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COST BENEFIT STUDIES ON DISASTER RISK REDUCTION IN DEVELOPING COUNTRIES

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The focus of development actors working in the area of disaster management has shifted substantially from disaster recovery to disaster risk reduction over the past decade, coinciding with the decade of the Hyogo Framework for Action (HFA) 2005-2015[2]. Amidst this strategic shift, there is now the need to work towards ensuring that investments made to reduce disaster risks are cost-effective and that the benefits reach all members of the population including the poor and vulnerable, who are often "affected disproportionately" (Global Assessment Report 2009, The Sendai Report 2012). The losses from natural disasters to mankind are undoubtedly massive—on average, globally every year over 100,000 people were killed and some 246 million people affected by natural disasters during the period 2002-2011 and the estimated average economic loss was US$131 billion per year (EMDAT 2013).

The purpose of this note is to briefly survey existing evidence in developing countries with regard to the benefits and costs of various disaster risk reduction interventions so as to provide some general lessons for disaster risk reduction (DRR) practitioners on the strengths and limitations of such existing work. In doing so, this note examines evidence on the economics of DRR in developing countries[3]. The note begins by providing a compara-

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[2] A Plan adopted by 168 nations in 2005 to "detail the work that is required from all different sectors and actors to reduce disaster losses" (UNISDR).

[3] Such as those available in Department of International Development (DFID)'s desk review of costs and benefits of Natural Disaster and Disaster Risk Reduction Measures (Environmental Resources Management 2005); GTZ Manual on Cost-Benefit Analysis of Natural Disaster Risk Management in Developing Countries (Mechler 2005); Guidance Note No. 8 prepared by ProVention on Economic Analysis, Tools for Mainstreaming Disaster Risk Reduction (Benson, Twigg and Rossetto 2006); the Information Note No. 3 by The Global Platform for Disaster Risk Reduction (GPDRR/ISDR) on Costs and Benefits of Disaster Risk Reduction (Moench, Mechler and Stapleton 2007); and the WB and UN (2011) joint publication Natural Hazards, UnNatural Disasters: Economics of Effective Prevention.

This working paper series is produced by the East Asia and Pacific Disaster Risk Management Team of the World Bank, with support from the Global Facility for Disaster Reduction and Recovery (GFDRR). The series is meant to provide just-in-time good practice examples and lessons learned from projects and programs related to aspects of disaster risk management.

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tive guideline for analysis. This is followed by a summary diagnostic of seventeen case studies[4] along five key dimensions comprising the guideline as follows: (1) Metric and methodology, (2) Sources of uncertainty, (3) Measuring fatalities and injuries, (4) Results obtained and, and (5) Disaggregated impacts. In the concluding section that follows, the note discusses the overall trends in the field of performing cost and benefit analysis of DRR measures and offers some recommendations for ways forward.

COMPARATIVE GUIDELINE

The literature on assessing the socio-economics of disaster risk reduction (DRR) in developing countries is an evolving one, and is limited compared to evidence from developed economies. Detailed economic analyses are few (Benson, Twigg and Rossetto 2006), are not comprehensive (Environment Resources Management 2005) and the use of tools such as cost-benefit analysis (CBA) has declined over time (WB and UN, 2011). The studies examined here differ greatly in their inclusion of detail, making it difficult to compare and contrast them along exact dimensions. In order to make a useful comparison, we have identified five broad dimensions and key questions for which we have some information for most of the studies. These are:

1. **Methodology and Metrics:**
   - What is the unit of analysis for the study? For example, are the costs and benefits calculated at the structure, project, community, district or a national level?
   - What is the major economic analysis? For example what does it compute? Benefit-Cost Ratio, Cost-effectiveness Ratio, Net Present Value, Internal Rate of Return, etc.? Or is it a qualitative study that does not quantify the benefits and costs at all?
   - Is more than one option for disaster risk reduction explored? Or is the study focused on a single risk reduction measure? If more than one option has been analyzed, what are they?
   - What are the data used and how is the analysis carried out? How are the risks estimated? Do the analyses look at limited past data to project future losses? Or do they have sufficient established hazard and vulnerability data base to estimate risk?
   - What are the discount rates adopted to estimate the present values of future benefits and costs?
2. **Sources of uncertainty:** What are the sources of uncertainty? How have the issues of uncertainty been handled?
3. **Measuring fatalities and injuries:** Have the fatalities and injuries been considered in measuring losses? If so how have they been evaluated?
4. **Results obtained:** What results have been obtained? Do the results suggest cost-effectiveness of the DRR measure explored?
5. **Disaggregated analysis:** To what extent are the distributional aspects of disaster risk reduction benefits and costs analyzed? In other words have the cost and benefits been disaggregated for different socio- economic groups such as on the poor, women and children?

ANALYSIS

This section summarizes the case-studies along the above dimensions. **Table 1**, **Table 2** and **Table 3** provide the summary. Of the seventeen disaster cases that were examined, eight are from Asia and Pacific (Fiji, India, Indonesia, Philippines, Taipei City), four are from the Caribbean (Dominica, Jamaica), two from Eastern Europe (Romania, Turkey) and three from South America (Argentina, Bogota City/Colombia, Peru). Hazard wise these studies deal with floods (Argentina, Fiji, India, Indonesia, Peru, Philippines and Romania), hurricane/typhoon/cyclone (Dominica, India, Jamaica, Vietnam), and earthquakes (Bogota City Istanbul, and Taipei City).

1. Methodology and Metrics

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[4] The selection of the 16 studies does not represent a scientific sample, and are a simple compilation of CBA studies. Additional 3 studies have been included that discuss disaggregated impacts.

Units of analysis

Seven of the studies take structures as the units on which to report the cost-benefit metric. Thus Pereira (1995) reports the incremental cost of mitigation measure for different types of buildings in Jamaica while Ghesquiere et al (2006) present the analysis for different structure types (schools, hospitals, fire stations, other public buildings) in Bogota, Colombia. Smyth et al (2004a) analyze for various retrofitting measures of buildings in Turkey. Hochrainer-Stigler et al (2010) make the analysis for replacing buildings to reduce flood damage in Uttar Pradesh, India, and for improving flood resilience in buildings vs. elevating property in Jakarta. Vermeiren et al (2004) estimate ex-post the incremental cost of mitigation which would have avoided the damage faced by a Seaport in Jamaica and by a School in Dominica. Two of the studies, flood protection projects in Argentina (World Bank 1996) and Romania (World Bank 2004), analyze the benefits and costs at the project level.

