THE FINANCIAL MANAGEMENT OF CATASTROPHIC FLOOD RISKS IN EMERGING ECONOMY COUNTRIES*

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ABSTRACT

This paper examines the potential of pre- and post-disaster instruments for funding disaster response and recovery and for creating incentives for flood loss mitigation in countries with emerging economies. As a concrete case, we discuss the disaster recovery arrangements following the 1997 flood disaster in Poland. We examine the advantages and limitations of *hedging instruments,* which are instruments for transferring the risk to investors either through insurance or capital market-based securities. We compare these mechanisms with *financing instruments* whereby the government sets aside funds prior to a disaster or taps its own funding sources after the event occurs. We show how hedging instruments can be designed to create incentives for the mitigation of damage to public infrastructure using the flood proofing of a water treatment plant on the River Oder in Poland as an illustrative example. We conclude that hedging instruments can be an attractive alternative to the financing instruments that have been traditionally used in developing countries to fund disaster recovery. Since very poor countries are likely to have difficulties in paying the price of protection prior to a disaster, we suggest that international lending institutions consider innovations for subsidizing these payments

1. INTRODUCTION

In the decade 1988-97, floods accounted for over half of the 390,000 recorded fatalities and a third of the damages from all natural catastrophes world-wide (Munich Re, 1998b). Most of the victims were in the developing world, which is typical of natural disasters more generally (Mitchell and Ericksen, 1997). Despite far greater capital stock in the developed world, most of the US$ 233 billion global flood losses over the past decade have also occurred in the developing countries, especially in Asia which claims 65 per cent of flood damages (Munich Re, 1998a).

While the fatalities from flood disasters appear to be declining partly because of improved warning systems, economic damages are rising mainly because of increasing concentration of populations and vulnerable assets in high-risk zones (Loster, 1999). Climate change may also be a factor influencing future flood losses. A warmer atmosphere absorbs more moisture leading to increased precipitation. For example, total precipitation has risen by about 10 per cent in the United States in the period 1910-1995, and the frequency of flooding has also become more severe in many parts of the country (MacDonald, 1998). A Dutch study of the Meuse River predicts that a 2 degree C global temperature increase accompanied by a 10 per cent increase in precipitation would more than double the average damage from flooding to property on the river. (see Tol, et al., 1999). Another factor that may cause increases in damage is the runoff from built property and concrete that may otherwise have been absorbed by the soil.

The purpose of this paper is to examine the potential of pre- and post-disaster instruments for financing disaster response and recovery and for creating incentives for flood loss mitigation in developing and emerging-economy countries. We focus on these countries because of the distinct and serious problems they face in preparing for and responding to major floods and other disasters. Low incomes for most of their residents combined with very limited private insurance have placed the burden of aiding the recovery process of disaster victims primarily in the hands of the government. In addition,

a large share of flood disaster losses in developing countries occurs in the public sector, namely to public buildings and infrastructure, where the impact on the entire economy can be substantial. For example, damage to electricity lifelines for any length of time can cause business interruption losses and lead to the insolvency of some commercial enterprises, not to mention the impact this may have on the residential sectorThe governments of emerging-economy countries are ill prepared to assume the financial costs of flood loss mitigation, response and rehabilitation. After a disaster, governments often experience difficulties in raising funds to assist the recovery process because of political or other constraints on borrowing, taxes, or diverting funds from other domestically or internationally financed projects.. This is particularly true following large-scale disasters where the damage is high relative to the country's gross domestic product (GDP), as with Hurricane Mitch that devastated Honduras in 1998.

There are two principal types of mechanisms available to governments to fund the costs of recovery: *hedging instruments* and *financing instruments.*[1] Hedging instruments are pre-disaster arrangements in which the government incurs a relatively small cost in return for the right to receive a much larger amount of money after a disaster occurs. Since the financial risk of the losses from future disasters is borne by another party, these hedging instruments are also referred to as *ex ante risk transfer mechanisms*. Insurance and capital market-based securities are examples of hedging instruments. The government obtains financial protection after a disaster by either paying a premium for insurance or interest on a capital market-based security.

Financing instruments are arrangements whereby the government either sets aside funds prior to a disaster or taps its own funding sources after the event occurs. An example of a pre-disaster measure is a public catastrophe fund where the government implicitly self-insures by setting aside money to finance some of the recovery needs following a disaster. Alternatively, the government can mobilize its own financing sources by such policy instruments as imposing taxes, borrowing domestically or internationally, or diverting from the public budget.

To make the discussion of these two types of instruments more concrete, in the next section we focus on the impact of the 1997 Polish flood. We then examine in Section 3 the advantages and limitations of hedging instruments and how they compare to more traditional financing instruments. In Section 4, we show how insurance and capital market-based securities can be designed to create incentives for the mitigation of damage to public infrastructure using the flood proofing of a water treatment plant on the River Oder in Poland as an illustrative example. We conclude that hedging instruments can be an attractive alternative to the financing instruments that have been traditionally used in developing countries to fund disaster recovery. Since very poor countries will have difficulties in paying the price of risk-transfer instruments, we suggest that international lending institutions consider innovations for subsidizing these payments

