The Financial Management of Catastrophic Flood Risks in Emerging-Economy Countries

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This article 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 or transition 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 hypothetical Topping River as an illustrative example. We conclude that hedging instruments can be an attractive alternative to financing instruments that have been traditionally used in the poorer, emerging-economy countries to fund disaster recovery. Since very poor countries are likely to have difficulty paying the price of protection prior to a disaster, we suggest that international lending institutions consider innovations for subsidizing these payments.

KEY WORDS: Flood; extreme events; disaster financing; mitigation; insurance; catastrophe; risk management

1. INTRODUCTION

This article examines the potential of pre- and post-disaster instruments for creating incentives for flood loss mitigation and for financing disaster response and recovery in emerging economies. We focus on emerging-economy countries and, more specifically, on the transition countries of central and eastern Europe, where Poland serves as an example. These countries face distinct and serious problems 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 investing in loss prevention measures and aiding the recovery process of disaster victims primarily in the hands of the government.

In addition, a large share of flood disaster losses in emerging-economy countries occur 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 sector. The governments of emerging-economy countries are ill prepared to

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assume the financial costs of flood loss mitigation, response, and rehabilitation. After a disaster, these governments often experience difficulty raising funds to assist the recovery process because of fiscal, political, and other constraints on borrowing, taxes, or diverting funds from other domestic budgets 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, which 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*.[3] 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, we focus on the impact of the 1997 Polish flood in the next section. Section 3 then examines 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 hypothetical Topping River as an illustrative example. We conclude that hedging instruments can be an attractive al-

ternative to the financing instruments that have been traditionally used in emerging economies to fund disaster recovery. Since very poor countries will have difficulty 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 more than 100 persons losing their lives and thousands left destitute. 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.[2]

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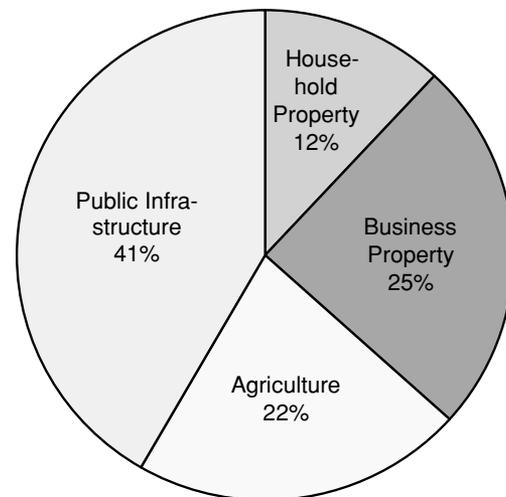
Source: Polish Statistical Bureau[3] (adapted).

Fig. 1. Direct losses from 1997 Polish flood.

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[3] This distinction between hedging and financing instruments has been made by Doherty.[1]
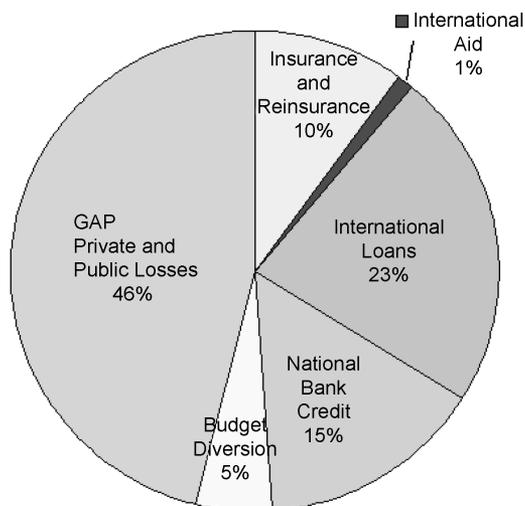
Source: International Federation of Red Cross and Red Crescent Societies[4] and Kuc[5].

Fig. 2. The 1997 Polish flood: response as percent of losses.

2.1. The Role of the Private Sector

Traditionally, the Polish central government has provided relief by compensating victims for their private losses, which has added significantly to the government's post-disaster expenses incurred from repairing or replacing damaged public infrastructure. As Fig. 2 illustrates, the private and public expenses incurred from the 1997 flood were financed by private insurance, international aid and loans, a credit from the national bank, and diversions from other governmental budgets.

This financing, however, did not fully reimburse public and private victims for their property and infrastructure losses. The difference of about 46% of losses that was not covered by donations, insurance, and loans is illustrated in Fig. 2 by the GAP.

