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Hedging Natural Catastrophe Risk in Developing Countries

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1. Introduction

International financial institutions like the World Bank are caught in the grip of two financial forces: the increasing demand from developing countries for borrowing to cope with the costs of natural hazard losses, and stagnant budgets that have not increased with the demand on their resources. The squeeze creates interest on the part of these institutions in the possible use of catastrophe hedges as a tool to provide post-disaster reconstruction financing for developing countries. In particular, the use of capital markets as a mechanism to absorb risk traditionally handled by insurance markets has sparked interest in the possible use of capital market tools as an alternative to post-disaster financing.

Over the past few years, with the co-operation of other international finance institutions, the World Bank has sponsored or supported several research initiatives to examine the role private markets may play in supplying post-disaster reconstruction financing (Pollner, 2000). In probing the role of hedges for catastrophe risks in developing countries, there emerge a series of novel policy and research questions.

One central question is the value of a hedge to a government with limited resources and competing demands for those resources. What benefit might compel a government in a poor country to spend its limited resources to hedge risk of future events? While answering this question is well beyond the scope of this article, a starting point is to understand the government's catastrophe risk and identify the existing strategies for coping with that risk. Those existing strategies have costs associated with them. If the cost of hedging provides greater value than the existing alternatives, then purchasing a hedge may make sense. If not, it is unlikely that these new initiatives will bear fruit in providing a market alternative to current practices.

A key ingredient in dealing with risk from natural hazard losses in poorer countries is the critical role of the government. Since these countries often have nascent risk transfer markets, the responsibility for absorbing natural catastrophe risk ultimately lies with the government. The failure of the government to provide risk shifting opportunities means that the victims of disasters bear all the costs of disasters. The economic good of risk shifting is lost.

To understand the role that risk hedging may play in assisting governments in providing post-disaster reconstruction resources, it is essential to link the proposed hedging to a measured risk. To measure government risk from natural hazards is not so simple.

Government risk from natural hazards arises from a wide variety of government functions. Often, the source of the risk is not well defined. The experience of Mexico is a good

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example. The government has a Fund for Natural Disasters (FONDEN). Included in FONDEN are government obligations to pay for reconstruction of damaged infrastructure owned by federal, state or municipal bodies, reimbursement of losses by homeowners and small businesses, and funding of work programmes for the poor (Kreimer, Arnold *et al.*, 1999). FONDEN has a current budget allocation of $1 billion a year. Evaluating the potential benefits of hedging the risk covered by FONDEN requires that each source of risk to FONDEN be identified, analysed and quantified. Once done, the evaluation of the comparative costs and benefits of hedging for each source of risk is possible.

Hedging may only be appropriate for some of the risk owned by the government. Hedging, or risk shifting, only works for risks with specific characteristics. The classical issues of moral hazard and adverse selection must be addressed as a component of evaluating the efficiency of a hedge.

This paper describes a method to understand the role of government in developing countries in coping with natural hazard risk. It defines three separate roles played by the government: its role as owner of risk from its investment decisions; its role in assuming risk of other economic agents in the country; and its role as protector of the poor. Identifying the role played by the government frames the relative costs and benefits for the government in hedging risk.

The paper begins by briefly describing the costs of natural catastrophes to developing countries and the current role of the international financial institutions in financing post-disaster reconstruction. The paper proceeds to provide a brief overview of the use of catastrophe hedges in the developed world. The paper then discusses the distinctive roles of governments in poor countries in dealing with natural catastrophe losses. This discussion is composed of three sections: the role of the government as owner of productive assets, the role of the government in resolving market failures for providing risk transfer alternatives to other economic agents in an economy, and the government as protector of the poor. The ability of catastrophe hedges to assist the government in performing each of its distinctive roles is reviewed. The paper concludes with a summary and suggestion for future work.

2. Current losses from natural catastrophes

Since the 1970s, the two largest reinsurance companies in the world, Munich Re and Swiss Re, have maintained comprehensive records on the frequency and severity of natural catastrophes. For the past decade, each firm has published comprehensive annual reports on the worldwide costs of natural catastrophes. In addition, Munich Re has published reports examining trends over the past 10 and 25 years, as well as a map describing all natural disasters in the last decade (Munich Re, 1998). Swiss Re also publishes reports on natural disasters on at least an annual basis, with additional reports issued on specific issues (Swiss Re, 1999).

