perspective paper

NATURAL DISASTERS

Ilan Noy

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Investing in Disaster Risk Reduction: A Global Fund

Ilan Noy

Department of Economics, University of Hawai'i, Mānoa

&

School of Economics and Finance, Victoria Business School, Wellington, New Zealand

noy@hawaii.edu

ilan.noy@vuw.ac.nz

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1. Fat Tails and Extreme Disasters

Before analysing appropriate intervention possibilities, and speculating about the most cost effective ways of dealing with natural disasters, it is productive to look at the likely risk. Cavallo et al. (2010) note that the distribution of disaster damages is highly skewed, with presence of extreme—'fat tail'—disasters whose costs (in terms of mortality, morbidity, and/or physical destruction) are vastly larger than the average disaster cost. The Haiti earthquake of January 2010, for example, led to mortality that was 10 standard deviations larger than for similarly strong earthquakes.[1] A 10-sigma event would be associated with extremely small probabilities in 'thin tail' distributions (like the Normal distribution). There were two other 10-sigma earthquake damages in the last 40 years (Tangshan-China in 1976 and Aceh-Indonesia in 2004).

In elucidating his 'dismal theorem', Weitzman (2011) argues that the presence of fat tails in the probability distribution of the likelihood of catastrophic event scenarios implies that standard cost-benefit analysis based on means is inappropriate. He argues that the fat tail risk should dominate all other considerations in evaluating the cost/benefit of interventions. In short, he concludes that catastrophic risks with very small probabilities demand aggressive investment in prevention.[2] Pindyck (2011) and Nordhaus (2011) critically explore the implications of Weitzman's argument.[3] Relevant to our focus here, Pindyck notes that the theorem will apply to any catastrophic event (with a fat tail distribution associated with either the probability of occurrence, the distribution of impact, or even the estimated probability distribution[4]). Nordhaus notes that the probability distribution of earthquake magnitudes is a classic example of a fat tail distribution.

Figure 1, shows the total number of people killed, per year, from natural disasters between 1975 and 2010. The graph is constructed from data available from EM-DAT, the most widely used and publicly available data source about natural disasters. The data clearly demonstrates that the distribution of mortality from disasters is fat tailed; and a similar conclusion can be drawn when examining disasters' financial damages over time (see figure 1 in the Kunreuther and Michel-Kerjan chapter).

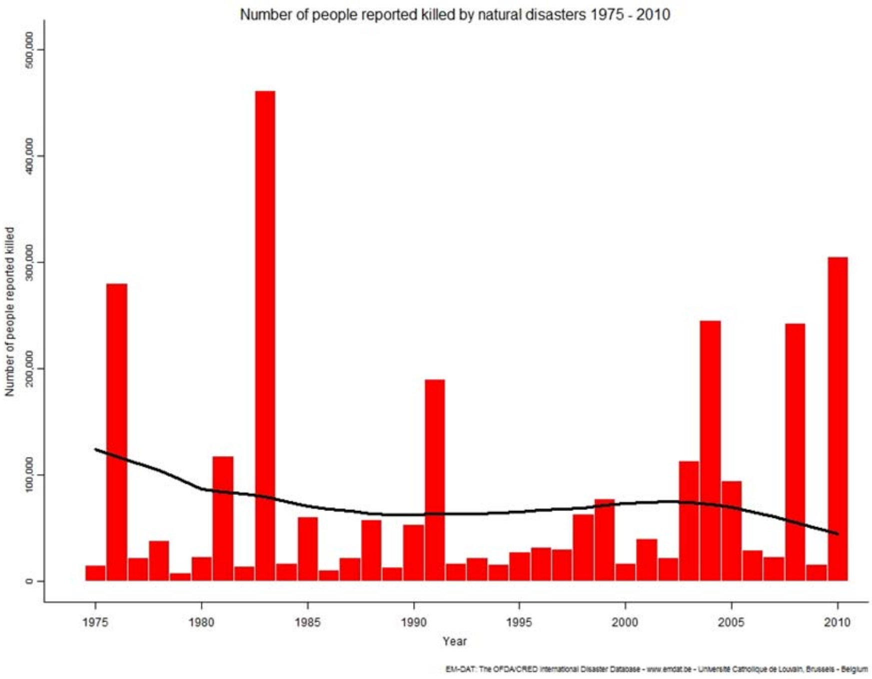
[1] Author's calculations using data from EM-DAT (supported by the Catholic University of Louvain, Belgium; www.emdat.be). By similar we mean any earthquake whose Richter measure is bigger than 7 (calculated for all earthquakes whose Richter≥7 for 1970-2003. The Haiti earthquake measured as a 7.0-7.1, while the 1976 Tangshan earthquake was 7.8, and the Aceh 2004 event was 9.1-9.3.