Venton and Venton (2004) analyze the disaster mitigation and prevention programs in Bihar and Andhra Pradesh, India at the village level. Hung and Chen (2007) make their analysis at an administrative unit level for Shihlin district in Taipei City. Dedeurwaerdere (1998) analyzes the benefit and costs for protecting the City of Angels in Philippines against floods and lahars (mud/debris flow), just as Mechler (2005b) analyzes the benefits and costs of protecting the Indonesian city of Semerang from floods, Holland (2008) looks at the benefit and costs of a flood early warning system in Nuava of Fiji. Mechler (2005a) makes the analysis at the river basin level in Piura, Peru and Kay and Wilderspin (2002) analyze the benefits and costs plantation wide in the coastal areas of Vietnam.

Quantitative vs. Qualitative

Sixteen of the studies employ quantitative methods to demonstrate the benefits of the respective mitigation measures carried out. Of these, three studies (Dedeurwaerdere, 1998 for Philippines, Holland 2008 for Fiji and Venton and Venton, 2004 for India) first assess benefits in a qualitative manner using interviews, focus group discussions and archives. As such they employ a mixture of qualitative and quantitative techniques. One study (Thomalla and Schmuck 2004 for India) employs purely qualitative methods.

Metrics

Benefit-Cost Ratio (also Cost-Benefit Ratio in some cases), Internal Rate of Return, Net Present Value[5] are the most commonly computed economic metrics across the quantitative case studies. Four of the studies provide the incremental cost and incremental benefits of the proposed mitigation measures (Pereira 1995 for Jamaica; Kay and Wilderspin 2004 for Vietnam; Vermeiren et al, 2004 for Jamaica and Dominca) while one estimates metrics such as Pure Risk Premium and Probable Maximum Loss (Ghesquiere et al 2006 for Colombia).

Mechler (2005b for Indonesia), Smyth et al (2004a), Ghesquiere et al (2006) for Colombia, The World Bank for Argentina (1996) and Romania (2004), Hochrainer-Stigler et al (2010) for India and Indonesia) generate loss exceedance curves based on past hazard and vulnerability data to estimate losses associated with varying disaster probabilities. Mechler (2005a) considers the approach taken in his Peru study "back-ward looking" because it assesses limited past disaster impacts to get a rougher understanding of flood protection in Peru. This approach is "less rigorous" and "less data-intensive" compared to the approach taken in his Indonesian study which is "forward looking, risk based" (Mechler 2005b) and provides a more rigorous framework because it combines information on historic data on hazard and vulnerability to estimate risk and the risk reduced. Dedeurwaerdere (1998), on the other hand, draws a probability tree-based on past hazard and vulnerability data to estimate the avoided losses from the disaster. Hung and Chen (2007) use available land use maps, surveys and an earthquake loss estimation system (HAZ-Taiwan) to make an earthquake "risk-benefit" analysis.

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[5] Simply put, NPV gives an estimate of the net benefit of a proposal; the internal rate of return describes the discount rate at which the present value of costs equals the present value of benefits; and CBR provides the relative size of the costs compared to benefits. Users should be aware of the specific context of the analysis in interpreting these indicators for decision making.

Options analyzed

Typical to the cost-benefit analysis methodology, several of the studies analyze the "with" and "without" scenario which means that they examine the loss associated with the disaster with the mitigation measure, and without the mitigation measure. Some studies discuss a single mitigation option while some analyze multiple options for DRR. For example, Pereira (1995) investigates ex-post, three mitigation options—bearing wall systems, building frame systems and moment resisting frame systems—that could have potentially prevented the Gilbert (1988) scale hurricane damage on Jamaican buildings. On the other hand, Ghesquiere et al (2006) examine the benefits of retrofitting structures against not retrofitting in Colombia for an earthquake vulnerability reduction program. Smyth et al (2004a) analyze the benefit and cost of various retrofitting options (original, braced, partial and full shear wall). Hung and Chen (2007) in their application of seismic risk-benefit analysis are more focused on examining benefits and costs associated with three hypothetical earthquakes of varying magnitudes and frequencies for different kind of land uses. Holland (2008) examines the "with" and "without" scenario of having an early warning system for floods.

Dedeurwaerdere (1998) examines ex-ante, three options for protecting a Philippino city from the disaster risks of floods/ lahars, namely through watershed restoration by rain forestation, river channel improvements and bamboo plantation. On the other hand The World Bank (2004) explores flood defense projects; large defense projects and small dam safety projects designed to prevent flood disasters in Romania.

Discount Rates

The use of discount rates is aimed at bringing the future benefits and future costs to the present value. Discount rates ranging from 3 to 20% have been used to convert future values to the present value. Dedeurwaerdere (1998) uses a "discretionary" figure of 20%. Leaving aside this outlier, all other discount rates fall between 5% and 12%. Venton and Venton (2004) use 10% for India, based on local lending rates from moneylender and banks. All four of the Mechler (2005a, 2005b) and the World Bank (1996, 2004) studies use 12% as the discount rate. For five of the remaining quantitative studies the discount rate is either not available or not employed.

2. Sources of Uncertainty

Lack of hazard and vulnerability data, difficulty in evaluating indirect losses, and dealing with climate change impacts are cited as major sources of uncertainty in performing the economic analysis for disaster risk reduction measures. Historic data on hazard (magnitude, frequency and duration) and vulnerability are not known in most of the studies which makes it difficult to perform cost-benefit analysis of the DRR measures on hazards of different scale. In this context, sensitivity analysis assists in examining the reliability of the computed metrics. Eight of the cases carry out sensitivity analysis of the results by varying one or more of the following: (i) the discount rate (ii) the benefits (iii) the costs (iv) project start date (v) duration/frequency of hazard, (vi) life of a structure or (vii) a combination of the above. Sensitivity analysis is not available in the other quantitative studies.

