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Sovereign financial disaster risk management: The case of Mexico

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Abstract

In 2006, Mexico became the first transition country to transfer part of its public-sector natural catastrophe risk to the international reinsurance and capital markets. The Mexican case is of considerable interest to highly exposed transition and developing countries, many of which are considering similar transactions. Risk financing instruments can assure governments of sufficient post-disaster capital to provide emergency response, disaster relief to the affected population and repair public infrastructure. The costs of financial instruments, however, can greatly exceed expected losses, and for this reason it is important to closely examine their benefits and alternatives. This paper analyzes the Mexican case from the perspective of the risk cedent (the Ministry of Finance and Public Credit), which was informed by analyses provided by the International Institute for Applied Systems Analysis (IIASA). The rationale for a government to insure its contingent liabilities is presented along with the fiscal, legal and institutional context of the Mexican transaction. Using publicly available data, the paper scrutinizes the choice the authorities faced between two different risk-transfer instruments: reinsurance and a catastrophe bond. Making use of IIASA's catastrophe simulation model (CATSIM), this financial risk management decision is analyzed within the context of a public investment decision.

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1. Introduction

Governments often have responsibility for a large portfolio of public infrastructure assets that are at risk to storms, floods and other natural disasters, and are morally or explicitly obligated to provide post-disaster emergency relief and assistance to affected households and business. In contrast to wealthy countries, developing country governments frequently face post-event deficits in financing relief and reconstruction, which can have serious effects on their long-term development and their ability to finance needed social and economic programs. Developing country governments typically finance their post-disaster expenses by diverting from their budgets or from already disbursed development loans, as well as by relying on new loans and

donations from the international community. These sources can be insufficient, come with a time lag and not provide incentives for risk reduction (Linnerooth-Bayer et al., 2005). Realizing the shortcomings of after-the-event approaches for coping with disaster losses, pro-active financing of disaster risks is becoming an important cornerstone for tackling the substantial and increasing effects of natural disasters (Gurenko, 2004).

The 1985 earthquake in Mexico City sensitized Mexican authorities to the benefits of pro-actively engaging in prevention and financial disaster risk management. Nearly 9000 people lost their lives, and direct economic losses from this disaster were estimated at \$7 billion (in 2006 \$) or 2.7% of the GDP in the year of the event (CRED, 2006). Colossal expenses on rehabilitation and reconstruction resulted in an increase in the fiscal deficit of \$1.9 billion over the next 4 years. Despite inflows from private sector (business and households) insurance and foreign donations, the earthquake is estimated to have had a negative effect of \$8.6 billion on Mexico's balance of payments over

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this period (Jovel, 1989). In order to be financially better prepared and improve efficiency in public-sector risk management, legislation was passed in 1994 requiring federal, state and municipal public assets to be insured. In 1996 the authorities created a financial risk management program (FONDEN) and began budgeting for contingent disaster spending. Subsequently, the government created a catastrophe reserve fund within FONDEN (the FONDEN trust), which accumulates the unspent disaster budget of each year. Recognizing that FONDEN (the program and the trust) would not have sufficient funds to cover losses from a major event, the authorities recently took a further step in their financial planning and engaged in an international risk-transfer transaction to provide financial protection to the fund. Mexico has thus become the first transition country to transfer its public-sector catastrophe risk to the international reinsurance and capital markets.

The Mexican case is of considerable interest to highly exposed transition and developing countries, many of which are considering similar transactions. Risk financing instruments can assure governments of sufficient post-disaster capital for providing emergency response, repairing public infrastructure and assisting the low-income population. However, the financial costs of risk-financing instruments can greatly exceed expected losses. Furthermore, there are attractive competing uses to which government funds can be allocated. It is therefore important to examine risk financing in the context of a public investment decision by taking into account the opportunity costs or foregone benefits of investments in other public programs.

This paper analyzes the Mexican case from the perspective of the risk cedent (the Ministry of Finance and Public Credit), which was informed by analyses provided by the International Institute for Applied Systems Analysis (IIASA). The analysis examines the economic benefits and costs of investing public resources in two risk-transfer instruments—reinsurance and a catastrophe bond—considering other investment choices. This is made possible with IIASA's interactive catastrophe simulation model (CATSIM). While CATSIM provided insight into the conceptual framing and rationale for the Mexican transaction, the final risk-transfer decision in 2005 required detailed engineering and hazard analysis that went beyond the scope of CATSIM. Based on an aggregated and stylized model of the Mexican economy and disaster exposure, CATSIM serves to illustrate the relevant objectives, costs and tradeoffs. The tool cannot provide an optimal decision or strategy, but proved useful in illustrating the decision criteria and tradeoffs for the Mexican transaction. It can thus be helpful for governments considering similar transactions.

The paper is organized as follows: In Section 2, the rationale for a sovereign government to insure its contingent disaster obligations is presented, followed by a discussion in Section 3 of the context of the Mexican transaction. In Section 4, the CATSIM model is introduced

as a framework to systematically analyze public-sector financial risk management decisions. Section 5 assesses the financial vulnerability of Mexico to natural hazards. In Section 6, the discussion turns to examining the choice the authorities faced between two different risk-transfer instruments: reinsurance and a catastrophe bond. Making use of CATSIM, in Section 7 the financial management decision taken by the Mexicans is analyzed within the context of a public investment decision. Section 8 discusses the actual transaction undertaken by the Mexican authorities followed in the concluding section by a discussion of insights gained and implications for other countries with similar risk exposure and financial vulnerability.

2. Rationale for insuring the public sector

2.1. Defining financial vulnerability

Should governments insure or purchase alternative risk financing instruments to protect themselves from catastrophic losses? According to an early theorem by Arrow and Lind (1970), governments should not insure if they are not averse to risks, i.e., if financial risks faced by the government can be absorbed without major difficulty. In theory, thus, governments are not advised to incur the extra costs of transferring their disaster risks if they carry a large portfolio of independent assets and/or they can spread the losses of the disaster over a large population. Because of their ability to spread and diversify risks, Priest (1996) refers to governments as “the most effective insurance instrument of society.” Furthermore, the extra costs of insurance can be significant; for example, Froot (2001) reports costs up to seven times greater than the expected loss, due to high transaction costs, uncertainties inherent in risk assessment, the limited size of risk-transfer markets and the large volatility of losses.

The case against sovereign insurance, however, may not hold for highly exposed developing country governments, especially those that are not sufficiently diversified or cannot spread losses over the tax-paying public. In these cases, governments may justifiably act as risk-averse agents. This means that the Arrow–Lind theorem may not apply to governments of countries that have:

- high natural hazard exposure,
- economic activity clustered in a limited number of areas with key public infrastructure exposed to natural hazards, and
- constraints on tax revenue and domestic savings, shallow financial markets and high indebtedness with little access to external finance (Mechler, 2004).