2. FINANCING DISASTER REHABILITATION: THE CASE OF THE 1997 POLISH FLOOD

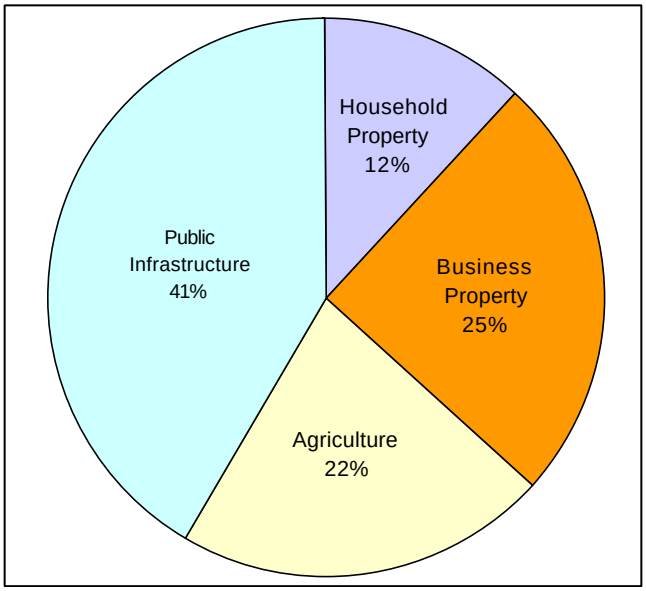
In the summer of 1997, torrential rains caused several major rivers to break through flood dikes and cause disastrous flooding in southwestern Poland, the Czech Republic and the eastern part of Germany. Poland was the hardest hit with over 100 persons losing their lives and thousands left destitute. Precipitation of this magnitude had not occurred in the country in over 1000 years, and the flood was classified as having less than a 1 in 1,000 chance of occurring despite the possibility that climate change may be playing a role in increased precipitation (Munich Re, 1998a).

Direct property damage from the 1997 Polish flood has been estimated at about US$ 3 billion or 2.7 per cent of Poland's GDP (Polish Statistical Bureau, 1998). As shown in Figure 1, these losses were to household property (12%), business property (25%), agriculture (22%) and public buildings and infrastructure (41%) (Polish Statistical Bureau, 1998). These damage figures do not include indirect losses in production and business

[1] This distinction between hedging and financing instruments has been made by Doherty (1997).

disruption, which can be quite significant. In the discussion that follows, we focus on the financial responses of the private and public sectors to overall losses from the Polish flood disaster.

Figure 1. Direct losses from 1997 Polish Flood.



Source: Polish Statistical Bureau, 1998 (adapted)

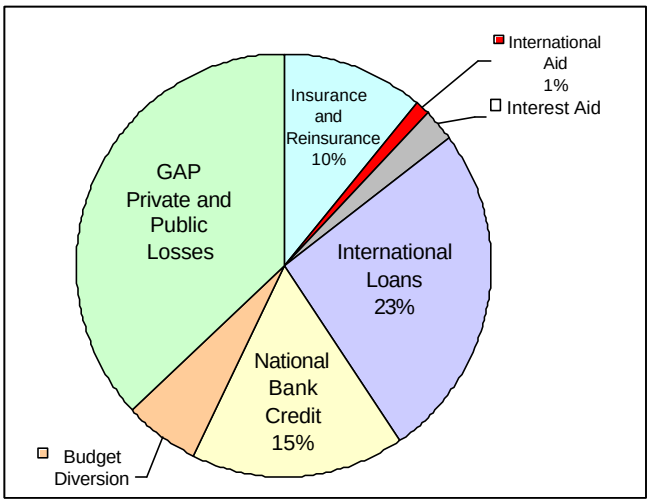
2.1 The Role of the Private Sector

In Poland, a concept of individual responsibility and a viable private insurance market for providing protection is in its infancy. As shown in Figure 2, only about 10 per cent of the losses from the 1997 flood was covered by insurance **(**International Federation of Red Cross and Red Crescent Societies, 1998**)**. Prior to 1997, the Polish General Insurance Company (Powszechny Zaklad Ubezpieczen) was offering an insurance package covering natural disasters, including the flood risk (Kindler, 1999). However this coverage was rather expensive, and most households and firms in the region did not purchase insurance.[2] In Poland, private insurers recorded close to US$ 0.25 billion in claims from

[2] Poland is not an exception in this regard. Globally, only about 8 per cent of flood losses are insured, mainly in countries, such as the United States or France, with public insurance programs. (Swiss Re., 1999)

the 1997 flood. Approximately half of these insurance losses were absorbed by international reinsurers (Swiss Re., 1997).

Figure 2: The 1997 Polish Flood: Response as Percent of Losses



Sources: International Federation of Red Cross and Red Crescent Societies, 1998; Kuc, 1999.

One hindrance to the private insurance market in Poland and throughout much of Europe is the lack of a concept of individual responsibility for the risks and losses. People increasingly expect protection from government against floods and hold the public sector responsible for compensating the victims. Floods are only partially seen as natural disasters or "Acts of God" and are often framed as policy disasters, e.g., failures of effective public policies for prevention and mitigation (Rosenthal, et al., 1998). In Poland, the public viewed the central government as largely responsible for the 1997 flood damage, mainly through its neglect in maintaining the system of dikes and preventing excessive exploitation of the forests (International Federation of Red Cross and Red Crescent Societies, 1998). Indeed, as the Polish flood waters rose, the Prime Minister made a public statement that uninsured victims had only themselves to blame for their financial losses and should not expect government help. This remark raised such a public outcry that the Prime Minister was forced to apologize (Stripple, 1998).