2.1. Direct losses from catastrophes

The statistics are clear: over the past 40 years, economic losses from natural disasters have been dramatically increasing. Between 1987 and 1997, the direct economic loss from natural catastrophes was $700 billion for an average yearly loss of $70 billion. Comparing the 1990s to the 1960s, the number of natural disasters has increased by a factor of 3.2, economic losses have increased by a factor of 8.5, and insured losses have increased by a factor of 16.0 (Munich Re, 2000). Catastrophes are a function of physical events impacting human

settlements. Growing concentrations of populations and fragile infrastructures in hazard-prone regions are the main causes of the increased costs of disasters.

Despite the concentration of capital assets in the developed world, as opposed to the developing world, the economic impacts of catastrophes are relatively evenly split. While windstorms and flooding each account for approximately 30 per cent of the annual average direct damage from catastrophes, their impacts on the developed and developing world are significantly different. For example, windstorms are responsible for 70 per cent of damage to private property from natural catastrophes in the United States. Asia bears 70 per cent of the world's flooding damage. Earthquake damage during the past few decades has been evenly split between the developed and developing world. As a result, the developing world bears approximately $35 billion in direct costs of natural catastrophes, the same as the developed world (Freeman, 2000a). Based on the enormous disparity in the gross domestic product (GDP) for the two regions of the world, the *per capita* cost of natural catastrophes in relation to the GDP is 20 times higher in the developing world (Gilbert and Kreimer, 1999) than in the developed world.

2.2. Losses as a portion of gross domestic product

Often the losses in developing countries can be significant portions of GDP. Swiss Re has identified a series of developing countries for which losses from floods are expected to exceed 1 per cent of GDP (Swiss Re, 1998). Among those countries are Argentina, Ecuador, Honduras, Nicaragua and China. Munich Re identifies 28 developing countries that have suffered direct losses of more than $1 billion from natural disasters in the past 20 years (Munich Re, 1998). These are Algeria, Egypt, Mozambique, China, India, Bangladesh, Taiwan, Indonesia, the Philippines, Korea, Afghanistan, Armenia, Georgia, Iran, Mongolia, Thailand, Argentina, Brazil, Chile, Colombia, Cuba, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua and Venezuela. For small countries, losses of much less than $1 billion can still have significant long-term consequences.

2.3. Disasters and infrastructure

Natural disasters destroy essential urban and rural infrastructure. In Asia, the average infrastructure loss from flooding is estimated to be approximately $12 billion during the past decade. In the United States, more than half the expenditure of the Federal Emergency Management Agency (FEMA), the federal agency devoted to disaster response and reconstruction, is for infrastructure reconstruction (*USA Today*, 2000).

2.4. The special role of the World Bank in infrastructure reconstruction

In the developing world, the World Bank has a special role as the leader in arranging post-disaster infrastructure reconstruction. Over the past 20 years, the World Bank has funded post-disaster reconstruction projects for more than 56 countries, and has loaned more than $14 billion (Gilbert and Kreimer, 1999). A special focus of the World Bank post-disaster assistance is on infrastructure. This includes loans for transportation systems (roads, airports, harbors, bridges), energy systems (including energy generation, transmission and distribution), and essential social services (sanitation, healthcare and education facilities). Historically, the World Bank acts as the lead lender in post-disaster reconstruction lending, setting the terms on which other members of the international aid and finance community provide

assistance to damaged countries (Kirkby, O'Keefe *et al.*, 1997). Consequently, the policy expertise of the World Bank influences the behaviour of the international donor community.

In providing post-disaster reconstruction financing, the World Bank is placing an increasing burden on its resource base. The amount of funds available for all development assistance has remained constant for the past decade. Disaster assistance now accounts for 12 per cent of all overseas development assistance from all sources (Kirkby, O'Keefe *et al.*, 1997). This percentage continues to climb as the costs of disasters escalate. Since the pool of funds is meant to satisfy a wide range of development needs, the increasing demands of disaster relief cause considerable institutional pressure. The examination of other options to deal with the cost of post-disaster financing reflects a concern to deal with these constraints. A primary focus of the recently established Disaster Management Facility at the World Bank is the evaluation of private market alternatives to deal with post-disaster financing needs of developing countries (World Bank, 2000).

