Ecological Economics 72 (2011) 97–105

Contents lists available at SciVerse ScienceDirect

Ecological Economics

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

Analysis

Economic development and losses due to natural disasters: The role of hazard exposure

Ingmar Schumacher [a,b,*], Eric Strobl [b]

[a] Banque centrale du Luxembourg, 2 boulevard Royal, L-2983, Luxembourg
[b] Ecole Polytechnique Paris, Rue de Saclay 91128 Palaiseau Cedex, France

ARTICLE INFO

Article history:
Received 27 February 2011
Received in revised form 26 July 2011
Accepted 6 September 2011
Available online 18 October 2011

Keywords:
Natural disasters
Disaster losses
Economic development
Hazard exposure

ABSTRACT

Our contribution is to show that the relationship between wealth and disasters is mainly formed by the exposure to disaster hazard. We first build a simple analytical model that demonstrates how countries that face a low hazard of disasters are likely to see first increasing losses and then decreasing ones with increasing economic development. At the same time, countries that face a high hazard of disasters are likely to experience first decreasing losses and then increasing ones with increasing economic development. We then use a cross-country panel dataset in conjunction with a hazard exposure index to investigate whether the data is consistent with the predictions from the model. In line with our model, we find that the relationship of losses with wealth crucially depends on the level of hazard of natural disasters faced by countries.

1. Introduction

There are certainly few issues more disturbing than the prospect of losing one's hard-earned belongings to the forces of nature. One single instant of a wave, a tremble of the earth, or a passing by of a hurricane is often enough to destroy one's house, one's work, and one's belongings, if not one's life. Periodic news coverage, such as pictures from flooded houses in New Orleans, hurricane-torn houses in Burma, dried fields in Sub-Saharan Africa or the earthquake damages in Chengdu in China, reminds us of this possibility. Unfortunately, from a global perspective such events are a lot more frequent than one might imagine. For example, in 2007 alone there were approximately 450 of these natural disasters worldwide, affecting around 211 million people, and causing economic losses amounting to 74 billion US dollars.[1]

One of the main stylized facts that has arisen from the still relatively new academic literature on natural disasters seems to be that the economic and human losses associated with natural disasters are larger the poorer a country is.[2] This was first shown by Burton et al. (1993) and Tol and Leek (1999) for a sample of 20 nations and later confirmed in more comprehensive studies covering a large panel of countries by Kahn (2005) and Toya and Skidmore (2007). More recently, Rashky (2008), and subsequently Kellenberg and Mobarak (2008), demonstrate that the relationship between damages from natural disasters and income is characterized by an inversely u-shaped relationship, where damages first increase and then decrease with wealth. Yet, surprisingly, beyond arguing, for example, that "as a country develops, it devotes greater resources to safety, including precautionary measures…" (Hideki and Skidmore, p. 20) there are, to our knowledge, few studies investigating the underlying mechanics driving this link, especially those of a theoretical nature.[3,4]

Arguably a key element in understanding how losses from natural disasters are related to income is the expected hazard of these events. More specifically, Toya and Skidmore (2007) note that there are two relevant components to the disaster–income relationship, namely, (1) increases in income increase the demand for safety, and (2) higher income enables individuals to employ costly precautionary measures in response to this demand. So, if two countries face the same level of hazard one should expect the one with higher income to spend more on precautionary measures and hence to suffer fewer losses if a natural disaster occurs. Similarly, given two countries with equal wealth one would expect the one with a higher hazard to have a higher demand for reducing the exposure to this hazard via precautionary measures.

* Corresponding author. Tel.: +352 4774 4560.
E-mail addresses: ingmar.schumacher@polytechnique.edu (I. Schumacher), eric.strobl@polytechnique.edu (E. Strobl).

[1] Most of these costs are due to storm damages, floods and earthquakes (EM-DAT database).

[2] For example, Anbarci et al. (2005) note that to "say that the level of fatalities resulting from an earthquake is inversely related to a country's per capita level of income is hardly novel" (p. 1907).

[3] Kahn (2005) and Toya and Skidmore (2007) do examine what county characteristics (e.g., education and quality of institutions) are correlated with the relationship between economic development and disaster losses, but only in an ad hoc manner.

[4] While there is a literature that deals with decision-taking under uncertainty and prevention, it has generally not specifically addressed natural disasters. The two main exceptions in this regard are the articles by Lewis and Nickerson (1989), which deals with the amount of self-insurance under uncertainty, as well as Anbarci et al. (2005), which relates inequality and collective action to self-insurance within a natural disaster context.

0921-8009/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecolecon.2011.09.002

Thus, of two equally wealthy countries the one with a lower hazard should suffer greater losses in the case of a natural disaster since it is likely to have invested less in precautionary measures.

Of course, as it is with wealth, the hazard of natural disasters occurring is not evenly distributed across the globe. For instance, tropical cyclones are generally prevalent only in certain coastal areas (ex: US North Atlantic and Gulf of Mexico coastlines, Caribbean Sea, and South Pacific), while major earthquakes are likely to occur in locations where tectonic plates collide (ex: US, Turkey, and Chile). Hence it seems reasonable to assume that the cross-country losses–income relationship is likely to depend on the (expected) hazard of natural disasters that nations face.[5] In other words, if the difference in hazard is large enough then a low hazard country may very well suffer larger losses than a higher hazard country.