In addition, the cases examined fare poorly when it comes to accounting for indirect losses resulting from a disaster, such as losses in terms of business interruptions, reduction in crop yields, reduction in revenue from reduced tourist inflow, losses to livelihoods, losses due to service closures, etc. Finally, what are rarely addressed in the examined cases are the climate change impacts and the uncertainties thereof. Particularly in infrastructure design, climate change-related uncertainty can increase "the probability of either under-adaptation or over-adaptation" (Hallegatte, 2006).

3. Valuation of fatalities and injuries

One of the most contentious issues related to performing economic analysis of disaster risk reduction measures is the value assigned to deaths and injuries. Values running in the millions of dollars have been assigned in studies carried out in the developed country context (for example FEMA assigns US$ 3 million per fatality) while some studies do not take into account fatalities and injuries at all. Three of the studies examined accounted for the fatalities and injuries explicitly. For

Colombia, Ghesquiere et al (2006) use US$ 500,000 per fatality while for India, Venton and Venton (2004) computed the cost using the average daily wage rate—about Rs. 35 (Approx. US$ 0.6 in May 2013 exchange rate) per day. For Peru, Mechler (2005a) used 150,000 sols (Approx. US$ 57,000 in May 2013 exchange rate) per fatality. Three of the studies do mention fatality losses but the value assigned is not available. The remaining nine, including the qualitative studies, do not take into account fatalities. In benefit-cost analyses by Smyth et al. (2004a, 2004b) of earthquake strengthening measures for apartment buildings and schools, none of the strengthening measures considered passes the benefit-cost test unless the value of lives saved is included in the analysis. In the analysis for Istanbul, Turkey two of the strengthening measures pass the benefit cost test when avoided deaths are valued at US$1 million each. In the case of the school building strengthening program, strengthening measures pass the benefit-cost test when lives saved are each valued at US $400,000.

Studies such as by Cropper and Sahin (2009) suggest methods of estimating the value of mortality risk reductions (i.e., of the Value of a Statistical Life or VSL) and the value of avoided injuries associated with disasters in performing DRR CBA analysis for developing countries where often reduced death and injury are not monetized. They provide a literature survey on published VSL values for developing countries and a framework for judging whether these values are appropriate for CBA.

4. Results

All of the studies demonstrate higher benefits of disaster risk reduction measures compared to the costs incurred. For example, the incremental cost of including earthquake resistant features in building design in Jamaica would have been less than 3% compared to the losses that amounted to 2% to 100% (Pereira 1995) of the building costs. Such cost would have been a small 1% of the building costs compared to a benefit of 35-40% for mitigating hurricane disaster of the Gilbert scale in Jamaica (Pereira 1995) had the DRR measures been integrated in the initial building design. Similarly 4.2% of the original construction cost was spent on reconstructing the Seaport from Hurricane David in Dominica in 1979, whereas only an additional 1.9% would have been sufficient to mitigate the losses incurred had it been incorporated into initial reconstruction. Also 40.7 % of the original construction cost was spent in reconstructing a school compared to only an additional 11.5% that would have been sufficient for mitigating the 1988 Gilbert scale hurricane (Vermeiren, Stichter and Wason 2004). Smyth et al (2004a) consider four damage levels associated with damage to an apartment building in Turkey in the event of an earthquake.

In Taipei City, higher losses in industrial, education and commercial type land uses and lower losses in agricultural type land use were predicted by Hung and Chen (2007). Expected average annualized earthquake losses were estimated to decrease by approximately NT$ 1 M (approx. US$ 30,000 in May 2013 values) per year. In Bogota city, Pure Risk Premium was expected to decline from US$ 7.4 per million to US$ 1.5 per million when the buildings are retrofitted (Ghesquiere et al 2006). Similarly Probable Maximum Loss for a 1 in 1000 year earthquake for a retrofitted school would be 4% of the asset value compared to 30% without the retrofits.

An Internal Rate of Return (IRR) was estimated to be between 12% and 79% for the mitigation measures for various subprojects proposed in the Argentina Flood Protection Project carried out by the World Bank (1996). The overall project internal rate of return falls from 20.4% to 7.5% if the project is initiated 5 years later making a case not to delay the project. Dedeurwaerdere (1998) computed a benefit cost ratio of 30 for rain forestation farming, 14.7 for bamboo plantation and 3.5 for river channel improvement for protecting the City of Angeles in the Philippines. Despite the high BCR, the forestation project had the lowest Net Present Value.

In Vietnam, planning and protection of 12,000 hectares of mangroves cost US$ 1.1 million compared to the reduction of dyke maintenance by US$ 7.3 million per year. Deaths reduced to zero and livelihoods if 7750 families were positively affected. In Romania, an IRR between 13% and 31% and a BCR between 1.5 and 4.4 for dam sub-projects, and an IRR between 13.2% and 42.3% and a BCR between 1.1 and 2.1 for the flood defense sub-projects were computed for the Hazard Risk and Emergency Preparedness Project

(World Bank 2004). The overall project had an IRR of 26% and a BCR of 2.2. Venton and Venton (2004) computed for Bihar, India a BCR of 3.8 and a NPV of Rs. 3.7 Million (Approx US$ 100,000) and in Andhra Pradesh a BCR of 13.4 for the respective disaster mitigation and preparedness interventions in the selected villages. Similarly for the Rohini river basin in Uttar Pradesh, Hochrainer-Stigler et al (2010) find that with the commonly used discount rate of 12%, only two of the six measures against flooding appear to have high economic returns (building new mud or brick homes on a plinth); and that it does not pay to build a new house in brick instead of mud if the only benefit is reducing flood.

In Peru, a BCR of 3.8 and an IRR of 1% was computed for flood protection (Mechler 2005a) while in Indonesia, a BCR 2.5 and an IRR of 23% was computed against floods and tidal inundations (Mechler 2005b). Similarly Hochrainer-Stigler et al (2010) find that the results show benefit-cost ratios substantially higher among mixed-wall structures than among masonry ones as flood protection measures, while elevating the property by 1m also has mostly favorable results, with the benefit cost ratios ranging up to 6.7. In Fiji, the early warning system would have a benefit cost ratio of 3.7 to 7.3 at a 10% discount rate for 1 flooding event of a 1 in 20 year return period (Holland 2008).