These conditions are fundamental to determining the financial vulnerability of a state. Governments are financially vulnerable to disasters if they cannot access sufficient funding after a disaster to cover their liabilities with regard to reconstructing public infrastructure and providing

assistance to households and businesses. Such a *financing gap* is a useful measure of sovereign financial vulnerability. The repercussions of a financing gap can be substantial. The inability of a government to repair infrastructure in a timely manner and provide adequate support to low-income households can result in adverse long-term socio-economic impacts. As a case in point, Honduras experienced extreme difficulties in repairing public infrastructure and assisting the recovery of the private sector following Hurricane Mitch in 1998. Five years after the Mitch's devastation, the GDP of Honduras was 6% below pre-disaster projections.¹ In considering whether Honduras and other highly exposed countries should protect themselves against financing gaps and associated long-term negative consequences, it is important to keep in mind that risk management measures have associated opportunity costs, which means that they can reduce GDP by diverting financial resources from other public-sector objectives, such as undertaking social or infrastructure investments.

2.2. Risk financing options for reducing financial vulnerability

Governments can choose among a variety of traditional and novel pre-disaster risk financing instruments for reducing their financial vulnerability. The most common ones are discussed below:

- A *reserve fund* holds liquid capital to be used in the event of a disaster. Ideally, the fund accumulates in years without catastrophes; however, from experience there is considerable political risk of fund diversions to other pressing government needs, especially after long periods without serious disaster incidence.
- *Insurance and other forms of risk transfer* provide indemnification against losses in exchange for a payment. Insurance is an important pre-disaster, risk-transfer institution in that it distributes disaster losses among a pool of at-risk households, businesses and/or governments and to the reinsurance markets. With primary and reinsurance markets attracting capital from international investors, insurance has become an instrument for transferring disaster risks over the globe. In the early 1990s, large losses from US catastrophes strained the capacity of the reinsurance markets and raised the price of reinsurance (see Fig. 6). This insurance crisis led to the development of new financial instruments to transfer catastrophe risk exposures, including *catastrophe bonds*, but also to other types of index-based securities that are traded on the equity 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), but shares the insurer's or

government's losses by sacrificing interest or principal following the event.

- *Contingent credit* arrangements do not transfer risk spatially, but spread risk intertemporally. In exchange for an annual fee, the risk cedent has access to a pre-specified post-event loan that is repaid at contractually fixed conditions. In the case of sovereign risk financing, international finance institutions offer such instruments. Contingent credit options are commonly grouped under alternative risk-transfer instruments.

For the case of Mexico, a reserve fund, reinsurance and a catastrophe bond were the instruments of choice, and thus the focus of the CATSIM analysis. Contingent credit schemes were not considered as the Mexican authorities prefer to avoid new debt commitments that would put pressure on the national budget and jeopardize Mexico's favorable credit rating.

Due to the extreme nature of the losses and the substantial costs involved in such transactions, disaster insurance and other risk financing instruments generally absorb only specified *layers* of risk, defined by an attachment and exit point (with the lower and upper limits based on the recurrence period of the events). Low layers of risk, for which the risk cedent is able to raise sufficient funds for financing the losses, will typically be retained. Extreme layers of risk will also not be transferred to other agents because of the high and exponentially increasing costs of transfer. One important factor in the costs is the uncertainty associated with extreme losses, which necessitates large sums of backup capital "reserved" by the agent accepting the risks in order to fulfill its obligation in case of an event.

An example of a layered risk-transfer portfolio is illustrated in Fig. 1. In this case, the lower threshold (attachment point) is the 100-year event (the event has an annual probability of less or equal to 1%) with losses of \$1 billion. The upper threshold (exit point) is the 200-year event with losses of \$2 billion. The lower threshold is determined by the government's *financial vulnerability* since it specifies the disaster risk for which the government is in need of additional financial resources for protecting its portfolio of public assets and providing emergency response and relief.

3. The management of natural disaster risks in Mexico

Mexico lies within one of the world's most active seismic regions and in the path of hurricanes and tropical storms originating in the Caribbean Sea, Atlantic and Pacific Oceans. Seismic hazards have caused the largest losses in the past, and earthquakes are thus considered the most severe hazard facing the country. Fig. 2 shows a map of past earthquakes by magnitude and depth of ground shaking beginning from the first recorded event in 1524. In the 20th century alone, there have been 29 earthquakes of magnitude equal or greater than 7.5 on the Richter scale.

¹Own calculations.

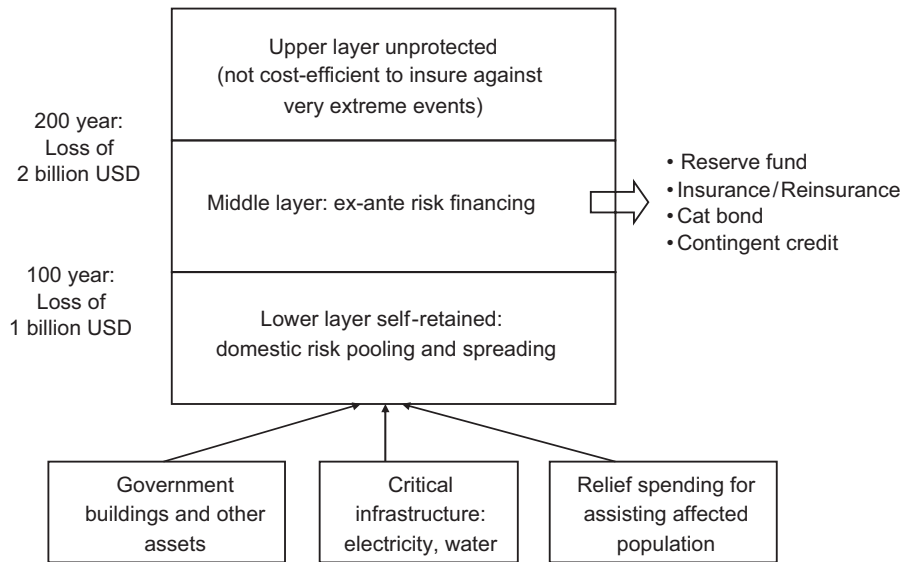


Fig. 1. A structure for financially managing the public sector's disaster risk liabilities.

