Financing Natural Disaster Risk Using Charity Contributions and *Ex Ante* Index Insurance

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Abstract
The scale of loss from natural disasters in low-income countries often exceeds the resources of internal and external sources of relief funding. Catastrophe bonds offer the opportunity to transfer the risk of low-probability, high-loss events to the capital market where there is greater capacity to absorb disaster losses. This paper details some problems inherent in traditional sources of disaster relief and proposes an alternative mechanism for catastrophe risk transfer that unites financial innovations and donor communities.

Introduction

Natural disasters disproportionately affect low and middle income countries (LMIC), which are limited in their capacity to absorb widespread damage brought about by catastrophic events. According to the World Bank, 94 percent of natural disasters and 97 percent of deaths related to natural disasters between 1990 and 1998 occurred in developing countries (World Bank, 2001). The average cost of a natural disaster as a proportion of GDP is 20 percent greater for LMIC than for high-income countries (Freeman, 2000).

In the wake of a natural disaster, LMIC must divert funds from limited budgets, take on additional loans and/or accept international aid to provide humanitarian aid and reconstruction. Though research on the long-term economic impact of natural disasters on LMIC is mixed, it is evident that natural disasters do negatively impact the poorest, marginalized sectors within an affected community. Frederick Cuny wrote, "A disaster makes it very evident that the poor are vulnerable because they are poor" (Cuny, 1983:54). Marginal groups may suffer extreme losses from a natural disaster while the economic impact may not be felt nationwide since these groups contribute only a small amount to GDP. The rest of the economy may experience positive growth post-disaster, while affected sub-groups remain marginalized and even excluded from the reconstruction efforts.

Market Failure

The insurance markets in most LMIC are underdeveloped. Risk exposure and weak infrastructure of many LMIC often limits the supply of insurance. Likewise, lack of information and high poverty rates translate into very little demand for formal insurance mechanisms. In these cases, informal insurance mechanisms provide limited hedging against certain independent risks. However, informal insurance can be more costly and may become "insolvent" when a catastrophe affects an entire community (World Bank, 2000/2001).

While insurance is designed to reduce the public burden of individual loss, it is less useful for managing the economic impact and correlated losses of a catastrophic event (Petak, 1998). Natural disasters cause highly correlated losses which are essentially uninsurable. Unlike independent events, such as fires or auto accidents, weather-related catastrophes typically affect a large proportion of people within a single area. Consequently, highly correlated losses translate to a larger than expected number of insurance claims. In the aftermath of a catastrophic event, indemnity obligations can overwhelm insurance companies, threatening them with insolvency. Without access to global markets, local insurers must spread correlated losses temporally rather than spatially, however retaining this risk drives up the cost of insurance. Large reinsurance companies can offer some protection from correlated losses by creating a pool of independent catastrophic risks across the globe.

Catastrophic risks fail to meet standard conditions of insurability. The six conditions of insurability are: 1) there must be a large number of exposure units; 2) the loss must be accidental and unintentional; 3) the loss must be determinable and measurable; 4) the loss should not be catastrophic; 5) the chance of loss must be calculable; and 6) the premium must be economically feasible (Rejda, 1995:23). Natural disasters violate the last three conditions. Whereas risk pooling reduces risk exposure for independent events, it increases an insurer's catastrophic risk exposure by insuring a large group that may suffer simultaneous losses from a natural disaster. Though catastrophic events may be infrequent, ambiguity surrounding the frequency and severity of natural disasters is high. This uncertainty makes the pricing of catastrophe insurance difficult as losses are not independent nor are they completely correlated. Risk loading is a common practice used to raise premium rates to account for the uncertainty of loss. As a result, the people who are most vulnerable to natural disasters are the least able to afford risk mitigation and management.

Yet even where catastrophe coverage is available, it has been observed that there is low demand for catastrophe insurance, even in high-income countries. Kunreuther (1979) examined the psychology behind peoples' decision to purchase insurance—particularly the lack of coverage against cataclysmic events-- and found that most people are unwilling to pay for low probability events, even when the potential damage incurred can be great. This behavior is used to rationalize government response. Even when insurance coverage is mandated, as with the U.S. National Flood Insurance Acts (1973, 1994), the government still assumes responsibility for providing aid to those who declined to purchase insurance and suffered losses (Barnett, 1999).

