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*Integrating Mitigation With Risk-Transfer Instruments**

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INTRODUCTION

This chapter is motivated by the following question: what are the financial benefits to national governments by encouraging or requiring property owners to invest in cost-effective mitigation measures? By *financial benefits* we mean the reduction in expenditures incurred by the government to protect itself against the catastrophic losses following a future natural disaster.[1] By a *cost-effective mitigation measure* we mean one in which the discounted expected benefits over the life of the property exceed the discounted expected costs.

Studies on the rationale for mitigation have focused primarily on the benefits to the individual property owner of investing in loss-reduction measures. Limited attention has been given to the added benefits to the public sector in reducing its vulnerability. Yet this is a major problem facing emerging economies that are subject to the whims of nature in the form of floods, hurricanes/typhoons and earthquakes.

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International institutions, such as the World Bank, have an interest in promoting cost-effective mitigation measures to reduce the damage to property and infrastructure after a major catastrophe. The ProVention Consortium, a global coalition of governments, international organisations, academic institutions, private-sector and civil-society organisations, was formed to reduce disaster risk in developing countries, and make disaster prevention and mitigation an integral part of development efforts.[2] The international institutions associated with the ProVention Consortium, such as the World Bank, can play a key role in providing economic incentives for governments to promote cost-effective mitigation measures.

This chapter is organised as follows. The next section defines what we mean by cost-effective mitigation by specifying the benefits, costs and relevant trade-offs that need to be considered in evaluating different measures. The following section focuses on how mitigation can be combined with risk-transfer instruments to aid national governments in their disaster planning efforts. These concepts are illustrated in the section that follows, with a case study of how the government of Turkey can protect itself against the catastrophic damage from future earthquakes. We then suggest ways that international institutions, such as the World Bank, can promote the adoption of cost-effective mitigation in emerging economies by linking these measures with risk-transfer instruments. The concluding section suggests directions for future research.

DEFINING COST-EFFECTIVE MITIGATION

In this chapter we define a mitigation measure to mean an upfront investment that reduces losses from a future disaster or catastrophic accident. Mitigation measures can be undertaken on property (eg, homes and businesses) as well as on infrastructure (eg, electricity lifelines, water supply).

Benefits from mitigation

There are a number of benefits that accrue from mitigation, which may justify the investment cost. We will illustrate these points using earthquakes as an example; however, the concepts are very general and apply to protective measures against technological

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accidents (eg, avoiding another Bhopal or *Exxon Valdez* accident). They include the following elements:

- *Reducing direct losses*. This refers to physical damage to a structure or infrastructure caused by the disaster or accident as well as the loss of lives or injuries that might have been avoided had a mitigation measure been put in place. For example, bracing the cripple wall and bolting the structure to the foundation to reduce damage and save lives following an earthquake.
- *Reducing indirect losses*. This refers to longer-term losses that could have been avoided had a mitigation measure been put in place. For example, there will be costs to relocate residents who are forced to leave their apartments if their building is severely damaged. These expenses would not be incurred if the structure had been retrofitted so as to withstand damage from the earthquake. With respect to firms, business interruption costs could have been avoided if the property withstood damage from a disaster. There are also other costs such as emotional stress from having to relocate to another facility, which are also included in the definition of indirect losses. (see Heinz Center, 2001).
- *Reducing losses to neighbouring structures*. If there are interdependencies between units, then mitigation measures have an even more powerful impact on the reduction of losses. To illustrate, if a mitigated building collapses and damages another building that would have been left standing otherwise, then this is an additional benefit from mitigation. A similar interdependency exists between a region's infrastructure and the impact on residents and businesses served by these lifelines. By investing in mitigation measures to reduce the risks associated with infrastructure damage one can avoid the consequences of a disruption in electricity and provision of water. (see Kunreuther, 2003).
- *Reducing financial costs from catastrophic losses*. One of the less appreciated benefits of mitigation is the reduction in catastrophic losses from a disaster, and hence a reduction in the costs incurred by the public sector for financial protection. In the case of Turkey, the Turkish Catastrophe Insurance Pool (TCIP) was established after the 1999 earthquake to cover damage to

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residential property after future disasters. The government-backed insurer felt a need to purchase reinsurance to protect itself against the significant insurance payments that would have to be made following a large-scale disaster. If all of the residential buildings were designed or retrofitted to meet building codes there would be a considerable saving in these financial costs.

