate that mitigated temporary inflation effects and output distortions.

[10] We replicate Table 3 by substituting 'total affected people' for 'death toll' in earthquakes while maintaining the specifications exactly the same, and found qualitatively similar results. The results are available upon request.

5.2. *Robustness Checks*

Our first robustness check is with respect to the categorization of democracy. Epstein *et al.* (2006) employ trichotomous categorization of regimes and find strong support for the modernization hypothesis, while Przeworski *et al.* (2000) find no evidence for it using a dichotomous classification. This finding suggests that our results related to earthquake-driven income changes may differ with respect to discrete categorizations of democracy. Further, if our interpretation that the direct effect captures voters' affective reaction to earthquakes is correct, then autocratic countries should be less likely to exhibit this reaction, due to the oppressive nature of those regimes. Bearing out this falsification test, Table 4, Model 4.1 reports that, after controlling for country-specific heterogeneity, common time shocks and country-specific long-term associations in the related variables, the direct effect is estimated to be insignificant in autocratic countries (i.e., countries with a Polity2 score between –10 and 0). However, the implication changes astonishingly when only partially democratic countries (with Polity2 scores between 1 and 7) are considered. There is a dramatic shock effect in the order of an increased Polity2 score of 4.6 as a result of one thousand deaths in every one million people. This finding strongly suggests that, in partially democratic countries, outrage expressed by citizens may lead to political change, and the net outcome is a significant improvement in democracy.[11] In Model 4.3, using fully democratic countries (i.e., with Polity2 scores between 8 and 10 points), no evidence is found for a direct or indirect effect of earthquakes on political change. The lack of a significant direct effect here is

[11] To check if earthquakes have any bifurcation effect on different political regimes, we ran the same specification as in Model 4.1, by dividing the observations based on the median of the Polity2 score (which is –1), and found no evidence as such (not reported).

noteworthy, suggesting that, with all the necessary measures having been taken, people in fully democratic countries are, overall, not prone to punish the incumbent regime following earthquakes.[12]

The second robustness check is related to sample composition. Since earthquake hazard is not distributed evenly all over the world, it may seem that our results can be driven by a few countries with frequent earthquakes. Following Toya *et al.* (2010), we conduct robustness checks concerning the ‘Ring of Fire’ countries (i.e., Canada, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Indonesia, Japan, Malaysia, Mexico, New Zealand, Nicaragua, Panama, Papua New Guinea, Philippines and the United States). The results, reported in Table 5, are comforting. In particular, Model 5.1, excluding the Ring of Fire countries, finds that the occurrence of one thousand deaths in every one million people increases per capita GDP by 0.42 per cent, which leads to a decrease in the Polity2 score by 3.85 per cent, that is, (0.769/20)×100. The direct effect is also significant and drives a democratic improvement. On the other hand, we estimate the same specification as in Model 5.1 but only for the observations of ‘Ring of Fire’ countries.[13] This sensitivity analysis can also be considered as another falsification test regarding the direct effect of earthquakes in that, within the ‘Ring of Fire’ countries, and considering our long time span of analysis, voters may become accustomed to living with earthquakes and may

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12 However, earthquake shocks decrease the per capita GDP significantly. This is probably because most of the fully democratic countries are already developed, and hence exhibit more exposure to financial damage due to earthquakes. Perhaps not surprisingly, this negative income shock due to earthquakes does not translate into political change, possibly because the opportunity cost of contesting the incumbent government is very high.

13 The estimation results are available upon request.

exhibit no affective reaction to losses. The results indicate that the direct shock effect of death toll in earthquakes in earthquake-prone countries is, expectedly, absent. [14]

The third robustness analysis checks whether our results are held in terms of different earthquake intensities. Model 5.2 of Table 5 excludes major earthquakes that are in the Richter magnitude scale of 8 and above. It shows that the occurrence of one thousand deaths in every one million people increases per capita GDP by 0.38 per cent, which leads to a decline in the Polity score by 1.65 points. This result is qualitatively similar to what we found in Model 2.1, that is, the net effect of earthquakes corresponds to an improvement in democracy.[15]

Final robustness check of the presence of direct effect of earthquakes is related to the intensity of earthquakes in terms of their magnitudes. An earthquake with 7 in Richter magnitude scale is equivalent to 10 earthquakes with Richter magnitude 6 in terms of our measure of total ground motion. However, *one* earthquake with 7 in comparison to *ten* earthquakes with magnitude 6 should generate varying reactions among the citizens. To check whether repetitive catastrophes fail to surprise citizens such that the latter become insensitive to such events, Model 5.3 of Table 5 augments our baseline Equations (1) and (3) by including the *number* of earthquakes occurred

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[14] A valid concern regarding the *Death* variable in equation (3) is that it might capture international disaster relief and aid efforts, whereby a greater amount of aid relief, attracted by a higher death toll, might spuriously affect citizens' perception of the incumbent regime in a positive direction. To rule out such a possibility blurring our interpretation of the direct effect, we control for disaster aid in equation (3). Although quality of the data on international aid (obtained from EM-DAT 2011) is a concern due to possible misreportings, our basic results remain intact after this exercise (unreported).

[15] However, unlike Model 2.2, once we exclude major earthquakes from the benchmark sample, the direct effect of total affected people in earthquakes on the Polity2 score becomes significant (not reported). Perhaps people are tolerant to the incumbent regime in the case of massive earthquakes, assuming that these are the 'acts of God' (i.e., events that are beyond the control of humans). On the other hand, if earthquakes are at medium intensity (i.e., less than magnitude 8), affected people react to the regime, assuming that the incumbent government could have minimised the casualties and economic losses.

with a Richter scale of 5 and above in a given year for each country. In this way, we take out the effect of frequencies of earthquakes from the log of total ground motion from Equation (1) of Model 6.3. Likewise, Equation (3) checks our interpretation of the absence of a shock effect on democratic conditions if earthquakes strike frequently. The insignificant direct effect on when the frequency of the earthquakes is controlled suggests that frequent earthquakes fail to surprise citizens, in which case the current political regime remains more stable. The frequency of earthquakes itself has a positive and significant sign, indicating a democratic improvement.

6. Possible Mechanisms

We now turn to mechanisms through which the direct (i.e., affective) and indirect (i.e., income) effects of earthquakes on political change may arise.

6.1. *Mechanisms for the Income Effect of Earthquakes*

Our empirical findings suggest a positive relationship between earthquake fatalities and income, supporting the creative destruction hypothesis. We investigate how earthquakes may improve the income level and provide suggestive evidence in favour of our findings using two channels, including technology transfer and investment stimulation mechanisms.