2.2. The Role of the Public Sector

The Polish public budget financed the 1997 post-disaster recovery and rehabilitation in three main ways: emergency response and cleanup; direct compensation or subsidized loans to the victims; and repair of damage to public property and infrastructure (Stripple, 1998). In the summer of 1997, the Polish government responded to the flood with more than a half billion US dollars in flood relief. In addition, there was extensive damage to public buildings and infrastructure - to over 500 schools, more than 3,000 kilometers of roads, around 2,000 kilometers of rail lines, and hundreds of bridges. These damages have been estimated to be close to US $ 1.2 billion or 41 percent of the total direct losses (see Figure 1). A large share of the infrastructure damage was to water and sewage treatment facilities. This underlines the importance of mitigating damage to water treatment facilities, a topic that we will turn to in Section 4.

The Polish government was not prepared for these financial outlays. In the absence of a catastrophe reserve, funds were initially diverted from other budgeted expenses resulting in the freezing of public construction projects **(**International Federation of Red Cross and Red Crescent Societies, 1998**)**. As shown in Figure 2, the central government provided funds to cover approximately 15 per cent of the total losses with a credit from the National Bank. This credit has been repaid at the market rate of interest (Kuc, 1999).

Even after borrowing from the National Bank, the Polish government was not able to fulfill all its promises and obligations for relief and infrastructure repair in a timely manner (Stripple, 1997). For example, it was estimated that due to lack of funds it would be several years before all the roads and bridges were repaired (Swiss Re, 1997). Limited financial assistance was provided from outside the country. For Poland and the Czech Republic, the United Nations Disaster and Humanitarian Aid agency recorded US$ 10.3 million in relief assistance. Assuming that half of this sum was allocated to Poland, this covered only about one per cent of the total direct losses (see Figure 2).[3]

[3] Throughout the developing world, international aid for natural disasters is relatively small. In 1996, for instance, catastrophe aid on the part of OECD countries was considerably less than US$ 3 billion (International Federation of Red Cross and Red Crescent Societies, 1998).

In Poland, aid also came in the form of low-interest loans from other countries, which amounted to about 23 per cent of the losses (see Figure 2). The European Investment Bank and the World Bank each approved US$ 300 million to repair public infrastructure (roads, railways, bridges, and water facilities). In addition, the European Bank for Reconstruction and Development offered ECU 100 million in loans to damaged Polish and Czech cities. (International Federation of Red Cross and Red Crescent Societies, 1998). Since loans are repaid by the future taxpayers in Poland, only the subsidized interest counts as disaster assistance.

With plans to join the European Union, the flood caught Poland in a tight fiscal austerity program. Hence, the central government declared that for the future it would transfer at least partial responsibility for disaster relief to new regional authorities. The second-level administrative authorities (voivodeships) have since been consolidated and given more financial resources. A third-level authority, the district, has been established to link the voivodeships with the communities. These regional authorities may play a more significant role in implementing risk management strategies for dealing with floods and other natural disasters (Makowski, 1999).

2.3. Issues and Questions raised by the Polish Case

In sum, the floods of 1997 in Poland illustrate the important role the Polish government plays in financing relief and rehabilitation after a flood disaster. The reasons for this include: (1) the lack of a concept of private responsibility and little private insurance; (2) the view that reducing the damages from natural disastersand compensating victims are primarily the collective responsibility of the government; (3) the relatively high losses to public buildings and infrastructure from the flood; and, (4) the relatively small contribution of international aid and other forms of international loss spreading.

Individual households or businesses can take steps to prevent losses from floods, such as using water-resistant materials and water-tight closures for doors, windows and

other openings, building new structures at higher levels, or even moving out of flood-prone areas. Few, however, adopt these measures. In Poland, where per capita GDP is only slightly more than four thousand U.S. dollars, the population living in high-risk areas cannot afford even relatively inexpensive measures to retrofit buildings or to relocate out of the floodplain.

The pre- and post-disaster response of the Polish government raises the following general questions regarding the financial risk management of disasters that we will address in the remainder of this paper:

- What are the financial options available for governments to finance disaster recovery?
- What are the advantages and disadvantages of these financial options?
- What equity considerations need to be considered in choosing among these options?
- How can financing options provide positive incentives for the adoption of cost-effective loss mitigation measures?

3. GOVERNMENT OPTIONS FOR FUNDING DISASTER RECOVERY

Some combination of hedging and financing instruments is essential for aiding recovery from disasters in developing and emerging-economy countries. New infusion of capital is needed, given the small amount of private insurance, the limited ability of government to tap its reserves after a disaster and the miniscule amount of international assistance that can be expected (e.g., 1% of total damage in the case of the 1997 Polish floods). Delays in infrastructure repair if recovery funds are not available will increase the length of time of household disruption and business interruption. These indirect costs are likely to greatly exceed the direct losses from the disaster (National Research Council, 1999).

Such delays can also lead to secondary economic effects, such as deterioration in trade and government budget imbalances and increased incidence of poverty (Benson, 1997; Freeman, 1999b). A timely recovery, on the other hand, will positively influence economic growth in the country. Macroeconomic models suggest that disaster shocks and rapid recovery periods following major catastrophes can have a significant positive effect on economic growth in the country (MacKellar, et al., 1999).

Below we briefly discuss the efficiency and equity considerations that distinguish hedging instruments from financing instruments. We then make the case for considering hedging instruments as an important source of funding for future disasters.

3.1 Hedging Instruments

Like a private company, a government can hedge its risk of incurring large capital expenditures for post-disaster response and rehabilitation either by purchasing traditional insurance or issuing insurance-linked securities, such as catastrophe bonds, that can be bought and sold in the capital markets. A catastrophe bond (cat bond) is an instrument whereby the investor receives an above-market return when catastrophes do not occur, but shares the insurer's or government's losses by sacrificing interest or principal when catastrophes do occur. With cat bonds or other capital market instruments, insurers (and governments as insurers) can pay to transfer catastrophe risk to investors.