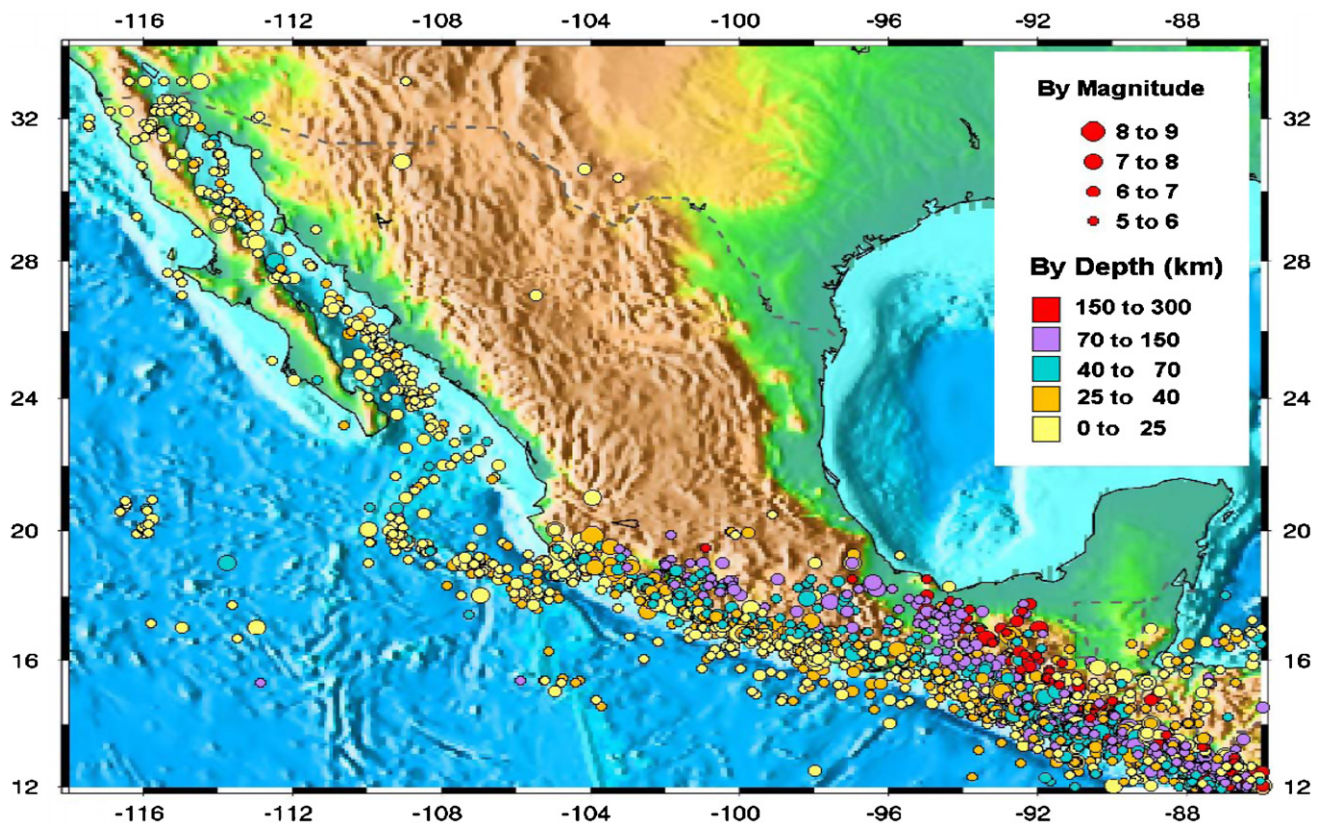


Fig. 2. Epicenters of earthquakes in Mexico since 1524. Source: AIR, 2005.

Mexico's population and economy are highly exposed to this hazard, and the most exposed areas generate around 60% of GDP and concentrate 59% of the Mexican population (World Bank et al., 2000).

In the event of a disaster, the Mexican government is legally responsible for providing emergency aid and economic support to its low-income population (18% of Mexico's population is under the national poverty line

(World Bank, 2006)). In the past, large fiscal liabilities and imbalances have resulted from severe disasters. Given its high financial vulnerability, the Mexican government has been striving to improve its management of contingent fiscal liabilities, especially those resulting from natural hazards and other exogenous shocks. Since federal, state and municipal governments are required to insure their public assets, the government is protected from paying the

reconstruction of public infrastructure. However, the required level of insurance, particularly for very large events, remains a concern (World Bank et al., 2000).

In 1996, the national government created a budgetary program called FONDEN (Fund For Natural Disasters) to enhance the country's financial preparedness for natural disaster losses. As a budgetary item, FONDEN is established at the start of each fiscal year by the Mexican parliament as part of the federal government budget plan. FONDEN provides last-resort funding for uninsurable losses, such as emergency response and disaster relief. In addition to the budgetary program, in 1999 a reserve trust fund was created, which is filled by the surplus of the previous year budget item. FONDEN's objective is to prevent imbalances in the federal government finances derived from outlays caused by natural catastrophes. The fund does not support reconstruction of private infrastructure, nor does it act as insurer of last resort. It grants financial support only to those private individuals that, due to their poverty status, require government assistance. Fig. 3 shows FONDEN's budgeted and spent funds for natural disasters over the last decade, including the average balance and one standard deviation around this mean.

As shown in Fig. 3, budgeted FONDEN resources have been declining over the last few years. Moreover, demands on FONDEN's resources are volatile, and outlays have often exceeded budgeted funds. As a consequence the reserve fund has diminished, and finally in 2005, after the severe hurricane season affecting large parts of coastal Mexico, the fund was exhausted. The uncertainty associated with FONDEN to provide sufficient post-disaster finance led officials of the Ministry of Finance and Public Credit (hereafter referred to as the Finance Ministry) to consider hedging against natural disaster shocks.

The question thus facing the Mexican authorities was to transfer a layer of FONDEN's risks in order to assure sufficient post-disaster finance for covering the government's potential liabilities. This would reduce the strain on the post-event fiscal budget and ensure continuity of

Mexico's social and other investment programs. If the government viewed risk transfer as desirable, it confronted the question which financing instrument or combination of financing instruments to purchase for this purpose. The characteristics of FONDEN, its peculiar operating logistics and, in particular, the recurrence of the catastrophes confronted by FONDEN suggested instruments tailored specifically to the Mexican context.

One consideration within this context was justifying additional insurance for what is already a Mexican (self-) insurance fund. Because FONDEN can cover the losses of frequent less severe events, the Finance Ministry could not justify insuring low layers of risk (it might even be construed as gambling with public resources). If, however, FONDEN cannot reliably cover losses from high-severity disasters, a hedging instrument could be justified to provide capital for disaster relief and emergency actions, such as the removal of rubble to save lives from earthquakes. This requires that payments made to FONDEN from the insurer or risk holder are both prompt and transparent. Since government agencies at all levels must provide for insurance protection independently of FONDEN resources, the instrument should indemnify only losses that exceed the financial capacity of the (insured) federal, local or municipal government agencies. Given these considerations, the Mexican authorities placed the following conditions on the selection of a risk-financing instrument:

- it must not interfere with the legal functioning of FONDEN,
- it must meet the immediate needs of FONDEN,
- risk must be minimized; in other words, the uncertainty concerning payment from the third party (risk bearer) must be minimal, and
- the premium or other costs associated with the risk financing transaction should also be minimized.

Although the Mexican authorities are planning to extend risk transfer to include all major hazards, the current risk-

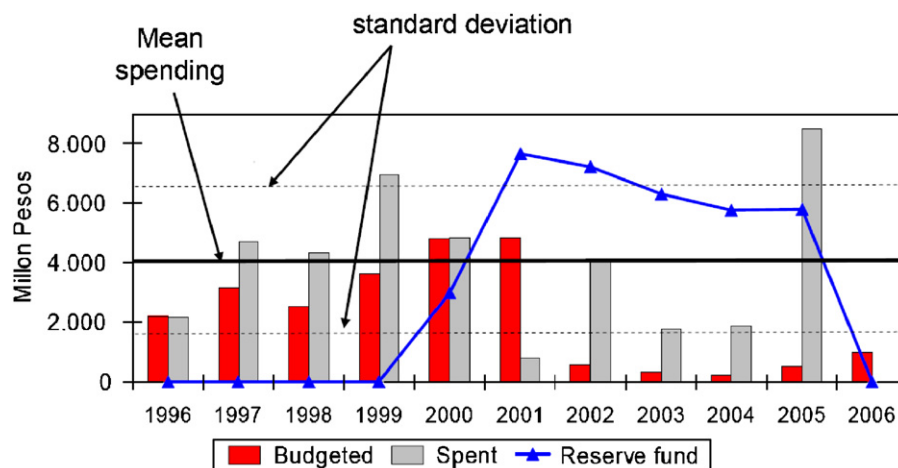


Fig. 3. Budget and resources of FONDEN. Source: Ministry of Finance and Public Credit of Mexico.

transfer decision and the CATSIM analysis, focused only on seismic risk.