3. Hedging of catastrophe risk in the developed world

One of the most important recent innovations in the field of catastrophe risk management is the development of natural catastrophe derivatives. Historically, risk shifting for catastrophe losses has occurred through insurance. As is well known, insurance works best when it pools a large number of independent (uncorrelated) risks of known probability. Statistically speaking, improved certainty about the likelihood and severity of loss occurs as a result of pooling a large number of such risks. Under the *law of large numbers*, the probability of each measured event (such as a loss) of a given type tends to approach the mean probability of all the aggregated events as the sample size increases. A large group of entities undertaking a given risk activity can normally achieve a better estimate of the magnitude and frequency of potential losses by aggregating their risks than they can individually (Hodgson, 1997).

However, natural disaster risks are not independent. If a severe earthquake strikes, there is a high probability that many structures will be damaged at the same time. Hurricane Mitch destroyed 60 per cent of the infrastructure in Honduras (IMF, 1999). The loss of each individual is not independent; rather it is correlated to the losses of others in the same position. The variance of individual loss is actually the variance of all the losses that occur from the specific disaster. Since the law of large numbers does not apply, aggregating risks is unproductive. The reserves of the insurance company would equal or exceed the reserves that individuals would have to maintain if uninsured. The natural comparative advantage of insurance is lost when dealing with catastrophes (Priest, 1996).

3.1. Catastrophe hedges other than insurance

A new strategy to deal with the risk shifting of catastrophe loss has developed since 1996: catastrophe-linked derivatives. These instruments bring risk directly to the capital market, bypassing the traditional path of insurance. Since the cost of catastrophe insurance is dominated by capacity limitations, and the capital markets have unlimited capacity, pricing theoretically should be very competitive for these products in the long term (Doherty, 1997).

Considerable interest has developed regarding the use of derivatives as complements or replacements for catastrophe insurance. The strategy is to create a financial instrument that is negatively correlated (negative co-variance value) to the risk of a portfolio of stocks or bonds. By creating a derivative with its return negatively correlated to a portfolio of stocks, the ownership of the derivative is attractive to a stock portfolio owner. The correlation matrix

(or beta) between catastrophe risk and other financial instruments may be as low as −0.13 (Hodgson, 1997). As a result, these hedges should be of interest to portfolio investors.

The derivative should be of interest to owners of risk. To operate as a true hedge, the instrument should be negatively correlated to the risk of loss from the catastrophe. Insurance, since it pays if a catastrophe loss is incurred, is perfectly negatively correlated. Derivatives can be fashioned to mirror the performance of catastrophe insurance.

The range of catastrophe derivatives is both diverse and growing. Since 1996, nearly $4 billion of catastrophe derivatives have been placed in the capital markets (Goldman Sachs, 2000).

3.2. Hedging measurable risk

For catastrophe hedges to operate, it is essential that the risk to be hedged be properly quantified. The value of the hedge is dependent on its negative correlation to the risk it is intended to reduce. Without a clear understanding of the nature of the risk being hedged, the value of a hedge at a given price is speculative.

In the next sections, the article will explore problems associated with measuring catastrophe risk in the hands of government in developing countries.

3.3. Cost of hedging risk

Hedging of risk is costly. Whether the hedge is insurance or a derivative instrument, the shifting of risk to another party is expensive. Someone facing a risk situation derives value if he can find another to assume some of the risk and is willing to pay something for this value. The party assuming the risk is worse off by assuming the risk and will not do so unless compensated. Risk shifting is in the interest of both parties only if there is a price acceptable to both (Arrow, 1996).

An insurer or purchaser of a derivative will charge something more than the expected value. To charge only the expected value provides no profit opportunity. The insurance industry is based on the profit from charging more than the expected or actuarially determined value (Berliner, 1982). This additional amount in excess of the actuarially determined value is generally termed the "risk premium".

The risk premium for shifting catastrophe risk is very high. By some estimates, the price may be five to six times more than the actuarially determined value (Froot, 1999).

The amount that the owner of risk is willing to pay to transfer risk is a function of his relative risk aversion. To be willing to pay more than expected loss, there must be some risk aversion. Otherwise, there is no basis for a risk-shifting transaction.

