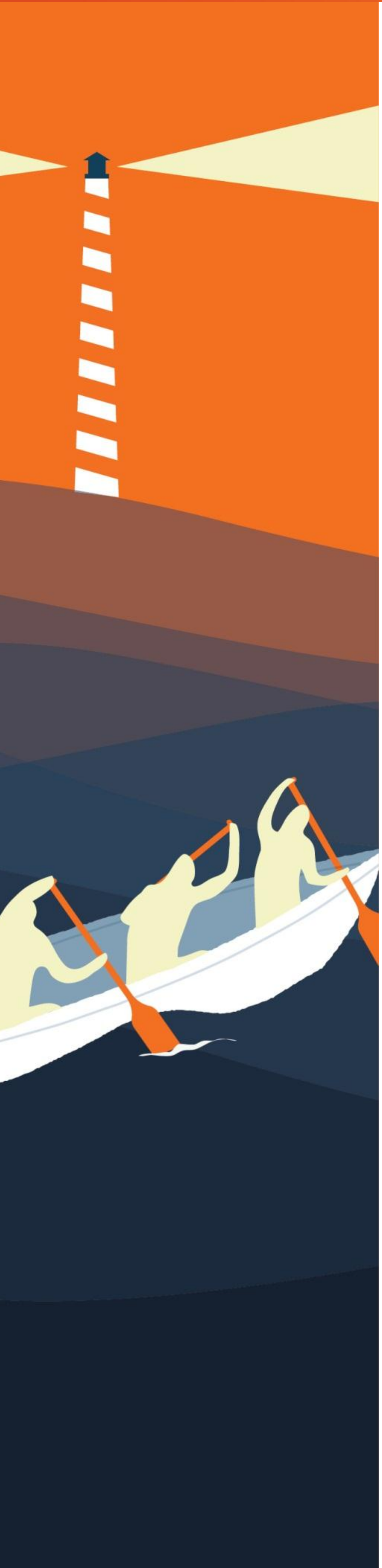
world development report 2014



Background Paper

Benefit-Cost Analysis for Risk Management:
Summary of Selected Examples

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Background paper for the World Development Report 2014

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Introduction

When preparation for risk is poor, or unexpectedly large shocks overwhelm what preparation is in place, the consequences can be devastating. Whether shocks are idiosyncratic or systemic, shocks such as illness, loss of employment, crime, economic crises and natural hazards can cause substantial distress, have large economic costs, and lead to loss of life. Crises are costly. But the measures required to better prepare for shocks are also costly, while the benefits—given people don't know which shocks will occur or when—are often uncertain. So households, firms and policy makers face the question: does it pay off to prepare for possible losses? Or is it better to face the consequences if and when a risk materializes? Benefit-cost analyses provide one means of trying to evaluate these questions.

Weighing benefits against costs

At the center of any cost-effectiveness calculation are estimates of the likely costs and benefits of an intervention. Many studies attempt to calculate the total cost of an intervention by estimating the direct costs of an intervention in a particular area and then extrapolating across time or geographical area. These cost estimates are then compared to the benefits of preparation should a shock occur. The direct benefits of preparation usually include averted loss of life or disability, and averted material damages. Some indirect benefits—such as improved productivity when illness is averted—may also be relevant, but most studies focus more narrowly on direct benefits alone.[1] Many studies provide a range of estimates, based on more pessimistic (or optimistic) assumptions.

Whether an intervention is ultimately considered cost-effective depends on several other factors—most notably, the probability of a shock occurring. Intuitively, large shocks that are very likely to occur are the ones for which preparation is most worthwhile.[2] Some studies estimate the costs that

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1 See, for example, Ozawa and others 2012 for a systematic review of the cost-effectiveness of vaccination, which includes a discussion on the proportion of studies that consider direct versus indirect benefits of vaccination. Poulos and others 2004 show how taking social costs and benefits into account (over and above public sector costs and savings alone) can substantially change conclusions about whether given programs are cost-effective.

2 By contrast, low-probability high-impact events are potentially the most difficult to evaluate. An intervention may be cost-effective on average because it is highly beneficial when high-impact events do

risk management can help to avert based on the average annual cost of a given shock historically (including average number of lives lost per year and so on). By rooting their calculations in average historical data, these studies implicitly take into account how frequently shocks occur. Other studies take the probability of shocks into account more explicitly—comparing the actual cost of an intervention to the potential benefit should a shock occur, weighted by the probability of that shock occurring. In studies that take this approach, interventions typically appear more cost-effective as the time horizon is lengthened and the occurrence of shocks thus become more likely. It is thus appropriate for the time horizon of benefit-cost analyses to match the time horizon of the intervention in question; otherwise the benefits are likely to be underestimated.

