ARTICLE IN PRESS

Economic Modelling xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/econmod

Earthquakes don't kill, built environment does: Evidence from cross-country data

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ARTICLE INFO

JEL classification:
O21
Q54
Q55

Keywords:
Earthquakes
Built environment
Human casualties
Real GDP

ABSTRACT

Earthquakes are often attributed to a myriad of human casualties, but its variation is quite remarkable across countries. This paper first presents a conceptual analysis to understand why earthquake casualties vary across countries. After that, using a rich panel dataset of countries observed over half a century, from 1950 to 2009, this paper provides empirical evidence that the middle-income countries are more susceptible to earthquake casualties because of its higher level of vulnerable buildings relative to the low- and high-income countries. This finding retains its robustness when I use different income-based criteria of country classification, control for earthquake probabilities, capture institutional effects, and devise alternative specifications. The results suggest that the governments can significantly reduce earthquake casualties by emphasising on the *quality*—rather than *quantity*—of built environment through enforcing quake-resistant regulations.

1. Introduction

The way individuals interact with the physical environment by and large sets their levels of disaster risks. Such human-nature nexus varies widely across regions, and in turn, disaster-related losses—such as earthquake death toll—differ disproportionately across countries. To provide an anecdote, during 1950–2009, despite India experienced a lower level of earthquake exposures—both in terms of the number and its intensities—it scored twenty times more death toll relative to Japan (see CRED, 2011). In particular, the 2001 Gujarat earthquake with the Richter magnitude scale of 7.7 in India killed more than 20,000 people and destroyed nearly 400,000 buildings. However, with the same intensity, the 1994 offshore Sanriku earthquake in Japan destroyed only 48 houses and claimed three human lives. Likewise, in the case of Vancouver city in Canada, Chang et al. (2012) indicate that the probability of having same level of human casualties in an earthquake remains similar between 1971 and 2006, even though the population at risk has doubled by this period. Such dipping down the earthquake casualty rate per capita is mainly driven by the upgradation in national buildin codes. So, the notion that an earthquake itself kills human is, of course, naive, seeking a more careful scrutiny to understand the determinants of earthquake death toll. This paper rationalises that the tradeoff between *quantity* and *quality* of built infrastructure can largely explain the differences in earthquake fatalities across the low-, middle-, and high-income countries.

The recent strand of literature accounts for several reasons why heterogeneity in earthquake fatalities prevails across countries (see, for instance, Horwich, 2000; Anbarci et al., 2005; Noy, 2009; Fomby et al., 2013; Felbermayr and Gröschl, 2014; Klomp and Valckx, 2014). One of the most dominant arguments is that the opportunity costs of earthquake mortality prevention policies (e.g., formulation and enforcement of building codes, failure to retrofit buildings and enactment of quake-sensitive urban planning) tend to be higher for countries with a lower level of per capita income (see Keefer et al., 2011). In other words, households and governments in less developed countries have stronger preferences of tapping scarce resources in constructing more vulnerable houses over building lower number of earthquake-resistant infrastructure to gain more spaces for accommodation. Once a country develops, it tends to invest more resources in reducing disaster risks (see Toya and Skidmore, 2007). More recently, in the case of California, USA, Eriksen and Simon (2017) show that the vulnerability to disasters varies between communities and even households residing in the same community in terms of their levels of affluence. Precisely, the level of economic development provides implicit insurance against earthquakes through building safer infrastructure (see Anbarci et al., 2005; Kahn, 2005).

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[1] I thank the journal's editors and an associate editor for constructive comments. I also thank Nejat Anbarci, Prasad Bhattacharya, Debdulal Mallick, Md Abdur Rahman, Ronald Ratti, Jayanta Sarkar, Mehmet Ulubaşoğlu, and the participants to the Economic Modelling Conference 2017, Melbourne, Australia for many insightful comments and useful suggestions. All errors are my own.

http://dx.doi.org/10.1016/j.econmod.2017.08.027
Received 15 August 2017; Received in revised form 23 August 2017; Accepted 24 August 2017
0264-9993/

Please cite this article as: Rahman, M.H., Economic Modelling (2017), http://dx.doi.org/10.1016/j.econmod.2017.08.027

Given that none of the extant research attempts to peruse the questions I am hereafter, this paper augments and advances this line of research in at least three dimensions. First, I extend the vein of literature that argues in favour of a quadratic relationship between development and natural disasters (see Kahn, 2005; Stromberg, 2007; Kellenberg and Mobarak, 2008; Loayza et al., 2012; Fomby et al., 2013). In particular, using the quadratic specification, Kellenberg and Mobarak (2008) found an inverted-U shaped relationship between real GDP and the human death toll from floods, windstorms and landslides. However, in case of earthquakes, they found quite the opposite result—a U-shaped relationship—that has been interpreted as a product of an outlier. Unlike the quadratic specification, this paper grounds on a trifurcation econometric approach to testing the hypothesis that earthquake casualties vary disproportionately across three country groups by income (i.e., the low-, middle-, and high-income nations).[2] I argue that the quality of buildings varies linearly across the low-, middle- and high-income countries, but the earthquake-related vulnerabilities score the highest in the middle-income economies. The paper challenges the conventional wisdom, and finds that the middle-income countries suffer more human casualties in earthquakes than the low-income countries. Such classification of countries enables us to capture the role of the *quantity* as well as the *quality* of buildings in determining earthquake mortality and survivors.