In the context of developing countries, the willingness of governments to pay for a catastrophe hedge is dependent on defining for them the value of the hedge as compared to other alternatives for the government to deal with risk. The more ambiguity associated with the catastrophe risk owned by the government, the higher the cost of the hedge. The more expensive the hedge, the less likely a government will be to purchase the hedge.

4. Catastrophe risk and governments in developing countries

In understanding the role that catastrophe hedges may play in assisting developing countries to provide post-disaster reconstruction financing, it is necessary to identify the risk that insurance or a potential derivative is meant to hedge. While a natural catastrophe causes

significant losses in developing countries, the payment of those losses may not be the responsibility of the government. Only those losses that the government is responsible for paying constitute a "risk" to the government. As a consequence, it is likely that the government will only be interested in hedging the risk that it perceives it owns. By contrast with the situation in most advanced economies, the responsibility of the government for losses from natural disasters is often poorly defined. This section will propose an approach to identify the risk "owned" by governments in developing countries, and locate the trade-offs for the governments in evaluating hedges as a tool to transfer their risk.

Generally, three sources of risk can be identified for a government: risk stemming from its own investment decisions; risk it assumes for other economic agents in the economy; and risk of the poor.

4.1. Risks from government investment decisions

A government's provision of essential public goods and services needed generates risk. Both the nature of the risk and the appropriate policy tools to absorb the risk are influenced by how the risk is created. A government fulfils one of its primary obligations when it decides to invest government revenue in essential public goods and assets, such as infrastructure. In the developing world, over 90 per cent of all essential infrastructure is owned by governments (World Bank, 1994). The main source of funding for new infrastructure is still public investment. In making the investment decision, a government assumes risk, just like any other economic agent making an investment. Investments made in a natural-hazard-prone region carry the risk that the investment will be damaged or destroyed by a hurricane, earthquake, or other natural peril. The risk, associated with the physical environment, can be quantified using catastrophe modelling.

Catastrophe modelling provides the opportunity to combine scientific risk assessment with historical records to estimate the probabilities of disasters of different magnitudes and the resulting damage. Catastrophe models are the set of databases and computer programs that analyse the effect of different scenarios on hazard-prone areas. The information generates an expected annual loss over a long period of time. The estimated annual loss is the foundation for preparing hedges to deal with the risk of the expected loss (Kleindorfer and Kunreuther, 1999).

To fund losses following a disaster, governments must be able to secure financial resources, often by accessing savings. The sources of real savings available for capital formation are limited. They include domestic and foreign, private and public sources (Meier, 1995). For purposes of simplicity, these resources can be divided into internal and external resources.

4.2. Internal savings

As a general proposition, governments in the developed world have sufficient internal savings to absorb risk associated with their investment decisions. The standard theory is that the cost of public risk-bearing in the hands of each individual in a country is *de minimis* and should therefore be considered small in the hands of the government. The cost of risk in the hands of government is the same as the cost of risk in each individual's hands. The cost of risk in each individual's hands approaches zero the smaller the risk is to the total wealth of a country, or the larger the population through which the risk can be transmitted using taxes. As noted by the Nobel Laureate Kenneth Arrow, "When the government undertakes an

investment it, in effect, spreads the risk among all the taxpayers" (Arrow, 1992). When risk is negligible in the hands of each taxpayer, as represented by each taxpayer's gain or losses from the government's investment decision, the risk is also negligible in the hands of the government. The government should therefore invest based on the highest expected return, unadjusted for risk. Let risk be absorbed through the government's power of taxation, not by adjusting the investment decision to account for risk (Arrow and Lind, 1970).

This basic proposition has significant implications when dealing with the potential use of catastrophe hedges by governments. The economic theory supports the presumption that governments are risk-neutral economic agents. As a result, there is no theoretical justification for them to engage in risk-shifting transactions like hedging. They are assumed to be the best economic agents to absorb risk.

While the topic of risk aversion and developing countries is beyond the scope of this paper, there are clear indications that many developing countries should not be risk neutral. Rather, if expected losses swamps the ability of the governments to cope based on internal resources, it should be risk averse. For example, Hurricane Mitch caused direct and indirect damages in Honduras equivalent to $6 billion, or one year's gross domestic product. With a population of 6.2 million and 53 per cent of the population below the poverty line, the cost of $1,000 per person overwhelms all potential internal savings. In fact, most developing countries lack the internal resources to absorb external shocks (Ferranti, Perry *et al.*, 2000).