Authors' choices for key parameters can also affect cost-effectiveness results.[3] Perhaps most importantly, authors must decide on what value to place on an averted death. The Copenhagen Consensus provides a benchmark for the value of averted death that is used in several of the studies discussed below. The agreed Copenhagen Consensus for the value of human life per disability-adjusted life year (DALY) is between $1000 and $5000. Depending on authors' assumptions about life-expectancy, this would translate to value of an averted death at mid-life between $35,000 and $175,000; the value an averted death of a child would be higher.

Since the benefits from risk management accrue in the future, while the costs are often predominantly upfront, authors of benefit-cost analyses must also make a choice of what discount rate to use to weigh (or discount) future costs and benefits. In economic theory, this discount rate reflects how an individual might value consumption today compared to consumption in the future. There is considerable debate, however, about what values to assign the discount rate in practice.[4] Many authors thus provide different sets of calculations corresponding to a variety of values for the discount rate.

There are a number of other factors that could influence whether a particular project makes sense to a particular decision maker—including how risk averse they are, whether they are credit constrained, the likely distributional impact of a project, or the political context in which risk management decisions must be considered. However, such factors are typically not taken into account in most benefit-cost analyses.[5] This underscores a fundamental tension of benefit-cost analyses: while they

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occur, even if it is not cost-effective for most no or low-impact scenarios. See Ghesquiere, Jamin and Mahul 2006 for an illustrative discussion in the case of earthquakes in Colombia.

[3] See Kenny 2012 for a thorough discussion of how variations in underlying assumptions can influence the results of benefit-cost analysis.

[4] For policies that have inter- (as well as intra-) generational effects, there is also a debate about whether the value of the discount rate should decline over time, to reflect increasing uncertainty about costs and benefits that affect generations further out in the future. See Arrow and others 2012 for a full discussion.

[5] The Arrow-Lind Theorem demonstrates that risk aversion can be safely ignored for public investment projects under certain conditions. These conditions are that: (i) the government initially pays all costs and appropriates all benefits (thereafter distributing net benefits through tax policy), (ii) the net benefits are statistically independent from individuals' income in the absence of a project, and (iii) the net benefits of a

may be necessary to improved decision making that carefully articulates potential benefits and costs, they may not be a sufficient basis for policy decisions. In many cases, benefit-cost analyses could be enriched through careful qualitative discussion of factors that are most difficult to quantify. [6]

Choice of studies

The risks that are relevant for development are many, but cost-effectiveness studies are not available across all categories. Cost-effectiveness studies are most common in categories where the risk-management interventions in question are very specific, and the groups of people who benefit are relatively easy to define. This note focuses on the categories where such studies are most common: nutrition, disease, and natural hazards.

Studies that examine the cost-effectiveness of risk management interventions report their results in a variety of ways. Some studies calculate the net benefit (total benefit less total costs) in local currency or US dollars, while others calculate costs of a program in terms of disability-adjusted life years (DALYs). To aid direct comparison across studies that report results in equivalent units, this note focuses on studies that report their results in terms of a simple benefit-cost ratio, which provides an intuitive way to gauge when the benefits of an intervention exceed the costs (i.e. when the ratio is greater than one). The choice to focus on this sub-set of studies does exclude part of the literature on cost-effectiveness of risk management, but the results are not qualitatively different.[7]

It is clear from the discussion of methodology above that this type of benefit-cost analysis relies substantially on the judgment of the studies' authors regarding the values of underlying assumptions. How then can we trust their results? The selected examples below all provide detailed accounts of their assumptions and calculations; base their calculations on widely accepted benchmarks, where available; and/or have been published in peer-reviewed journals.

Discussion of selected examples

Table 1 below provides detailed summary statistics for the benefit-cost ratio across a range of studies in each category. The minimum and maximum, as well as the mean and median across all studies are provided for each category. There is considerable heterogeneity in the underlying studies: some studies focus only on a given intervention in a specific geographical area, others consider a hypothetical intervention in a number of different countries, and some try to generalize across countries. Thus the minimum and maximum values give a sense of the range in the underlying estimates. Given that the average is skewed by some large benefit-cost estimates in several of the risk

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project are spread over a sufficiently large population (so that each individual's share of the net returns tends to zero). However, risk aversion is often not taken into account, even when these conditions may not hold.