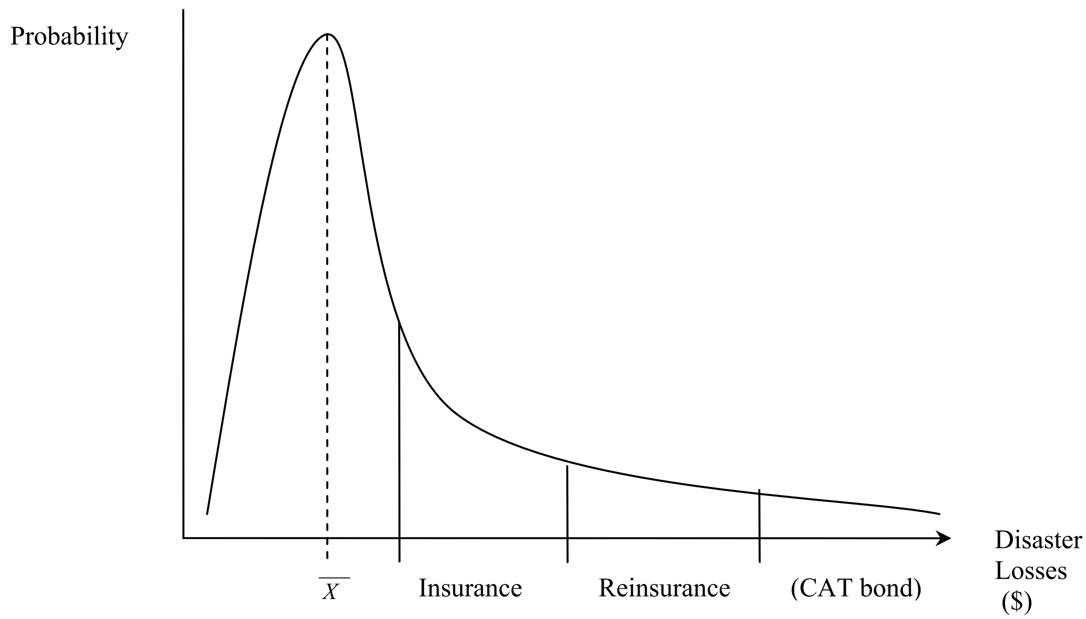
While the affected governments bear the brunt of the costs of major catastrophes, the over-burdened budgets of LMIC will be highly inadequate to meet these needs following certain disasters. External disaster financing from bilateral and multilateral emergency aid provides an additional source of financial assistance. However, limitations of international assistance prevent the most efficient provisioning of disaster relief. Two major concerns regarding international aid are delay in the disbursement of funds and unreliable funding (Fowler, 1997; IFRC, 2001). Money coming from international relief organizations must be raised; while bilateral aid must travel through the political pipeline where it is may be tied to conditions for its use. Reliance on damage assessments, fundraising, and administrative approval also creates delays in the disbursement of relief aid. Additionally, this type of humanitarian response reinforces risk-taking behavior, meaning that more damages will result from subsequent disasters.

Charity Catastrophe Bonds

Current applications of catastrophe ("CAT") bonds are limited to providing liquid capital for commercial uses (and high-yield bonds for investors). CAT bonds emerged in response to Hurricane Andrew in 1992 as an instrument for reinsurance companies to hedge their own risk of insolvency resulting from catastrophic events. Reinsurance companies provide access to contingent capital for primary insurers when indemnities exceed a specific level. Just as reinsurers serve to reduce the credit risk of the primary insurer, catastrophe bonds reduce the credit risk of the reinsurer by providing a source of back-up capital. Primary providers of insurance can also use catastrophe bonds to reinsure some of their own exposure.

Like reinsurance, CAT bonds are intended to hedge against the upper limits of catastrophic loss. Figure 1 illustrates the distribution of losses for a covariant event. Variance from the mean is abnormal, making it difficult to insure against the "tail risk" due to the large losses associated with infrequent but catastrophic natural disasters. A catastrophe bond segments out the tail risk to a third party. For countries with developed insurance sectors, insurers and reinsurers can manage lower layers of loss, incorporating a catastrophe bond to manage only the most extreme losses.

Figure 1: Probability Distribution Function for Covariant Losses



For poor countries that are vulnerable to large losses from natural disasters, small nations in particular, a charity catastrophe bond could provide additional capital for disaster relief efforts. This source of contingent capital could be structured to encourage more efficient use of disaster relief funds through *ex ante* planning, access to unconditional capital, and objective means of allocation.