Discounting future benefits

A mitigation measure normally yields benefits over a relatively long time period. Hence it is necessary to discount these expected savings so as to determine the net present value (NPV) of the investment. If the government is evaluating the mitigation measure, then it is appropriate to convert future benefits to the present by using the social discount rate (SDR). The SDR is the rate at which analysts should discount the benefits and costs of a project. In practice, the SDR is often set for analysts by a government oversight agency such as the Congressional Budget Office in the United States (see Boardman *et al*, 2001).

A key question that needs to be addressed is what discount rate to utilise. There has been a lively debate between economists in recent years about the appropriate SDR to use in evaluating alternative projects undertaken by the government. There is now widespread agreement that the real rate of social time preference should be used, as detailed by Bradford (1975), unless the project is large enough to affect interest rates in the capital market. In the analysis that follows we will utilise a constant SDR so that the same discount rate is used to evaluate costs and benefits between years t and $t + 1$ for any value of t.[3] A proposal by the US Panel on Cost-Effectiveness in Health and Medicine recommends the use of a 3% real SDR for cost-effectiveness studies with sensitivity analysis at rates between 0% and 7%. (see Weinstein *et al*, 1996).

Evaluating trade-offs between benefits and costs

To determine whether a particular mitigation measure is cost-effective, one computes the expected benefits over the life of the investment with its expected cost. To be more precise, suppose that a particular mitigation measure yields expected benefits of $E(B_t)$ for a particular structure in period t. If the structure is estimated to

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endure for T years and the social discount rate is d, then the discounted expected benefits (B*)

$$B^* = \sum_{t=1}^{T} E(B_t) / (1+d)^t$$

Assume that the cost of mitigation (C) is incurred in period 0 and that there are no ongoing expenses associated with the measure over time. In other words, if an apartment building is retrofitted to withstand shaking from a severe earthquake, there are no maintenance or other costs after the measure is put in place. In this case the net present value (NPV) of investing in mitigation is simply NPV = $B^* - C$. Whenever NPV > 0, then the measure will be deemed cost-effective.

ROLE OF RISK-TRANSFER INSTRUMENTS

Risk-transfer instruments complement mitigation measures in that they provide funds to the victims of a disaster to aid the recovery process. The most basic risk-transfer instrument is *insurance*, where the policyholder pays a small premium in return for claim payments from the insurer should he or she suffer losses from a disaster. When a government-backed insurer provides insurance protection to potential victims, as in the case of Turkey, then one needs to examine the linkage between mitigation and insurance at two levels: the individual policyholder and the governmental unit providing coverage (eg, TCIP in Turkey).

Individual policyholder

An individual who purchases insurance would like to be rewarded with a premium reduction to reflect the lower risk of losses from investing in a mitigation measure. To see the linkage between these two policy instruments, suppose that there is a probability p that an earthquake will occur in Istanbul next year and will cause damage to an unmitigated apartment building of L liras. If a mitigation measure is put in place, then suppose the damage is reduced to $L' < L$ lira.

If an insurance policy with premiums based on risk had been purchased to cover the entire loss should a disaster occur, then

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the building owner would expect to pay pL for coverage prior to mitigation and pL' should mitigation be instituted. Assume that the probability of an earthquake and the damage to the apartment building remains constant over time. The discounted insurance premium savings (I*) from mitigation over the life of the apartment building is

$$I^* = \sum_{t=1}^{T} p\,(L - L')\,/\,(1+d)^t$$

If a building owner made the above calculation, they would always voluntarily invest in mitigation if $I^* > C$. In other words, the discounted premium reduction exceeds the upfront cost of mitigation.