In Poland, the concept of individual responsibility and a viable private insurance market for providing protection are in their infancy. As shown in Fig. 2, only about 10% of the losses from the 1997 flood were covered by insurance (International Federation of Red Cross and Red Crescent Societies).[4] Prior to 1997, the Polish General Insurance Company (Powszechny Zaklad Ubezpieczen) was offering an insurance package covering natural disasters, including flood risk.[6] However, this insurance was rather expensive, and most households and firms in the region did not purchase coverage.[4] Private insurers recorded close to

U.S. $0.25 billion in claims from the 1997 flood. Approximately half of these insurance losses were absorbed by international reinsurers.[7]

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, for example, lack of effective public policies for prevention and mitigation.[8] In a recent survey of the Hungarian public, the majority of the respondents viewed the government as primarily responsible for preventing losses from floods, as well as for compensating flood victims for their losses.[9]

Similarly 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.[4] 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.[10]

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.[10] In the summer of 1997, the Polish government responded to the flood with more than half a billion U.S. dollars in private flood relief. In addition, there was extensive damage to public buildings and infrastructure—to more than 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 U.S. $1.2 billion or 41% of the total direct losses (see Fig. 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 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

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4 Poland is not an exception in this regard. Globally, only about 8% of flood losses are insured, mainly in countries, such as the United States or France, with public insurance programs.[11]

public construction projects.[4] As shown in Fig. 2, the central government provided funds to cover approximately 15% of the total losses with a credit from the National Bank. The drawback of financing disaster recovery with this type of credit is that it is potentially inflationary, although in Poland the credit was quickly repaid at the market rate of interest.[5]

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.[10] For example, it was estimated that due to lack of funds it would be several years before all the roads and bridges were repaired.[7] Limited financial assistance was provided from outside the country. For Poland and the Czech Republic, the United Nations Disaster and Humanitarian Aid agency recorded U.S. $10.3 million in relief assistance. Assuming that half of this sum was allocated to Poland, this covered only about 1% of the total direct losses (see Fig. 2).[5]

In Poland, aid in the form of low-interest loans from other countries covered about 23% of the losses (see Fig. 2). The European Investment Bank and the World Bank each approved U.S. $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.[4] Because the future taxpayers in Poland repay loans, only the subsidized interest counts as international 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 in 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.

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 financ-

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[5] 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 U.S. $3 billion.[12]

ing relief and rehabilitation after a flood disaster. The reasons for this include: (1) the lack of a concept of private responsibility and limited availability of private insurance; (2) the view that reducing the damages from natural disasters and compensating victims is 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 U.S. $4,000, 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 in Poland and other emerging-economy countries that we will address in the remainder of this article.

- What are the financial options available for governments to finance disaster recovery?
- What are the advantages and disadvantages, as well as the political constraints, 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

Following the 1997 floods, *ex post* financing did not cover Poland's full losses and there were delays in repairing private homes and businesses, as well as roads, transmission lines, and other critical infrastructure. In poorer emerging-economy countries, these difficulties can be far more severe. In contrast to Poland, these countries' national debt burdens may make it impossible to issue government bonds or turn to other forms of borrowing following a major disaster. Additionally, the tax burden on the public may already be so high that there is no possibility of raising

funds domestically. This makes these countries dependent on subsidized loans and other forms of international aid.

Especially for very poor countries, some combination of hedging and financing instruments may be essential for aiding recovery from disasters. New infusion of capital is needed, given the small amount of private insurance, the limited ability of government to issue more debt or tap its reserves after a disaster, and the usually small amount of voluntary international aid that can be expected. Delays in infrastructure repair if recovery funds are not available will increase the length of household disruption and business interruption. These indirect costs are likely to greatly exceed the direct losses from the disaster.[13]

Such delays can also lead to secondary economic effects, such as deterioration in trade and government budget imbalances and increased incidence of poverty.[14,15] 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.[16]

As we discuss below, the relative merits of hedging instruments versus financing instruments will depend on their costs, the political constraints, the risk aversion of those who absorb the catastrophe losses, and equity considerations. After discussing the characteristics of the different instruments, we examine the case for considering hedging instruments as an additional 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 a specific catastrophe does not occur (e.g., an earthquake of magnitude 7.0 or greater in the vicinity of Tokyo), but shares the insurer's or government's losses by sacrificing interest or principal following the event. With CAT bonds or other capital market instruments, insurers and reinsurers (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 computerized catastrophe models that make it possible to estimate the risks and potential losses of future disasters more accurately than in the past.[6] The idea that governments in addition to private insurers and reinsurers might benefit from new hedging instruments has recently been proposed by Freeman *et al.*[18] Government or sovereign risk-transfer instruments could be designed in much the same way as they are 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 U.S. capital market alone is in the order of U.S. $26 trillion[19] and the average annual damage from floods is around U.S. $23 billion.[2] Hence these losses could be easily absorbed using these new financial instruments as sources of funds. However, these instruments have an associated cost to the risk-ceding government. 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.[19]