Existing catastrophe bonds could be designed to provide a source of contingent capital for developing countries following a natural disaster. This external funding would provide resources for disaster relief and recovery in such a way that could overcome some of the limitations of traditional sources of disaster aid. Furthermore, removing the catastrophe exposure in LMIC would open the door for the development of formal insurance sectors for managing more frequent, independent risks. As these markets emerge, financing of catastrophe risk can be more fully internalized.

A charity CAT bond would be structured similarly to existing commercial CAT bonds. The main difference is in the objective. Similar to a reinsurance contract, a charity CAT bond would guarantee a pre-determined payment of money contingent upon the occurrence of a pre-specified natural disaster. In this situation, however, the financing would come from bond investors while the premiums would accumulate from charitable donations. A charity CAT bond would leverage contributions to disaster relief by promoting more efficient use of disaster relief funds while generating returns that could increase the amount of available funds in the event of a natural disaster. In the absence of a disaster, the investor would experience a return on their investment.

Recently, increased attention has been given to researching alternative applications for CAT bonds in developing countries. Based on the difficulties LMIC have financing disaster management internally, Kunreuther and Linnerooth-Bayer (2002) make the case that CAT bonds could be incorporated as a risk-transfer mechanism for developing countries. The authors suggest that a CAT bond, with subsidized premiums, could act as a substitute for a reinsurance contract to provide a source of contingent capital. They support the use of risk transfer mechanisms for emerging economies rather than disaster risk financing instruments which can over-burden government resources.

For countries with limited government resources, risk transfer (hedging) can have many advantages over ex post disaster financing in both the short and the long run by providing fast access to capital, and avoiding budgetary diversions and additional loans. Another important advantage is that unlike free disaster assistance, hedging instruments can be designed to provide incentives for disaster planning and mitigation (Kunreuther and Linnerooth-Bayer, 2002; Skees, et al., 2002).

Weather derivative contracts are one type of hedging instrument that has begun to emerge as a substitute for yield-based crop insurance. This type of insurance can be used to manage weather-related crop risks without providing incentives for poor management (Skees, et al., 2002; Skees, 1999). For example, indemnity payments are based on rainfall levels and can hedge against droughts or excessive rainfall. A nearly identical structure can also be used to establish CAT bonds for more extreme, infrequent risks while individuals or communities can bear the cost of managing lower layers of risks. Skees, et al., discuss several alternative instruments for utilizing the wealth of capital markets to aid the rural poor. They propose that index-based rainfall insurance could provide more efficient hedging than traditional forms of crop insurance.

An indexed-based trigger allows for immediate access to capital in the event of a catastrophe, circumventing time delays and reducing transaction costs. An indexed-based trigger also reduces opportunities for moral hazard, as the event measure can be independently verified and cannot be influenced by manipulation. A parametric index can be based on wind speed, Richter scale measurements, or rainfall depending on the event to be measured. Payment would be calculated from the index, and could account for both severity and proximity to populations (an indicator of impact). A basic payment structure would determine the percentage payout based on the difference between the strike level (the trigger) and the recorded measure of the event, *x*, when *x* exceeds the strike value (Skees, 2001; Martin, et al., 2002).

Percentage Payment = (x-strike)/strike

For example, an earthquake index could have a strike of a 7.0 Richter scale reading. An earthquake with a magnitude above this level would trigger bond payment. The contract can be designed to scale payments incrementally for measures in excess of the strike to account for increased severity. A similar structure could be used to cover excess rainfall within a period of time or wind speed. The use of an index for determining relief payments for natural disasters may be best suited for quickly-emerging disasters (floods, earthquakes, hurricanes), than for those that emerge slowly (e.g., drought). Nonetheless, certain thresholds of too little rain can be indexed and used to make payments when there are severe droughts.

The tradeoff with using an index to reduce moral hazard is an increase in the basis risk. Index contracts depend upon a strong correlation between the event creating the index and the losses of the individual who is insured.

Establishment of such an index would be useful for numerous applications. The weather data required to create and make use of the index is a public good which has many beneficiaries.

Weather information is valuable to the agricultural sector, civil engineering and city planning, etc. This information can also help support the development of weather derivative markets as substitute for traditional insurance in LMIC for lower layers of risk (Skees, et al. 2002). Creation of a weather index requires a thorough risk analysis to determine the appropriate trigger levels. This assessment of exposure can identify a country's vulnerabilities and aid in disaster planning and mitigation (Varangis, Skees, and Barnett, 2001). Because of the many benefits that can be derived from compiling this information, the World Bank and similar institutions should have a vested interest in supporting the infrastructure for weather stations, data analysis, etc.