4. Model-based analysis of risk financing strategies: the IASA CATSIM model

In the words of a leading expert on disaster risk financing, any *ex ante* risk financing strategy should be based on “an in-depth understanding of a country’s risk exposure, a thorough analysis of the potential benefits of mitigation efforts, and cost tradeoffs between different types of risk-financing instruments, and last but not least, on assessing the country’s internal financial capacity to retain the risk” (Gurenko, 2004). IASA’S CATSIM model takes these considerations into account by providing a stylized interactive model-based framework to assist public policy makers of financially vulnerable countries to design *ex ante* risk financing strategies (Mechler et al., 2006; Hochrainer, 2006).

CATSIM analyzes the risk-transfer decision in the wider context of a public investment decision by assessing both the direct financial as well as the opportunity costs in light of the government’s fiscal and macroeconomic constraints. For representing the fiscal and macroeconomic context, CATSIM builds on a simplified economic growth model with a focus on the public sector. An important modeling component is a detailed public finance module for analyzing the ability of the state or central government to finance unexpected liquidity needs—referred to as the government’s financial vulnerability. The model employs Monte Carlo simulation to generate random shocks to a state or country’s capital stock. More than 3000 scenarios for losses from catastrophic events are generated for a decade or other specified time period. The CATSIM tool is equipped with a graphical interface that allows the user to interactively change default parameters, such as the probability of extreme events and the government’s debt and other determinants of financial vulnerability. Since the user can interactively change important parameters and assumptions, risk-financing strategies can be examined in a transparent and iterative fashion.

As shown in Fig. 4, the stepwise modeling framework generally takes account of (1) the risks (in probabilistic terms) the government faces with regard to public-infrastructure losses² and post-event emergency response and relief liabilities for private-sector damage, (2) the financial resilience of the public sector, determined by the governments’ ability to raise funds for financing the losses, (3) the vulnerability of the government to direct losses or its financing gap as a combination of the above, (4) the fiscal and macroeconomic consequences of the disaster losses and the opportunity costs of financing the losses and (5) the

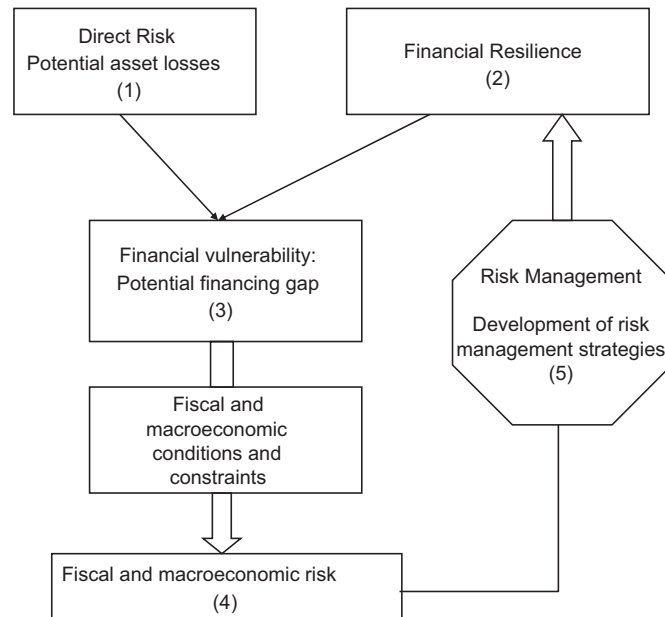


Fig. 4. CATSIM framework for analyzing financial risk management decisions.

cost effectiveness of mitigation and selected pre-disaster risk financing instruments for decreasing financial vulnerability by closing the financing gap.

Financial instruments considered by CATSIM include reinsurance and catastrophe bonds, and in addition a catastrophe reserve fund and contingent credit arrangements. In addition, CATSIM includes a generic option for mitigation and preparedness measures. Model results illustrate the respective costs and consequences of mitigation and alternative financing strategies with regard to important indicators, such as economic growth and the government’s borrowing capacity (Hochrainer et al., 2004; Hochrainer, 2006). The incremental steps of the CATSIM analysis form the basis of the Mexican case reported in the following sections.

5. Assessing Mexico’s financial vulnerability with CATSIM

As outlined, the assessment of financial vulnerability provides the platform from which to plan financial risk management measures. Basing their analysis on past demands and spending by FONDEN, staff at the Mexican Finance Ministry set a vulnerability threshold at roughly \$500 million, above which the fund would not be able to cover post-disaster outlays. This amount was calculated as the sum of average FONDEN spending over the last years (as shown in Fig. 3, around 4 billion Pesos or \$310 million) plus one standard deviation around this spending (2400 million Pesos or about \$190 million). If a disaster were to occur that required outlays beyond this sum, it is expected that FONDEN would not be able to fulfill its legal obligations for response and relief, and additional sources would be needed. Thus, FONDEN would be financially vulnerable beyond such a loss.

²As discussed, disaster risk to Mexico’s public infrastructure is legally transferred via insurance, so public asset reconstruction represents a liability for the Mexican government only to the extent that insurance is actually not bought or extreme risks are not covered.

As shown in Fig. 4, Steps one and two of CATSIM—assessing the direct risk facing the government and its resilience to this risk—combine to determine the government's financial vulnerability. Risk is defined as a combination of probability and losses, which in turn depend on the frequency and intensity of the hazard (for example, the intensity of ground shaking), the elements exposed to those hazards and their physical vulnerability. Financial vulnerability is determined by assessing the probability of government default on its post-disaster liabilities, which depends on the strength of the government's fiscal and economic situation.

5.1. Step one: assessing Mexico's public-sector risk

Step one of the CATSIM analysis adopted a top-down approach making use of aggregated data on the earthquake hazard, contingent liabilities and their sensitivity. A recent study by the World Bank provided a broad estimate of the probabilistic losses to Mexico's capital stock (public and total) due to seismic hazards. The public capital stock for Mexico was valued at approximately \$940 billion. Furthermore, FONDEN exposure for relief spending and emergency response was estimated at \$420 billion (about 45% of total public assets) (World Bank et al., 2000). Assuming relief and emergency response expenditure in constant proportion to public-sector asset losses as a first-order approximation, and losses and recurrence periods as established in World Bank et al. (2000), the following potential losses to the FONDEN portfolio due to seismic hazard can be estimated (see World Bank et al., 2000):³

- 20 year event: \$40 million,
- 50 year event: \$200 million,
- 100 year event: \$2.0 billion,
- 500 year event: \$2.9 billion.

For example, according to this analysis an earthquake expected to occur once every 20 years (a 20-year event) would necessitate response and relief spending by the national government estimated at roughly \$40 million.