[6] See Arrow and others 1996 and Mechler 2008 for rich discussions of what benefit-cost analyses can offer policy makers, as well as their limitations.

[7] See systematic reviews of benefit-cost analysis in particular categories—for example, Fewtrell and others 2005 for water and sanitation interventions, and Ozawa and others 2012 for vaccinations.

categories, the median gives a sense of the central value across the range of studies. Full details of the estimates from each study are provided in annex A.

Table 1 Benefit-cost ratios for various risk management interventions

estimated benefit-cost ratios	Min	Median	Mean	Max
Early warning systems	0.93	**5.0**	15.7	57.0
Structural measures to limit damage from:				
Earthquakes	0.01	**2.5**	3.1	6.5
Floods	0.01	**5.1**	11.1	60.1
Tropical storms	1.50	**3.4**	5.5	18.6
Improved water & sanitation	1.27	**3.7**	12.1	61.5
Vaccines	0.11	**2.3**	2.5	7.7
Nutritional interventions	1.00	**10.7**	61.1	648.0

Three things are particularly notable in table 1:

First, **the range of values in each area is very large**. For studies that examine a range of interventions in the same context, this variety is likely to reflect the fact that some interventions may be more appropriate or effective than others. Meanwhile, for studies that examine a similar intervention across a range of countries, this variety may reflect differences in the underlying probabilities of shocks occurring and, to some extent, different costs of implementation.[8] For both types of studies, a wide range of values may also arise from the sensitivity of estimates to variations in underlying assumptions.

Second, the **minimum value is very low in some categories**. This is particularly the case for large structural investments aimed at reducing damage from some natural hazards, where the damages if a hazard event takes place can be high but the probability of such an event occurring may be low (such as earthquakes and flooding). It is also the case for interventions that are costly because they require spending on a large number of individuals (such as vaccination programs)—rather than spending in a relatively small at-risk area—or require complementary interventions in order to really be effective.[9] In such cases policy makers may conclude that an intervention is not worthwhile, or may consider an alternative means of preparation for that risk (for example, spending money on preparing key buildings such as hospitals for earthquakes, rather than all buildings, or spending

[8] Interventions that are highly cost-effective in one place may not be somewhere else, highlighting the importance of carefully considering the context of an intervention, rather than assuming it is worthwhile because it has been shown to be cost-effective somewhere elseFor example Kunreuther and Michel-Kerjan 2012 consider a proposal to retrofit all schools in the 35 most seismically active developing countries to make them more robust to earthquakes. For a value of life of $40,000 and a discount rate of 3 per cent, their results vary from a benefit-cost ratio of 0.01 (Argentina) to 4.97 (the Solomon Islands).

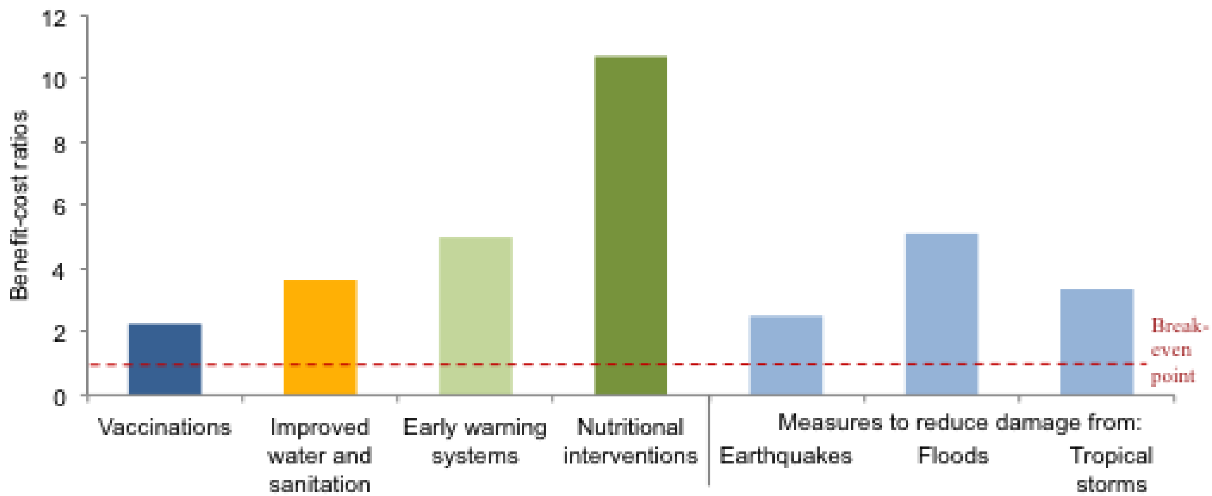
[9] See Jeuland and Whittington 2009, for example, for a discussion of the need for clean-water interventions to complement cholera vaccination programs in order to maximize the probability of being effective.