[2] Another prominent environmental economist, M. Scott Taylor, expresses similar concerns (Taylor, 2009).

[3] All three papers were published as a symposium. Weitzman developed his 'dismal theorem' in Weitzman (2009).

[4] So that even if the real but unknown probability distribution is thin-tailed, with enough uncertainty about the real parameters of the distribution, the estimated probability distribution will be fat tailed. Weitzman (2011), Pindyck (2011) and Nordhaus (2011) define more precisely the characteristics of thin- and fat-tailed distributions.

Figure 1: Mortality from Disasters 1975-2010



In their critical evaluation of Weitzman's arguments, both Pindyck and Nordhaus essentially conclude that the extreme implications of the 'dismal theorem' – that we should invest close to everything in preventing these small probability catastrophic events – are probably exaggerated (for reasons they explore in detail). Yet, both appear to agree that it is still likely that the fat tails should figure more prominently in discussions of cost-benefits.

Cavallo et al. (2010) also note that most large disasters (defined as those whose costs are above the mean) are caused by either earthquakes or storms. Therefore, even if Weitzman's extreme and dismal conclusion is not robust — see Milner (2011) for an evaluation of objections and Barrett (2011) for an alternative view of the importance of uncertainty— there is still a case to be made that we are under-investing in preparing for these low-probability catastrophic earthquakes and tropical storms.

As an illustration, table 1 details the cost of catastrophic disasters as measured by mortality and damages, in the last two decades. The table includes the most destructive disaster of recent times; distinguished by the five most common and harmful natural disaster types (droughts, storms, earthquakes, volcanic activity and floods). It also includes data on the total human cost of the largest 10 disasters in each disaster type category. The information presented demonstrates clearly that, at least according to this metric, earthquakes are by far the most dangerous/damaging, followed by storms. We would arrive at the same conclusion if we focused on monetary damages. Preventing/mitigating the risk of earthquakes and/or storms is thus the most important.

TABLE 1: DISASTERS 1992-2011

	Number Killed
Largest disaster by type	
Drought (Indonesia, 1997)	672
Earthquake (Haiti, 2010)	222,570
Flood (Venezuela, 1999)	30,000
Storm (Myanmar, 2008)	138,366
Volcanic eruption (Indonesia, 2010)	322
Sum of ten largest disasters by type	
Drought	1,988
Earthquake	685,127
Flood	50,374
Storm	183,134
Volcanic eruption	775

Policy should focus on: (1) the catastrophic low-probability events; and (2) on risks from earthquakes and storms (sudden-onset events). Regionally, the most exposed geographical regions are Central, East and South-East Asia and the Caribbean (for sudden-onset events), and Sub-Saharan Africa (for slow-onset disasters such as droughts).[5]

In the following sections, I focus on three issues that are, in my view, the most pertinent to addressing the need to deal with catastrophic, low-probability storms and earthquakes (most likely to occur in Asia and/or the Caribbean): (1) the large benefits and benefit/cost ratios from early-warning systems; (2) the feasibility of an international disaster risk reduction intervention fund and its guiding principles, and (3) an evaluation of the Copenhagen Consensus methodology that relate to the Kunreuther and Michel-Kerjan challenge paper.

2. **Early-Warning Systems**

A cost-benefit analysis for prevention and mitigation of future possible events is, of course, inherently inaccurate. As Nordhaus notes: “the data speak softly or not at all about the likelihood of extreme events” so that any policy-related evaluation will be extremely challenging and fraught with disagreements – all the more so for the rarer still ‘fat tail’ events. Beyond these obvious and common problems to any cost-benefit analysis, early warning systems (EWS) pose two additional problems: type I and II errors, and the temporal nature of the early warning.