These relatively new instruments have been made possible mainly because of new scientific studies, engineering analyses and advances in information technology. These developments offer an opportunity to estimate the risks and potential losses of future disasters more accurately than in the past. More sophisticated risk assessments have reduced the uncertainty associated with estimating the probabilities that disasters of different intensities and magnitudes will occur in specific regions. Engineering studies, building on the experience of past disasters, have provided new information on how structures and infrastructures perform under the stress of natural forces. The development of faster and more powerful computers enables one to combine these data in ways that

were impossible even five years ago.[5] The idea that governments in addition to private insurers and reinsurers might benefit from hedging instruments has recently been proposed by Freeman (1999a). Government or sovereign risk-transfer instruments could be designed in much the same way as for insurers. The main benefits of these instruments are that governments avoid having large capital outlays after the event and have a timely source of capital for disaster expenditures. If premium or interest payments are taken from general tax revenues, these hedging instruments spread the flood or other disaster burden to the general tax-paying public. The size of the US capital market alone is in the order of US$ 26 trillion (Insurance Services Office, 1999) and the average annual damage from floods is around US $23 billion (Munich Re, 1998a). Hence these losses could be easily absorbed using these new financial instruments as sources of funds. The efficiency and fairness of these instruments to emerging-economy countries will depend on their cost, how the costs are distributed, and the country's alternatives for raising post-disaster capital. Moreover, the attractiveness of these hedging instruments will increase if they encourage cost-effective measures for reducing the losses from floods and other disasters.

In an ideal world, the wide distribution and diversification of catastrophic risks would result in premiums on insurance contracts or interest on cat bonds that approximate the actuarial contract loss. In practice, the costs of risk transfer are above the actuarial fair price of these instruments. The fair premium does not account for the administrative costs, marketing expenses and risk management services of the insurer/reinsurer. For insurance and cat bonds that are tailored to reflect the specific conditions of the country and the hazard, these costs can be higher than for more routine risks (Insurance Services Office, 1999).

Turning to catastrophic insurance coverage, Froot and O´Connell (1997) contend that the premium is considerably above its actuarially fair price. They attribute this to insufficient capital reserves and the chance of insolvency, less than perfect competition in some markets, ambiguity aversion by the insurer, inefficient underwriting practices,

[5]For more detail on these computer-based models and their opportunities as well as their limitations see Kunreuther and Roth Sr. (1998).

adverse selection, moral hazard, and/or government regulation.[6] Recently, however, the premiums for catastrophic loss coverage offered by the insurance and reinsurance industry have been declining due to the large amounts of funds available for providing protection (Freeman, 1999).

In comparison, the interest premium on catastrophe bonds is higher than the premiums currently charged for catastrophe insurance coverage. An important question for the viability of catastrophe bonds is whether these high costs reflect only a temporary unfamiliarity on the part of investors with this new asset class. Bantwal and Kunreuther (1999) suggest that the high spreads on cat bonds may result from more fundamental issues that need to be resolved before they can play a significant role in transferring catastrophic risks. In particular, they contend that ambiguity aversion, myopic loss aversion, and fixed costs of education can account for the reluctance of institutional investors to enter this market.

If there are further declines in insurance premiums and/or the interest premium on cat bonds decreases, can we expect these hedging instruments to become important for financing public disaster recovery in developing and emerging-economy countries? Like any insurance instrument, this will depend on the degree of risk aversion of the government purchasing the instrument. It will also depend on ttheirrelative attractiveness compared to more conventional financing options.

3.2 Financing Options

The public authorities in emerging-economy countries have several alternatives for financing disaster response and rehabilitation, including a catastrophe tax, a catastrophe reserve fund, government-debt instruments, international bank loans and a diversion of funds from their current budgets.

A catastrophe tax

[6] The insurance premium may reflect additional risk management services that need to be taken into account. We are indebted to Paul Freeman for clarifying this point.

After a disaster, the government can raise funds for disaster rehabilitation with a tax. Like hedging instruments, a tax spreads the costs of the disaster response across the general public. If there is a social consensus that those not affected by the disaster should absorb a portion of the losses, a tax will be considered a fair way of paying the costs. If the public is risk averse and prefers smaller tax payments on a regular basis to the risk of a larger disaster tax, this would be a reason for the government to pay the extra costs for a hedging instrument. A tax also has the disadvantage that there may be large transaction costs to its implementation, and the funds will not be immediately available. For these reasons, in Poland, a tax was considered but rejected following the 1997 floods (International Federation of Red Cross and Red Crescent Societies, 1998).

A catastrophe reserve fund

Many countries maintain a catastrophe reserve fund financed from tax revenues and invested in readily liquid assets. This financing option also spreads the costs among the taxpayers, but it differs importantly from a post-disaster tax. There is an additional cost equal to the foregone return from maintaining liquid funds and an additional benefit in having the funds immediately available. In principle, insurance companies also operate with a reserve to cover large outlays; however, private insurers are more concerned than the government that their reserves are sufficient to avoid insolvency. In the absence of a solvency constraint, the government can assess the comparative attractiveness of a catastrophe fund by weighing the costs of holding liquid reserves in comparison with the costs associated with hedging instruments.