money on preparing to effectively respond to a shock if it occurs, rather than trying to prevent it from occurring).[10]

Third, **risk management appears cost-effective in all categories, sometimes overwhelmingly so**. This is depicted graphically in figure 1 below (the break-even line depicts the point at which the benefits of a project outweigh the cost). Notwithstanding the large range of estimates and low minimum values in some categories, the median values of estimates are above the break-even point in all categories. In several categories they are considerably higher. In almost all cases even the 25th percentile of the range is above the break-even point.

Figure 1 The benefits of risk management often outweigh the costs

Median across studies in each category



Conclusion

Risk is inherently characterized by uncertainty. This makes it difficult to know—for certain—whether a risk management intervention will ultimately prove worthwhile. Benefit-cost analysis provides one means of identifying the cases in which specific interventions to manage risk do appear to be cost-effective.

This note has summarized the insights from a selected sample of benefit-cost analyses across a range of categories. The range of estimates within each category can be substantial, reflecting a diversity of intervention types and locations, and the sensitivity of estimates to variations in the underlying assumptions. However, while the point estimates may not be exact, they give a good sense of the

10 See Kull and others 2008 for an interesting comparison of behavioral versus structural measures as means of reducing disaster risk.

orders of magnitude involved. Risk management appears cost-effective in many cases, sometimes overwhelmingly so. A regimen of mineral supplements designed to reduce malnutrition and its related health risks, for example, may yield benefits 15 or more times greater than the cost of the program.[11] Similarly, improving early warning systems in developing countries could yield estimated benefits 4 to 36 times greater than the cost.[12] This suggests that preparation for risk often has high returns: although the costs of preparing for risk can be high, the costs that can be averted may be substantially higher.

[11] See Hoddinott, Rosegrant, and Torero 2012.
[12] Hallegatte 2012. Also see Rogers and Tsirkunov 2010 for a broad discussion of the benefits and challenges of benefit-cost analysis for early warning systems.

Annex A

Author	Results
Early warning systems	
Hallegatte 2012	Upgrading early warning capacity in all developing countries: BC ratio 4-36
Holland 2008	EWS for flood risk in Fiji: BC ratio 3.6-7.3
Kull, Mechler and Hochrainer-Stigler 2013	EWS for flood risk in Pakistan: BC ratio 1.6
Subbiah, Bildan and Narasimhan 2008	Case studies on early warning systems: - Bangladesh, Sidr cyclone case study: BC ratio 40.85 - Sri Lanka, May 2003 flooding case study: BC ratio 0.93 - Vietnam, 2001-2007 improved weather forecasting capacity: BC ratio 10.4 - Bangladesh, 2007 flood case study: BC ratio 558.87 - Thailand, 2007 flood case study: BC ratio 1.76
Woodruff 2008	EWS for flood risk in Samoa: BC ratio 1.72-1.92
Measures to limit damage from earthquakes	
Ghesquiere, Jamin and Mahul 2006	Earthquake vulnerability reduction project in Colombia: BC ratio 1.6-2.5
Kunreuther and Michel-Kerjan 2012	Proposal to retro-fit schools to withstand damage from earthquakes (cross-country analysis): BC ratio 0.01-6.45
MMC 2005	Average BC ratio across FEMA earthquake mitigation grants: 2.5
UN and World Bank 2010	Case study on retrofitting homes to prevent damage from earthquakes in Istanbul: BC ratio 4.6
Measures to limit damage from flooding	
Burton and Venton 2009	Case studies on measures to reduce damage from flooding in the Philippines: BC ratio 0.7 (dykes), 4.9 (sea wall), 24 (footbridge)