5. Distributional analysis

A few of the studies make reference to vulnerable groups in their analysis. For example, although briefly, the Romania analysis (World Bank 2004) makes reference to how the vulnerable population are expected to benefit from the proposed projects. Some 124,000 of the 453,364 beneficiaries of flood defense areas were classified as poor and estimated to represent 90% of the most vulnerable groups in Romania. The Venton and Venton (2004) study looks at the impact upon the vulnerable in general and also in relation to how they can be effectively evacuated. The options used by Hochrainer-Stigler et al (2010) for the flood protection measure in the Rohini Basin of Uttar Pradesh, India considers both mud houses and brick houses, thereby making the cost-benefit analysis inclusive of the poor (who generally have mud houses). However none of the studies examined explicitly disaggregate data by various socio-economic groups (by gender, caste-ethnicity, race, able and disabled, etc.) to examine the differential benefits and costs that DRR measures can have upon different groups. Thus, it is not known the extent to which the marginalized/vulnerable groups have been or will be served by the proposed mitigation measures.

Although not directly CBAs, there are researches which explore how different groups are impacted by disasters, which allows us to speculate who would benefit the most from DRR measures. For example, Pradhan et al (2007) examine the risk of mortality due to floods that occurred in 1993 in Southern Nepal. Their examination of over 41,000 children and adults revealed more flood-related deaths amongst girls and women compared to boys and men. They also found flood related-deaths were associated with lower socio-economic status and having a thatched roof.

Similarly in a qualitative study conducted after the 1998 floods, Rashid and Michaud (2000) found adolescent females in Bangladesh, already at a disadvantage due to cultural restrictions, to be even more vulnerable and at a greater disadvantage in a post- flood environment. Lack of latrines and private places translated to them not being able to remain "secluded" as is expected by societal norms, which in turn added to their stress. Also, Winchester's (2000) statistical analysis for South India shows that having an established income and asset base are important variables in reducing one's vulnerability to disasters. Such income and asset base enables them to earn "social and economic credit worthiness" in the local economy.

DISCUSSION AND CONCLUSION

This survey of case studies on benefits and costs of DRR reveals three trends. First, there is now endorsement that investing in DRR is equally—if not more—necessary than post-disaster operations. In all the cases analyzed, DRR measures provided higher benefits than costs incurred which reinforces the message that governments, donors and development agencies need to intensify their efforts towards, and increase investments in risk reduction. The consensus is that there are high economic and social returns of DRR actions—both by

DRR projects on their own or when integrated with development projects. It must be noted here that despite the strategic shift towards ex-ante risk reduction, it is estimated that only about 3.5% of total international development assistance was allocated for disaster-related activities during the period 1991-2010, and of that only about an eighth on disaster prevention and preparedness (GFDRR and ODA, 2013).

Second, there is some degree of ambivalence about the appropriateness of the commonly-employed cost-benefit analysis (CBA) method to analyze costs and benefits of DRR. That is, the CBA is prone to "critical limitations" (Moench, Mechler and Stapleton 2007), the true benefit-cost ratio is never known (Dedeurwaerdere 1998), and the results appear dependent on parameters on which there is no consensus (Hallegate et al 2012). The key limitations are: difficulty in monetizing the intangible benefits; the need to make too many assumptions regarding hazard and vulnerability; lack of historical hazard data to predict loss in a probabilistic manner; discretionary discounting of future costs to present values, etc.

The cost-benefit analyses presented are based on real cost savings or monetary benefits, and are found to be inadequate when it comes to assessing benefits of an intangible nature. Many of the studies have avoided counting for the reduced fatalities and indirect benefits which are social in nature. This limits the true cost-benefit analysis as the results obtained does not take into account the full range of costs and benefits associated with the DRR activities.

The wide variation found in the methodologies, assumptions, discount rates and sensitivity analysis suggest that economic analysis of DRR measures is highly context sensitive. Following Mechler's (2005) classification, many of the cases examined adopt a "backward looking, impact-based" approach. In the absence of reliable historical hazard and vulnerability data, it is difficult to perform cost-benefit analysis in a probabilistic manner or in a "forward looking, risk-based manner". Most of the cost-benefit studies acknowledge that data on hazard and vulnerability is limited. This is a big challenge faced by the DRR community in conducting comprehensive economic studies of proposed DRR measures. Investing in data collection on hazard and vulnerability is a necessary first step to perform a sound economic analysis.

The question that arises next, however, is whether more data collection would address the "deep uncertainties" related to highly complex phenomena such as climate change, mega-disasters, uncontrolled urbanization, changes in land-use patterns, and unprecedented decline/growth in population. Uncertainty then poses a bigger challenge to performing CBAs, only part of which can be resolved by improving data. Hallegatte and Przyluski (2010) argue that uncertainties in costing disasters come both from insufficient data and inadequate methodologies. While some uncertainties arise from our inability to fully assess indirect losses, others arise from differences in values and preferences (such as in the use of discount rates, valuation of human life) which can be measured in a consensual way. Cropper and Sahin (2009) note that death and injury are often not monetized for developing country context, and suggest methods for estimating the value of mortality risk reductions (i.e., of the Value of a Statistical Life or VSL) and the value of avoided injuries associated with disasters in performing DRR CBA in such context.

The limitations in terms of monetizing the intangible benefits, the need to make assumptions regarding hazard and vulnerability, lack of historical hazard data to predict loss in a probabilistic manner, and the need to account for uncertainty in making sound DRR investment decisions are well reflected in the case studies examined here. Despite these limitations, the CBA tool remains powerful (Dedeurwaerdere 1998, Mechler 2005, Venton and Venton 2004), provides good evidence for analyzing the benefits and costs of DRR and are useful when "issues are complex and there are several competing proposals" (World Bank and UN, 2011). Indeed, irrespective of the limitations, the CBA is more useful as a process in itself than outcome (Hallegate et al 2012; Kull et al 2013) where stakeholders, if enabled, can participate in sharing information and opinion, observing what constitutes benefits or costs and how the results are achieved.