Government debt instruments

A common way for emerging-economy governments to raise funds after a disaster is to borrow from their central bank reserves or to issue government bonds. In Poland, a credit from the National Bank covered 15 per cent of the 1997 flood losses. While the interest on government issued bonds will generally be less than the interest on cat bonds or the premiums on insurance, there are also disadvantages to this form of financing. There may be concerns about transferring the disaster costs in part to future generations who will be burdened by this debt. In addition, issuing bonds or borrowing from central bank

reserves will contribute to the budget deficit. This financing instrument may also transfer a part of the burden to the domestic and international investors in these bonds to the extent that the government defaults on its debt. The bond rating will depend on this default risk, which determines the cost to the government of borrowing funds.

International Loans

Emerging-economy governments also have the opportunity to borrow at low interest rates from international lending organizations. This is a major financing source in the developing world. The World Bank estimates that it has loaned US$ 14 billion over the last two decades to aid developing countries in their natural disaster response and rehabilitation (Freeman, 1999b), and the Asian Development Bank estimates that 5.6 per cent of its loans in the last decade were for this purpose (Arriens and Benson, 1999). In Poland, loans totaling about 22 per cent of the direct losses from the 1997 flood were provided by the World Bank, the European Investment Bank and the European Bank for Reconstruction and Development (International Federation of Red Cross and Red Crescent Societies, 1998).

Of course, the low interest charged on these loans make them a very attractive financing instrument to emerging-economy governments. Through the interest subsidies, a portion of the costs are passed on to the shareholders of the international lending organizations (and eventually the taxpayers from the countries who provide funds to these organizations). Depending on the terms of the loan, the rest of the costs are paid by the present and future taxpayers of the borrowing country.

Budget Diversions

Finally, governments of emerging-economy countries raise money for disaster response and rehabilitation by diverting funds from other budgeted items such as ongoing public infrastructure projects. This was the case in Poland after the 1997 floods , where the

government froze infrastructure projects and used the freed-up funds for disaster recovery. This can be a rational response to a disaster if the marginal value of the funds for disaster response is higher than from its originally intended use. However, there may be hidden costs that are not taken into account, such as he costs of disruption of projects and the longer-term negative signals this sends to the international investment community.

International lending organizations are concerned about this form of disaster financing, since often funds are diverted from infrastructure projects that they are financing. The World Bank estimates, for example, that during the past decade up to 35 per cent of its lending for infrastructure projects in Mexico has been diverted to finance disaster relief (Freeman, 1999b).

3.3. The Case for Hedging Instruments

The relative merits of hedging instruments versus financing instruments willdepend on their costs, the risk aversion of those who absorb the catastrophe losses, and equity considerations. The government should take account of these relative merits in deciding on the appropriate = mix of financing and hedging instruments for covering the costs of future disasters. In making this choice, there are two additional and very important considerations. First, how will the damages from the next disaster be affected by the financing strategy insofar as it gives or does not give incentives for preventing or mitigating losses? This consideration will be the topic of the next section. Second, might there be political or other constraints in implementing financing instruments that greatly limit their applicability for covering disaster losses?

Consider the case in which there are no constraints on financing disaster response. Most developed countries have practically unlimited possibilities for post-disaster borrowing and highly rated bonds, and for this reason the case for governments using hedging instruments as a cost-efficient alternative is greatly diminished. According to a representative of the Austrian Finance Ministry, raising post-disaster funds by issuing highly rated Austrian bonds is less expensive than an ex ante risk-transfer instrument (Eder,

1999). The transaction costs are lower for standard government bond issues, as are the interest rates, since there is little risk to the investors. After a declared catastrophe the Austrian National Bank does not need the approval of the parliament for a budget change, so it can issue these bonds at very short notice. There may still, however, be equity advantages to a hedging instrument, since all the costs are borne by present-day citizens rather than by future generations.

The situation can be quite different for emerging-economy governments. The higher risk of defaulting on their debt may make it difficult to raise funds especially after a major disaster in the country.[8] More specifically, hedging instruments would be especially important to a country when it suffers severe losses relative to its GDP. With very large damages, such as in the recent case of Honduras, the country will likely require funds for recovery far beyond the capacity of its conventional financing sources. For these "mega" disasters, there are clear advantages to taking steps in advance by purchasing hedging instruments. These instruments not only provide funds that would otherwise be difficult or impossible to raise, but the money is available immediately after a disaster (unless the trigger for the hedging instrument is based on losses from the disaster that may take time to fully estimate). By hedging its losses, the country will be able to accelerate its recovery. There may also be political constraints on government borrowing due to fiscal austerity. This is the case in Poland and other transition-economy countries that are attempting to meet the budgetary requirements for entry into the European Union.

Hedging instruments can also play an important role for national governments to diffuse the responsibility for recovery to the regional or municipal levels if there is a view that those affected by the risk should bear some or all of the financial responsibility for recovery. By requiring these lower levels of government to protect their infrastructure with insurance or to purchase cat bonds, the national government will not have to provide funds for the recovery process in the event of a disaster loss. Otherwise, the political pressure at

[8] This was not the case in Poland, where the default risk on Polish debt as viewed by the investment community did not change significantly following the 1997 flood. One reason for this was that domestic demand for the Polish bonds remained stable after the disaster. (Treacher, 1999).

the local level for federal disaster relief is likely to be too great to resist. If, on the other hand, there is a social ethic that disasters are the responsibility of the general taxpayer, then such requirements for financial protection at the local level would be inappropriate.