5.2. Step two: assessing the resilience of the Mexican government to earthquake losses

Step two of the CATSIM analysis estimates the availability of funds on the part of Mexico's national government to provide relief and emergency assistance *if a*

³A risk modeling firm (AIR) was contracted to generate detailed information on hazard, vulnerability, exposure and direct risks to the government. As this information is proprietary, the present analysis emphasizes the rationale and issues behind the decision process rather than the data (see Mechler et al., 2004), and resorts to publicly available data as reported in World Bank et al. (2000). There is considerable uncertainty around the estimates and parameters used in this study and since reporting on the sensitivity analysis is beyond the scope of this paper, results have to be understood as illustrative.

disaster should occur in the current period. While financial vulnerability is defined as the lack of access on the part of a government to domestic and foreign funds for financing post-disaster reconstruction investment, emergency response and relief, the Mexican analysis only considered the vulnerability of the FONDEN fund in providing emergency response and relief. Beyond relying on FONDEN, the Mexican government can raise funds after a disaster by:

- accessing international assistance,
- diverting funds from other budget items,
- imposing or raising taxes,
- taking a loan from the Central Bank (which either prints money or depletes its foreign currency reserves),
- borrowing by issuing domestic bonds,
- borrowing from multi-lateral finance institutions (MFIs), and
- issuing bonds on the international market.

Each of these ex post financial sources is characterized by costs to the government as well as factors that constrain its availability.

5.3. Step three: estimating the government's financial vulnerability

The CATSIM model combines steps one and two to generate information on the government's potential financing gap—or financial vulnerability (Mechler, 2004). As discussed, the average budgeted and accumulated disaster-related government resources within FONDEN in the past have only been sufficient to cover losses of up \$500 million, which, as shown in Fig. 5, corresponds approximately to the 50-year event. For more severe earthquakes expected to occur less frequently, the government will depend on other financial sources, including international assistance, more (unbudgeted) diversion from the budget, domestic credit, lending by MFIs and the international capital markets. Taken into account budgeted and unbudgeted resources, the CATSIM analysis suggests that there will be sufficient finances to cover the government's post-disaster liabilities up to an amount of approximately \$ 1.7 billion. This corresponds to the 91-year event (an event with a recurrence period of 1 in 91 years or annual probability of 1/91), above which the government experiences a financing gap; i.e., generating response and relief spending beyond such an event would be exceedingly difficult. In Fig. 5 this financing gap is shown as the upper most layer.

5.4. Step 4: estimating fiscal and macroeconomic risk

The opportunity costs of diverting budgetary resources to pay for disaster relief and emergency response can be approximated given estimates of (1) potential losses and the government's financial vulnerability (financing gap), (2) the fiscal and macroeconomic consequences of limited

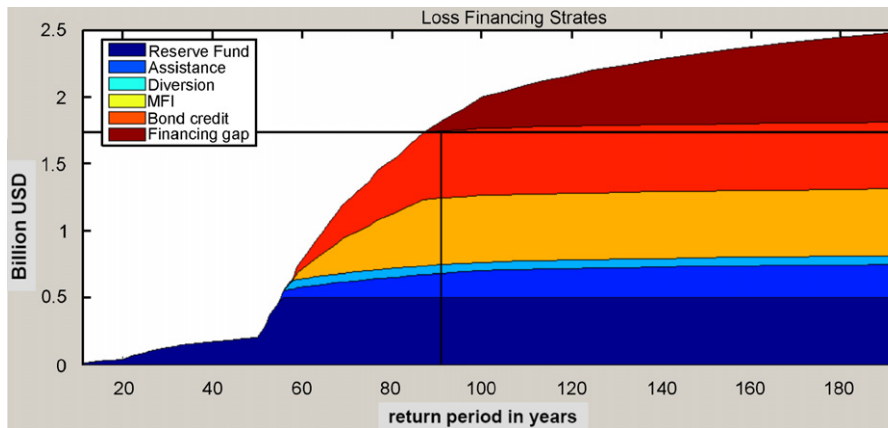


Fig. 5. Assessing financial vulnerability and the financing gap for the case of earthquake risk in Mexico.

absorptive capacity and (3) the economic consequences of losing capital stock. CATSIM represents these opportunity costs (or indirect risk) in terms of the probability distributions of the effects on budget variables or GDP.⁴

6. Comparison of reinsurance and a catastrophe bond

Given an estimate of financial vulnerability, the analysis can turn to assessing Mexico's risk-transfer strategies and their pros and cons. This section gives important background information on the two instruments considered by the Mexican authorities: reinsurance and catastrophe bonds. These instruments are compared in terms of their pricing and credit capacity.

6.1. Reinsurance

Governments wishing to insure their assets, as well as response and relief liabilities, turn to reinsurers (or internationally operating insurers) because of their capacity to absorb public infrastructure risks of even large countries. Reinsurers seek (or are required) to hold sufficient reserves to meet claims in the event of disasters, and typically they transfer a part of their risk to other companies. The reinsurance market has had significant growth in its capacity—from less than \$40 billion in 1994 to about \$70 billion (in current terms) in 2002 (Swiss Re, 2004). As shown in Fig. 6 average catastrophe premiums (World Rate On Line Index⁵) are cyclical and have slightly decreased in recent years—termed a “soft market”. The attacks on New York City in September 2001 had a great impact on world reinsurance prices, including those for natural disaster risks.

Besides premium, an important consideration for governments selecting among reinsurance companies is their credit risk, which reflects the capability of the company to

honor its acquired obligations. The Mexican authorities identified companies with expertise, experience and sufficient capacity and reserves to assume FONDEN's risks and, at the same time, with low credit risk. As shown in Table 1, most of the 34 companies examined had fair to good credit ratings (AA to A-), but only two had a top rating of AAA (and thus the lowest credit risk as judged by Standard & Poor's Index). Premiums differ according to credit rating, i.e., insurers with high ratings are able to demand a higher premium in the market; however, no information is (publicly) available on the premium differentials associated with credit rating. The following CATSIM-based analysis will examine two cases: an AAA rated and a B rated reinsurer (the B rating was chosen to account for the non-rated insurers).

6.2. Catastrophe bond

By hedging catastrophe risk for a payment, catastrophe bonds serve the same purpose as reinsurance. Yet, the risks are not absorbed by international insurers but directly by financial markets via investors, who receive a contingent interest rate calculated on the basis of the estimated risk. Post-event payments do not stem from insurance company reserves but from global capital markets. The transfer process involves the entity transferring risk (the insured, in this case, FONDEN) and investors (for example, pension fund managers). As illustrated in Fig. 7, a Special Purpose Vehicle (SPV) controlled by an independent agency is created to manage the capital over the specified period of the bond.

Investors purchasing catastrophe bonds face no credit risk since their invested capital is kept in a collateralized account invested in risk free securities (e.g. UK or US government backed bonds). Managers of the SPV provide information to investors on the probable principal loss (total or partial) in the event of a catastrophe of determined characteristics (for example, an earthquake measuring 8 on the Richter scale). If the specified event

⁴More detail on the indirect risk calculations is beyond the scope of the paper. Summary results of these calculations are given in Section 8.

⁵Rate on line is the premium expressed as a ratio of the financial cover.