The framework required to develop a parametric weather index would also serve to support multiple instruments for managing weather risk at several layers: 1) individual insurance against weather events; 2) insurance sold to collective groups that could become mutual insurance providers; 3) private/government reinsurance; and 4) indexed securities for disaster assistance. Skees, et al. emphasize the importance of effective financial markets to the growth and resilience of the rural sector. Creation of charity catastrophe bonds would facilitate the transition towards accessible markets for risk management, savings and investment.

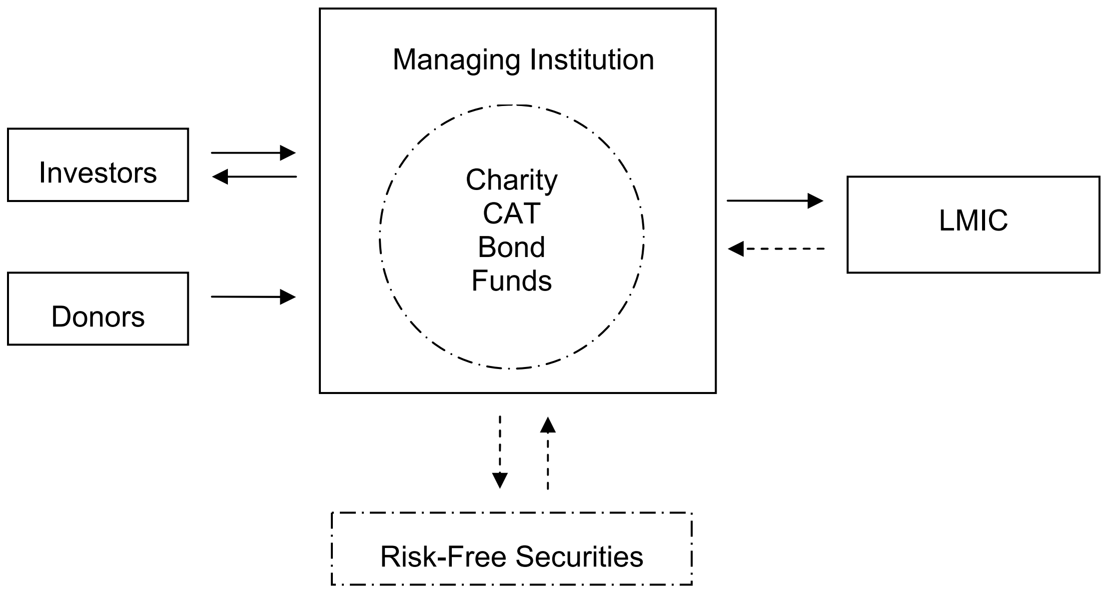
The goal of a charity catastrophe bond is to provide an alternative source of disaster relief funds for infrequent, extreme events that are essentially uninsurable due to the widespread damage they cause. Other market-based mechanisms could be encouraged for hedging against more frequent, less severe risks, as reliance on free aid for all but the most extreme natural disasters provides no incentive for individuals and communities to reduce their exposure to regularly occurring events. Low-income countries are least able to absorb catastrophe risk and would benefit the most from a catastrophe bond that is pure charity. Countries with higher per capita incomes would be able to bear a portion of the cost of this risk transfer, while high income countries can internalize a fully commercial product.

Whereas the premiums paid to purchase reinsurance transfer the insurers' catastrophe risk to a third party, charity bond premiums would pay to transfer the catastrophe risk to the capital markets (Kunreuther and Linnerooth-Bayer, 2002). The principal and interest would be held in escrow or placed in risk-free securities until occurrence of a triggering event, in which case the funds would then be disbursed as disaster relief. In the absence of a triggering event, investors would regain their principal and accumulated interest upon the bond's maturity. Figure 2 illustrates the proposed structure of a charity CAT bond.

Investors who have both a desire to diversify their portfolios and a philanthropic heart would purchase these bonds from a managing financial institution (e.g. an investment bank). Investors purchase the bonds and in the event of a natural disaster, all or most of their principal will go towards disaster relief. Otherwise, they receive a premium above the risk-free rate.