In reality individuals do not make decisions regarding discounted savings according to this rational model of choice. Residents and businesses located in hazard-prone areas frequently misperceive the risks that they face by underestimating the chances of the disaster and do not think about the resulting consequences. Hence they will not consider either investing in mitigation measures or purchasing insurance. Individuals may have relatively short time horizons over which they want to recoup the cost of their investment in a protective measure. Even if the expected life of the apartment building is 25 or 30 years, the owner may only look at the potential benefits from reducing the risk over the next 3 to 5 years. The need for a quick return is also consistent with having a high discount rate regarding future payoffs (Kunreuther, 1996).

Property owners with budget constraints are likely to be reluctant to incur the upfront costs associated with protective measures because they feel they cannot afford these expenditures. Individuals may also have little interest in investing in protection if they believe that they will only be financially responsible for a small portion of their losses should a disaster occur, either because of limited assets (eg, declaring bankruptcy) or anticipation of liberal disaster relief. The above problems are particularly acute in emerging economies, where the poorest people are marginalised from society and forced to live on the most vulnerable land. These people do not have the resources to invest in protective measures.

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Government-backed insurer

A government-backed insurer that provides coverage faces the same problem that an individual property owner does – how to protect itself against a catastrophic loss. Unless it has large reserves to cover all the claim payments, it will want to purchase some type of risk-transfer instrument that can take the form of an indemnity contract or an insurance-linked security, more commonly known as catastrophe bonds or cat bonds.

In this chapter we focus on an indemnity contract, namely an excess-of-loss reinsurance policy. It requires the government-backed insurer to retain a specified level of risk, with the reinsurer agreeing to cover all losses above this amount. In return for this protection, the government-backed insurer pays the reinsurer a premium that reflects the expected loss, as well as a loading factor to cover administrative costs.

As an alternative to an indemnity contract, the government-backed insurer may want to utilise a cat bond to obtain needed funds should a severe disaster occur. A cat bond requires the investor to provide money upfront that will be used by the government if some type of triggering event occurs. In exchange for a high return on investment, the investor faces the possibility of losing either a portion or its entire principal investment. The amount paid to the insurer depends on how the cat bond is constructed and the nature of the disaster. Notably, the insurer does not face any credit risk from the cat bond: the money to pay for the losses is already in hand.[4] Many of the cat bonds issued today are tied to a disaster-severity index (eg, covering damage from a certain earthquake magnitude event within a specified region) rather than to actual losses.[5] Since these parameters are normally independent of actual losses, payments can be made immediately after the disaster occurs.

Risk-transfer instruments have two important roles to play in a country's disaster-management strategy. They provide the government-backed insurer with funds to compensate disaster victims following a catastrophic event. Without this type of financial backup mechanism, a large catastrophic loss may make it impossible for the government to cover all the legitimate claims because of the financial demands placed on it by other recovery needs. This is one reason why countries like Turkey and Honduras have turned to

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the World Bank for relief following a disaster. The purchase of risk-transfer instruments also enables the insurer to increase its capacity for providing more coverage to individuals at risk, because it knows that it will be in a position to cover additional losses given this protection.

Mitigation can reduce the costs of risk-transfer instruments to the insurer in the same way that it reduces the costs of insurance to the individual policyholder. When one adds up the reduction in damage to each individual structure if all of them were required to adopt mitigation measures, then the reduction in catastrophic losses from a major disaster could be considerable. To see the impact that this will have on payments for risk-transfer protection, we can extend the simple example for a single policyholder to n identical policyholders. Each faces a probability of a severe earthquake of p and a loss reduction from adoption of a mitigation measure of $L - L'$. The reduction in the catastrophic losses from a disaster is now $n(L - L')$. This saving should be reflected in a lower cost to the government-backed insurer of the risk-transfer instrument that it is purchasing.

Role of exceedance probability curve

One of the ways to determine what impact a catastrophic loss would have on the claims payments from a government-backed insurance programme is to construct an exceedance probability (EP) curve. For a given portfolio of insured structures at risk, an EP curve is a graphical representation of the probability that a certain level of loss will be exceeded within a given time period. Special attention is paid to the "right-hand tail" of this curve, where the largest losses are situated. EP curves can be utilised to determine how much protection the government-backed insurer would like to have in the form of risk-transfer instruments, so that their total claims payments are unlikely to be greater than a pre-specified amount.