Given the limitations, the analysis suggests that there is a need to develop clear protocols and guidelines as to what constitutes reliable CBA of DRR interventions, taking into account the development in the field thus far. Such guidelines should make recommendations on executing each step of the CBA—option identification, stakeholder identification and consultation, costs and benefit estimates over a period of time, choice of discount rate, computing net present value of project options, performing sensitivity analysis, and offering recommendations—as it applies to DRR interventions. Related to this, alternative ways of weighing costs and benefits need to be explored and used to handle "deep uncertainties". One such approach is the Robust Decision Making (RDM) methodology which was developed by RAND Corporation over the last decade and has been employed in areas of water management, renewable energy and flood risk management, amongst others. The RDM methodology - rather than predicting a best-estimate future- iterates models to "determine how plans perform in a range of plausible futures", and thereby help decision makers "identify conditions under which their plans will perform well or poorly" (RAND 2013).

Finally, most of the analyses we examined do not look into the distributional aspects of DRR costs and benefits. That is, to what extent DRR interventions benefit differentially the socially and economically vulnerable—such as the poor, women, children, the old, disabled and people of disadvantaged caste/ethnicity—needs more research. Conventional CBA focus on overall returns and not how costs and benefits are distributed (Kull et al 2013) and whether CBAs can appropriately capture distributional impacts is a contested issue, in particular if different weights can be attributed to different group of people to account for distributional impacts. There are differing views on this topic, for example, Joahnsson-Stenman (2005) argues that it is difficult to defend both the proposition that distributional concerns should always be used in CBA, and that they should never be used. Increased research in this direction would enhance not only our ability to understand who benefits from DRR measures and how resources can be used to benefit those most vulnerable to disasters, but also what critical roles DRR interventions can play in reducing poverty, and prioritizing measures to be taken.

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Table 1: Economic Studies of Disaster Risk Reduction

SN	Title of Research	Year	Disaster type	Country
1	Costs and Benefits of Disaster in the Construction Industry (Pereira)	1995	Hurricane/Earthquake	Jamaica
2	Staff Appraisal Report Argentina Flood Protection Project (LAC, The World Bank)	1996	Floods	Argentina
3	Application of the Selected Cost-Benefit Model to Natural Disaster Management Case-Study of Floods/Lahars in the Pampanga Region (Dedeurwaerdere)	1998	Floods/Lahar	Philippines
4	Mangrove Planting Saves Life and Money in Viet Nam (Kay and Wilderspin /IFRCRCS)	2002	Typhoon (Wukong)	Vietnam
5	Costs and Benefits of Hazard Mitigation for Building and Infrastructure Development: A Case Study in Small Island Developing States (Vermeiren, Stichter and Wason)	2004	Hurricane (David), 1979	Dominica
6	Costs and Benefits of Hazard Mitigation for Building and Infrastructure Development: A Case Study in Small Island Developing States (Vermeiren, Stichter and Wason)	2004	Hurricane (Gilbert), 1988	Jamaica
7	Project Appraisal Document for a Hazard Risk Mitigation and Emergency Preparedness Project: Economic Analysis of Flood Risk Reduction Investments (ECA, The World Bank)	2004	Floods	Romania
8	Disaster Preparedness Programs in India-A cost Benefit Analysis (Venton and Venton)	2004	Floods (Bihar); Floods/droughts (AP)	India
9	“We All Knew that a Cyclone was Coming”: Disaster Preparedness and the Cyclone of 1999 in Orissa, India (Thomalla and Schmuck)	2004	Cyclones	India
10	Probabilistic Benefit-Cost Analysis for Earthquake Damage Mitigation: Evaluating Measures for Apartment Houses in Turkey. (Smyth et al)	2004	Earthquake	Turkey
11	Case Study Piura, Peru, Cost-benefit Analysis of Natural Disaster Risk Management in Developing Countries (Mechler)	2005	Floods	Peru
12	Case Study Semarang, Indonesia, Cost-benefit Analysis of Natural Disaster Risk Management in Developing Countries (Mechler)	2005	Floods and tidal inundation	Indonesia
13	Earthquake Vulnerability Reduction Program in Colombia: A Probabilistic Cost Benefit Analysis (Ghesquiere, Jamin and Mahul)	2006	Earthquake	Colombia
14	The Application of Seismic Risk-Benefit Analysis to Land Use Planning in Taipei City (Hung and Chen)	2007	Earthquake	Taiwan
15	An Economic Analysis of Flood Warning in Navua, Fiji (Holand)	2010	Flood	Fiji
16	The Costs and Benefits of Reducing Risk from Natural Hazards to Residential Structures in Developing Countries (Hochrainer-Stigler et al): Flood Risk in Jakarta	2010	Flood	Indonesia
17	The Costs and Benefits of Reducing Risk from Natural Hazards to Residential Structures in Developing Countries (Hochrainer-Stigler et al): Flood Risk within the Rohini River Basin in Uttar Pradesh	2010	Flood	India

Table 2/1: Economic Study of Disaster Risk Reduction-Metrics, Options, Units, Discount Rate and Fatality Reporting