Technology transfer. Consistent with the ‘Build Back Better’ principle, earthquakes may facilitate the installation of more productive technologies following the destruction of domestic capital stock (see Kennedy et al 2008). One mechanism for such creative destruction is documented in a well-cited study by Cuaresma et al (2008), who show that developing economies receive high technology from technology-abundant countries ensuing natural disasters. Recent examples of such transfers include the introduction of low-cost emergency shelters by the US-based Shelter2Home in Haiti following the 2010 earthquake (Lainé, 2010), and the transfer of solar lamps working with LED technology by German Solar Energy Foundation to affected regions following Typhoon Haiyan- 2013 in the Philippines. Thus, based on the assumption that technology transfer occurs from high-tech to low-tech countries following disasters, we check the creative destruction effect through a sample split. Differentiating the level of technology across countries by the number of patents obtained,[16] column 5 of Model 6.2 shows that—in low-tech countries, where the number of patents is lower than the sample median—one thousand deaths in every one million people as a result of earthquakes *increase* per capita GDP by 0.367 per cent in a given year. This positive impact is consistent with the afore-mentioned technology transfer phenomenon. By contrast, column 8 of Model 6.3 indicates that, for high-tech countries, one thousand deaths in every one million *decrease* per capita GDP by 1.065 per cent. This result is plausible, as countries with high levels of technology are highly unlikely to 'build back better' through technology transfer. What is observed is the destruction of capital stock which is replaced by the country's own means (as in the case of Hurricane Katrina in the US). Appendix A5 checks these results with 2SLS and finds qualitatively similar findings

Investment stimulus. Earthquakes may trigger a multitude of financial activities by boosting investment on post-disaster recovery and reconstruction, which would in turn foster employment opportunities followed by increased income levels. This stimulus is likely to be observed in economies with high-investment regime where new investment can be generated relatively easily

[16] The dataset on the number of patent applications for each country is taken from the World Development Indicators (WDI, 2012), where the median of total number of patent applications in our dataset is 1226.

using the accumulated capital stock. See Appendix B.1 for an illustrative case study of China on creative destruction through investment stimulus. Based on this conjecture, models 7.2 and 7.3 of Table 7 show the results for two sub-samples— countries with low investment regimes and high investment regimes, respectively.[17] The results indicate that earthquake death toll does not affect income in countries with low investment regime. On the contrary, as depicted in Model 7.3 (in particular, column 8 of Table 7), earthquake death toll increases per capita GDP in countries with investment share in GDP above the median. We check this hypothesis with 2SLS and find similar findings (*see* Appendix A6). Thus, one can consider investment stimulus as a relevant mechanism through which earthquakes may lead to increased income levels.

One may also posit that financial stimulus can be triggered by international aid, as earthquakes are likely to attract external assistances. We augment our baseline estimation model in Table 2 with disaster-specific international aid in the income equation. However, we find no evidence of earthquake-related international aid effect on income. See Appendix A7.

6.2. *Mechanisms for the Affective Effect of Earthquakes*

We interpret the direct effect of earthquakes as the affective shock experienced by citizens, which may also be fueled by the incumbent regime's poor performance in emergency response. While it is empirically challenging to approximate the regime's post-eartquake emergency response for a panel like ours, we provide evidence on the affective shock through election proximity and insurance premiums as mechanisms.

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[17] The median investment share of GDP per capita in our sample is 19.61 percent and the average investment share in below-median countries is 11 percent.

Election proximity. Cole et al. (2012) demonstrate that voters punish the incumbent party for weather events beyond its control.[18] However, fewer voters punish the incumbent regime if it takes appropriate measures (e.g., distribution of relief goods and services) to address the emergency response and recovery phases effectively. Using this intuition, we augment our benchmark democracy equation with three additional variables where a binary indicator of the national elections in the past year[19] is interacted with three most recent lags of earthquake death tolls. Model 8.2 in Table 8 demonstrates that the direct effect of earthquakes on democracy disappears once we control for these interactions. Importantly, the coefficient of the interaction term involving one year-lagged death toll and elections is estimated to be positive and significant, while the interaction terms involving the prior lags of the earthquake death toll are insignificant. This finding indicates that when national elections and earthquakes both occur within a given year, the polity score is increased significantly by 5.3 points in the following year. This outcome can arise in two possible ways. The first possibility is the case where the earthquake occurs before the elections within the year such that citizens punish the regime in the elections for its failure to address post-earthquake emergency response. Presumably this punishment paves the way for the election of a more democratic regime. The second possibility is that the earthquake occurs after

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[18] Recent evidence also shows that voters may punish governments for events beyond their control. For instance, Achen and Bartels (2004) find that leaders are punished for droughts, floods, and even for shark attacks.

[19] Using the National Elections across Democracy and Autocracy (NELDA) dataset, we construct the election year dummy variable if any election—including presidential, legislative, parliamentary, and constituent assembly—takes place in a given year (see Hyde and Marinov 2012). We utilize the elections indicator with both contemporanous value and one year-lagged value in alternate models. The significant effect is observed when elections are used with one-year lag, possibly because a lag exists between elections and change in the democratic conditions due to time needed to form a government after the elections, and/or to implement policies that lead to the change in political landscape.

the elections in that year, such that the newly elected government's willingness to support the victims and to reduce the citizens' affective shock is substantial. This finding nevertheless confirms that in both situations, earthquakes improve the democratic conditions through the election mechanism.

Insurance premiums. The affective shock experienced by citizens due to earthquakes may particularly be fueled by the incumbent regime's poor performance in post-disaster response. However, this effect is likely to be weaker or even absent in countries where disaster-related damages are covered by insurance packages. We infer that the level of total insurance premium in a country would proxy the extent of insured risks; the higher the total premium, the broader the coverage of insured disaster risks, thus the lower the possibility of a regime-changing affective shock.[20] With this hypothesis at disposal, we run our benchmark model (i.e. Model 2.1) by splitting the dataset into two sub-samples— countries below the median of average per capita total insurance premium and countries above the median of the same.[21] Table 9 demonstrates that the affective shock effect of earthquakes on democracy is absent in countries with higher per capita

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[20] Insurance packages can be both life and non-life. One might ask whether insurance premiums can differ across two countries because of their differences in disaster risks. Another question is whether insurance premiums can reflect anomalies in the local insurance market. To answer the first concern, note that ours is a within-country analysis meaning an increase in insurance premiums within a locality is likely to be due to better coverage of disaster risks over time. Regarding the second concern, that insurance premiums reflect a market anomaly (perhaps, a supply-demand disequilibrium) is a possibility, but note that in most countries the insurance market is competitive and comprise multinationals that have relatively standard pricing policies across countries. In addition, any supply-demand disequilibrium in the market that might arise due to weak and/or weak demand is partially accounted for in our regressions by controlling log per capita and its quadratic.