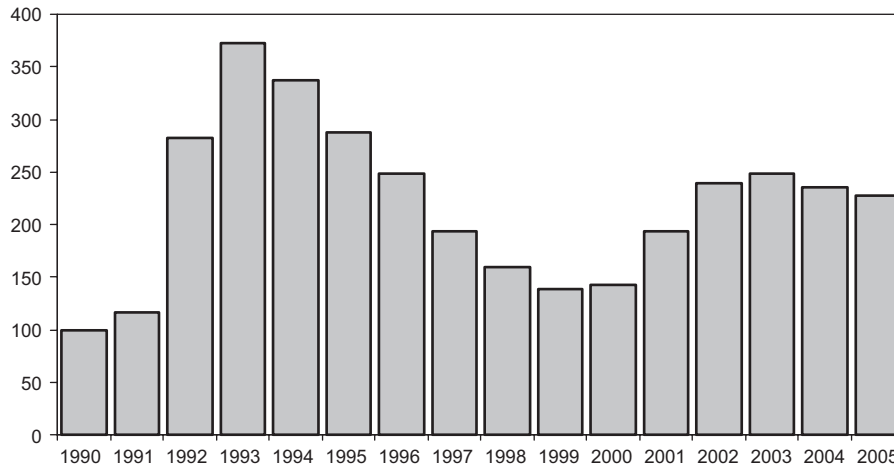


Fig. 6. World rate on Line Index. Source: Guy Carpenter, 2005.

Table 1
Distribution of credit rating of insurance or reinsurance companies

S&P	No.
AAA	2
AA	1
AA-	7
A+	5
A	5
A-	8
NR	6
Total	34

Source: Standard & Poor's (2005).

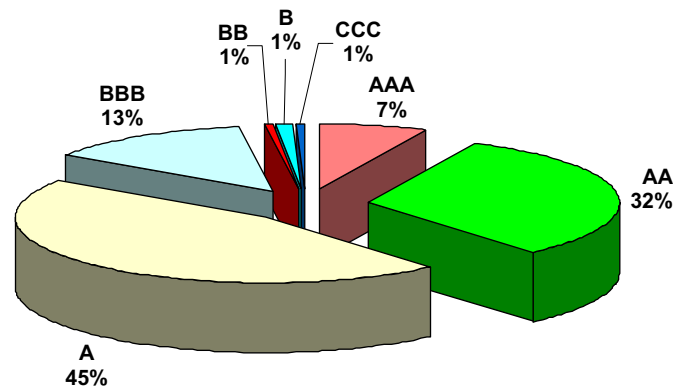


Fig. 8. Rating distribution of international reinsurance companies. Source: own compilation with data of Standard & Pools.

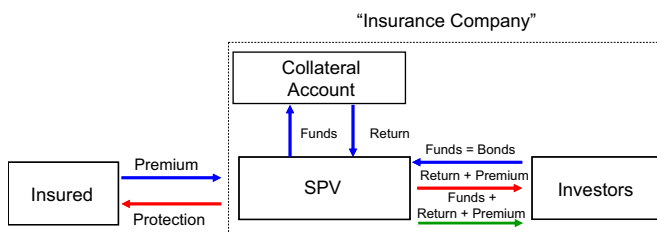


Fig. 7. Risk-transfer process for cat bond.

occurs, payment is triggered, meaning that the funds flow to the insured party.

Catastrophe bonds made possible by recent advances in catastrophe modeling have emerged only in the last decade. The catastrophe bond market has been growing at a relatively steady and considerable pace from four transactions in 1997 with a total cover of \$ 0.6 billion to 12 transactions in 2005 at approximately \$2 billion. Total cover is currently \$5 billion, up from approximately \$3.5 billion in 2003 (Guy Carpenter, 2006). There are few examples of losses in catastrophe bonds, such as Georgetown Re, Kelvin Ltd. and recently in 2005 when KAMP Re, a \$190 million catastrophe bond protecting insurers in the US, was triggered by Hurricane Katrina and inflicted a total loss of the invested principal.

6.3. Comparing reinsurance and a catastrophe bond

Although it may appear that reinsurance and catastrophe bonds provide the same product to the client, there are important differences in their credit risk and pricing structure.

6.3.1. Credit risk

With respect to insurance or reinsurance the insured party implicitly acquires the credit risk of the company. In the case of large or multiple losses, reinsurance companies may readjust premiums or even default. Even if contracts are multi-annual, a reinsurer can place adjustment conditions in the annual price setting of the policies. In theory (and substantiated by anecdotal evidence), insurers with lower credit ratings offer their services at lower prices. Fig. 8 shows the distribution of reinsurer credit ratings in the international markets. Only 7% of reinsurers hold the best credit rating of AAA.

The situation is different in the case of a catastrophe bond. Because a secure collateralized account is created to hold the resources to cover the protected event, there is no credit risk. The multi-annual structure of the SPV is

designed to make the funding immune to market fluctuations, i.e., the premium is fixed throughout the instrument's maturity. However, the agency transferring risk must assume the costs involved in creating the SPV, and thus the elimination of credit risk by the SPV is an additional cost borne by the insured party.

6.3.2. Pricing structure

The premium paid for a catastrophe bond has two components: The main component is the pure risk premium, or the pecuniary value of the risk born by the investors in the SPV. The pure risk premium is essentially derived from the annual expected loss and the value of the insured amount (Lane, 2004). Under competitive markets this represents the probability of losing resources invested in the transfer vehicle. The second component is the fixed costs of the transfer process, including fees for:

- legal services,
- setting up an SPV,
- the financial entity (structuring and placement fees),
- the rating agency,
- the catastrophe modeling agency,
- the verifying agency, and
- the indenture trustee.

Estimating the expected annual loss from the disaster event is an additional and substantial cost for which it is necessary to develop or acquire the licenses of actuarial risk estimation models along with technical assistance. Moreover, depending on the complexity of the risk and the size of the insured party, there are costs associated with the acquisition of information and data for the model. The fee can range from 0.1% or 0.4% of the total issuance cost. The financial structure is set based on the legal form of the SPV, which, in turn, depends on the needs of the insured. In most cases, fiscal considerations have an important presence in the structure definition as well as in the physical location of the SPV. A great majority of insured parties choose a location in countries with lax fiscal (tax) codes.

The premium of a reinsurance contract includes transaction costs, capital costs and a profit margin, in addition to the expected loss estimate. Typically, and in sharp contrast to catastrophe bonds, the transaction costs are relatively low, approximately 1% of the cover amount (Lane, 2004). This is not the case for capital costs. In those cases where reinsurers lack wide diversification and are exposed to catastrophic losses, the costs of holding sufficient capital to protect against risk scenarios are sizeable (Pollner, 2001). Furthermore, depending on the structure and location of the insured, it is necessary to consider the front-end fee and administrative costs. Finally, reinsurers can add to this "load" to reflect the general outlook of the market. This helps explain why premiums are highly cyclical and related to the global capital market.

Table 2
Reinsurance vs. cat bond

	Credit risk	Costs
Reinsurance	Risk of default of reinsurer	Includes transaction costs, capital costs, profit margin, in addition to expected loss. Reinsurers can also add a "load" and thus premiums are cyclical and related to global market Premiums differ according to credit rating
Catastrophe bond	No credit risk	Placement bond costs can be substantial. To date, cat bond are generally costlier than reinsurance

Table 2 summarizes the differences between reinsurance and catastrophe bonds in terms of their credit risks and costs.

These differential characteristics provide the backdrop for the following model-based discussion of Mexico's choice of reinsurance versus a catastrophe bond.