Financing instruments may also be difficult or very costly to implement. In some circumstances, for example after the Chernobyl accident, countries have imposed a disaster tax. But politicians are generally reluctant to turn to this often unpopular alternative. A catastrophe reserve fund may be politically more expedient, but there are high costs to holding a large reserve of liquid funds. Finally, budget diversions are not only costly, but they disrupt government planning. Moreover, if the funds are diverted from internationally financed projects, they can diminish investor confidence in the country.

The expense of and constraints on government borrowing after a disaster may be the most compelling reasons for governments to engage in the use of hedging instruments. Yet as pointed out above, governments of emerging-economy governments cannot easily afford the premium on insurance or the interest payments on catastrophe bonds. Organizations that provide loans to developing countries, such as the World Bank, may be able to play an important role here. Specifically, the World Bank could serve as a broker by purchasing these bonds from developing countries at a low interest rate and then issuing them to private investors. This would enable the countries to obtain the bonds at lower cost while protecting the World Bank's investments in these countries. This type of arrangement would reduce the need for the World Bank to provide subsidized disaster assistance, a role it played following the Polish floods of 1997 (International Federation of Red Cross and Red Crescent Societies, 1998). In fact, humanitarian aid may be able to cover most of those losses that are uninsured.

4. LINKING LOSS PREVENTIONWITH INSURANCE AND CATASTROPHE BONDS

As noted above, a critical consideration in deciding on the comparative merits of hedging versus financing instruments is the effect this decision will have on the extent of anticipated damages. This section examines how insurance and catastrophe bonds can be

combined with loss mitigation measures to reduce the overall damages of catastrophic events. We begin our discussion by focusing on a specific mitigation measure----flood proofing a public structure to reduce future flood losses. Floodproofing measures have proven to be highly successful for preventing contact with or entry of flood waters and reducing damages from any water that does permeate the structure.

Floodproofing a structure involves the use of water-tight seals, water resistant materials, water-tight joints, improving the strength of walls against hydrostatic presses, sealants which are impervious to water and water-tight closures for doors, windows and other openings (White and Haas 1975; Thomas, 1994). The structure we will focus on here is a water treatment plant, which provides clean water to residents and business in the surrounding area. Water treatment plants are often located in floodplains so they are near well fields or the surface water that supplies the system. If the plant is flooded then it can have severe impacts on the operation of businesses as well as on the daily lives of residents in the area who rely on water from the plant.

The costs of shutting down a water treatment plant can often be much greater than the repair of the structure itself. For example, the 1993 Mississippi River floods in the United States flooded the Des Moines (Iowa) Water Works plant that serves the city of Des Moines and adjoining communities. The plant was out of operation for 12 days and water was not safe to drink for another 7 days. Businesses and government offices were forced to close because of lack of fire protection; bottled water and portable toilets had to be provided the residents. In fact utility loss resulting from the 1993 Midwest floods was a much more important cause of business closure in Des Moines than direct flood damage. Many businesses in the city had to suspend operations because of the loss of electricity, water, and sewer and waste water services than because of a lack of customers and employee access to the business. (Interagency Floodplain Management Review Committee 1994).

Contaminated water was also a major problem during the 1997 flood in Poland since there was considerable damage to water treatment plants, as pointed out in Section 2.

Health officials broadcast warnings to use only bottled water to the thousands of evacuees returning to their homes, fearing outbreaks of dysentery, hepatitis, salmonella and typhoid. In response, volunteer organizations from Austria and other countries set up temporary water treatment facilities in the stricken areas (International Federation of Red Cross and Red Crescent Societies, 1998).

4.1 Estimating the Costs and Direct Benefits of a Mitigation Measure

In order to determine whether it is worthwhile to undertake a specific mitigation measure one will want to undertake some type of benefit-cost analysis. Consider the decision on whether to floodproof a water treatment plant in the River Oder basin. One first needs to determine the costs associated with a specific set of mitigation measures. These include the relevant materials, person power and time associated with making the plant more flood resistant. It is not easy to estimate these expenditures precisely, so it is useful to put some bounds around the figures to reflect the degree of uncertainty surrounding the estimates. This will enable the government to evaluate the desirability of a particular mitigation measure over a wide variety of assumptions regarding the costs of the project.

Mitigation measures reduce the direct and indirect impacts to the region following a disaster. Both of these effects need to be specified in evaluating the floodproofing of a water treatment plant. In order to undertake such an analysis, it is necessary to assess the flooding of the River Oder. Hydrologists and engineers need to determine the probability that the River Oder will rise to certain levels and estimate the resulting direct damage to the water treatment plant with and without floodproofing. They could then construct a probability-damage matrix such as the one depicted in Table1 below:

Water Treatment Plant

Flood Height of River Oder	Probability of Flood Height	Damage with Flood Proofing	Damage without Flood

			Proofing

Table 1 Probability-Damage Matrix to Water Treatment Plant

If the only losses incurred from flooding were the costs of repairing the water treatment plant, then it would be a relatively simple matter to calculate the expected benefits from the mitigation measure. One would compare the damage to the plant for floods of different heights with and without flood proofing the structure. The reduction in damage associated with each flood height would then be multiplied by the probability of this type of flood occurring. One would then sum all the figures to obtain the expected benefits from flood proofing for any given year.

It is then necessary to consider the number of years that the plant would be operational and discount each future year's benefit to the present time period by using some agreed-upon discount rate. This would enable one to determine the expected discounted benefit of floodproofing the plant. The mitigation measure would be considered attractive if the total costs of floodproofing the water treatment plant were **less** than its expected discounted benefits.