[21] The data on insurance premiums are sourced from Sigma database (*See* Swiss Re, 2010). The world median of average per capita total direct insurance premiums (life and nonlife) is USD 140. Notably, the sample of countries with average insurance premiums greater than the median does not completely overlap with the cohort of developed countries used in Table 3. For instance, there are 61 developed countries of which 19 are with average insurance premiums less than its median. Besides, several developing countries including Chile, Jamaica, Malaysia and South Africa have average insurance premiums greater than the world median.

insurance premiums, but it is statistically very strong in countries with lower per capita insurance premium. Notably, in all these exercises, our shifter variables were estimated to be statistically significant.

7. Conclusions

Using the ground-motion amplitude derived from the Richter magnitude scale as a novel instrumental variable and covering almost all independent countries in the world from 1950 to 2007, our analysis indicates that earthquake shocks have two contradicting effects on democratic conditions. First, contrary to the conventional wisdom in the exogenous shocks literature (e.g., rainfall and natural disasters), where such incidents severely diminish the speed of economic development and social welfare, this paper shows that the effect of earthquakes on income is positive, which is consistent with the ‘creative destruction’ hypothesis’. Further, this outcome increases the opportunity cost of contesting the incumbent regime, which makes a more autocratic regime easier to attain or sustain (Acemoglu and Robinson, 2001; Bruckner and Ciccone, 2011). Overall, this evidence points to the indirect (i.e., income) effect of earthquakes on political change. Our result additionally documents that, contrary to the literature which finds an ambiguous effect on democracy, there is a negative and significant *indirect* effect of income on democracy *when* the income shocks are driven by earthquakes.

On the other hand, earthquakes may *directly* drive movements into democracy. We have interpreted this evidence as the reaction of voters to earthquake shocks where they release their wrath against the incumbent regime, holding them responsible for many human lives lost. The likelihood of such direct effect may spiral further through social networking (i.e., via informal collective action), since earthquakes in general unite the victims. Our analysis provides strong and robust evidence for democracy-improving *direct* effect of earthquakes.

Together, the direct and indirect effects robustly suggest that the occurrence of one thousand deaths in every one million people in earthquakes improves democratic conditions by 1.2 points in the Polity scale of [–10, 10]. In the sample of developing countries, the similar effects accelerate democratisation even more rapidly. While this evidence does not indicate a complete regime transition, it suggests that earthquake shocks have important direct effect on democracy as well as through the income channel in a significant set of countries. Further, the paper documents two intuitive mechanisms for each of the direct and indirect effects through which the said effects may arise, namely, technology transfer and financial stimulus mechanisms for the income channel, and election proximity and the extent of insured risk for the affective shock channel. Our results are robust to restrictive specifications and several sensitivity checks and falsification tests, which take into account the differential income levels, political regimes, different samples and earthquake intensities. In sum, the earthquake shocks open a new democratic window of opportunity, but this window is narrowed by improved economic conditions. Apart from the level of democracy, improvements in the efficiency of governments as providers of public services, decentralization of resources and responsibilities or changing the form of governments as outcomes of earthquake shocks may offer further extensions to this line of research.

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Figures and Tables

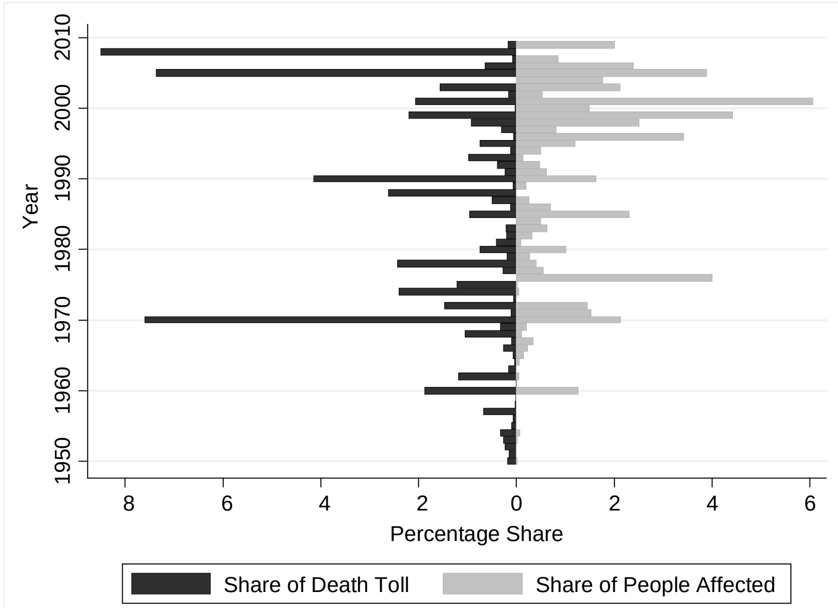

Fig. 1. *Death Toll and Total Affected Population due to Earthquakes from 1950 to 2007*

Note.: Intensity of death toll for each country is measured by $\left(\frac{\sum_{i=1}^{N} D_{i,t}}{N} / \frac{\sum_{j=1}^{n} P_{j,t}}{n}\right) \times 100$; where $D_{i,t}$ is the total number of deaths in earthquakes of country i at time t and N is total number of earthquakes occurred within the same time period, $P_{j,t}$ is the total population of country j at time t and n is the number of years for which population data is available. Data definitions and sources are given in Appendix A1. Observations are initially averaged by country for each year, and then percentile distribution of the average number of death toll as well as total affected people due to earthquakes are calculated for each year from 1950 to 2009.

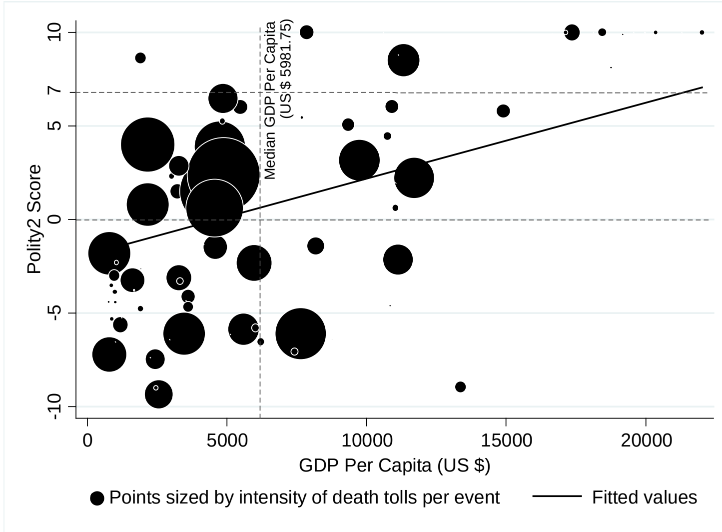

Fig. 2. *Linkage between Earthquake Death Toll, GDP per Capita and Polity2 Score*

Notes. The size of each dot is proportional to the intensity of death toll measured by $\frac{\sum_{i=1}^{N} D_{i,t}}{N} / \frac{\sum_{j=1}^{n} P_{j,t}}{n}$ where $D_{i,t}$ is the total number of deaths in earthquakes of country i at time t and N is the total number of earthquakes occurred within the same time period, P is the total population and n is the number of years. Likewise, the GDP per capita and Polity2 score are measured as the average values of each country from 1950 to 2009. Polity2 score below 0 are autocratic; between 0 to 7 partial democratic; and above 7 fully democratic countries (Epstein *et al.*, 2006). The regression line yields a coefficient of 0.0004 (standard error = 0.00015). Data definitions and sources are provided in Appendix A1. Observations are averaged by country from 1950 to 2009; each of 162 dots represents a country.