7. Assessing Mexico's risk-transfer strategies with CATSIM

The fifth step of the CATSIM analysis is the development and evaluation of financial risk management strategies. In consultation with the Mexican authorities, the question analyzed by CATSIM was whether to transfer a middle-layer of risk, and (if so) with a catastrophe bond or reinsurance? The following options considered by the Finance Ministry and IIASA were:

- risk transfer with a catastrophe bond,
- risk transfer with reinsurance companies exhibiting different credit risks (AAA and B ratings based on default probabilities),
- no risk transfer.

Since only the middle layer risk is transferred, both the insurance and catastrophe bond contracts have an attachment point (A) representing losses above which the insured receives a claim payment, and an exit point (E) representing losses above which the insured receives no additional payment. The payment depends on the size of the damage (y). The payment (C) is thus characterized as follows:

$$C(y) = \begin{cases} 0 & \text{if } y < A, \\ y - A & \text{if } A < y < E, \\ E - A & \text{if } y > E. \end{cases}$$

It can be recalled that the financial vulnerability analysis (Section 5) identified a financing gap beyond the 91-year event. Given the substantial uncertainties around this estimate, for this stylized analysis the attachment point was set at the 100-year event, and the exit point at the 150-year return period. Thus the middle-layer to be transferred was the 100–150 year earthquake risk.

In order to take account of important differences with respect to credit risk, cyclical premiums and transaction costs when simulating reinsurance and catastrophe bond instruments, the following information and assumptions formed the basis of the modeling exercise:

- The *insurance* premium calculation was based on cyclical data (Guy Carpenter, 2005) over the period 1990–2004. The starting-year premium was calculated on the basis of loading factors presented by Pollner et al. (2001). It is assumed that this baseline is not altered within the observation period because of exogenous factors (e.g. climate change). However, due to the fluctuations in the world insurance market apparent in the Guy Carpenter data, the loading factors and therefore the premium changes.
- The costs of the *catastrophe bond* are independent of these cycles, but catastrophe bonds are characterized by high transaction costs. Consistent with experience, the transaction costs were assumed to total 2% of the risk cover. The premium calculation for the catastrophe bond was based on a method proposed by Lane (2003).
- Finally, estimates of credit risks were based on information on reinsurance companies ranging from AAA to B ratings (Standard & Poor's, 2005). From this information, the authorities can expect a default risk of 0.62% from the AAA rated reinsurance company and 16.5% from the B rated company. As no information on premium related to credit rating is publicly available, based on expert opinion, this analysis assumes that there is a 10% loading differential between the AAA and B rated companies.

The CATSIM model was run stochastically over a time horizon of 12 years⁶ (leading to more than 18,000 scenarios). The risk financing instruments—reinsurance and catastrophe bond—were evaluated in terms of several indicators, including:

- their annual costs,
- the financial protection offered,
- the probability of a financing gap occurring over the respective time horizon,
- the expected value of the financing gap with the instrument in place, discounted over the 12-year time horizon, and
- the expected impact of the instrument on the discretionary government budget (given that a large amount of the budget is oriented towards social and investment programs as well as debt repayments, this indicator calculates the flexibility in budgetary resources).

With respect to the above indicators, Table 3 compares AAA and B rated reinsurance, a catastrophe bond and no

financial risk transfer for providing protection for the 100–150 year event.

Based on the assumptions of the analysis (which the Mexican authorities could interactively change), the catastrophe bond and reinsurance (AAA and B rated) are relatively effective both in terms of their average performance and their volatility when compared to the case of no financial protection for FONDEN. As shown in Fig. 9 the probability of a financing gap and the expected financing gap are strongly reduced in all cases (approximately 40% and 60%, respectively) as well as the volatility as measured by the standard deviation (about 50%).

The reduction of the financing gap, and thus Mexico's vulnerability to major catastrophes, strongly motivates the risk-transfer decision. However, vulnerability reduction comes at a cost, and paying insurance premium and catastrophe bond interest deflects resources from other discretionary government investments. CATSIM demonstrates this tradeoff, and thus places the risk-transfer decision in the context of a public investment strategy. Although beyond the scope of this paper, CATSIM can illustrate the effects of risk transfer on economic growth, country debt and other indicators relevant to the public investment strategy. The indicator in Table 3 is the change in the discretionary budget with and without risk transfer, and thus the change in the ability of the Mexican government to invest in other economic and social programs. On average, there are diminished discretionary budget resources available with risk financing instruments in place; however, importantly, the volatility of the budgetary resources is reduced. This, along with the other indicators, is illustrated in Fig. 9.

Comparing a catastrophe bond and reinsurance, the catastrophe bond could be viewed as more desirable for reducing the probability of a financing gap and the expected gap indicators. Given its higher cost, however, the catastrophe bond performs less well with respect to the expected discretionary budget. Yet, the bond performs as well as reinsurance in reducing the volatility of budget resources.

These results should be interpreted as only illustrative of CATSIM's capacity to demonstrate the types of information and analysis useful for decisions on sovereign risk transfer. The reported results are highly sensitive to the assumptions on pricing and credit risks, among others (CATSIM performs sensitivity analyses, but a discussion is beyond the scope of this paper). Importantly, the CATSIM model can be used interactively, and Mexican Finance Ministry authorities had the opportunity to change the assumptions and parameters to gain an understanding of the sensitivity of their policy options on the risks and characteristics of the risk-transfer instruments.

8. The Mexican risk-transfer decision

The CATSIM model, based on highly aggregated and publicly available data, informed the final decision

⁶A 12-year time horizon was chosen based on a 3-year renewal period of the cat bond under investigation.

Table 3

Differences in response variables with reinsurance, cat bond and without financial ex-ante protection for 100–150 year events over 12 years (standard deviations in brackets)

	Reinsurance (AAA rating)	Reinsurance (B rating)	Catastrophe bond	No financial risk transfer
Annual costs (mill. US\$)	37	34	39	0
Financial protection (mill. US\$)	100–150 year layer			0
Annual expected financing gap (mill. US\$)	17 (176)	18 (188)	16 (176)	47 (367)
Probability of financing gap (%)	11	11	10	18
Discretionary budget (mill. US\$)	4419 (122)	4419 (154)	4418 (122)	4421 (608)

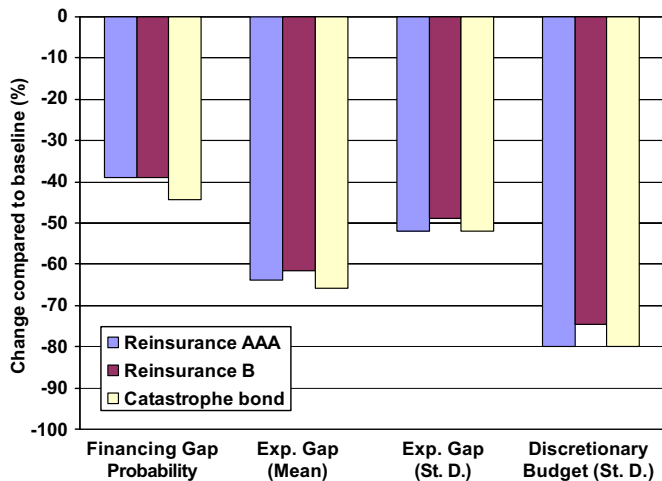


Fig. 9. Results of risk financing instruments as compared to the baseline case without (additional) financial protection.

undertaken in early 2005 by providing a stylized analysis of FONDEN's risk and the potential of risk-transfer instruments. It was clear from the CATSIM analysis that more disaggregated information would be needed for the actual commercial transaction. For this purpose, international consultants provided disaggregated engineering and financial detail on the risks and financial options across Mexico's earthquake zones. After contemplating a number of options related to the type of risk-transfer instrument and the geographic detail to be covered, the authorities decided to combine a catastrophe bond and reinsurance. Negotiations commenced with a major reinsurer and an investment bank.