With regard to catastrophic insurance coverage, the relationship between the premiums and the actuarially fair price will vary depending on the available funds that insurers and reinsurers have for providing coverage. Several years ago, Froot and O'Connell[20] contended that the premium for catastrophe protection was considerably above its actuarially fair price. They attributed this differential to insufficient capital reserves, imperfect competition in insurance and reinsurance markets, ambiguity aversion by the insurer, inefficient underwriting practices, adverse selection, moral hazard, and/or government regulation.[7] More

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[6] For more detail on these computer-based models and their opportunities, as well as their limitations, see Reference 17.

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

recently, however, the premiums for catastrophic loss coverage offered by the insurance and reinsurance industry declined due to the large amounts of funds available for providing protection. Following the terrorist attacks of September 11 there was increasing concern by the investment community about providing coverage for catastrophic events and the price for this protection has risen; in the case of terrorist coverage, such insurance became unavailable or extraordinarily expensive.[21]

The interest premium on catastrophe bonds also reflects a concern by investors for the uncertainty of the risks associated with catastrophic events. 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[22] 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 emerging-economy countries? Like any insurance instrument, this will depend on the degree of risk aversion of the government purchasing the instrument. This risk aversion, in turn, will depend on how the costs are passed on. If, for example, they are spread across many taxpayers such that no one individual bears significant losses, then in theory the government will be risk neutral. The importance of hedging instruments in the portfolio of a public authority will mainly depend on their relative 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.

3.2.1. Catastrophe Tax

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.[4] Finally, a catastrophe tax is often not possible for the governments of very poor countries since their taxpayers are already at the limit of what they can pay.

3.2.2. 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 with less transaction costs. A major problem with a fund is that it may not be able to supply sufficient funds, especially if the disaster occurs shortly after the fund is created. 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 and for this reason they diversify their insurance portfolio. 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.

3.2.3. 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% of the 1997 flood losses. Although the interest on government-issued bonds will generally be less than the interest on CAT bonds or the premiums on insurance, there are disadvantages to this form of financing. There may be concerns about transferring

the part of the disaster costs 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.

3.2.4. International Loans

Emerging-economy governments 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 U.S. $14 billion over the last two decades to aid developing countries in their natural disaster response and rehabilitation,[15] and the Asian Development Bank estimates that 5.6% of its loans in the last decade were for this purpose.[23] In Poland, loans totaling about 22% 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.[4]

Of course, the low interest charged on these loans makes them a very attractive financing instrument to emerging-economy governments. Through the interest subsidies, a portion of the costs is passed on to the shareholders of the international lending organizations and, eventually, to 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.

3.2.5. Budget Diversions

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 the 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% of its lending for infrastructure projects in Mexico has been diverted to finance disaster relief.[15]

3.3. The Case for Hedging Instruments

The relative merits of hedging instruments versus financing instruments will depend on their costs, the political constraints, 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 contrast to poor countries, most developed country governments have highly rated bonds and practically unlimited possibilities for post-disaster borrowing. For this reason, the case for these 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* hedging instrument.[24] 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 case for hedging instruments for Poland and other emerging-economy countries is not so clear. In a study of risk-transfer instruments for financing flood losses in Poland, Lizak[25] concludes that conventional financing instruments will have lower expected costs to the government. Yet, if a flood predicted to occur once every 100 years should occur early on in that period, the government authorities would incur less costs if they had purchased a CAT bond at the market rate. This study does not take into consideration the constraints the Polish government may have on financing alternatives, for example, the political constraints on government borrowing due to the fiscal

austerity necessary for European Union membership. Yet, even this constraint is flexible as the Maastrich Treaty makes allowance for an exceptional and temporary budget deficit above the specified 3% if it results from an unusual event outside the control of the member state concerned.[8]

The case for hedging instruments is stronger for very poor countries that have difficulty raising funds after a major disaster because of low per capita GDP and an associated high risk of defaulting on their debt.[9] For "mega" disasters in very poor countries, 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.