Second, I employ an improved quantitative framework over the extant literature to unfold the conjecture between the built environment and earthquake casualty rates. I estimate the effect of earthquakes on human casualties for different country groups using an *interaction approach*. After that, I separately estimate such nexus for each of three country groups. Such strategy of split-sampling estimation allows us to exclude income measure (e.g., real GDP) from our estimation framework, which intuitively bypasses the ubiquitous problem of endogeneity. Further, unlike Anbarci et al. (2005) and Kahn (2005), I use a physical measure—i.e., ground-motion propagation—of earthquakes that is exogenous to all other determinants of earthquake casualties (see Keefer et al., 2011). This approach allows us to pin down the causal relationship rather than a mere statistical association between economic development and earthquake fatalities.

Third, most of the studies in this line of research club all types of disasters (e.g., floods, Storms and earthquakes) and relate how the total number of human casualties in such catastrophic events is determined by the level of economic development (see, for instance, Stromberg, 2007; Loayza et al., 2012). Departing from this stance, I focus only on earthquake hazard, given that each type of disaster is unique in its merit, and hence, their effects tend to be heterogeneous across different country groups by income.

This paper also fits well in the broader literature on the Environmental Kuznets Curve (EKC) hypothesis in that the built environmental quality becomes vulnerable in the early stages of economic growth, but it improves gradually with the maturity of the economy (see Grossman and Krueger, 1996; Shafik and Bandyopadhyay, 1992; Ekins, 1997). Indeed, the empirical approach expounds this hypothesis further indicating trichotomous association—rather than quadratic—between the built environment and economic development.

The estimates show that the level of development plays a key role in explaining why nations experience more human casualties in earthquakes. I found that the middle-income countries incur more human casualties in earthquakes relative to the low-income nations. This is possibly because the higher level of built infrastructure in the middle-income countries is made of heavy materials (e.g., bricks and stones) that make them more vulnerable to earthquakes. In contrast to the high-income nations, I find that the quality of built infrastructure (e.g., in terms of implementing building codes) in the middle-income ones is lower that makes them more vulnerable to earthquake casualties. After controlling for the country fixed effects, the estimates indicate that the geography is unlikely to trump the role of economic development out in explaining cross-country variation in earthquake casualties. Also, the variation in the quality of disaster risk reduction (DRR) institutions is unlikely to explain the heterogeneous effect of earthquakes on human casualties across countries grouped by its level of income.

These results suggest that countries can significantly minimise earthquake-related casualties by enforcing quake-proof construction regulations. In particular, the middle-income countries may have to be more proactive in enacting policies that replace the tendency of investing on vulnerable buildings with the cultue of building earthquake-resistant structure. For high-income countries, the results advocate that it is worthwhile to continue investing on earthquake-proof structure (e.g. more effective building codes and better urban planning). Finally, countries in the low-income group are better off investing on earthquake-proof buildings, rather than following the trajectory of the middle-income countries by constructing vulnerable infrastructure.

The paper's next section provides a conceptual framework explaining why earthquake casualties vary across countries. Data sources used in the empirical analysis are described in Section 3. After that, Section 4 presents the estimation method by focusing on the model specifications. Section 5 analyses the main results emphasising on the variation in earthquake casualties across the low-, middle-, and high-income countries. Section 6 concludes by pointing out some policy implications of the findings indicated in this paper.

2. The conceptual framework

The ownership of built structure—generally in the form of residential houses and commercial buildings—is one of the most primitive property rights. Each country has a set of rules governing this right that is commonly termed as 'National Building codes.' These codes specify the minimum standards relating to the construction and occupancy of durable as well as non-durable building structures. Such standards and its level of enforcements vary across countries, which largely set earthquake risks.

Let us consider a simple case where a country can choose to construct only one of these three building types: temporary structured buildings (e.g., less-durable structures made of bamboo, straw, tin and various light-weight raw materials), unreinforced masonry buildings (e.g., more-durable structures made of heavy-weight materials that are vulnerable to earthquakes), and engineered buildings (i.e., most-durable buildings that resists earthquake shocks at a certain level). We suppose, a typical building structure in the low-, middle-, and high-income countries is represented by the temporary, unreinforced masonry, and engineered buildings, respectively.

In Fig. 1, both $\angle OCB$ and $\angle O'C'B'$ are both 45°; the minimum building stock requirement is shown by BC (or $B'C'$) in which every point on BC represents the same level of buildings. As mentioned earlier, the minimum building stock requirement is the least level of buildings a country must have to fulfil its basic needs for accommodation. In other words, every country must construct at least this minimum level of buildings, irrespective of its income level (e.g., to its extreme point, individuals may even build their residences/commercial places using raw materials—tree logs, straws and leaves—that are freely available from common properties). Overall, a country chooses to build the best quality building structures that is conditional on fulfilling its minimum requirement.

Using its all resources, suppose that the low- and middle-income countries can construct any combination of buildings within the regions OAC and OBD, respectively. For the low-income countries, only point C satisfies its minimum level of building stock requirement

[2] Kellenberg and Mobarak (2008) employed a quadratic modelling approach to estimate the GDP-disasters nexus, but they used trichotomous country classification to interpret their negative binomial estimates. I departed from this approach and used the trichotomous strategy in model specifications and their interpretations of estimates.