4.3. Accessing external savings

With limitations on both the extent and accessibility of internal savings, it is not surprising that developing countries now place considerable reliance on external savings to meet post-disaster needs. For infrastructure investment, the source of external savings is public external savings. Public external savings is provided as either grants or loans by the governments of the developed world or through international financial institutions such as the World Bank, the regional development banks, and UN specialized agencies. As noted earlier, the funding of infrastructure reconstruction is a special expertise of the World Bank (Kreimer, Eriksson *et al*., 1998). In large measure, this is because there is little interest in funding for bridges, roads, and other components of core physical assets by most members of the international aid community. Other providers of capital are more willing to support reconstruction of other types of structures, such as schools (Kirkby, O'Keefe *et al.*, 1997).

The nature of risk shifting that is made possible through access to external savings is varied. For developing countries entitled to Official Development Assistance (ODA), which currently means countries with *per capita* income less than $700 per annum, the "loan" is offered at highly subsidized rates. Usually, these loans are 86 per cent discounted present value, expressed as a percentage of face value (Klein, 1994). For example, the World Bank loans to the lowest income countries are interest-free, bear a service fee of 0.75 per cent, and can have maturities as long as 40 years, with ten-year grace periods. The present value of these credits is only 14 per cent of the face value of the amount loaned.

Standard World Bank loans have a low grant element. The World Bank is a financial intermediary. It borrows in the financial markets and re-lends the proceeds. Interest charges on the loans must cover its cost of borrowing plus 50 basis points to cover operating expenses of the World Bank.

4.4. Viability of hedging government investment risk

Hedging of risk from infrastructure investment decisions most resembles the type of risk handled by catastrophe insurance. Infrastructure damage is property loss. Property damage is one of the mainstays of the insurance industry worldwide. While it is not easy to quantify the potential loss exposure of a government's infrastructure portfolio to catastrophe loss, the use of sophisticated catastrophe models makes this task possible. In the past few years, the expected annual loss from natural catastrophes to infrastructure has been completed for several Latin American countries through research partially sponsored by the World Bank (Freeman, 2000b; Freeman, MacKellar *et al.*, 2000). The techniques for hedging property loss are well known, and a consistent demand for the product exists. Techniques to overcome the twin problems of moral hazard and adverse selection have been developed. In examining the role that catastrophe hedges can play in the developing world, it makes sense to address a problem that the market has successfully resolved elsewhere. That said, no developing government has ever hedged its risk of infrastructure loss.

The government hedging decision process must weigh the cost of hedging against the cost of accessing internal or external resources. For most of the poorer countries, that decision hinges on the ability of the government to obtain subsidized external post-disaster financing to fund infrastructure reconstruction. The more likely the ability to access external savings, the less desirable is the cost of hedging risk.

5. Government assumption of risk of other economic agents

A second area of risk for governments is their willingness to assume the risk of others in the economy. In dealing with natural hazard risk, there are abundant examples of governments assuming a portion of the risk of loss to others from damage. The creation of a government-subsidized insurance scheme is the most common example. The natural hazard programmes in France and Spain are two European examples. The flood insurance programme in the United States and the natural hazard programme in New Zealand are two non-European examples (Pollner, 2000). In economic terms, these programmes are examples of the government providing a private good.

There is considerable worldwide activity in promoting different schemes to use the government as a tool to provide catastrophe risk shifting for homeowners and others. The creation of the recent Turkish Catastrophe Insurance Pool (TCIP) is a good example. Contributions to the TCIP are required from all existing and future privately owned property. The payments made will contribute to a fund that will pay homeowners up to $28,000 in the event that a catastrophe damages their home. The government is required to make payment regardless of the level of funding of TCIP (Gulkan, 2001). Proposals are being explored in Mexico, the Caribbean, Central America and Africa to engage the government in providing risk-transfer options for farmers, homeowners and businesses in case of natural catastrophe losses (World Bank, 2000). Various proposals to hedge the risk assumed by the governments with these options have emerged. The recent placing of a reinsurance layer over the TCIP is one concrete example of the hedging proposed.