A failure to warn against an actual hazard is associated with a serious cost, but also issuing a warning when the hazard does not materialize is costly; these costs include not only the unnecessary evacuations and preparedness measures (which can at times be very costly)

[5] For discussion about regional exposures and future risks, see Peduzzi et al., 2009 and Noy, 2012.

but also the damage to the EWS reputation that will reduce its future efficacy in decreasing disaster damages.[6] These calculations are further complicated by the dynamic nature of EWS. An earlier forecast of an event is more efficient as the warning it provides allows people more time to prepare for the hazard (by evacuating, or making changes to protect property and lives) yet more advanced warning is less precise, thus increasing the possibility of inadvertent errors (especially false alarms).

Even though benefit/cost ratios for EWS are difficult to construct, the evidence that the easiest prevention and mitigation is achieved by developing effective early warning systems is overwhelming (see for example the paper by Hallegatte in this volume and the World Bank background papers referred therein).

Storms Warning Systems

Storm early-warning systems are straight forward to develop, scientifically feasible, and fairly cheap. The success of both Bangladesh and Cuba, both very poor countries, in developing effective early warning systems that are connected to a net of public shelters from strong tropical storms clearly demonstrates the cost-effectiveness of this approach. During tropical cyclone Sidr (2007), Bangladesh effectively evacuated 3 million people from vulnerable coastal areas. The storm did lead to significant mortality (4,324 people died), and damages. But, cyclone Nargis that hit nearby in Myanmar the following year led to 138,366 people losing their lives, after little warning or evacuation, even though Nargis was weaker than Sidr (in terms of measured wind-speed).[7] The discussion by Hallegatte in this volume, as well as in Rogers and Tsirkunov (2011), elaborates on hydro-meteorological early-warning systems, and concludes that the benefit/cost ratio associated with a universal implementation is very high (in one case, Subbiah et al., 2008, calculate a benefit/cost ratio for an EWS for storm-induced floods in Bangladesh of 558.87![8]).

Tsunami Warning Systems

The Pacific already has long had the Pacific Tsunami Warning Centre (PTWC) located in Honolulu, Hawaii, and financed largely by the U.S. government (through NOAA).[9] Following the Aceh tsunami of December 2004, the countries of the Indian Ocean have also started implementing their own mechanism similar to the PTWC. While implementation is not yet complete, the system is operational, and it clearly demonstrates the feasibility of poorer regions developing their own advanced warning systems (with external funding).

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[6] Subbiah et al. (2008), for example, arbitrarily assumes that 1 in 10 warnings are wrong, and that the cost of one misleading warning is exactly equivalent to the benefit from one correct warning, and thus reduces the total benefit calculated for a EWS by 20%.

[7] Data in both cases is taken from EM-DAT.

[8] Notwithstanding the precision in which this cost/benefit ratio is stated in the original analysis, it does rely on very detailed data regarding damages caused by flooding from cyclone Sidr. Importantly, it does not include the benefits in terms of lives saved or people unharmed, and assumes saving from better warnings that appear understated (10% of actual incurred damages to housing and personal property, for example).

[9] The PTWC had already issued Pacific-wide tsunami warnings after the 1960 large earthquake in Chile.

The main stumbling block, in terms of costs and institutional feasibility, is not the actual prediction of the tsunami hazard, but developing the decision mechanism to decide on the issuing of tsunami alerts, the transmission of this alert to residents of coastal areas, efficient evacuation and evacuation monitoring (and in some cases – enforcement). Yet, the development of mass communication in the last decade has enabled a much easier, cheaper, and faster dissemination of alerts. Now, alerts can be transmitted via SMS/text or email to subscribers, universal SMS/text or email to all cell phone/internet users in the hazardous region, TV and radio, social media (services like Facebook and Twitter), and actual sirens located along the coasts.[10]

Evacuating away from tsunamis, moreover, is easier than evacuating away from tropical storms, since only the regions very close to the coast are affected, and a short evacuation upland is generally sufficient. The decision and transmission mechanisms developed for hydro-meteorological hazards can also be used for tsunami alerts. Thus, the cost of developing an effective alert system (assuming the meteorological alert system is already in place) is fairly small but benefits are potentially very large. An effective tsunami alert system in, for example, Sri Lanka, could have saved every single life lost in the tsunami of 2004 (more than 32,000 people lost their lives in Sri Lanka).