SN	Research	Year	Metric computed	Options	Unit of Analysis	Discount Rate	Fatality/ injury Reporting
1	Costs and Benefits of Disaster in the Construction Industry (Pereira)	1995	Incremental cost for mitigation measures at the design/ construction stage of the building.	For Earthquake: Bearing wall systems/Building frame systems/ Moment Resisting frame systems. For Hurricane: Alusteel or galvalume sheeting/ Zinc sheeting	Structure	N/A	Not considered
2	Staff Appraisal Report Argentina Flood Protection Project (LAC, The World Bank)	1996	(Economic) Internal Rate of Return, Net Present Value	Benefits computed under conditions with and without the implementation of the subproject.	Project	10%	Not considered
3	Application of the Selected Cost-Benefit Model to Natural Disaster Management Case-Study of Floods/ Lahars in the Pampanga Region (Dedeurwaerdere)	1998	Benefit Cost Ratio, Net Present Value, Cost-effectiveness analysis	Watershed restoration (rain forestation) River channel improvements Bamboo Plantation	City	20%	Not considered
4	Mangrove Planting Saves Life and Money in Viet Nam (Kay and Wilderspin/ IFRCRCS)	2002	Cost Effectiveness	Single option of Mongrove forests discussed.	Plantation	N/A	N/A
5	Costs and Benefits of Hazard Mitigation for Building and Infrastructure Development: A Case Study in Small Island Developing States (Vermeiren, Stichter and Wason)	2004	Incremental cost	Single option of cost of restoration/reconstruction. The question asked: What mitigation measure would have been required during the design and construction of each project, to avoid losses from the particular extreme event that affected the projects?	Structure (Sea Port)	Price inflation per year 7.9%	Not considered
6	Costs and Benefits of Hazard Mitigation for Building and Infrastructure Development: A Case Study in Small Island Developing States (Vermeiren, Stichter and Wason)	2004	Incremental cost	Single option of cost of restoration/reconstruction. The question asked: What mitigation measure would have been required during the design and construction of each project, to avoid losses from the particular extreme event that affected the projects?	Structure (School)	Inflation 7.9%/year	Not considered

Table 2/2: Economic Study of Disaster Risk Reduction-Metrics, Options, Units, Discount Rate and Fatality Reporting

SN	Research	Year	Metric computed	Options	Unit of Analysis	Discount Rate	Fatality/ injury Reporting
7	Project Appraisal Document for a Hazard Risk Mitigation and Emergency Preparedness Project in Romania: Economic Analysis of Flood Risk Reduction Investments (ECA, The World Bank)	2004	Internal Rate of Return, Benefit Cost Ratio	Flood defense projects/ Large dam safety projects/ Small dam safety projects; For Flood defense projects, do nothing alternative/ 5% probability protection/ 1% probability protection; For dam safety do nothing/one-stage rehab/two stage rehab/ complete replacement options analyzed.	Project	N/A	Fatality rate of 1% of affected population expected, but value not estimated
8	Disaster Preparedness Programs in India-A cost Benefit Analysis (Venton and Venton)	2004	Benefit Cost Ratio, Net Present Value, Cost-effectiveness analysis	What would have been the impact of the hazard on the community before the DMP intervention had taken place? What is the impact now that the DMP has taken place?	Community	10%	Rs 35 per day (daily average wage rate)
9	"We All Knew that a Cyclone was Coming": Disaster Preparedness and the Cyclone of 1999 in Orissa, India (Thomalla and Schmuck)	2004	Qualitative	Shelters, early warning	Community	N/A	N/A
10	Probabilistic Benefit-Cost Analysis for Earthquake Damage Mitigation: Evaluating Measures for Apartment Houses in Turkey. (Smyth et al)	2004	Probabilistic Analysis	No retrofit, braced retrofit, partial shear wall retrofit, full shear wall retrofit	Building	3%	$1 to $4 million
11	Case Study Piura, Peru (Cost-benefit Analysis of Natural Disaster Risk Management in Developing Countries) (Mechler)	2005	Net Present Value, Benefit Cost Ratio, Internal Rate of Return	Installing an artificial retention system encircled by a dam in the upstream area (Polder): Case with and without a polder examined; Project life of 30 years. (Other options, namely elevating the existing dikes and creating an exit for Rio Piura to the sea also proposed.)	River basin	12%	150000 Sols per fatality; health injuries not considered

Table 2/3: Economic Study of Disaster Risk Reduction-Metrics, Options, Units, Discount Rate and Fatality Reporting

SN	Research	Year	Metric computed	Options	Unit of Analysis	Discount Rate	Fatality/ injury Reporting
12	Case Study Semarang, Indonesia (Cost-benefit Analysis of Natural Disaster Risk Management in Developing Countries) (Mechler)	2004	Net Present Value, Benefit Cost Ratio, Internal Rate of Return	Integrated management of flooding and water supply; project life of 50 years assumed. (Other options, namely dam protecting harbor and installation of more drainage pumps also proposed.)	City	12%	N/A
13	Earthquake Vulnerability Reduction Program in Colombia: A Probabilistic Cost Benefit Analysis (Ghesquiere, Jamin and Mahul)	2006	Catastrophe Risk Modeling: Probabilistic BCR, Loss Exccedance Curve	Retrofitting structures versus not retrofitting	Structures (Buildings, fire stations, hospitals)	12%	US$ 500000 per fatality
14	The Application of Seismic Risk-Benefit Analysis to Land Use Planning in Taipei City (Hung and Chen)	2007	Risk-benefit ratio calculated to express the level of seismic risk attached to different land use plans.	Benefits and costs associated with three hypothetical earthquakes of different magnitudes, frequency and locations.	Li (basic unit of admin. in Taipei City)	N/A	Four level (severity 1 for minor injuries to severity 4 for instantly killed)
15	An Economic Analysis of Flood Warning in Navua, Fiji (Holand)	2008	Benefit Cost Ratio	Single option	Early Warning system	10%	Not considered
16	The Costs and Benefits of Reducing Risk from Natural Hazards to Residential Structures in Developing Countries (Hochrainer-Stigler et al) :Flood Risk in Jakarta	2010	Benefit Cost Ratio	(1) Improve flood resilience and resistance of the property. (2) Elevate the property by 1 meter.	Structure (building)	5-12%	Not considered
17	The Costs and Benefits of Reducing Risk from Natural Hazards to Residential Structures in Developing Countries (Hochrainer-Stigler et al): Flood Risk within the Rohini River Basin in Uttar Pradesh	2010	Benefit Cost Ratio	Six options of demolishing mud house/brick house and replace it with a mud house/ brick house built on a raised plinth/ replacement in year 1/end of lifetime.	Structure (building)	5-12%	Not considered

Table 3/1: Economic Study of Disaster Risk Reduction-Sensitivity, Data Source, Analysis, Results, Strengths and Limitations