Kull, Mechler and Hochrainer-Stigler 2013	Structural measures to reduce flooding: - Pakistan: BC ratio 1.3 (floodplain relocation), 1.9 (expressway), 9.3 (retention pond), 8.6 (river improvement), 25 (combined pond and river improvement) - India: BC ratio 1.8 (embankment maintenance)
Kunreuther and Michel-Kerjan 2012	Proposal to reduce damage from flooding (cross-country analysis): BC ratio 14.5 (elevating houses), 60.1 (community wall)
MMC 2005	Average BC ratio across FEMA flood mitigation grants: 5.1
Woodruff 2008	Measures to reduce flooding in Samoa: - Floodwalls: BC ratio 0.11-0.64 - Diversion channel: BC ratio 0.01-0.09 - Flood proofing buildings by increasing floor height: BC ratio 0.53-8.07 (existing homes), 2.22-44.38 (new homes)
UN and World Bank 2010	Case study on flood-proofing a house: BC ratio 3.7 (Jakarta), 5.7 (India)
Measures to limit damage from tropical storms	
Kunreuther and Michel-Kerjan 2012	Proposal to retrofit homes to reduce damage from tropical storms (cross-country study): BC ratio 2-18.6
MMC 2005	Average BC ratio across FEMA wind mitigation grants: 4.7
UN and World Bank 2010	Case study on hurricane-proofing a house in St Lucia: BC ratio 1.5
Improved water and sanitation	
Hutton and Haller 2004	Health benefits from various interventions to improve water and sanitation, across WHO developing sub-regions: - Halving proportion of people without access to improved water sources: BC ratio 5.24-28.3 - Halving proportion of people without access to improved water sources and sanitation services: BC ratio 3.16-34.95 - Universal improved water access and sanitation services: BC ratio 6.55-42.5

	- Universal improved water access and sanitation plus disinfected water at point of use: BC ratio 5.82-61.47 - Universal regulated pipe water and sewage connection: BC ratio 1.27-14.49
Whittington and others 2008	- Provision of deep boreholes and public hand pumps in rural Africa: BC ratio 3.2-3.6 - Campaigns to achieve open-defecation free communities in South Asia: BC ratio 2.7-3.0 - Biosand filters for point-of-use water treatment: BC ratio 2.7-3.1 - Large multipurpose dams in Africa: BC ratio 1.8-3.7
Vaccines	
Jeuland and Whittington 2009	- Community based cholera program: BC ratio 0.11-2.79 - School based cholera program: BC ratio 0.4-7.67
Uzicanin and others 2004	- Measles immunization programs in South Africa: BC ratio 0.73-1.15 (Western Cape), 1.76-3.52 (Mpumalanga).
Zahdi and others 2009	- Hepatitis A vaccination in Brazil: BC ratio 2.26
Nutritional interventions	
Behrman, Alderman and Hoddinott 2004	Nutritional supplements: - Iodine: BC ratio 15-520 - Iron (pregnant mothers): BC ratio 6.1-14 - Iron: BC ratio 176-200 - Vitamin A: BC ratio 4.3-43 Other nutritional interventions: - Breastfeeding campaigns in hospitals: BC ratio 4.8-7.35 - Integrated nutritional childcare programs: BC ratio 9.4-16.2 - Intensive pre-school nutritional programs: BC ratio 1.4-2.9
Horton, Alderman and Rivera 2008	Nutritional supplements: - Iodine (salt iodization): BC ratio 12-30 - Iron fortification: BC ratio 7-8 Other nutritional interventions: - Package of measures that is highly effective at reducing mortality (including vitamin A

	supplementation and breast-feeding promotion): BC ratio 30-250 - Package of measures that is effective at reducing mortality (including iron supplementation for pregnant women, therapeutic use of zinc for diarrhea, biofortification and community-based nutrition education): BC ratio 6-50 - De-worming 2.4-6
Rajkumer, Guakler and Tilahun 2012	- Targeted supplementary food: BC ratio 1 - Treatment of severe malnutrition: BC ratio 2 - Iodized salt fortified with iron: BC ratio 3 - Zinc children 6-24 months old: BC ratio 3 - Iron and folate: BC ratio 8 (pregnant women), 24 (children 6-24 months) - Vitamin A supplements: BC ratio 13 - Community health promotion of optimal breastfeeding: BC ratio: 27 - Deworming: BC ratio 62 (all), 648 (pregnant women) - Iodine: BC ratio 81 (salt fortification), 110 (iodated oil), 486 (iodated oil, pregnant women)

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