Earthquake Warning Systems

Earthquake early-warning systems are feasible but are highly local, and can probably best be developed at the national level. There is little scope for international cooperation in developing them, except for sharing of technology. Japan is the only country with a comprehensive early warning system (Mexico, Romania, Taiwan and Turkey have more limited earthquake EWS in place), but these systems only provide advanced warning of a few seconds; the exact timing depends on distance from the epicentre, with locations further away receiving more advance notice (maybe up to a minute).[11] Even this short advance warning, however, enables implementation of many life-saving procedures (stopping trains, shutting down power stations, evacuations of buildings and other vulnerable areas, etc.).

For developing countries, establishing communication systems that can transmit earthquake alerts in the appropriate speed and to a wide-enough area is likely to be a difficult undertaking and its feasibility and associated costs are largely unknown. While we therefore cannot recommend establishing earthquake EWS given the absence of current knowledge about costs and the difficulty in predicting benefits, this does not preclude future public and international investment in them, especially once the appropriate communication and transmission systems are in place for other types of disaster EWS.

[10] DEWS, a project financed by the European Commission, is developing such multi-channel systems for the Indian Ocean (see Esbrí, 2011).
[11] For more detail, see Grasso, 2009.

The implementation problems effecting EWS are similar across a large variety of natural disasters. In particular, designing the appropriate decision mechanism for issuing alerts, and actual projection of alerts to the appropriate population centers, local government, and households, are all similar. Thus, there are significant economies of scale from developing these capacities. In particular, the design of EWS in developing countries should focus, from the very beginning, on designing systems that can serve as a platform for multiple hazard EWS, and any explicit cost-benefit analysis of specific EWS should account for this positive externality. It is also important to note that the estimated benefit/cost ratios of EWS are almost invariably much higher than other mitigation proposals and more so for post-event interventions which are typically very costly.

3. Developing DRR Policy Internationally with a Global Fund (GF-DRR)

Why we need a Global Fund?

If EWS are indeed as cost effective as we previously claimed, why are they not being implemented wholeheartedly? The answer is most likely political. When facing budgetary choices, between investing in disaster risk reduction (DRR) with uncertain and long-horizon payoffs and other fiscal priorities that can be implemented quickly and benefits accrued immediately, most political systems will prefer myopic policies that invest in the short-term. This, compounded with a 'not in my term of office' view that discounts the likelihood of catastrophic events in the electorally-relevant future is bound to lead to an under-investment in DRR policies.

Beyond that mismatch between the political and economic horizons, a lack of electoral accountability also does not seem to create the 'correct' incentives for preventive DRR measures. Healy and Malhotra (2009), for example, investigate U.S. voter behaviour following natural disasters, they argue that voters reward incumbents for post-disaster relief spending, but do not punish them for failure to undertake any preventive measures; even though these measures, according to their calculations, have a benefit cost ratio of 15. In a follow up study, Healy and Malhotra (2010) also show that, in the U.S., incumbents get punished electorally not because of tornado damages, but rather when the government fails to declare the tornado a disaster (and therefore federal assistance is not forthcoming). In a related paper, Garrett and Sobel (2003) document how 50% of FEMA (Federal Emergency Management Authority) payments in the U.S. are guided by political considerations rather than by any cost-benefit assessment, further confirming the Healy-Malhotra description of the electorate. Disasters, in short, are seen as 'acts of god' and are thus not widely viewed as preventable.

Cole et al. (2012) document very similar incentive structures facing politicians in India in post-disaster situations. Non-democratic governments appear to be even less responsive to

DRR opportunities, but are also held accountable for post disaster assistance. One of the frequently used examples is the mismanagement of foreign aid after the Managua earthquake of 1972 by the Somoza regime; a mismanagement that by all accounts contributed to its downfall. Given this perceived sense of reduced accountability for failure to implement DRR measures, the incentives for DRR policy implementation are limited.

This lack of incentives is apparently also present in the investment made by external organizations and most importantly International Non-Governmental Organizations (I-NGOs). The I-NGOs typically manage to receive most of their revenue through donations in the aftermath of large disasters, and have clear incentives to allocate many resources in the immediate aftermath. Investing in prevention and mitigation, however, is less attractive for fund-raising purposes, and is therefore undertaken much less (see also the discussion in Kunreuther and Michel-Kerjan).