Suppose the insurer requires that a specific mitigation measure be adopted on all property in seismically active portions of the country. One can then determine the impact that a loss-reduction measure will have on insurance losses for earthquakes of different magnitudes and intensities by constructing two EP curves – one with and one without a mitigation requirement. Naturally, the EP

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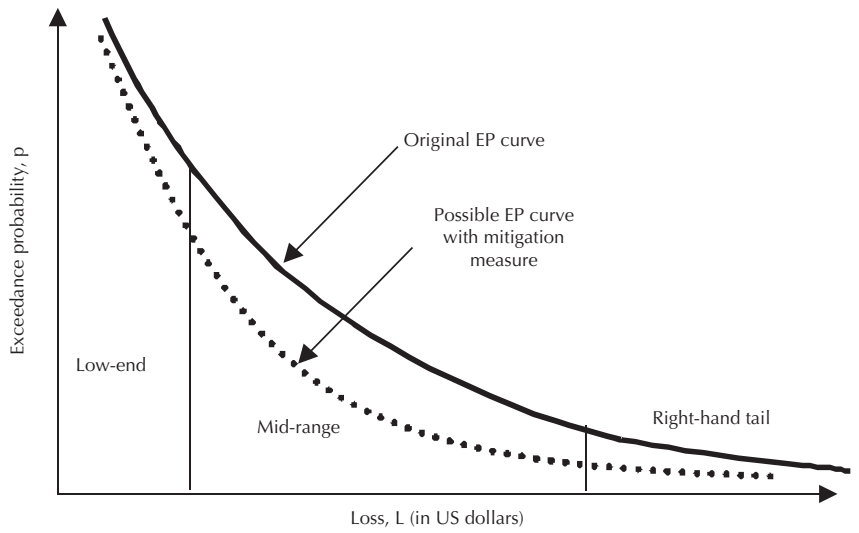
Figure 1 A government insurer's exceedance probability curve



curve if mitigation is required lies below the EP curve when mitigation is not required, as shown in Figure 1. The net benefits of mitigation measures also depends on the cost of the various risk-bearing and risk-transfer methods.

Two key questions that the insurer can address using an EP curve are:

- what types of mitigation measure are most appropriate for dealing with the hazard(s) that the country faces?
- what risk-transfer mechanisms are appropriate for reducing the magnitude of their claim payments following a major disaster?

APPLYING THESE CONCEPTS TO TURKEY

The city of Istanbul is very likely to experience strong shaking from a large earthquake in the Marmara Sea during the next 30 years (see Parsons *et al*, 2000). Studies undertaken by seismologists in the past few years have revealed that the stress relieved during an earthquake does not simply dissipate, but moves down the fault and concentrates in sites nearby. Hence when the Izmit area, less than 100 kilometres east of Istanbul, experienced a M = 7.4 quake in August 1999, the stress transferred during that shock has raised

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the probability of a severe quake in Istanbul sometime in the coming year from 1.9% to 4.2%. Over the next 30 years these odds are estimated to be 62% (see Stein 2003).[6]

Without preparation and prevention, the people of Istanbul face a high risk of suffering significant losses from earthquake damages, including loss of life. The Greater Metropolitan Municipality is taking steps to address mitigation for critical infrastructure, as well as provide public education concerning non-structural approaches to risk reduction in homes. However, there are no steps in place to address the structural fragility of the city's thousands of residential apartment buildings.

Based on an incomplete engineering inventory, approximately 5,000 of these buildings have been assessed as likely to experience complete structural failure when subjected to strong shaking, risking loss of life of occupants of these buildings. Another class (40,000+) is likely to experience significant structural damage with the potential to cause death or serious injury. Poor performance of buildings in areas east of Istanbul, with similar construction design and quality, was demonstrated in 1999 by two very severe earthquakes (see Smyth *et al*, 2004).