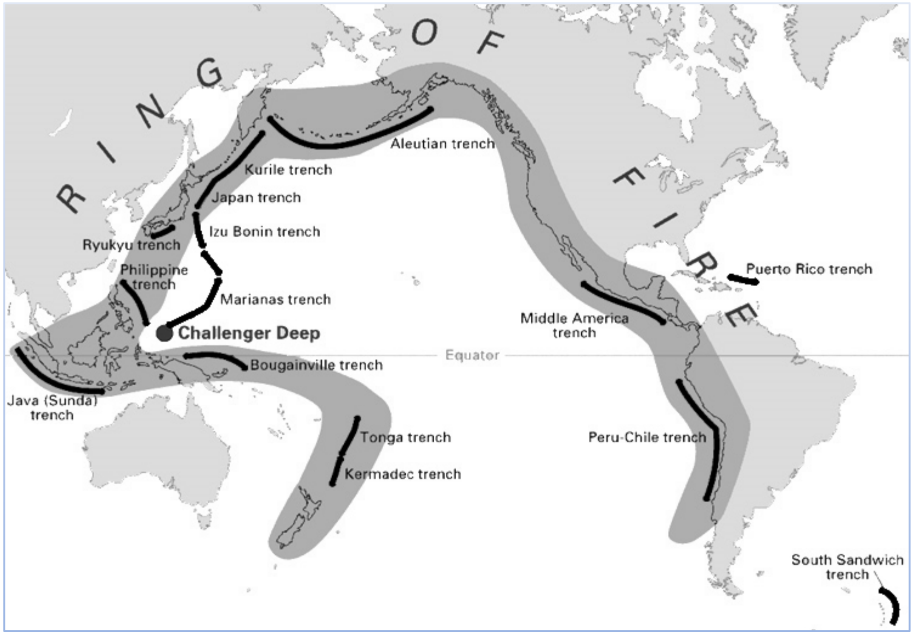

Fig. 3. *Earthquake Hazard Map: The Ring of Fire Zone*

Source. Kious and Tilling (1996).

Notes. The Ring of Fire zone is formed by the volcanic arcs and oceanic trenches encircling the Pacific Basin. The trenches are shown in black lines.

Table 1

Descriptive Statistics

Variable	Mean	Std. Dev.	Observations
Log Ground Motion in Earthquakes (in Millimeters), t	0.3168	1.5997	11303
Death Toll in Thousand Population, *t*	0.0058	0.1628	10951
Total Affected in Thousand Population, t	0.7413	20.4938	10951
Log Real GDP per capita, t	8.4621	1.1288	8368
Log Neighbours' Average GDP, t	25.6536	1.7695	8476
Polity2, *t*	0.0726	7.5125	7608
Neighbours' Average Polity2, t	0.9289	6.7809	8266

Table 2

Earthquake Death Toll, Income, and Democracy

Model	**2.1: Effects of Death Toll**			**2.2: Effects of Affected Population**		
	Death Toll per Thousand Population, *t*	**Log Real GDP per capita,** ***t***	**Polity2,** ***t***	**Total Affected per Thousand Population,** *t*	**Log Real GDP per capita,** ***t***	**Polity2,** ***t***
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Log Ground Motion in Earthquakes (in mm), t	0.018 (0.002)***			2.588 (0.208)***		
Log Real GDP per Capita, t	2.951 (1.693)*		–1.567 (0.263)***	319.1 (218.8)		–1.272 (0.262)***
Squared Log Real GDP per Capita, t	–0.136 (0.100)			–14.67 (12.93)		
Death Toll per Thousand Population , t		0.374 (0.055)***	1.782 (0.996)*			
Total Affected per Thousand Population , t					0.002 (0.0004)***	0.012 (0.008)
Log Neighbours' Average GDP, t		–0.023 (0.012)*			–0.022 (0.012)*	
Neighbours' Average Polity2, t			0.130 (0.016)***			0.130 (0.016)***
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trend	Yes	Yes	Yes	Yes	Yes	Yes
Common Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,257	6,257	6,257	6,257	6,257	6,257

Notes. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 3

Earthquake Death Toll, Income, and Democracy:

Developing Versus Developed Countries

Model	**3.1: Developing Countries**			**3.2: Developed Countries**			**3.3: Per capita GDP> US$4000**		
	Death Toll per Thousand Population, t	**Log Real GDP per capita, *t***	**Polity2, *t***	**Death Toll per Thousand Population, t**	**Log Real GDP per capita, *t***	**Polity2, *t***	**Death Toll per Thousand Population, t**	**Log Real GDP per capita, *t***	**Polity2, *t***
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Log Ground Motion	0.02			0.0008			0.026		
in Earthquakes (in mm), t	(0.002)***			(0.0001)***			(0.003)***		
Log Real GDP	–1.078		–2.624	0.043		0.233	–14.43		–0.044
Per Capita, t	(2.790)		(0.345)***	(0.084)		(0.289)	(17.54)		(0.375)
Squared Log Real GDP	0.117			–0.002			0.766		
Per Capita, t	(0.175)			(0.005)			(0.921)		
Death Toll per		0.369	2.325		0.729	25.521		0.068	2.760
Thousand Population , t		(0.050)***	(0.983)**		(3.422)	(41.024)		(0.042)	(0.905)***
Log Neighbours'		0.025			–0.068			–0.043	
Average GDP, t		(0.016)			(0.017)***			(0.011)***	
Neighbours'			0.043			0.260			0.192
Average Polity2, t			(0.019)**			(0.026)***			(0.018)***
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Common Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,537	4,537	4,537	1,720	1,720	1,720	3,302	3,302	3,302

Notes. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. Estimations by substituting 'Total affected per thousand population' for 'Death toll per thousand population' provide qualitatively similar results. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 4

The Trifurcation Effect of Earthquake Death Toll:

Different Sub-Samples Based on Political Regime

Model	**4.1: Polity from –10 to 0**			**4.2: Polity from 1 to 7**			**4.3: Polity from 8 to 10**		
	Death Toll per Thousand Population, *t*	**Log Real GDP per Capita, *t***	**Polity2, *t***	**Death Toll per Thousand Population, *t***	**Log Real GDP per Capita, *t***	**Polity2, *t***	**Death Toll per Thousand Population, *t***	**Log Real GDP per Capita, *t***	**Polity2, *t***
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Log Ground Motion	0.052			0.014			0.002		
in Earthquakes (in mm), t	(0.004)***			(0.002)***			(0.0003)***		
Log Real GDP	1.404		–1.217	–0.767		–1.824	–0.012		0.518
Per Capita, t	(2.089)		(0.231)***	(3.243)		(0.835)**	(0.978)		(0.318)
Squared Log Real GDP	–0.063			0.086			–0.004		
Per Capita, t	(0.121)			(0.204)			–0.053		
Death Toll per		0.079	0.606		0.268	4.646		–0.840	5.386
Thousand Population , t		(0.039)**	(0.475)		(0.088)***	(2.253)**		(0.378)**	(5.321)
Log Neighbours'		–0.055			0.160			–0.033	
Average GDP, t		(0.022)**			(0.025)***			(0.009)***	
Neighbours'			0.082			–0.047			–0.0004
Average Polity2, t			(0.0170)***			(0.032)			(0.012)
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Common Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,906	2,906	2,906	1,107	1,107	1,107	2,104	2,104	2,104

Notes. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 5

Earthquake Death Toll, Income, and Democracy:

Considering Ring of Fire Countries, Major Earthquakes and Frequency of Earthquakes

Model	**5.1: Sample Excluding Ring of Fire Countries**			**5.2: Sample Excluding Major Earthquakes**			**5.3: Model Including Frequency of Earthquakes**		
	Death Toll per Thousand Population, t	**Log Real GDP per capita, *t***	**Polity2, *t***	**Death Toll per Thousand Population, t**	**Log Real GDP per capita, *t***	**Polity2, *t***	**Death Toll per Thousand Population, t**	**Log Real GDP per capita, *t***	**Polity2, *t***
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log Ground Movement	0.0164			0.017			0.022		
in Earthquakes (in mm), t	(0.00157)***			(0.002)***			(0.002)***		
Number of 5+ Richter-							–0.025		0.346
scale Earthquakes, t							(0.010)**		(0.135)**
Log Real GDP	0.609		–1.830	2.666		–1.654	2.901		–0.155
per capita, t	(1.321)		(0.276)***	(1.665)		(0.263)***	(1.704)*		(0.261)
Squared Log Real GDP	–0.0141			–0.120			–0.134		
Per Capita, t	(0.0782)			(0.098)			(0.101)		
Death Toll in		0.420	3.225		0.382	1.964		0.361	–0.973
Thousand Population, t		(0.0856)***	(1.598)**		(0.058)***	(1.051)*		(0.054)***	(1.203)
Log Neighbours' Average		–0.0120			–0.021			–0.023	
GDP, t		(0.0124)			(0.012)*			(0.012)*	
Neighbours' Average			0.164			0.130			0.131
Polity2, t			(0.0172)***			(0.016)***			(0.016)***
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Common Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,327	5,327	5,327	6,247	6,247	6,247	6,257	6,257	6,257

Notes. 'Ring of Fire' countries, where around 90% of the world's earthquakes occur, include: Canada, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Indonesia, Japan, Malaysia, Mexico, New Zealand, Nicaragua, Panama, Papua New Guinea, Philippines and the United States. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 6

The Creative Destruction Effect of Earthquakes: Technology Transfer Mechanism

Model	**61: All Countries with Available Patents Data**			**6.2: Countries Below Median Number of Patents**			**6.3: Countries Above Median Number of Patents**		
	Death Toll per Thousand Population, t	**Log Real GDP per capita, *t***	**Polity2, *t***	**Death Toll per Thousand Population, t**	**Log Real GDP per capita, *t***	**Polity2, *t***	**Death Toll per Thousand Population, t**	**Log Real GDP per capita, *t***	**Polity2, *t***
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log Ground Movement	0.008			0.012			0.004		
in Earthquakes (in mm), t	(0.002)***			(0.003)***			(0.001)***		
Log Real GDP	0.515		-2.372	1.528		-2.532	0.541		-2.513
per capita, t	(2.823)		(0.579)***	(5.924)		(0.862)***	(1.765)		(0.798)***
Squared Log Real GDP	0.024			-0.013			-0.048		
Per Capita, t	(0.160)			(0.346)			(0.097)		
Death Toll in		0.433	3.443		0.367	5.042		-1.065	6.758
Thousand Population, t		(0.084)***	(2.025)*		(0.081)***	(1.925)***		(0.197)***	(4.937)
Log Neighbours' Average		0.011			-0.012			0.007	
GDP, t		(0.014)			(0.029)			(0.013)	
Neighbours' Average			0.230			0.043			0.266
Polity2, t			(0.027)***			(0.040)			(0.035)***
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Common Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,824	2,824	2,824	1,368	1,368	1,368	1,454	1,454	1,454

Notes. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. The median of total number of patent applications in our dataset is 1226. Notably, the sample of countries with more than the median of number of patents does not completely match with the cohort of developed countries used in Table 3. For instance, in 2005, out of 39 countries with more than the median of number of countries, 21 countries exclude from the cohort of developed countries. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 7

The Creative Destruction Effect of Earthquakes: Investment Stimulus Mechanism

Model	7.1: Full Sample			7.2: Sample with Countries Below Median Investment Share			7.3: Sample with Countries Above Median Investment Share		
	Death Toll in Thousand Population, t	**Log Real GDP per capita, t**	**polity 2, t**	**Death Toll in Thousand Population, t**	**Log Real GDP per capita, t**	**polity 2, t**	**Death Toll in Thousand Population, t**	**Log Real GDP per capita, t**	**polity 2, t**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log Ground Movement in	0.018			0.009			0.022		
Earthquakes (in mm), t	(0.002)***			-0.054			(0.002)***		
Log Real GDP per capita, t	3.125		-1.570	-106.7		-0.720	2.325		-2.361
	(1.748)*		(0.266)***	(444.1)		(0.370)*	(2.659)		(0.405)***
Squared Log Real GDP	-0.146			6.359			-0.09		
Per Capita, t	(0.103)			(26.99)			(0.149)		
Death Toll in		0.373	1.724		-0.016	-1.884		0.176	2.015
Thousand Population, t		(0.055)***	(0.995)*		-0.082	(1.673)		(0.050)***	(1.015)**
Log Neighbours'		-0.0250			-0.034			-0.016	
Average GDP, t		(0.012)**			(0.019)*			-0.012	
Neighbours' Average			0.127			0.087			0.063
Polity2, t			(0.016)***			(0.023)***			(0.020)***
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Common Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,047	6,047	6,047	3,155	3,155	3,155	2,892	2,892	2,892