In many cases, initiating the development of DRR policy is clearly needed, and can probably be best developed with external support/incentives from the multilateral organizations. The World Bank, in particular, has been working on this front, but a dedicated fund, a Global Fund for DRR (GF-DRR), that will incentivise and support this work can and should result in the optimal allocation of resources for this task. Many developing countries lack a coherent planning for disaster preparedness and risk reduction, and the knowledge collected by the international organizations (esp. the World Bank), together with the funds to support this planning, can lead to a very cost effective implementation of a much more global DRR policy.

An appropriate DRR policy funded by the GF-DRR may involve funding of Early Warning Systems, but may also involve other preparatory steps; DRR may mean retrofitting essential infrastructure for earthquakes (especially hospitals and power stations), moving people permanently away from wave-surge prone coastal regions or river flood-plains, or establishing more robust communication networks that will not collapse in the aftermath of a catastrophic event. The appropriate steps needed depend on the broadly-defined institutional details, the current state of the economy, and predictions regarding likely future disaster risks.

Since all three factors (institutions, economy and disaster risk) are inherently local and widely varying, it would be difficult to attempt to devise a universally appropriate DRR, or to argue for a universal implementation of any specific policy. The degree of involvement of the GF-DRR will also change according to these three factors (i.e., economy, institutions and risk profile) and the political incentive structure in each country.

For example, the Haiti earthquake of 2010 was unique, in among other characteristics, that it deeply affected a core urban/metropolitan region, unlike most other catastrophic events of the past decade that hit mostly rural areas (the Aceh tsunami of 2004, the Pakistan Kashmir earthquake of 2005, the Sichuan earthquake of 2008, cyclone Nargis in 2008, or the

Tohoku quake and tsunami of 2011[12]). Urban disasters are different, and preparing for them present unique challenges that are different from preparing to deal with a rural event (Clermont et al., 2011). Thus, each country should evaluate independently the risks facing rural and urban areas, and determine its own policy mix that allows it to implement a DRR plan. There are, however, best practices in disaster risk reduction and it is undoubtedly true that having a well-rehearsed contingency plan in place (including most crucially logistics and communication planning) is necessary to achieve a dramatic reduction in disaster risk.

Much preparation of DRR is taking place, and that has been the case since antiquity. Much more needs to be done, however, especially since economic conditions are changing, and risk patterns are appearing to change as well. Future economic exposure to tropical storms, for example, is predicted to quadruple by 2100, with roughly half of this increase associated with higher population and property in vulnerable areas and half resulting from changing patterns in terms of new predicted storm tracks and storm intensities (Mendelsohn et al., 2012[13]).

These climatic and demographic changes have of course been occurring for some time, but by all accounts they will likely continue if not accelerate. As noted by the United Nations' International Strategy for Disaster Reduction (UNISDR), in the past 30 years, the proportion of world population living in flood-prone river basins has already increased by 114%, while that living on cyclone-exposed coastlines has grown by 192% (UNISDR, 2012).

This paper eschews recommending specific and concrete action-plans because the cost/benefit associated with each specific recommendation for a specific hazard in a well-specified location will necessarily be very different. The investment in quake-proofing schools in developing countries is a case in point. Earthquake hazard is very local and can be very different even within a country. Furthermore, the hazard in urban schools, which would typically be multi-story, is much greater than in rural schools. In countries in which there are two shifts in schools so that the school is occupied for about 12 hours a day (e.g., parts of Argentina), the benefit/cost ratio would necessarily be double that of other areas in which schools only operate with one shift (for maybe 6 hrs/day). Equally confounding, an analysis of building schools in Congo will necessarily yield a very high estimate of benefits to costs, but so would almost any other successful intervention there. The hurdles facing investment in public goods in Congo is not a lack of opportunities with high yields, but the implementation barriers that face any investment in public goods in that country.

Creating the Correct Incentives for Robust DRR Plans

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[12] The New Zealand Christchurch earthquake of 2011 is another example of a large urban disaster (the largest in New Zealand history, and one of the most costly in relations to the size of a developed/high-income economy).