Turkish insurance programme

Following the August 1999 earthquake in the Izmit area, the government created the Turkish Catastrophe Insurance Pool (TCIP) in September 2000.[7] All existing and future privately owned property, except for non-engineered rural housing and fully commercial buildings, is required to contribute to TCIP. As of 14 May 2003, more than 1.9 million insurance policies had been issued in Turkey with 776,755 purchased by Istanbul residents.[8] This makes TCIP, a government-backed insurer, the second largest catastrophe pool in the world.

In order for the TCIP to protect itself against large-claim payouts following a future catastrophic earthquake in the Istanbul area, it has purchased excess-of-loss reinsurance through a consortium organised by Willis/Guy Carpenter. The consortium involves approximately 60 different companies covering different layers of reinsurance with Munich Re as the major stakeholder. During the first year of operations of TCIP there was US$550 million of

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reinsurance and in 2002 there was US$750 million. As of September 2003 there was US$840 million reinsurance and US$900 million of claims-paying capacity in place comprised of commercial reinsurance, the World Bank's contingent line of credit and the TCIP's surplus.[9]

Mitigation of apartment buildings in Istanbul

Gulkan (2001a) has proposed that TCIP take the lead in developing guidelines for encouraging the adoption of mitigation measures for existing structures in Turkey. Linking mitigation guidelines with the TCIP provides an effective leveraging of insurance to promote proper mitigation measures. It would also reduce the cost of both insurance and reinsurance, due to lower expected damage and fewer fatalities. Such a programme builds on concepts discussed in Balamir (2001) and Gulkan (2001b) regarding changes in disaster policy in Turkey with respect to urban and land-use planning.

In Smyth *et al* (2004), a cost-benefit analysis was performed on several seismic retrofitting measures on a common and vulnerable type of reinforced-concrete apartment building in Istanbul. The analysis was performed probabilistically through the development of fragility curves of the structure in its different retrofitted configurations. By incorporating the probabilistic seismic hazard for the region, expected losses were obtained for arbitrary time horizons. By including realistic cost estimates of the retrofitting schemes and costs of direct losses to the building, one can estimate the net present value of the retrofitting measures. Suppose one utilises a social discount rate of 3% and there were 10 lives lost if an unretrofitted apartment building collapsed in a severe earthquake. The analysis shows that the expected benefits of partially retrofitting the structure would exceed the cost of mitigation for any time horizon greater than five years.[10]

Given the cost-effectiveness of retrofitting the specific type of Istanbul apartment examined in Smyth *et al* (2004), we extend the analysis by expanding the universe to 30 buildings, each one assumed to be identical to the prototype structure examined above. In principle, such an analysis can be applied to any number of buildings assuming that appropriate families of fragility curves are available for every building type.

LINKING MITIGATION WITH RISK-TRANSFER INSTRUMENTS

To examine the impact that mitigation has on the cost of operating the TCIP, we assume that each of the 30 apartment buildings valued at US$250,000 is fully insured against earthquake damage.[11] One can then construct exceedance probability (EP) curves for the following two cases:

- none of the 30 apartment buildings is retrofitted.
- all 30 buildings are retrofitted using the braced retrofit solution described in detail in Smyth *et al* (2004). This was the least expensive retrofitting scheme involving the addition of braces at the four corners of the original building, in the exterior bays along both framing directions and throughout the entire height, and would cost approximately US$65,000 per building.

The first step in the construction of the EP curves for the block of 30 buildings considered is to compute the EP curve of a single building. This is accomplished by combining the information of the building's four fragility curves and the annual probability curve for exceeding various peak ground acceleration (PGA) levels in Istanbul (see Smyth *et al*, 2004, for plots of all these curves). Such EP curves are established both for the original unretrofitted building and for the braced retrofit solution.

Once the single-building EP curves are determined, it is straightforward to compute the probability of exceeding a certain level of damage as well as the probability of being between two levels of damage. The values of the latter probabilities are used to determine the probability of a specific "overall damage outcome" of the block of 30 buildings. For example, one outcome might be: 1 building collapses, 2 buildings with major damage, 3 buildings with moderate damage, 9 buildings with minor damage and 15 buildings with no damage. All possible overall damage outcomes for the 30 buildings are considered to establish the EP curves for a one-year time horizon, as plotted in Figure 2.