The role of donors would be to contribute to the premium on the bonds, supplementing the contingent relief funds while simultaneously encouraging investment in CAT bonds. From one aspect, donations to the charity bond funds are essentially an investment in the development of market-based securities for managing catastrophic risk. Philanthropists who might typically donate to relief efforts after an event has occurred can leverage their money and good intentions via *ex ante* donations so that their contributions can be used more efficiently if needed. One constraint concerning the use of donations to generate the bond premiums is that a substantial amount of donations would need to be secured in advance of investments so that a minimum rate of return could be identified for investors.

Figure 2: Proposed Structure for a Charity Catastrophe Bond



If bond payment were not triggered during the life of the bond, then investors would regain their principal plus accumulated interest. The return on principal would be dependent upon the amount of charitable donations made to the fund. It should also be possible for the holding company to invest the CAT bond funds into short-term liquid investments, such as T-bills, that would provide a low, risk-free return in addition to the accumulated premiums.

Were a natural catastrophe to occur, a parametric index would indicate the amount of payment to be disbursed by the managing institution. Relief funds could be distributed through a variety of mechanisms. One option would be to establish a consortium of international relief organizations and local NGO's that would receive the funds to be used in relief efforts within he affected country. Another option would be to disburse relief funds directly to the government to support government disaster assistance; however there would be legitimate concerns regarding equity and misuse of funds. Alternatively, the CAT bond funds could be filtered down through local organizations such as co-operatives or micro-finance institutions. This type of structure would enable local groups to offer insurance for smaller scale events by having access to relief funds for higher levels of loss though the CAT bond. In this situation, the charity CAT bond would provide a layer of reinsurance against aggregate losses.

The disbursement of funds would be pre-arranged so that payment would be immediately available following a catastrophic event. A third party financial institution could manage the bond funds and disbursement, to significantly lower the risk of misuse of funds and credit risk.

Incorporating CAT bonds into a relief system could overcome some of the problems associated with free disaster aid. The decision to provide international disaster aid is most often made *ad hoc* without any conditions or criteria for proper use and equitable distribution of resources. Without planning, corruption and politics can negatively influence the flow of disaster aid (Skees, et al., 2002). Transferring the risk to capital markets would theoretically relieve international aid organizations of some of their fundraising obligations, allowing more time and resources to be spent on their primary concern—disaster relief (Freeman, et al., 2002). However, the cooperation (and endorsement) of international relief organizations and participating governments may be essential to the effectiveness of this concept.

The advantage of CAT bonds over traditional reinsurance lies in lower transaction costs and the absence of default (credit) risk. Nell and Richter suggest that, in theory, CAT bonds should be less expensive than purchasing reinsurance. They conclude that the high premiums for reinsurance reflect the risk aversion of the reinsurer, as witnessed by higher premiums charged for higher levels of loss. At the moment, however, premiums on commercial CAT bonds are quite high, generating returns of 4-8% above LIBOR[1].

Bantwal and Kunreuther (1999) examined the reasons behind high premiums on CAT bonds. They determined that in terms of Sharpe ratios[2] CAT bonds are more favorable than bonds of comparable risk. In fact, they suggest that an investor would be highly risk averse to <u>not</u> invest in CAT bonds. However, the justification for high rates for catastrophe reinsurance equally justifies the high yields on catastrophe bonds. The uncertainty surrounding the probability and magnitude of loss creates a demand for large returns on bond investments. Bantwal and Kunreuther also point to myopic loss aversion on behalf of investors as a factor restricting market size. The notion of sudden and total loss of principal, even at very low odds may limit investor interest in catastrophe-linked securities. Additionally, the cost of education to investors for researching and understanding new catastrophe-linked securities may be large. Standardization of these products over time should help reduce this constraint.

Technological improvements have allowed researchers to develop improved weather models which can help to assess the risk exposure of specific locations regarding specific natural events. Construction of these models will be limited by the availability of historical and reliable country weather data. Still, it is expected that as disaster loss models become more accurate and as experience with CAT bonds grows, premium rates will decline and demand for these products will grow. Development of new bond structures that limit risk exposure, such as a pooled portfolio of global CAT risks, will also further the market interest in these instruments.