The obligation of governments to fulfil commitments made in these programmes is a risk to them. The payment of future sums based on the occurrence of catastrophic natural events is a claim on future government revenue. This claim may be as powerful as the claim to rebuild essential government-owned infrastructure.

5.1. Addressing market failure

The fundamental distinction that needs to be made in dealing with market failure risk assumed by government and investment risk lies in the quantification of the risk. Market-failure risk can be very complex to understand. This is particularly true in countries with limited experience with market mechanisms to begin with. Resolving market failures involves a series of distinctive issues that need to be properly considered, and most are beyond the scope of this article (Stiglitz, 1988). In the instance where the government is providing risk shifting options to its citizens, it has the same problems as market providers in offering insurance. These problems include resolving the dual issues of adverse selection and moral hazard. Proper resolution of adverse selection and moral hazard is essential to quantify the risk assumed by the government. If the government-sponsored insurance programme only includes the highest risk elements in a society (adverse selection) or changes the behaviour of those exposed to risk (moral hazard), then the actuarial estimates used to quantify the level of risk assumed by the government will be wrong. While private insurance firms are often adept at distinguishing between risks to help resolve issues of adverse selection and moral hazard, governments have proven to be ill equipped to impose stringent underwriting criteria to reduce either adverse selection or moral hazard (Freeman and Kunreuther, 1997).

5.2. Hedging and government action to address market failures

The hedging of governmental risk arising from the provision of government-sponsored insurance is considerably more difficult than hedging risk associated with government investment decisions. This difficulty mainly arises from the inability to properly quantify the risk being hedged. The quantification of the risk must first rely on the catastrophe-modelling process used to quantify the expected annual loss. But the modelling must be adjusted to account for ambiguity that may arise from the impact of adverse selection and moral hazard. Once that process is complete, a comparison between the cost of the hedge and the ability of the government to access internal and external resources post-disaster to finance the risk must be undertaken. This last step is similar to the process required for evaluating hedging for government investment decisions.

6. Natural catastrophes and the poor

A third major area of risk for governments in natural disasters is the claims of the poor on government assets in times of crisis. This claim is particularly acute in poorer countries with large segments of the population subject to significant hardship with minor losses of income.

6.1. The impact of catastrophes on the poor

The most important issue for the poor is the maintenance of a minimum level of income. Risk accounts for a large share of transient poverty in as much as it reduces the income of the poor below minimum levels. Natural disasters impact the poor in three specific ways.

First, catastrophes impact both wage earners and subsistence farmers by creating shortages and bottlenecks in labour income and food production. Catastrophes can throw very poor families into absolute destitution.

Second, catastrophes both directly and indirectly destroy the assets of the poor. Catastrophes destroy homes, farmland, crops and other essential productive assets. In

uncertainty, families with a stock of productive assets can suffer loss of income and still protect themselves by drawing down savings or buffer stocks. In the event of a catastrophe, however, these savings are unlikely to be sufficient, in which case real assets (including agricultural land and livestock) will be depleted. This is the indirect impact of catastrophes on personal savings.

Third, the poor have a large and important stake in public infrastructure projects. Rural transport, electrification and irrigation projects, which play an established role in poverty reduction, are damaged by catastrophes. Replacement is often delayed and resources for reconstruction are diverted from other poverty-reducing development projects.

Catastrophes attack the poor at three levels: they diminish income, reduce personal assets and destroy essential public infrastructure.

6.2. Informal coping mechanisms and the poor

In dealing with the risk of income variance for the poor, a number of informal coping strategies have evolved. By means of community and kinship networks, rural households develop a diverse portfolio of potential resources. Because members know each other, the problem of moral hazard is reduced. Any member who acts in a way to increase her or his own risk would be known and denied the help that the network would otherwise provide. Obligatory membership in the network of all members of a clan or community addresses the adverse selection problem. Unfortunately, these informal networks rely on personal knowledge of all the participants, so they tend to be geographically constrained. Since natural disasters impact entire geographic regions, their impacts overwhelm most of these informal networks (Freeman, 2000a).