Turning from the national government to the municipal and regional levels, there may be other considerations regarding the desirability of hedging. For instance, hedging instruments could play an important role for national governments to diffuse the responsibility for recovery to lower-level authorities if there is a view that those affected by the risk should bear some or all of the financial responsibility for recovery. In Hungary, the municipal governments already perceive little assistance from the national government and, for this reason, many authorities have insurance on public infrastructure. In other cases, the national government might lessen its financial responsibility by *requiring* the local or regional authorities to protect their infrastructure with insurance or by the purchase of CAT bonds. Otherwise, the political pressure at the local level for federal disaster relief may 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 unpopular alternative, and the citizens of very poor countries may be at their taxation limit. A catastrophe reserve fund may be politically more expedient, but there are high costs to holding a large reserve of liquid funds and the fund may not have time to accumulate sufficient capital before the disaster occurs. 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 reason for governments to engage in the use of hedging instruments. Yet, as pointed out above, emerging-economy governments cannot easily afford the premium on insurance or the interest payments on catastrophe bonds. Organizations that provide loans to these countries, such as the World Bank, may be able to play an important role here.

To illustrate, the World Bank could serve as a broker by purchasing these bonds from emerging economies at a low interest rate and then issuing them to private investors. This would enable the government to obtain the bonds at lower cost while protecting the World Bank's investments in these countries. This type of arrangement would reduce the World Bank's need to provide subsidized disaster assistance, a role it played following the Polish floods of 1997.[4] In fact, humanitarian aid may be able to cover most of those losses that are uninsured.

4. LINKING LOSS PREVENTION WITH INSURANCE AND CATASTROPHE BONDS

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 hedging instruments in the form of catastrophe bonds can be combined with loss mitigation measures to reduce the overall damages of future disaster. We illustrate these concepts by focusing on a specific mitigation measure—flood-proofing a public structure to reduce future water damage.

Flood-proofing a structure involves the use of water-tight seals, water-resistant materials, water-tight joints, improving the strength of walls against hydrostatic presses, sealants that are impervious to water, and water-tight closures for doors, windows, and other openings.[27,28] Such measures have proven to be highly successful for preventing contact with or

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[8] Council Regulation (EC) No. 1467/97 of July 7, 1997, Article 104s(2).

[9] 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.[26]

entry of flood waters and reducing damages from any water that does permeate the structure.

The structure we will focus on here is a water-treatment plant that 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, this 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 seven 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 wastewater services than because of a lack of customers and employee access to the business.[29] Contaminated water was also a major problem during the 1997 flood in Poland because there was considerable damage to water-treatment plants. Health officials broadcast warnings to the thousands of evacuees returning home that they should use only bottled water, in fear of 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.[4]

4.1. Estimating the Costs and Direct Benefits of a Mitigation Measure

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 flood-proof a water-treatment plant located on the banks of the hypothetical Topping River. 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 generally is not easy to specify

these expenditures precisely, so some upper and lower estimates should be provided to reflect the nature of this uncertainty. The government can then evaluate the desirability of a particular mitigation measure over a realistic range of estimates 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 flood-proofing of a water-treatment plant. To undertake such an analysis, it is necessary to assess the degree of flooding of the Topping River. Hydrologists and engineers need to determine the probability that the Topping River will rise to certain levels and estimate the resulting direct damage to the water-treatment plant with and without flood-proofing. 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 loss-reduction 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 flood-proofing the plant. The mitigation measure would be considered attractive if the total costs of flood-proofing 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 Topping River 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 = up-front 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., $d = 0.10$)
- $T =$ relevant time horizon (e.g., $T = 10$ years)

The decision as to whether to invest in a risk mitigation measure is determined by comparing the up-front cost of mitigation (C) with the expected discounted benefits [E(B)]. Assume that if a flood occurs on the Topping River 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:

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

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 twice the direct expected annual benefits so that over the 10-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 flood-proof the structure based on an analysis of direct expected benefits. If the water-treatment plant were expected to last for more than 10 years, 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.[30] 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. Mitigating damage to water-treatment plants through flood-proofing would reduce the need to provide bottled water and toilet facilities to those residents who are not able to receive water. If a functioning water-treatment plant could have prevented some business interruptions, with the attendant disruptive effects on employees and the social fabric of the community, this would be considered an additional benefit of flood-proofing.[10]

More generally, one needs to take into account the *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.

In the context of the Polish case, had the feared outbreak of disease from contaminated water during the 1997 floods actually occurred, then the human suffering and deaths, as well as the hospital costs and loss of work time, would have been additional costs of the damaged water-treatment plant.