Methodology & Results

A Monte Carlo simulation was used to illustrate the structure of a charity catastrophe bond representing coverage of both a single event and a portfolio of potential events. Random numbers between 0 and 1 were generated in a matrix representing 1000 possible outcomes for *independent* geographic regions for a single year. A value less than or equal to 0.01 was used to represent occurrence of a 1-in-a-100-year event, triggering a payment of 100% of principal. For a CAT bond covering a single region/event, the expected return is calculated by weighing the probability of no triggering event, p_0, against the probability of a triggering event, p_1, where P_t is

[1] The London InterBank Offered Rate, the lending rate between banks, is a common benchmark for short-term interest rates. As of September 3, 2002 the 12 month rate was USD 1.89, down from 3.56 in August

[2] Sharpe ratio=return over the risk-free rate/standard deviation of returns

the amount of principal in year t, i is the interest rate, and d is the percent deduction in the principal following a triggering event. With an interest rate of 10%, the expected return is calculated to be 7.9%:

$$E(return) = \$P_t * p_0 * (1+i) + \$P_t * p_1 * (-d)$$
$$E(return) = \$P_t * 0.99 * 1.10 - \$P_t * 0.01 * 1$$
$$E(return) = \$1.089\ P_t - \$0.01\ P_t = \$1.079\ P_t$$
$$E(return) = (\$1.079\ P_t / \$P_t) - 1 = 7.9\%$$

The variance was estimated based the outcomes of all 1000 draws (n = 1000):

$$\sigma^2 = \left[(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \ldots (x_{1000} - \bar{x})^2 \right] / (1000 - 1)$$

With coverage of only a single region, the variance is 3.85% with an expected return of 7.9% based on a 10% premium. Figure 5 illustrates how variance on returns decreases as regions are added. Dramatic reductions in the variance can be achieved by pooling only a few regions. As more regions are added to the portfolio, the likelihood of total loss of principal declines. With a single event, the probability of total loss of capital equals the probability of a catastrophic event, 0.01 in our example. When countries are pooled in a bond portfolio, the maximum payment per country is only a portion of the principal, *P/n*, where *n* is equal to the number of regions included in the portfolio (assuming the probability of a triggering event in each region are given equal weight). Given that the disaster events across countries are assumed to be independent, the likelihood that all included regions will experience a catastrophic event in the same year is the product of their individual disaster probabilities:

$$p_{total\ loss} = (p_1) * (p_2) * (p_3) \ldots * (p_n)$$

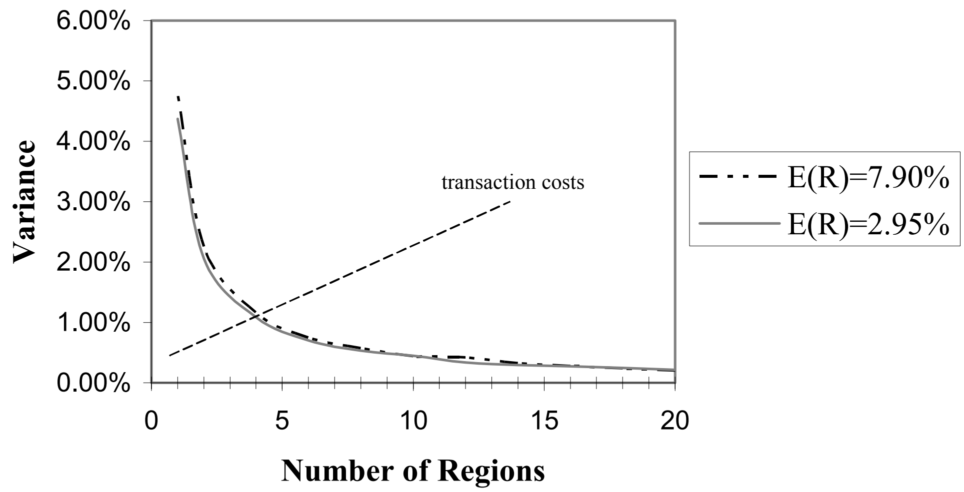
Assuming our portfolio covers 1-in-a-100-year independent events in 5 countries the probability of total investor loss equals one in a billion:

$$p_{total\ loss} = (0.01)^5 = 0.0000000001$$

As Figure 3 shows, after the addition of six or seven region-events, little more reduction in variance is realized. This is an important distinction as the benefits of pooling regions are shown under the assumption that the catastrophes are independent across these countries/regions; there is zero correlation between the occurrence of natural disasters in one area and another. Therefore, reducing investor catastrophe exposure would require identifying only a small group of countries possessing independent catastrophe exposures. The transaction costs of pooling countries into "bundled" catastrophe bond could be quite high. Still, the transaction costs would rise with each additional country, but there may be some economies of scale and the marginal cost of adding each additional country should decline. Likewise, with a smaller pool, risk exposure increases. Therefore, it is encouraging that grouping even a small number of countries greatly reduces investor risk exposure. The optimal portfolio could be determined by the intersection of the transaction costs (indicated by the dashed line in Figure 3) and the variance.