[13] The predictions in Mendelsohn et al. (2012) do not account for the future impacts on storm damages from predicted sea-level rises, bleaching/destruction of coastal reefs, and drying up of coastal mangrove forests. All of these are likely to increase damages further.

The International Monetary Fund (IMF) has been involved in post-crisis intervention for several decades. The lessons the IMF learned, in terms of avoiding perverse incentives—e.g., moral hazard and adverse selection—and leading countries to adopt ex-ante sound policies, are as relevant to natural disasters. In particular, a GF-DRR that operates not unlike the IMF's Flexible Credit Line may create the right incentives for the establishment of a robust DRR policy. Essentially, the idea is that countries will be constantly evaluated for their DRR plans, and given 'Seals of Approval.' A country whose plans are favourably evaluated will have access to support for DRR projects from the GF-DRR and in addition will have access to an Emergency Disaster Fund should it be required (as part of the GF-DRR, one can establish triggers that automatically provide affected countries access to pre-specified sums as grants or concessional loans).

Tying a GF-DRR with Insurance Markets

An additional positive externality would be to enable countries who receive this 'seal of approval' for their DRR plans to more easily insure themselves explicitly (with re-insurers) or implicitly by issuing Catastrophic Bonds (CAT bonds) and further enable multi-year insurance. Kunreuther and Michel-Kerjan's paper in this volume discuss CAT bonds and multi-year insurance schemes in detail.

While macro-level explicit or implicit insurance has been growing in popularity in the last decade, the vast majority of CAT bonds, for example, are still issued by local organizations or specialized insurance companies. Governments, at the local or the national level, do not yet appear to avail themselves of these insurance opportunities, and the establishment of a global fund may be the catalyst that will increase utilization of these new financial tools for handling catastrophic risk.

4. A Criticism of the Cost-Benefit Copenhagen Consensus Methodology

Three criticisms of the Cost/Benefit methodology used by the Copenhagen Consensus come to mind: (1) The associated probabilities and uncertainties, especially of fat tails, are not accounted for in a satisfactory way; (2) The decision to use VSL, instead of cost-per-life-saved, and the actual VSL/DALY values being used are very low (though the Kunreuther and Michel-Kerjan challenge paper also report their results using much higher VSL); and (3) The implicit Classic Utilitarian welfare function is not explicitly stated and is ethically objectionable.

The 'fat-tails' problem was already discussed; however, it may be beneficial to stress that a feasible and largely acceptable way to treat these fat tail risks in public policy has not yet emerged. My own interpretation of the precautionary principle suggests that we should place a greater weight on these fat-tail events than is currently done and that is implied in the methodology that the Copenhagen Consensus has adopted.

The decision to use VSL essentially puts on equal footing monetary damages, which are reversible, to life-and-limb damages which typically are not. It is true that from a consequentialist point-of-view, monetary damages can also result in irreversible impact on mortality and morbidity.[14] But, under alternative ethical frameworks, direct and indirect impacts may be viewed as very different in their value content and their normative implications. The Copenhagen Consensus ameliorates this problem somewhat by focusing only on developing countries, but this is only a second-best, given the vast differences between these countries.

Kunreuther and Michel-Kerjan already note this in their conclusions; pointing out that when emphasizing mortality (saving lives) their conclusions are different than when they use the total cost calculation that sums up the value of statistical lives with other costs; the former leads them to recommend earthquake proofing while the latter to recommending the construction of flood defenses. Given the observed correlation between poverty and disaster-related mortality, focusing only on mortality has the additional advantage that it will further emphasize programs that benefit the poor in general and the poorest countries in particular.

The distributional implications of the choice to use cost-per-life calculations rather than VSL in benefit/cost analysis are also connected to my objection to the utilitarian framework that is being used. While most economists have little objection to consequentialism as a guiding principle in policy evaluation, I disagree with a classic utilitarian framework that ignores distributional concerns or does not prioritizes the most vulnerable. Thus, I would have preferred that the Copenhagen Consensus use a procedure that prioritizes assistance to the poorest and the least capable to initiate protection autonomously, rather than just relying on the hope that a benefit/cost analysis will yield such an outcome.