4.2 An Illustrative Example

For simplicity, and without loss of generality, assume that there is only a single type of flood that can occur on the River Oder and that the probability of such an event and the resulting losses are constant over time. We can characterize the problem as to whether the government should mitigate the water treatment plant by defining the following terms:

C = upfront cost of mitigation measure

p = annual probability of flood (e.g. p= 1/100)

L = damage to water treatment plant without flood proofing (e.g. L = 500)

L' = damage to water treatment plant with flood proofing (e.g. L' = 300)

d = annual discount rate (e.g. d =.10)

T = relevant time horizon (e.g. T = 10 years)

The decision as to whether or not to invest in an RMM is determined by comparing the upfront cost of mitigation (C) with the expected discounted benefits [E(B)]. Assume that if a flood occurs on the River Oder within the T year time horizon, the water treatment plant will be restored to its pre-disaster condition and be functional again. Then [E(B)] can be characterized as follows:

$$E(B) \quad \sum_{t=1}^{T} p\,(L - L'))/(1+d)^t \qquad (1)$$

Consider the following simple example using the figures illustrating the notation above. Equation (1) now becomes:

$$E(B) = \sum_{t=1}^{T=10} (1/100)(500-300)/(1.10)^t \qquad (2a)$$

$$E(B) = \sum_{t=1}^{T=10} 2\,/(1.10)^t = 12.3 \qquad (2b)$$

On the average, the mitigation will yield 2 worth of direct expected annual benefits, so that over the ten-year time horizon it will yield total discounted expected benefits of 12.3. If the mitigation measure costs less than 12.3, then it is cost-effective for the government to floodproof the structure based on an analysis of directed expected benefits. If the water treatment plant were expected to last for more than 10 years then E(B) would of course be greater than 12.3.

4.3 Indirect Benefits of Mitigation Measures

Floods and other disasters produce indirect or secondary impacts over time, such as family trauma and social disruption, business interruptions and shortages of critical human

services. These impacts need to be considered in evaluating specific mitigation measures. (Heinz Center, 1999). The costs of some indirect impacts are easy to quantify, such as the expenditures associated with providing bottled water to residents because the water treatment plant was not functioning. Other indirect impacts are less easy to determine and quantify. For example, how do you put a value on the loss of "community" associated with wholesale destruction of neighborhoods, of stress on families due to loss of homes or of fear and anxiety about having another home destroyed in a future flood?

In evaluating the benefits of a specific mitigation measure it is important to consider these indirect effects. Here are a few examples that one will want to take into account when undertaking such an analysis of floodproofing a water treatment plant

- Provisions of bottled water and toilet facilities of those residences that are not able to receive water because the treatment plant has been damaged. The need for these provisions may last for a number of days or weeks so the cost could be extensive. If the water treatment plant were functional because of floodproofing, then this would be an added benefit of investing in this measure.

- If businesses were interrupted because of the damage to the water treatment plant and the lack of fire protection, as in the Midwest floods of 1993, then this would be an additional indirect cost of the flood. Those businesses forced to close have immediate cash flow problems. Employees lose work, and customers who must go elsewhere for goods and services may not return when the business reopens. Other businesses require a certain amount of commercial activity in their geographic area in order to prosper. If a functioning water treatment plant could have prevented some of these business interruptions, then this would be considered an additional benefit of floodproofing.[9]

[9] To the extent that other operations in Poland not affected by the disaster fill in the gap opened up by nonfunctioning businesses, then this is a transfer rather than a loss. If Poland needs to rely on imports from other countries because their own businesses cannot provide goods and services, then this is a loss to Poland.

The above examples illustrate what economists term *externalities* associated with disruption of a particular facility. The damage to the water treatment plant created a set of losses to residents and businesses, specifically because they could not receive pure water. Had the feared outbreak of disease from contaminated water during the Polish floods actually occurred, then the human suffering and deaths, as well as the hospital costs and loss of work time, would have been an additional cost of the damaged water treatment plant.

4.4 Financial Incentives to Encourage Mitigation

As pointed out in Section 2 there are newly formed regional authorities in Poland to implement risk management strategies for natural disasters. There are several reasons why these regional authorities may be reluctant to utilize some of their budget for investing in cost-effective mitigation measures to reduce future flood losses for facilities such as a water treatment plant.

For one thing, the responsible public official may underestimate the risks associated with future floods by assuming that it will not occur over the next few years. Even if he or she correctly perceives the chances of a flood occurring and the resulting damage with and without floodproofing, there may be a tendency to underestimate the aggregate benefits of the mitigation measure by being somewhat myopic in considering the future. For example, if a public official only computes the benefits of floodproofing during his or her term of office, say 5 years, then the mitigation measure may not be seen as cost effective. In the above example, a floodproofing cost of 11 could be justified for a 10 year horizon but not for a 5 year time period. Coupled with short-time horizons, are budget constraints. A regional authority would rather not incur the upfront cost of floodproofing a facility, preferring to allocate these funds to measures that provide immediate benefits to the residents in his or her area, such as constructing a new school or hospital. Finally, there may be a lack of interest in loss prevention measures if the regional authority anticipates disaster assistance from the national government for repairing the facility after a flood.

For these and perhaps other reasons, it may be necessary to develop a set of requirements coupled with financial incentives to encourage the adoption of cost-effective mitigation measures. We will focus here on financial incentives but recognize that a risk management strategy will also need to include well-enforced regulations, such as building codes and land-use regulations.[10]

Role of Insurance

One way to provide funds to the regional authorities to cover the costs of repairing the water treatment plant would be through an insurance policy. However, it may be necessary for the national government to require the purchase of coverage. It is unlikely that the regional authority would voluntarily buy insurance for the same reasons that he or she is reluctant to invest in cost-effective mitigation measures---the funds are perceived to have better uses elsewhere.