SN	Title of Research	Year	Sensitivity analysis	Data source and analysis	Results	Major strength	Remarks
1	Costs and Benefits of Disaster in the Construction Industry (Pereira)	1995	N/A	Costs for changes in roof detailing understood based on the impacts of Hurricane Gilbert of 1988, and the effect of the specifications on the costs determined; Costs of earthquake resistant cost determined.	The incremental cost for including earthquake resistant features in to the building design usually costs less than 3% compared to 2-100% losses. Such cost is 1% and benefits 35-40% for hurricane mitigation.	Provides evidence in favor of making buildings earthquake and hurricane resistant.	Indirect losses not taken into account.
2	Staff Appraisal Report Argentina Flood Protection Project (LAC, The World Bank)	1996	Discount rate 8-12%; Cost increased by contingency amount; Benefits increased by the indirect benefit amount; Project delayed by 5 years; and Additional analysis using a mathematical model.	Historical flood data used for flood risk analysis; Actual damage costs calculated in probabilistic terms for various water levels through modeling and using GIS; Only direct costs (in terms of rehabilitation costs) computed, indirect costs not considered; Project life of 50 years;	Subproject IERRs between 12% and 79%; When project delayed, NPV estimated at $510M, $478M and $ 449M for a discount rate of 8%, 10% and 12% respectively; IERR falls to 7.5% when project delayed by 5 years--Provides a case for not to postpone the project.	May provide useful guidelines for similar analysis.	Loss calculation does not include losses due to employment, fatality.
3	Application of the Selected Cost-Benefit Model to Natural Disaster Management Case-Study of Floods/ Lahars in the Pampanga Region (Dedeurwaerdere)	1998	Not carried out	Probability based, modified Asian Social Institute Model; Data on natural disasters, damage estimates and current indicators collected through key development agencies. Uses a probability tree. Loss Exceedance curve	BCR Rain forestation farming: 30 Bamboo Plantation: 14.7 River channel improvement: 3.5 NPV higher for forestation.	Develops a simple probability tree for hazard occurrence and the losses avoided based on historic data.	Assumes availability of composite hazard and vulnerability data;Analysis hindered because of lack of data and/ or ambiguous/ inconsistent data.

Table 3/2: Economic Study of Disaster Risk Reduction-Sensitivity, Data Source, Analysis, Results, Strengths and Limitations

SN	Title of Research	Year	Sensitivity analysis	Data source and analysis	Results	Major strength	Remarks
4	Mangrove Planting Saves Life and Money in Viet Nam (Kay and Wilderspin/ IFRCRCS)	2002	N/A	N/A	Planning and protection of 12000 hectares of mangroves has cost US$ 1.1 million compared to reduce the maintenance by US$ 7.3 million per year; No lives lost; Submerged, coastal forests act as buffers against the sea, high devastating waves broken to harmless ripples.		
5	Costs and Benefits of Hazard Mitigation for Building and Infrastructure Development: A Case Study in Small Island Developing States (Vermeiren, Stichter and Wason)	2004	N/A	Damage assessment carried out post David; designs completed for repair and reconstruction work necessary to make port functional; Mitigation costs estimated for additional structural and nonstructural elements to resist "David- force" winds.	4.2% of the original construction cost was spent on reconstruction, whereas only additional 1.9% would have been sufficient to mitigate the losses incurred; Failure was due to use of incorrect or inadequate hazard information during design, and pressure on designers to maintain lowest possible costs.	Provides evidence for benefits of making structures resistant to hurricanes; Shows importance of analyzing correct and full hazard data during design.	Indirect losses not taken into account
6	Costs and Benefits of Hazard Mitigation for Building and Infrastructure Development: A Case Study in Small Island Developing States (Vermeiren, Stichter and Wason)	2004	N/A	Damage assessment carried out post David; designs completed for repair and reconstruction work necessary to make port functional; Mitigation costs estimated for additional structural and nonstructural elements to resist "David- force" winds.	40.7 % of the original construction cost spent on reconstruction, but only additional 11.5% would have been sufficient to mitigate the losses incurred	Provides evidence for benefits of making structures resistant to hurricanes; Shows importance of analyzing correct and full hazard data during design.	Indirect losses not taken into account

Table 3/3: Economic Study of Disaster Risk Reduction-Sensitivity, Data Source, Analysis, Results, Strengths and Limitations

SN	Title of Research	Year	Sensitivity analysis	Data source and analysis	Results	Major strength	Remarks
7	Project Appraisal Document for a Hazard Risk Mitigation and Emergency Preparedness Project in Romania: Economic Analysis of Flood Risk Reduction Investments (ECA, The World Bank)	2004	Project cost increased by 20%; Benefits reduced by 20%	Flood damage curves determined by detailed field surveys; Indirect benefits estimated as 50% of direct benefits; Incremental economic costs of the project derived from the financial costs by adjusting for taxes, credits and interests during construction, and shadow pricing forex. These costs include environmental costs and other costs such as land acquisition.	IRR between 16% and 31% for dam projects; IRR between 18% and42% and a BCR between 1.1and 1.5; Chosen subprojects represent good economic returns.	Makes a brief analysis by poor and non- poor people; Different probability alternatives analyzed.	Loss calculation does not include losses due to employment, fatality
8	Disaster Preparedness Programs in India-A cost Benefit Analysis (Venton and Venton)	2004	Discount rate varied between 5% and 15%. Drought and flood period per year also varied.	FGD using Participatory Disaster Risk Assessment Methodologies in non-DMP and DMP villages; Triangulation with village records; local experienced NGO's help; Natural, physical, human, social and economic impacts assessed at the micro/internal level.	Provides evidence for benefits of making structures resistant to hurricanes; Shows importance of analyzing correct and full hazard data during design.	Most vulnerable identified to ensure effective evacuation; Mixture of qualitative and quantitative; Beneficiaries involved.	Lessons learnt: Need for robust data, need for baseline data, weakness of FGD because it raises expectations.
9	"We All Knew that a Cyclone was Coming": Disaster Preparedness and the Cyclone of 1999 in Orissa, India (Thomalla and Schmuck)	2004	N/A	Rapid appraisals, interviews, information from media	Community based strategies such as Disaster Risk Committees, information dissemination, shelters effective for improving disaster preparedness.	Provides tool to make rapid appraisals of benefits and costs in the absence of quantitative data.	Need for verifying the benefits and costs quantitatively.