Suppose now that the TCIP wants to purchase reinsurance to cover losses that exceed US$1,000,000 (the small circles in Figure 2). If the reinsurer bases its premium on the actuarial risk for this coverage, one can utilise the two EP curves in Figure 2 to determine the savings in cost to TCIP from requiring that the 30 apartment buildings be retrofitted. As shown in Figure 2, the actuarial risk

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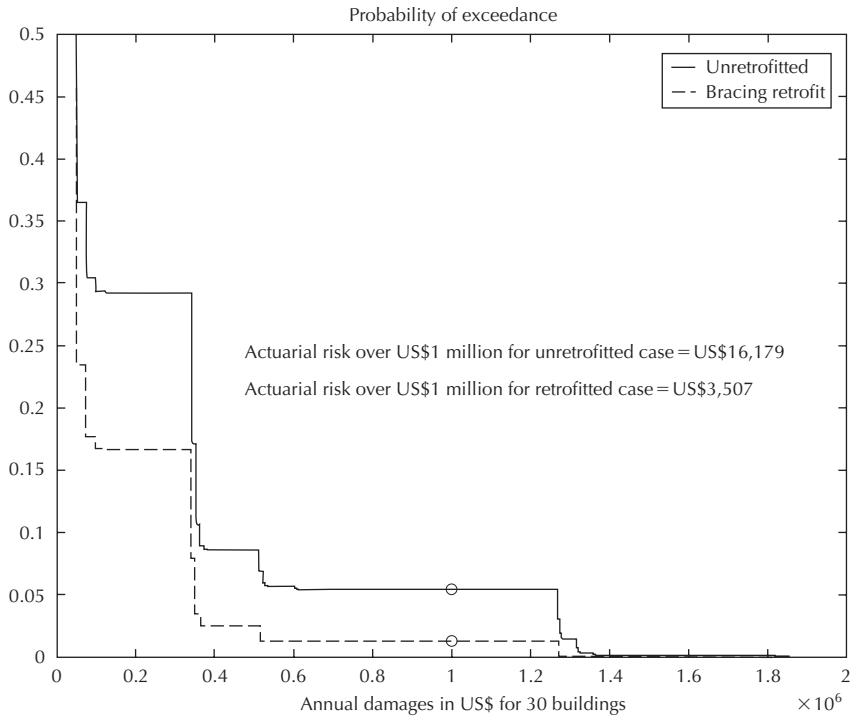
Figure 2 EP curves for block of 30 buildings with and without braced retrofitting



facing a reinsurer if no retrofitting measures are undertaken would be US$16,179; this risk would drop to US$3,507 if all buildings were mitigated with the braced retrofit solution described above. If the reinsurer charged a premium that was 1.5 times its actuarial risk to reflect administrative costs, then TCIP would save 1.5 (US$16,179 − US$3,507) = US$19,008 by requiring all the apartment buildings be retrofitted.

Suppose we now extend the analysis so that we expand the universe of apartment buildings to 1,000 times the block of 30 structures for a total of 30,000 buildings. As an approximation, the above figures would be multiplied by 1,000. In this case the reinsurance cost would be US$24.3 million if none of the apartment units were mitigated and US$5.3 million if all of them were retrofitted. The savings to TCIP in this case would be US$19 million.

ROLE OF INTERNATIONAL INSTITUTIONS

The above analysis suggests that governments like Turkey providing disaster insurance need to consider the benefits from well-enforced building codes that extend beyond the reduction in damage to individual structures. If one incorporates other benefits of mitigation such as a reduction in fatalities, injuries and indirect losses as well as the reduction in reinsurance premiums, then the case for mitigation is made even stronger.

The Turkish example raises a broader set of questions as to the role that international institutions, such as the World Bank, can play in encouraging emerging economies to adopt mitigation measures. They have a stake in promoting cost-effective mitigation measures because it promises to save them considerable expenses that they would otherwise incur following a future disaster. Developed countries also have a financial interest in making sure that emerging economies such as Turkey are on a sound economic footing.