It may even be possible to create a portfolio of countries that experience negative correlation between certain events. For example, in El Niño years the likelihood of abnormally high rainfall in the eastern Pacific increases with the expectation of reduced rainfall in Indonesia and Malaysia (NOAA Climate Prediction Center).

Figure 3: Effect of Risk-pooling on Variance of Returns



The bond could also be structured to provide regular coupon payments to the investor; however, rolling over the interest and principal into consecutive years allows for leveraging of the initial investment and generates growth of potential relief payments. The main objective of implementing a market-based instrument for catastrophe financing is to provide an alternative and reliable source of emergency capital that can be provided in an efficient and equitable manner. Therefore, the role of the CAT bond as an investment tool is secondary.

Summary & Conclusions

A charity CAT bond eliminates or reduces the premium for catastrophe coverage for low-income countries, yet requires *ex ante* measures for disaster coping in coordinated effort with government agencies and aid organizations. Potential long-run benefits of supplying disaster aid in this form include improved disaster preparedness, cooperation between aid organizations, and emergence of domestic insurance and other financial markets.

More immediate benefits can be realized through more efficient use of disaster relief funds. The proposed charity CAT bond could be structured in a way to address the limitations of traditional aid, allowing for objective, reliable and accessible emergency capital. Access to capital is often more effective than the provisioning of material items as it allows funds to be spent locally, encouraging local disaster management capacity and supporting the local/regional economy (IFRC, 2001; Smillie, 2001). Monetary resources also ensure that only needed supplies will be purchased, eliminating the burden often placed on disaster-stricken communities by the flood of unnecessary items.

Additionally, the supplemental aid provided by a charity CAT bond could prevent budgetary diversions by the government and multilateral development institutions. By smoothing the economic impact of natural disasters, affected countries can recover more quickly without experiencing severe economic shocks. The payment trigger can be tied to a severity index for objective and immediate determination. The liquidity and flexibility of these funds would enable relief organizations to quickly obtain supplies from local/regional sources in direct response to victims needs. Linking the indexes to early warning systems could allow for early payments that could be used to mitigate losses from an impending disaster.

Even though CAT bonds hedge against very low-probability events, pooling these risks globally would further reduce expected loss, increasing investor appeal. A pooled CAT bond would also expand the capital reserve available for disaster relief. CAT bonds which are tied to a parametric index can eliminate moral hazard and time delays in acquiring relief funding. Furthermore, when established in conjunction with *ex ante* rules of distribution, opportunities for misallocation of funds are reduced.

Transferring the risk of catastrophic natural disasters prevents undue economic shocks to the fragile economies of low-income countries. This in turn can facilitate the development of formal risk management mechanisms, including insurance and mitigation measures. Reliable financial markets can provide opportunities for income generation and economic development with increased access to financial markets. However, long-run solutions to disaster risk management are constrained by the abilities of the central government to provide regulations, legal frameworks and other services. Poorly defined property rights also will limit investments made in risk mitigation. Until the underlying problems of poverty and social inequality are addressed, marginalized sectors of society will remain vulnerable to the economic impact of natural disasters.

There are several other foreseeable constraints to the implementation of a charity catastrophe bond. First, investor interest in commercial CAT bonds remains relatively low. It may be some time before investors and donors feel comfortable with the new concepts contained in a charity CAT bond. In addition to the newness of the concept, there is uncertainty regarding donors' willingness to give before a disaster strikes. Without expressed interest in this concept, the initial costs for research and development may be perceived as prohibitive. Development banks have a role to play in lowering these initial costs. Once structured, however, the political economy could distort the effectiveness of the bond. Competition for credit between relief organizations can interfere with cooperation between different donors and relief organizations. Obviously, creating a consortium of aid organizations cannot be achieved without cooperation and coordination at all levels. Nevertheless, the structure of a charity catastrophe bond could make risks more explicit by pricing the risk. When information on risk exposure is identified, better decisions can then be made regarding risk management.

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