Notes. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. The median investment share in GDP per capita in our dataset is 19.61. Notably, the sample of countries with more than the median of investment share does not completely match with the cohort of developed countries used in Table 3. For instance, in 2005, out of 97 countries of which the investment share is more than its median, 53 countries exclude from the cohort of developed countries. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 8

The Affective Effect of Earthquakes: Election Proximity Mechanism

Model	**Model 8.1**			**Model 8.2**		
	Death Toll in Thousand Population, t	**Log Real GDP per capita, t**	**polity2, t**	**Death Toll in Thousand Population, t**	**Log Real GDP per capita, t**	**polity2, t**
	(1)	(2)	(3)	(4)	(5)	(6)
Log Ground Movement in Earthquakes (in millimeters), t	0.0187			0.019		
	(0.002)***			(0.002)***		
Log Real GDP per capita, t	3.013		-1.613	3.497		-1.394
	(1.734)*		(0.269)***	(1.697)**		(0.268)***
Squared Log Real GDP Per Capita, t	-0.140			-0.169		
	(0.102)			(0.100)*		
Log Neighbours' Average GDP, t		-0.027			-0.029	
		(0.012)**			(0.01)**	
Neighbours' Average Polity2, t			0.141			0.139
			(0.016)***			(0.016)***
Death Toll in Thousand Population, t		0.346	1.853		0.345	1.570
		(0.054)***	(0.982)*		(0.050)***	(0.980)
Death Toll in Thousand Population, t-1						-0.336
						(0.177)*
Death Toll in Thousand Population, t-2						-0.373
						(0.180)**
Death Toll in Thousand Population, t-3						-0.324
						(0.252)
Election year dummy, t-1						0.635
						(0.105)***
Death Toll in Thousand Population, t-1 * Election year dummy, t-1						5.303
						(3.060)*
Death Toll in Thousand Population, t-2 * Election year dummy, t-1						0.220
						(0.817)
Death Toll in Thousand Population, t-3 * Election year dummy, t-1						-0.195
						(0.347)
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trend	Yes	Yes	Yes	Yes	Yes	Yes
Common Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,922	5,922	5,922	5,922	5,922	5,922

Notes. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. We construct Election year dummy by assigning 1 if any form of national elections—including presidential, legislative, parliamentary, and constituent assembly— takes place in a given year, 0 otherwise (Hyde and Marinov 2012).*Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Table 9

The Affective Effect of Earthquakes: Insurance Premium Mechanism

Model	**Model 9.1: Sample with Countries Above the Median Insurance Premium**			**Model 9.2: Sample with Countries Below the Median Insurance Premium**		
	Death Toll in Thousand Population, t	**Log Real GDP per capita, t**	**Polity2, t**	**Death Toll in Thousand Population, t**	**Log Real GDP per capita, t**	**Polity2, t**
	(1)	(2)	(3)	(4)	(5)	(6)
Log Ground Movement in Earthquakes (in millimeters), t	0.007 (0.001)***			0.014 (0.003)***		
Log Real GDP per capita, t	0.957 (0.691)		1.556 (0.434)***	4.644 (4.463)		-6.069 (0.638)***
Squared Log Real GDP Per Capita, t	-0.044 (0.035)			-0.199 (0.259)		
Death Toll in Thousand Population, t		0.865 (0.245)***	4.039 (4.502)		0.394 (0.062)***	3.784 (1.350)***
Log Neighbours' Average GDP, t		-0.078 (0.013)***			0.077 (0.024)***	
Neighbours' Average Polity2, t			0.201 (0.025)***			-0.019 (0.031)
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trend	Yes	Yes	Yes	Yes	Yes	Yes
Common Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,801	1,801	1,801	2,007	2,007	2,007

Notes. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. The data on insurance premiums are sourced from Swiss Re, Sigma (*See* Appendix A1). The median of average per capita total direct insurance premiums (life and nonlife) in USD is 140. Notably, the sample of countries with average insurance premiums greater than the median does not completely match with the cohort of developed countries used in Table 3. For instance, there are 61 developed countries of which 19 are with average insurance premiums less than its median. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Appendix A1. Data and Sources

Variable	Description	Source
$Death$	Death toll per thousand people in earthquakes: the total number of deaths due to all earthquakes occurred in a given year in each country	EM-DAT dataset available at http://www.emdat.be/
$Affected$	Total affected per thousand people in earthquakes: the sum of total injured, homeless and affected people due to all earthquakes occurred in a given year in each country	EM-DAT dataset
Intl_aid	Disaster-specific international aid contributions: we converted this variable into 2005 US dollars using the United States' Consumer Price Index (CPI) for comparability purposes.	EM-DAT dataset available at http://www.emdat.be/
GM	Ground motion in earthquakes (in millimetres): constructed using Richter scale measure of earthquake events from 1950 to 2007, according to procedures described in the paper	Calculated from earthquake Richter scale data available at http://www.emdat.be/
$EQfrequency$	Number of 5+ earthquakes in Richter scale in a given year for each country	http://www.emdat.be/
Insurance	Average per capita total direct insurance premium (life and nonlife) in USD	Sigma database (Swiss Re, 2010) http://www.swissre.com/sigma/
y	Real GDP per capita (Constant Prices: Chain series)	http://pwt.econ.upenn.edu/
NY	Average GDP of neighbouring countries: constructed using real GDP per capita dataset from PWT	Calculated from Penn World Tables (PWT)
ki	Investment Share of PPP Converted GDP Per Capita at 2005 constant prices (%)	http://pwt.econ.upenn.edu/
Patents	Number of patent applications: filed through the Patent Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention.	http://data.worldbank.org/data-catalog/world-development-indicators
$Polity2$	Polity measure of democracy: the revised combined Polity score; the maximum range of this measure is from	Polity IV database (Marshall and Jaggers, 2005)

	–10 to 10; positive (negative) values indicate an improvement (deterioration) in democracy	
NP	Average Polity2 score of neighboring countries: constructed using Polity measure of democracy	Calculated from Polity IV database
Election Year	Dummy variable if any election—including presidential, legislative, parliamentary, and constituent assembly—takes place in a given year. Legislative/Parliamentary, Executive, Constituent Assembly	National Elections Across Democracy and Autocracy (NELDA) Dataset (Hyde and Marinov 2012) Available at http://hyde.research.yale.edu/nelda
$Population$	Total population in thousands	http://pwt.econ.upenn.edu/
Developed vs. Developing Country Classification	As classified in World Development Indicators (WDI, 2012).	http://data.worldbank.org/data-catalog/world-development-indicators