If the regional authority is forced to purchase insurance, then this policy tool can be used as an incentive for encouraging him or her to invest in cost-effective mitigation measures. More specifically, if a private insurer were to provide coverage against repairing damage to the water treatment plant, it would base its premium on the figures in the probability-damage matrix specified in Table 1 above.

The example in Section 4.2 illustrates how insurance could be utilized to encourage the regional authority to floodproof a water treatment plant. Assume that an insurer would provide full coverage, so it would pay for repairing the entire damage to the plant if a flood occurred. If the regional authority decided not to floodproof the water treatment plant, then the actuarially fair insurance rate would be determined by multiplying the probability of a flood (i.e., 1/100) by the resulting damage to the plant (i.e., 500). The resulting rate would be 5; if the plant were floodproofed then the actuarially fair premium would be 3 (i.e. 1/100 x 300). This means that the expected annual reduction in damage from investing in mitigation is 1/100 (500-300) = 2. Thus the insurer could reduce its premium for flood

[10] For a more detailed discussion of the role of building codes in developing a risk management strategy for reducing flood losses see Kleindorfer and Kunreuther (1999).

coverage by 2 to reflect the expected annual reduction in claims it would have to pay the government for repairing damage to the water treatment plant.

If the regional authority were faced with budget constraints that made it difficult to incur the upfront costs of mitigation, then the national government could provide it with a long-term loan for covering these costs. For example, if the cost of floodproofing the water treatment plant were 11, then a 20 year loan at an annual interest rate of 10% would require an annual payment of 1.06. The annual premium reduction of 2 for undertaking this mitigation measure would mean that the regional authority would save 0.94 (i.e. 2-1.06) each year. The decision to invest in cost-effective floodproofing would be automatic with required insurance and a long-term loan.

Role of Catastrophe Bonds

As pointed out in Section 3 catastrophe bonds can provide an additional source of funds to aid the recovery effort. They also provide an incentive for the regional authority to engage in loss mitigation measures if the funds for disaster recovery are based on a physical trigger rather than on losses. Additional advantages of a physical rather than a loss trigger are that it is easily verified without long delays and there is no incentive for the government to exaggerate its losses in order to collect more money through the bond (i.e. the index avoids the moral hazard problem).[11]

Suppose that the regional authority knew that if a future flood of the River Oder occurred it would receive a certain amount of zlotys to aid the recovery effort, and this amount would be based on the height of the river. To the extent that damage to public facilities and infrastructure could be reduced through mitigation measures, there would be a lower expenditure on rebuilding these facilities. This would enable the regional authority to

[11] See Croson and Kunreuther (2000) for a more detailed discussion of the advantages and limitations of cat bonds in providing protection against disaster losses.

allocate more money to disaster victims than he or she would have been able to do if the facilities had not been floodproofed.

The important point is that catastrophe bonds and insurance can be coupled with incentives and other regulatory mechanisms to reduce future disaster losses. They decentralize the decision making process to the regional level by providing economic incentives to take steps now in order to save money later.

5. CONCLUSIONS

The governments of developing and emerging-economy countries are largely responsible for flood disaster response and rehabilitation, as well as mitigation of the losses. Yet, they often experience difficulties in providing funds for these purposes. These difficulties can have long-term effects on the economies of these countries and the welfare of the public.

We have compared the relative merits of pre-disaster hedging instruments, such as insurance and catastrophe bonds, with financing instruments such as post-disaster taxes and government borrowing. We have shown that this comparison is multifaceted. It depends on the costs and availability of these instruments, the risk aversion of those who will ultimately absorb the losses, and equity considerations. We were particularly interested in the impact these instruments have on the adoption of disaster loss prevention measures.

The comparative attractiveness of pre-disaster hedging instruments will also depend on the nature of the hazard and the circumstances of the country. With respect to the severe 1997 flooding in Poland there are a number of factors that may constrain the availability of financing alternatives. In particular, post-disaster borrowing was limited by the budget austerity required for Poland's eventual entry into the European Union. Other financing options were also politically difficult, such as imposing a disaster tax, or economically undesirable, such as transferring funds from other budgetary commitments.

Hedging instruments will be particularly important for financing disasters that

comprise a large proportion of the country's GDP since after such events the government will have an extremely difficult time raising sufficient funds from its traditional sources. International lending organizations, such as the World Bank, will feel pressure following these events to provide loans to aid the recovery process, thus diverting funds from other development projects. If the country has insurance or has purchased cat bonds in advance of the disaster, this will channel funds from international capital markets to aiding the recovery effort.

For these reasons alone, hedging instruments such as insurance and catastrophe bonds may be desirable policy options for a country such as Poland to consider. An additional advantage is the economic incentives these instruments can create for preventing losses, thus encouraging regional government authorities to invest in cost-effective mitigation measures.

Poor countries, such as Poland, will have great difficulties in paying the costs of ex ante transfers. Since the World Bank and other lending organizations are concerned about the losses on their investments in these countries by having funds diverted to disaster relief, innovative financing mechanisms to aid these countries might be considered. Helping poor countries to afford these pre-disaster protective measures may not only be desirable on equity grounds, but would avoid having investors depicted as capitalizing on the potential catastrophic losses facing poor countries from future natural disasters.

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