4.4. Financial Incentives to Encourage Mitigation

In most emerging-economy countries, the authority and financing of disaster management is divided between the national, regional, and municipal authorities. In the past, municipalities in many central European countries have been dependent on the national government for their financial base, but this is changing as national governments place more responsibility on lower-level authorities. As pointed out in Section 2, there are newly formed regional authorities in Poland to implement risk management strategies for natural disasters. In Hungary, the 1995 Water Management Act continued state responsibility for operating and maintaining all state-owned structures, such as flood levees, through the 12 regional water authorities, but made local governments responsible for operating and maintaining municipal structures, such as water-treatment facilities.[31]

There are several reasons why these municipal and regional authorities may be reluctant to utilize some of their budget for investing in cost-effective mitigation measures to reduce future flood

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10 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 its own businesses cannot provide goods and services, then this is a loss to Poland.

losses for facilities such as a water-treatment plants. For one thing, the responsible public officials may underestimate the risks associated with a future flood by assuming that it will not occur over the next few years. Even if these authorities correctly perceive the chances of a flood occurring and the resulting damage with and without flood-proofing, they may underestimate the aggregate benefits of the mitigation measure by being myopic. For example, if a public official computes the benefits of flood-proofing only during his or her term of office, say three to five years, the mitigation measure may not be seen as cost effective. In the above example, a flood-proofing cost of 11 could be justified for a 10-year horizon but not for a five-year period.

In addition to short-time horizons, governments face severe budget constraints. A municipal or regional authority may decide not to incur the up-front cost of flood-proofing 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 local or regional authority anticipates disaster assistance from the national government for repairing the facility after a flood.

4.4.1. Role of Insurance

One way to provide post-disaster funds to municipal or regional authorities to cover the costs of repairing water-treatment plants and other public facilities would be through an insurance policy. If these authorities have readily available funds to repair infrastructure after a disaster, they will rationally not purchase insurance at a higher cost to them. Also, if the national governments are prepared to allocate post-disaster funds, which has been the case in many emerging-economy countries, the authorities will have little incentive to purchase insurance. However, with declining national budgets for disaster relief and rehabilitation, many municipal and regional authorities in the emerging-economy countries of central Europe have to depend increasingly on their own financial resources.

It is too early to assess the experience of the Polish regional authorities with regard to their disaster management strategies, including their portfolio of hedging and financing instruments. Taking another example, Hungary, it is notable that most municipal authorities voluntarily carry private insurance on public structures but not on their content. Ideally, the purchase of insurance can become an incentive for the local or regional authority to invest in cost-effective mitigation measures. More specifically, if a private insurer were to provide coverage against repairing damage to a water-treatment plant, it would base its premium on the figures provided by hydrologists and engineers with and without flood-proofing.

To illustrate how insurance could be utilitzed to encourage the flood-proofing of a water-treatment plant, consider again the Polish regional authority and the illustrative example in Section 4.2. Assume that an insurer offers to provide the authority with full coverage, such that it would pay for repairing the entire damage to the plant if a flood occurred. If the regional authority decided not to flood-proof 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) resulting in a premium of 5. If the plant were flood-proofed, then the actuarially fair premium would be 3 (i.e., $1/100 \times 300$). This means the insurer could reduce its premium for flood coverage by a 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 Poland's regional authority were faced with budget constraints that made it difficult to incur the up-front costs of mitigation, then one option is for a commercial bank or an international organization such as the World Bank to provide it with a long-term loan for covering these costs. For example, if the cost of flood-proofing the water-treatment plant was 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 local or regional authority would save 0.94 (i.e., 2 − 1.06) each year. The decision to invest in cost-effective flood-proofing would have to be viewed positively if the authorities carried insurance and could acquire a long-term loan.

4.4.2. 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 local or regional authority to engage in loss-mitigation measures. Suppose in Poland that the regional authority knew that if a future flood of the Topping River 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 when it flooded.

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 allocate more money to disaster victims than in the case where the facilities had not been flood-proofed.

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 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, political constraints, 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. Building on experience from the 1997 flooding in Poland, there are a number of factors that may constrain the availability of financing alternatives in the future. In particular, post-disaster borrowing may be limited by fiscal considerations and the political difficulties of imposing a disaster tax or transferring funds from other budgetary commitments.

Hedging instruments may be particularly important for financing disasters in countries anticipating disasters that comprise a large proportion of their GDP. After such events the governments of poor countries will have an extremely difficult time raising sufficient funds from 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.

An additional advantage of hedging instruments is the economic incentives these instruments can create for preventing losses, thus encouraging municipal and regional government authorities to invest in cost-effective mitigation measures. 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 have focused in this article 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.

Poor countries will have great difficulty 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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