NOT INTENDED FOR PUBLICATION

Appendix A2. Countries and Their Codes Included in the Sample

Country	Code	Country	Code	Country	Code
Afghanistan	AFG	Cyprus	CYP	Italy	ITA
Albania	ALB	Czech Rep	CZE	Ivory Coast	IVO
Algeria	DZA	Denmark	DNK	Jamaica	JAM
Angola	AGO	Djibouti	DJI	Japan	JPN
Argentina	ARG	Dominican Rep	DOM	Jordan	JOR
Armenia	ARM	Ecuador	ECU	Kazakhstan	KAZ
Australia	AUS	Egypt	EGY	Kenya	KEN
Austria	AUT	El Salvador	SLV	Korea Rep	KOR
Azerbaijan	AZE	Equatorial Guinea	GNQ	Kuwait	KWT
Bahrain	BHR	Eritrea	ERI	Kyrgyzstan	KGZ
Bangladesh	BGD	Estonia	EST	Lao P Dem Rep	LAO
Belarus	BLR	Ethiopia	ETH	Latvia	LVA
Belgium	BEL	Fiji	FJI	Lebanon	LBN
Benin	BEN	Finland	FIN	Lesotho	LSO
Bhutan	BTN	France	FRA	Liberia	LBR
Bolivia	BOL	Gabon	GAB	Libyan Arab Jamah	LBY
Bosnia-Herzegovinian	BIH	Gambia The	GMB	Lithuania	LTU
Botswana	BWA	Georgia	GEO	Macedonia FRY	MKD
Brazil	BRA	Germany	GER	Madagascar	MDG
Bulgaria	BGR	Germany Fed Rep	DFR	Malawi	MWI
Burkina Faso	BFA	Ghana	GHA	Malaysia	MYS
Burundi	BDI	Greece	GRC	Mali	MLI
Cambodia	KHM	Guatemala	GTM	Mauritania	MRT
Cameroon	CMR	Guinea	GIN	Mauritius	MUS
Canada	CAN	Guinea Bissau	GNB	Mexico	MEX
Central African Rep	CAF	Guyana	GUY	Moldova Rep	MDA
Chad	TCD	Haiti	HTI	Mongolia	MNG
Chile	CHL	Honduras	HND	Montenegro	MNE
China P Rep	CHN	Hungary	HUN	Morocco	MAR
Colombia	COL	India	IND	Mozambique	MOZ
Comoros	COM	Indonesia	IDN	Namibia	NAM
Congo	COG	Iran Islam Rep	IRN	Nepal	NPL
Costa Rica	CRI	Iraq	IRQ	Netherlands	NLD
Croatia	HRV	Ireland	IRL	New Zealand	NZL
Cuba	CUB	Israel	ISR	Nicaragua	NIC

Niger	NER	Singapore	SGP	Tunisia	TUN
Nigeria	NGA	Slovakia	SVK	Turkey	TUR
Norway	NOR	Slovenia	SVN	Turkmenistan	TKM
Oman	OMN	Solomon Is	SLB	Uganda	UGA
Pakistan	PAK	Somalia	SOM	Ukraine	UKR
Panama	PAN	South Africa	ZAF	United Arab Emirates	ARE
Papua New Guinea	PNG	Spain	ESP	United Kingdom	GBR
Paraguay	PRY	Sri Lanka	LKA	United States	USA
Peru	PER	Sudan	SDN	Uruguay	URY
Philippines	PHL	Swaziland	SWZ	Uzbekistan	UZB
Poland	POL	Sweden	SWE	Venezuela	VEN
Portugal	PRT	Switzerland	CHE	Viet Nam	VNM
Qatar	QAT	Syrian Arab Rep	SYR	Yemen	YEM
Romania	ROM	Taiwan (China)	TWN	Yemen Arab Rep	YMN
Russia	RUS	Tajikistan	TJK	Zaire/Congo Dem Rep	COD
Rwanda	RWA	Tanzania United Rep	TZA	Zambia	ZMB
Saudi Arabia	SAU	Thailand	THA	Zimbabwe	ZWE
Senegal	SEN	Togo	TGO		
Sierra Leone	SLE	Trinidad and Tobago	TTO		

Appendix A3. Checking the Exclusion Restrictions of Neighbor-Weighted IVs Using Trade-Weighted Variables

Model	A3.1: Direct Effects of Neighbours' Polity2 on per capita GDP			A3.2: Direct Effects of Neighbours' GDP on Polity2			A3.3: Direct Effects of Neighbours' Polity2 on per capita GDP *plus* Direct Effects of Neighbours' GDP on Polity2		
	Death Toll per Thousand Population, t	**Log Real GDP per capita, *t***	**Polity2, *t***	**Death Toll per Thousand Population, t**	**Log Real GDP per capita, *t***	**Polity2, *t***	**Death Toll per Thousand Population, t**	**Log Real GDP per capita, *t***	**Polity2, *t***
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Log Ground Motion	0.020			0.020			0.020		
in Earthquakes (in mm), t	(0.002)***			(0.002)***			(0.002)***		
Log Real GDP	2.573		-1.995	2.180		-1.964	1.175		-2.049
Per Capita, t	(1.432)*		(0.282)***	(1.505)		(0.283)***	(1.320)		(0.282)***
Squared Log Real GDP	-0.115			-0.091			-0.066		
Per Capita, t	(0.084)			(0.089)			(0.076)		
Death Toll per		0.330	2.457		0.330	2.469		0.330	2.559
Thousand Population , t		(0.054)***	(1.000)**		(0.054)***	(1.005)**		(0.054)***	(1.002)**
Log Neighbours'		-0.030			-0.029	0.022		-0.028	
Average GDP, t		(0.013)**			(0.012)**	(0.240)		(0.012)**	
Neighbours'		-0.000	0.135			0.142			0.135
Average Polity2, t		(0.001)	(0.017)***			(0.017)***			(0.017)***
Trade-weighted Polity2 Score, t-1			-2.650 (0.540)***						-2.664 (0.540)***
Trade-weighted Log GDP, t-1					-0.007 (0.009)			-0.007 (0.009)	
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Common Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,476	5,476	5,476	5,476	5,476	5,476	5,476	5,476	5,476

Notes. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Appendix A4. Trifurcation Effects of Total Affected Population in Earthquakes: Robustness Sub-Samples Based on Political Regime