Below, we suggest two ways that the World Bank could aid countries like Turkey in encouraging mitigation measures:

Premium reductions linked with government mitigation loans

If apartment owners are reluctant to incur the upfront cost of mitigation due to budget constraints, then one way to make this measure financially attractive to the property owner is for the World Bank to provide funds for mitigation through some type of long-term loan. To illustrate, a 20-year loan for US$65,000 to strengthen an apartment building at an annual interest rate of 10% would result in payments of US$7,527 per year. If the expected annual reduction in losses was greater than this amount and the insurance premium reflected this, then the insured property owner would have lower total payments by investing in cost-effective mitigation than they would have by not doing so.

There may be reasons to subsidise these loans for poorly constructed buildings occupied by low-income families. These residents may not be able to afford the costs of mitigation measures on their existing structure or the costs of reconstruction should their apartment suffer damage from a natural disaster. Equity considerations argue for providing this group with low-interest loans and grants for the purpose of adopting cost-effective mitigation

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measures or for them to relocate to a safer area. Since low-income victims are likely to receive disaster assistance from the government, subsidising these mitigation measures can also be justified by showing that they reduced expected hazard/disaster-related costs incurred by the government both before and after a disaster.

Issuing catastrophe bonds

The World Bank has the opportunity to complement the role played by private reinsurers today by issuing catastrophe bonds to government-backed insurers to cover some of their losses from catastrophic disasters. For example, in the case of Turkey the World Bank could agree to pay a predetermined amount to TCIP should an earthquake of magnitude 7.0 occur within a prespecified number of kilometres from Istanbul. As a condition for issuing this cat bond, the World Bank could require buildings in high-hazard areas to adopt cost-effective mitigation measures.

There are a number of open questions that need to be examined if the World Bank decides to explore this option:

- what are the prices of these new financial instruments likely to be?
- are there some creative ways one can combine reinsurance with capital market instruments to provide protection to governments in emerging economies against large-scale losses?
- what distribution channels should be used to get financial assistance from these instruments to individuals and communities affected by natural disasters?
- who is responsible for paying the premium on this bond?

CONCLUDING COMMENTS

The above illustrative example for Turkey can be extended to other countries where risk assessments have been undertaken on the likelihood of disasters of different magnitudes and intensities and the resulting consequences with and without mitigation measures in place. The key challenge for future research is to design public–private partnerships for reducing future losses and providing funds for recovery in emerging economies.

There are newly emerging initiatives by international financial institutions that can provide a meaningful platform to reduce the

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staggering losses from natural-hazard events. By combining mitigation, land-use planning, risk-transfer and reconstruction programmes as part of a risk-management strategy, we will have taken a giant step in changing the way we deal with disasters around the world.

1 There are other financial benefits to a national government from mitigation in the form of lower expenditures to aid victims following a disaster.

2 For a description of the objectives and ongoing activities of the ProVention Consortium see http://www.proventionconsortium.org. See Kreimer *et al* (1999) for an illustrative example of a case study under the auspices of the ProVention Consortium on of the use of economic incentives for encouraging earthquake mitigation measures in Mexico.

3 Harvey (1994), Weitzman (1994) and others have suggested that one use a lower discount rate for impacts that occur further in the future. For a detailed discussion of the theoretical and practical issues associated with selecting a social discount rate see Boardman *et al* (2001), Chapter 10.

4 The investor's upfront investment is generally placed in a trust, and paid to the ceding company in the case of a triggering event. This implies that the ceding company reinvest proceeds from cat bond premiums in liquid securities at approximately the risk-free rate.

5 For more details on the structure of recent cat bonds, see Standard & Poor's (2000) and US General Accounting Office (2003).

6 If the shocks were assumed to occur randomly, the odds would be just 20%.

7 For more details on the TCIP and insurance markets in Turkey see Boduroglu (2001) .

8 Personal communication with Polat Gulkan.

9 Personal communications with Eugene Gurenko and Polat Gulkan.

10 The value of a human life was assumed to be US$1 million.

11 In reality the TCIP provides maximum coverage of 20 billion TRL (approximately US$28,000) for each insurance policy (Gulkan, 2001). If there are 10 apartment units in the building, each of which is fully insured against earthquake damage, then the above assumption is realistic.

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