Table 3/4: Economic Study of Disaster Risk Reduction-Sensitivity, Data Source, Analysis, Results, Strengths and Limitations

SN	Title of Research	Year	Sensitivity analysis	Data source and analysis	Results	Major strength	Remarks
10	Probabilistic Benefit-Cost Analysis for Earthquake Damage Mitigation: Evaluating Measures for Apartment Houses in Turkey. (Smyth et al)	2004	Uses 3% discount rate but shows how to determine max discount rate for which mitigation will be most cost-effective	Fragility curves established analytically	None of the strengthening measures considered passes the benefit-cost test unless the value of lives saved is included in the analysis.	Importance of counting for fatalities is well demonstrated.	
11	Case Study Piura, Peru (Cost- benefit Analysis of Natural Disaster Risk Management in Developing Countries) (Mechler)	2005	Discount rate varied to 0% and 20%;Costs increased ad hoc to 30%; Not taking account of loss of life; Not taking account of indirect effects; Not taking account of increases in hazard exposure.	Past data at two time points on damages, vulnerability and hazard used to assess risk; Risks determined with and without mitigation options; Project life of 30 years assumed.	Base case: NPV 268M Soles, BCR 3.8, IRR 31%; Project remains economically viable in all other scenarios.	Detailed stepwise case study for Cost Benefit Analysis	Hazard recurrence based on two time points only; Additional benefits (eg irrigation) not quantified; Damages for larger region scaled down for the study.
12	Case Study Semarang, Indonesia (Cost-benefit Analysis of Natural Disaster Risk Management in Developing Countries) (Mechler)	2005	Not taking account increased in hazard exposure; Not taking account of increase of the subsidence problem; Not taking account of both the above (i.e., benefits constant over the life time)	A risk based “forward-looking” approach building on a detailed assessment of hazard and vulnerability. Assessment based on work by BGR/ GTZ, JICA, direct and indirect damages assessed, project life of 50 years assumed.	Base case: NPV 414 Billion, BCR 2.5 and IRR 23%; Project is viable in all other scenarios.	Detailed stepwise case study for Cost Benefit Analysis	Need for verifying the benefits and costs quantitatively.

Table 3/5: Economic Study of Disaster Risk Reduction-Sensitivity, Data Source, Analysis, Results, Strengths and Limitations

SN	Title of Research	Year	Sensitivity analysis	Data source and analysis	Results	Major strength	Remarks
13	Earthquake Vulnerability Reduction Program in Colombia: A Probabilistic Cost Benefit Analysis (Ghesquiere, Jamin and Mahul)	2006	By reducing benefits reduced by up to 40%.	Makes a probability cost benefit analysis. Computes Pure Risk Premium, Probable Maximum Loss, Loss Exceedance Curve.	Pure risk premium expected to decline from US$ 7.4 per million to US$ 1.5 per million when the building is retrofitted; Probable Maximum Loss for a 1 in 1000 year earthquake for a retrofitted school would be 4% of the asset value compared to 30% without the retrofits. Shows that proposed investments are viable.	Expands the standard cost-benefit analysis to capture the uncertainty related to the catastrophic event while conducting cost-benefit analysis.	The model is sophisticated and requires hazard and disaster data.
14	The Application of Seismic Risk-Benefit Analysis to Land Use Planning in Taipei City (Hung and Chen)	2007	N/A	HAZ Taiwan earthquake loss estimation system; Land use maps and surveys; Cluster analysis for vulnerability distribution; OLS regressions.	Higher losses in industrial, education and commercial type land uses Higher loss avoided in agricultural type land use; Expected average annualized earthquake losses is are estimated to decrease by approx. NT $ 1 M per year.	Assist city planners to evaluate appropriateness of their planning decisions and to steer urban growth; Uses risk based approach for decision making in land-use planning.	Haz-Taiwan model is based on census areas and assumes homogenous soil, demography and building-type conditions throughout each Li.
15	An Economic Analysis of Flood Warning in Navua, Fiji	2008	Discount rate (3 to 10%) and flood duration (1 in 10 and 1 in 20 years); worst, most likely and best response (to the warning)	Losses sustained in the 2004 flood are calculated and used to estimate the potential benefits from a flood warning system.	3.7-7.3 (Most likely scenario)		

Table 3/6: Economic Study of Disaster Risk Reduction-Sensitivity, Data Source, Analysis, Results, Strengths and Limitations

SN	Title of Research	Year	Sensitivity analysis	Data source and analysis	Results	Major strength	Remarks
16	The Costs and Benefits of Reducing Risk from Natural Hazards to Residential Structures in Developing Countries (Hochrainer-Stigler et al) :Flood Risk in Jakarta	2010	Discount rate (5to 12%) and life of the structure (10 and 25 years).	Analysis based on approximate flood extent maps and limited depth estimates for two past floods in January/February 2002 and February 2007. Hazard analysis also uses a 30-year monthly rainfall time series, observed at the Jakarta Observatory.	The results show BC ratios substantially higher among mixed wall structures than among masonry ones. Elevating the property by 1m. also has mostly favorable results, with B/C ratios ranging from 0.61 to 6.73.	Addresses 60% of Jakarta's structures.	Community-level protection such as flood defenses or improved drainage systems not considered. Fatality and assets not included in counting losses.
17	The Costs and Benefits of Reducing Risk from Natural Hazards to Residential Structures in Developing Countries (Hochrainer-Stigler et al): Flood Risk within the Rohini River Basin in Uttar Pradesh	2010	Discount rate (5 to 12%) and life of the structure (10 and 25 years).	Analysis based on historical flood data and on a survey of losses from floods; data on housing losses from past floods, namely major floods occurring in 1998 and 2007.	The results show that in all but one case it is not advisable from a benefit-cost perspective to demolish homes and rebuild them on a plinth.	Considers different socio-economic level when considering options (i.e., mud vs. brick house); Case extended by including climate change;	Fatality and assets not included in counting losses.

ENDNOTE

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