In this paper we thus set out to explicitly investigate how this interplay between wealth and hazard affects how natural disaster losses depend on the level of economic development. We, first, develop a theoretical model which is a simplified version of that presented in Schumacher and Strobl (2008), where countries choose their optimal level of prevention expenditure. We pay particular attention to the role of the hazard of a natural disaster. A larger hazard in this model means an increase in the marginal losses in case a disaster hits the country as well as a higher marginal benefit from prevention expenditure. We show that countries facing a low hazard are likely to see increasing losses for low wealth levels, while higher wealth levels lead to decreasing losses if prevention expenditure is sufficiently effective. In contrast to that, high hazard countries will see prevention expenditure even at very low levels of wealth, which leads to decreasing losses for sufficiently effective prevention expenditure. Losses will be increasing with increasing wealth for high hazard countries if further increases in prevention expenditure prove to be less and less efficient. This model helps us in providing an understanding of the driving mechanisms behind the relationship between the economic losses, the natural hazard exposure and economic development.[6]

Using a cross-country panel data set we next investigate whether the empirical evidence is consistent with the predictions of our model. To this end we construct a proxy of country level hazard exposure based on local (within country) risk probability indicators developed by Dilley et al. (2005). We then use this index to explore the role that differences in hazard exposure play in the possibly nonlinear income–losses relationship, as suggested by our theoretical model. Our econometric analysis demonstrates that the shape of the relationship between wealth and losses crucially depends on the hazard of natural disasters that countries face. More precisely, we generally find an inverse u-shaped link between losses and wealth for low and medium hazard countries, but a u-shaped relationship for high hazard countries. These results are robust to the implementation of alternative methodological approaches previously used in the literature.

The remainder of the paper is organized as follows. In the following section we outline our theoretical framework and its implications. In Section **3** we describe our data set. Our econometric specification and results are contained in Section **4**. The final section concludes.

2. Theoretical Model

Our intention here is to capture the essential relationship between economic development, prevention expenditure and the costs of natural disasters. The model presented here is a simplified version of that in Schumacher and Strobl (2008), which extends Lewis and Nickerson (1989), where we introduce risk over the state of nature and uncertainty over the extend of the damage. The predictions of the two models are very similar. We assume that a country (or a region) maximizes utility $u(I)$, which is a function of net wealth, $I=w-cx-L(w,x,y)>0$, where wealth is given by $w>0$, prevention expenditure $x\geq 0$ comes at marginal cost $c>0$, and losses are given by $L(w,x,y)$. Here, $y>0$ represents the strength of a disaster, where a larger y implies a stronger disaster. The functional forms assumed are $u_I>0$, $u_{II}<0$, $L_w>0, L_x<0, L_y>0, L_{xx}>0, L_{xy}<0, L_{xw}$. All variables are in totals.

Intuitively, our assumptions imply that the amount of wealth destroyed increases in the amount of wealth available, but is reduced by higher prevention expenditure, while stronger disasters increase losses. Furthermore, increasing prevention expenditure is expected to be less and less effective, and prevention expenditure is assumed to be more effective for larger disasters. Finally, we also assume $L_{xw}<0$, implying that the marginal loss for a given wealth level decreases in prevention expenditure. This last assumption is not innocuous and drives our subsequent results. It implies that the more a country spends on prevention expenditure, the lower will be the losses per unit of wealth increase. This seems a reasonable assumption also for the kind of larger scale disasters that we focus on empirically later.[7] Intuitively, imagine a hurricane that landfalls in a city. The more the city spends on adapting the housing to a hurricane strike the less will each house be affected by the hurricane. Or, in other words, for a low level of prevention expenditure, we expect the marginal loss per unit of wealth increase to be larger than for high levels of prevention expenditure.

The approach presented here can be read in two ways. Firstly, it can be viewed as a simplified model of Schumacher and Strobl (2008), capturing the essential underlying relationships between disaster hazard, wealth and prevention expenditure.

Secondly, one would ideally want to model the hazard of a natural disaster as a risky event, with a given distribution $p(g)$, and thus the expected event would be $y=E(g)=\int_0^\infty gp(g)dg$. Thus, $g=0$ would be the case of no disaster, while $g=\infty$ would indicate the worst possible scenario. On average, the expected event would then be $h=E(g)$. Thus, our function $L(w,x,y)$ indicates the expected, or average loss. A country with a larger hazard would then be one where the function p(g) attaches higher probabilities to states of the world with larger g's, i.e. with worse events. In a slightly different interpretation, we could view this model as one where a policy maker takes into account that with a certain probability the protection might fail. For example, we could write $L(w,x,y)=(1-y)\cdot 0+y\cdot \hat{L}(w,x)$. Thus, in this case $y\in(0,1)$ and it would be interpreted as the probability that the protection fails and a loss $\hat{L}(w,x)$ is incurred. Prevention expenditure would then become relevant when the protection fails. Interpreted in this way, then the model is more suitable for disasters for which one cannot influence the probability that protection fails but only the final losses, for example hurricanes.[8]

As yet another interpretation[9] we could write $L(w,x,y)=h(x,y)\,0+(1-h(x,y))\,\tilde{L}(w)$, with $h_x>0$ and $h_y<0$. In this case, the probability of a disaster creating a loss, i.e. the probability of a failure in the defenses, is decreasing with the prevention expenditure. The actual damages themselves, however, do not depend on the prevention expenditure but only on the exposed wealth. This interpretation would then be a useful one for studying disasters like flooding, since dams may reduce the probability that an event induces a loss. However, once a dam breaks the actual loss is only depending on the exposed wealth.

[5] Neither Toya and Skidmore (2007) nor Kahn (2005) explicitly takes account of expected risk in this regard.

[6] Hallegatte (2011) has recently developed a model showing that disaster losses can grow faster than wealth. He shows that it may be beneficial to invest in riskier regions with increasing economic development.

[7] Specifically, by this we mean those disasters that are sufficiently large as to have made their way into the EM-DAT database, which we use for our empirical study.

[8] Hence, it would be less suited to study flooding, since in this case one can mainly influence the probability that the event materializes in a loss by building a sufficiently high dam.

[9] We are grateful to the editor for suggesting this interpretation.