Model	**A4.1: Polity from –10 to 0**			**A4.2: Polity from 1 to 7**			**A4.3: Polity from 8 to 10**		
	Total Affected per Thousand Population, *t*	**Log Real GDP per Capita, *t***	**Polity2, *t***	**Total Affected per Thousand Population, *t***	**Log Real GDP per Capita, *t***	**Polity2, *t***	**Total Affected per Thousand Population, *t***	**Log Real GDP per Capita, *t***	**Polity2, *t***
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Log Ground Motion	4.809			5.830			0.255		
in Earthquakes (in mm), t	(0.456)***			(0.526)***			(0.0397)***		
Log Real GDP	157.4		–1.283	3.195		–0.113	–238.8		–0.477
Per Capita, t	(249.5)		(0.231)***	(707.8)		(0.820)	(135.0)*		(0.319)
Squared Log Real GDP	–6.608			5.165			14.190		
Per Capita, t	(14.49)			(44.58)			(7.367)*		
Total Affected per		0.0008	0.007		0.001	0.010		0.016	0.040
Thousand Population , t		(0.0004)**	(0.005)		(0.0002)***	(0.006)*		(0.003)***	(0.035)
Log Neighbours'		–0.054			0.180			–0.035	
Average GDP, t		(0.022)**			(0.024)***			(0.011)***	
Neighbours'			0.082			–0.050			0.001
Average Polity2, t			(0.017)***			(0.032)			(0.012)
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Common Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,906	2,906	2,906	1,107	1,107	1,107	2,104	2,104	2,104

Notes. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Appendix A5: The Creative Destruction Effect of Earthquakes through Technology Transfer: 2SLS Results

Model	A5.1: Countries with data on patents	A5.2: Countries with patents lower than the median	A5.3: Countries with patents more than the median
	(1)	(2)	(3)
Panel A: Dependent variable is Log Real GDP per capita, t			
Death Toll in Thousand Population, t	0.482	0.369	-0.988
	(0.259)*	(0.236)	(0.507)*
Panel B: First Stage for Death Toll per Thousand Population, t			
Log Ground Movement in Earthquakes (in mm), t	0.013	0.022	0.006
	(0.007)*	(0.014)	(0.003)**
Log Real GDP per capita, t	0.052	-0.328	-0.016
	(0.218)	(0.277)	(0.118)
Squared Log Real GDP Per Capita, t	-0.001	0.023	-0.001
	(0.011)	(0.019)	(0.006)
Observations	3,089	1,544	1,543

Notes. The objective of this analysis is to confirm the system estimation results of Table 6 using a single estimation technique. The median total number of patent applications in our dataset is 1226. The robust standard errors clustered at the country level are in parentheses. First-stage regressions in Panel B are estimated with OLS. In Panel A, Columns (1–3) are estimated with 2SLS. In Panel A of Column 2, the coefficient is significant at 12% level. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Appendix A6: The Creative Destruction Effect of Earthquakes through Investment Stimulus: 2SLS Results

Model	A6.1: Countries with data on investment share	A6.2: Countries with less than the median investment share	A6.3: Countries with more than the median investment share
	(1)	(2)	(3)
Panel A: Dependent Variable is Log of Real GDP Per Capita, t			
Death Toll in Thousand Population, t	0.264	-0.133	0.171
	(0.124)**	(0.0989)	(0.101)*
Panel B: First stage for Death Toll in Thousand Population, t			
Log Ground Movement in Earthquakes (in mm), t	0.0226	0.0219	0.0236
	(0.00792)***	(0.0135)	(0.0106)**
Log Real GDP per capita, t	-0.0479	-0.0234	0.0488
	(0.0354)	(0.0323)	(0.141)
Squared Log Real GDP Per Capita, t	0.00386	0.00119	-0.00149
	(0.00218)*	(0.00179)	(0.00710)
Observations	7,750	3,876	3,874

Notes. The objective of this analysis is to confirm the system estimation results of Table 7 using a single estimation technique. The median investment share of real GDP per capita in our dataset is 19.61. In parentheses are the robust standard errors clustered at the country level. First-stage regressions in Panel B are estimated with OLS. In Panel A, Columns (1–3) are estimated with 2SLS. The coefficient of Log ground movement in earthquakes in Column 2 is significant at 11% level. *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Appendix A7: Earthquakes, Disaster-Specific International Aid, and Income

Model	**Model A7.1**			**Model A7.2**		
	Death Toll in Thousand Population, t	**Log Real GDP per capita, t**	**polity 2, t**	**Death Toll in Thousand Population, t**	**Log Real GDP per capita, t**	**polity 2, t**
	(1)	(2)	(3)	(4)	(5)	(6)
Log Ground Movement in Earthquakes (in millimeters), t	0.028 (0.002)***			0.027 (0.002)***		
Log Real GDP per capita, t	3.734 (3.640)		-1.178 (0.338)***	3.094 (3.622)		-1.290 (0.339)***
Squared Log Real GDP Per Capita, t	-0.191 (0.215)			-0.155 (0.213)		
Death Toll in Thousand Population, t		0.142 (0.041)***	0.892 (0.899)		0.143 (0.041)***	1.209 (0.892)
Log Neighbours' Average GDP, t		-0.038 (0.013)***			-0.038 (0.013)***	
Neighbours' Average Polity2, t			0.156 (0.018)***			0.156 (0.018)***
Log Disaster-specific International Aid, t					-0.0001 (0.003)	
Observations	4,625	4,625	4,625	4,625	4,625	4,625

Notes. Three-stage least squares estimation. In parentheses are the robust standard errors clustered at the country level. We converted the data on disaster-specific international aid into 2005 US dollars using the United States' Consumer Price Index (CPI) for comparability purposes *Significant at 10% level; **significant at 5% level; ***significant at 1% level.

Appendix B1. An Illustrative Case Study of Investment Stimulus Following an Earthquake

In May 2008, an earthquake hit the Sichuan province in China claiming at least 80,000 human lives and shattering many years' accumulated capital stock. In a massive recovery and reconstruction effort following the disaster, China's National Development and Reform Commission—the administrative body that steers the Chinese economy—adopted a recovery plan that included building 169 hospitals, and 4,432 primary and secondary schools to replace the collapsed structures in affected areas (Watts, 2008). In addition, Watts (2008) report that around 2,600 schools that survived the earthquake would be retrofitted. The recovery program also comprised new houses for approximately three million rural households whose homes were destroyed during the earthquake and 860,000 apartments for urban dwellers. Moreover, a 150 km. urban highway connecting Chengdu (i.e., the provincial capital) and Mianyang was built. Various welfare programs were also initiated to support the 1.4 million extreme poor affected by the disaster (Watts, 2008). The State Information Centre— a Chinese government research body—estimated that such a massive post-earthquake rebuilding effort would cost $150 billion and was adequate to increase the national annual economic growth by 0.3 per cent. UNESCAP (2013) documented that the income level in Sichuan province has doubled during post-earthquake period—ranking the Sichuan economy the first among all provinces in Western China, which accommodated 200 of the Fortune 500 firms. Overall, the massive post-earthquake recovery plan spurred an instantaneous boost to the economy by replacing obsolete economic infrastructure with more productive capital stock.

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