6.3. Formal insurance and the poor

Formal insurance programmes, even those with government assistance to meet market failure problems as discussed in section 5, are unlikely to provide protection for the poor. At the level of the community or region, the co-variant risk problem affects formal insurance just as it does informal insurance. The moral hazard problem is particularly difficult for income replacement insurance programmes. It is extremely difficult to determine "lost income". Even in the developed world, income replacement insurance is severely limited (Newbery and Stiglitz, 1981). Generally, the insurance is payable on the occurrence of a defined external event. Unemployment and disability insurance are good examples of this type of insurance. Note that in both cases, the contingency is not low income *per se* but a more easily verified event like becoming unemployed or disabled.

6.4. Public-works programmes and the poor

By far the most likely candidate for injecting income into a community or region in the wake of a catastrophe is labour-intensive public works, including reconstruction and disaster mitigation projects. The moral hazard problem is avoided because such projects typically involve low pay and hard physical labour, and they preclude the recipient from engaging in other income-earning activities.

6.5. Hedging and government programmes to assist the poor

It is unlikely that hedging can provide any real support for a government programme to assist the poor. Government programmes to assist the poor are fraught with issues of adverse selection and moral hazard. The mere existence of the programmes themselves can increase the risk that the poor may be willing to take. In addition to the standard adverse selection and moral hazard problems, after a natural disaster the political pressure on the government to expand the pre-disaster limits it may have placed on reimbursement of losses is often impossible to resist (Froot, 1999). This additional component of political pressure further reduces the likelihood that any reasonable hedge on the government's obligation to assist the poor post-disaster can be provided. As well, meeting the short-term needs of the poor is the type of assistance most likely provided to a government post-disaster by the international aid community. The willingness of a government to spend current funds to hedge this risk is therefore highly unlikely.

7. Conclusion

It is an open question whether any government, whether in a developed or developing country, will ever hedge its risk of loss from natural disasters. Standard economic theory is that governments are the most efficient economic agent to deal with risk, and would therefore never pay more than expected loss to another to shift risk. Rather, the government relies on its power of taxation to internally shift the cost of risk. Governments are portrayed as risk-neutral economic agents.

In developing countries, it is likely that the theory applicable to governments in the developed world does not work. Rather, the cost of natural catastrophe risk is more than the government can bear, based on its ability to shift the cost of risk internally. Such governments must rely on accessing external resources to absorb risk. Theoretically, the value of hedging risk may be more than the cost of not accessing these external resources. If so, there may be a role for the hedging of risk by these governments.

To properly hedge risk, the risk itself must be defined. In dealing with governments in developing countries, it is necessary to analyse the risk from natural catastrophes owned by the government. It may be that some of the risk is so ambiguous that hedging is not a viable option.

This article defines three categories of natural catastrophe risk owned by governments in developing countries. The first is the risk of loss imbedded in the government's decision to build and own infrastructure in hazard-prone regions. This risk most resembles the type of risk that existing catastrophe hedges provide protection for. The risk is quantifiable, and the primary tool to deal with the risk is post-disaster borrowing, generally directed by the World Bank. It may be that hedging could provide an alternative to this risk management strategy, particularly if there is concern about the willingness of the World Bank to fund post-disaster infrastructure reconstruction loans.

The second risk is government attempts to resolve market failure to provide adequate risk shifting options for other economic agents in the economy. The provision of government-sponsored and subsidized homeowners insurance against natural catastrophe losses is an example of this risk. This risk is more complicated to isolate than the risk associated with government investment. The process of quantifying the risk must be carried out as with the government investment risk, but the additional concerns of moral hazard and adverse selection must be accounted for. Since the risk is more complicated and ambiguous, the

linkage of a catastrophe hedge to reduce the risk is more speculative. The role that hedging may play with respect to this risk is likely to be less than its role in assisting governments with its infrastructure risk.

The final risk is the obligation of the government to meet the needs of the poor post-disaster. The extent of this obligation is more ambiguous than either of the two other risks described. Consequently, the ability to hedge the risk is even more unlikely.

Catastrophe hedges play a crucial role in transferring risk of natural disaster losses in the developed world. The extension of hedges to the risk experienced in the developing world is an idea now just being explored. The ability to apply hedging concepts will require a clear understanding of the risk that the hedge is meant to reduce. This will demand that "government risk" be separated into its component parts. Only then can the relative costs and benefits of hedging as compared to existing tools used to manage risk be properly evaluated.

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