The resulting contract is linked to a parametric trigger (as compared to indemnity-based contracts where the actual losses provide the basis for the claim payment) in terms of magnitude and depth of seismicity for the three-year period 2007–2009. The two instruments provide a total cover of \$450 million for a premium/interest totaling \$26 million. An insurance claim payment is triggered if:

- an earthquake with specified magnitude and depth is recorded with its epicenter located in one of the specified zones, and if
- there is official declaration of a disaster by a federal agency.

The reasons for choosing a parametric trigger include both the ease of risk assessment (and the transparency to investors) and especially the ease of settling claims (and the elimination of the risk that investors will be pressured to pay the bill following an event). As shown in Fig. 10, the transaction identified three earthquake zones in Mexico that were estimated to be at greatest risk: two situated on the Pacific coast in central-south Mexico and one in central Mexico (including a large part of Mexico City).

Table 4 shows the magnitude and depth of the earthquake that triggers payment of the catastrophe bond and reinsurance in each of the three zones. Roughly, the trigger events as defined by the physical parameters correspond to 100-year events in each of the zones (AIR, 2005).

Zone 1 is covered entirely by the catastrophe bond for a premium of \$11 million over 3 years and an interest rate of 230 basis points (2.3% percentage points) above the market reference interest determined by the London Interchange Official Rate. In zones 2 and 5, a smaller portion of the cover is provided by the catastrophe bond and at a slightly higher cost of 235 basis points. The bond specification foresees that in case of a triggered event investors would lose both their invested capital as well as interest. The choice in favor of a mix between the catastrophe bond and reinsurance (with reinsurance cover dominating) can be attributed to the very competitive bidding process implemented by the Mexican government and the portfolio diversification opportunity offered to reinsurers and catastrophe bond investors. Both elements were key to the success of the risk-transfer transaction.

9. Summary

In contrast to wealthy countries, developing and transition country governments frequently face post-event deficits in financing reconstruction, response and relief, which can have serious effects on their country's long-term development and their ability to finance social and economic programs. The potential financing deficit provides the rationale for these countries—in violation of the Arrow-Lind theorem—to behave as risk-averse agents and consider financial risk management options for their contingent disaster liabilities, with instruments such as catastrophe reserve funds, traditional (re)insurance, catastrophe bonds or contingent credit contracts.

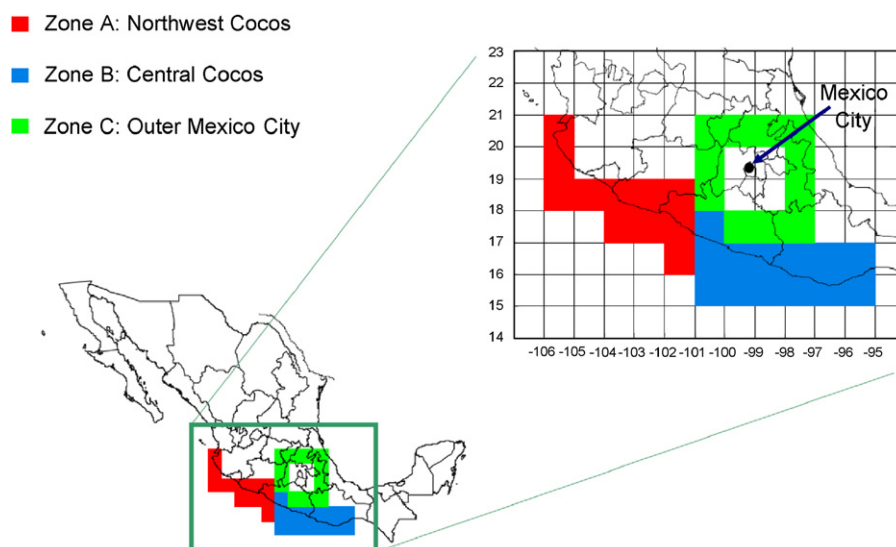


Fig. 10. Geographic zones included in the transaction.

Table 4
Details of risk transfer conditions in respective zones

Zones	1	2	5
Trigger: magnitude (Richter Scale)	8.0	8.0	7.5
Trigger: maximum depth (km)	200	200	150
Insured amount	\$150 m (cat bond)	\$150 m (reinsurance: \$140 m; cat bond: \$10 m)	\$150 m (reinsurance: \$140 m; cat bond: \$10 m)
Premium for 3 years	\$11 m (230 bp)	\$5 m (235 bp)	\$10 m (235 bp)

Note: bp: basispoints.

Mexico, with FONDEN and government reserve fund, is one of these pro-active countries. Faced with FONDEN's declining balance, government authorities recently considered protecting the fund with reinsurance and/or a catastrophe bond. With use of IIASA's CATSIM model, the Mexican decision for these instruments or alternatively for no protection, was analyzed given the government's objective of accessing secure and sufficient risk financing for FONDEN while minimizing costs. Reinsurance and catastrophe bonds are to some extent substitutable options for transferring sovereign disaster risk; however, there are important differences regarding their cost and credit risk. Three risk-transfer options (AAA and B rated reinsurers, and a catastrophe bond) for protecting the FONDEN program were evaluated and compared to the default case of no risk transfer.

Given the assumptions, the catastrophe bond performed somewhat better than reinsurance with respect to reducing the financing gap, slightly worse with respect to improving the funds available in the government's discretionary budget, and nearly equivalently for the reduction in volatility of budget resources. These results are highly sensitive to the underlying assumptions, and are meant only to illustrate a methodology for structuring the risk-transfer decision. The Mexican authorities had the

opportunity to change assumptions and parameters with the interactive CATSIM tool. The stylized, interactive CATSIM model informed the Mexican decision undertaken in early 2005 by providing a highly aggregated analysis of FONDEN's risk and the potential of risk-transfer instruments. International consultants subsequently provided engineering and financial detail on the risks and financial options across Mexico's earthquake zones.

In the final transaction undertaken by the government of Mexico in 2006, a mix of reinsurance and a catastrophe bond was chosen, to some extent due to the "soft" reinsurance market. Linked to a physical trigger, a total cover of \$450 million over the 3-year period 2007–2009 was purchased. Three regions in Mexico considered at highest risk were thus financially protected. As the CATSIM analysis demonstrated, both instruments have pros and cons; however, the chosen mix of insurance with a highly rated company and a catastrophe bond absent credit risk appear to provide adequate protection at least cost to the public sector, while providing sufficient budgetary and administrative flexibility. This transaction is likely to set an important precedent throughout the world for protecting highly exposed developing and transition country governments against the financial risks of natural catastrophes.

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