5. Some Comments on the Kunreuther and Michel-Kerjan proposals

After providing a very useful and insightful summary of the key issues regarding disaster mitigation in developing countries, the Kunreuther and Michel-Kerjan challenge paper examines four proposals: (1) retrofitting schools against earthquakes; (2) constructing dykes or elevating houses to prevent flood damage; (3) strengthening roofs in storm prone areas; and (4) constructing early-warning-systems.

The analysis the authors undertake in estimating the cost-benefit ratios for the first three proposals is ambitious and admirable, and involves the use of very detailed data in constructing both the EP curves and the cost of interventions. They clearly demonstrate that all these will have BCRs that are significantly bigger than 1 for higher VSL values and for a

[14] By 'consequentialism' I mean an ethical decision algorithm that examines consequences rather than the process itself or the procedures that led to the choice and adoption of that process.

fairly large group of countries, and that 75 billion US$ can easily be spent productively (i.e., with BCR>1) on each one of these programs. The remaining question that is left unanswered is whether these are the lowest hanging fruit. Below are a few suggestions that appear to imply that there may be easier fruit to pick.

Retrofitting buildings against earthquake damage is expensive, but since earthquakes cause high mortality, and early-warning systems for them are difficult and expensive to develop, in poor rural areas in particular, this seems to be a valuable strategy to pursue (if indeed EWS are unattainable). While schools are ubiquitous, they are typically only occupied for part of the day (usually around 6-8 hours per day) so it seems more sensible to also invest in restructuring other public infrastructure that is more continuously occupied, like hospitals or government buildings. Schools should be prioritized only if the lives of children are prioritized – but this is not made explicit in the analysis. The Sichuan earthquake of 2008 demonstrated painfully what are the costs if a destructive earthquake occurs during the school day (2:28 PM), but the two 2010 earthquakes that destroyed many buildings: Haiti (4:53 PM) and Chile (3:34 AM) did not occur during the school day and the high mortality among children in the Haiti case would not have been prevented had schools been more robustly constructed.

Two other proposals, constructing dykes or elevating houses for flood damage prevention, and improving roofing for wind-damage prevention, deal with natural disasters that usually do not pose a very high mortality risk if early warning systems are effectively deployed. Given my previous comments, I would have preferred a focus on mortality prevention. In the latter case, tropical storms do pose a very significant mortality risk, as was evident in the aftermath of Cyclone Nargis in 2008, but this risk can be mitigated quite effectively with a combination of appropriate early-warning-systems and the provision of storm-resistant public shelters. Schools are often used as public shelters, so constructing schools that are both storm and earthquake resistant may actually be, in many cases, a very efficient way of dealing with both storm and earthquake hazards. This strategy would be especially effective in countries that face high risk for both, as do many of the countries of the Pacific Rim.

Lastly, the difficulty of developing an effective early-warning-system should not be underestimated. On April 11, 2012, a powerful earthquake (8.6 on the Richter scale) occurred not far offshore Banda Aceh, the city that was inundated by the 2004 Boxer Day tsunami with about 25 thousand people killed (Doocy et al., 2007). By 2012, there was an early warning system in place for tsunami hazard in Aceh, but since everyone attempted to evacuate at the same time, roads became gridlocked very quickly as people were frantically trying to flee (Rondonuwu, 2012). Luckily, no significant tsunami was generated by the earthquake, but the inadequacy of a system developed specifically to prevent mortality if a repeat of the 2004 catastrophe were to occur was demonstrated quite starkly. Investment in effective EWS will thus not be as cheap or easy as it also needs to secure an effective response to the warnings the system supplies. Yet, the magnitude of benefits, in terms of life saved per dollar spent, are very large if these systems manage to prevent the very catastrophic disasters that occur quite frequently.[15]

As Kunreuther and Michel-Kerjan note: "Given the scale of the analyses we undertook…we had to make very simplifying assumptions. In reality, one would want to gather information about the hazard, type of exposure, return period of different events, type of buildings one consider, their vulnerability to that hazard, etc." For this reason, I propose the panel recommends the creation of a Global Fund for DRR that will work directly with governments by providing appropriate incentives to emphasize the establishment of early warning systems; all the while enabling a careful weighting of local circumstances and the most efficient allocation of scarce funds.

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[15] In the past decade, there has been about 1 event per year with more than 20 thousand deaths.

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