DRAFT

Dec 2, 1999

TSUNAMI

The Uninsured Elements of Natural Catastrophic Losses

Phase 1 Research Report

Introduction

This document reports on progress to date with respect to the TSUNAMI project on "The Uninsured Elements of Natural Catastrophic Losses." This project is being carried out jointly by the Risk Research Group, Centre for Environmental Strategy at the University of Surrey, and the International Institute of Applied Systems Analysis (IIASA), Laxenburg, Austria. The main objective of this research is to provide comparative information and insights on the uninsured losses from selected natural catastrophic events, as well as public policies and institutional arrangements affecting the extent of the losses and their distribution. Data permitting, the specific objectives are to:

- Present available data on the direct and indirect losses from natural disasters, and show how these losses are absorbed by individuals, businesses, lending organizations, and governments across selected hazards and countries;
- examine why a large proportion of these losses has been uninsured; and
- show how public legislation, public policies and other public/private actions (or non-actions) have affected the losses and the insurability of the losses;

The research focuses on floods and earthquakes in the United States, Europe and Japan. In this report, detailed case studies of the following catastrophic events are presented:

- U.S. Mid-western floods of 1993;
- German floods of 1993 and 1995 ;
- Polish flood of 1997;
- UK floods in April of 1998;
- California Northridge earthquake of 1994:
- Japanese Kobe Earthquake of 1995; and,
- Italian Umbria earthquake of 1997.

As background, these case studies describe the hazard and the main events of the disaster, the economies of the regions affected and the institutional arrangements for natural disaster risk management. Data permitting, the studies give estimates of the direct and indirect losses

to residential property, commercial property, industry and government infrastructure. The studies also trace the compensation of these losses to insurance and reinsurance companies, governments, financial institutions, and international aid givers. Finally, the cases document how the institutional arrangements changed after the disasters, and discuss the insurability and marketability of private insurance in the respective regions and countries.

1. Background: The global picture

Global Losses

The human suffering and economic losses from natural disasters are high and increasing. According to figures published by Munich Re (1998a), in the decade 1988-1997, major natural catastrophes cost the world's economies around US$ 700 billion. Although figures on natural disaster losses must be treated with caution given the lack of reliable reporting, a trend towards higher losses appears certain. Munich Re (1999) estimates that in this decade the number of natural catastrophes has been five times as great, and eight times as costly, as the decade of the 1960's. These losses seriously affect both the developing and developed world.

Despite the cautious interpretation by the Intergovernmental Panel on Climate Change, many scientists suggest that worsening weather extremes are a likely consequence of climate warming, although it is not possible to predict their magnitude and timing (MacDonald, 1998; Changnon, et.al, 1997). Another global change phenomenon, however, appears to be more directly and seriously implicated in increasing disaster losses. Changing patterns of land use, especially deforestation, and the increasing concentration of people and capital in vulnerable areas (for example, in the coastal regions exposed to windstorms, in the fertile river basins exposed to floods, and in urban areas exposed to earthquakes) are primary contributors to increasing disaster losses.

Most reported disaster losses can be attributed to floods, windstorms and earthquakes, which appear to be approximately evenly divided with respect to their global losses (Munich Re, 1998). Yet, the global pattern of these financial losses is uneven. As shown in Table 1, the overwhelmingly largest proportion of disasters and disaster victims reported by Swiss Re from 1995 to 1998 occurred in Asia, followed by North America, Europe and Africa. Excluding Japan, the Asian losses are largely from flood damages (Munich Re, 1998). Windstorm damage, alternatively, appears to disproportionately affect the developed world, and earthquake damage during the past few decades appears to be more evenly split between the developed and the developing countries (Freeman, 1999). Droughts, which impose the largest human suffering on the very poor countries of Asia and Africa, are generally underreported (International Federation of Red Cross and Red Crescent Societies, 1998).

Insured and Uninsured Losses

Private insurance is an important market institution for transferring the risks of large losses to a third party. As primary and re-insurance markets become more international – attracting capital from investors throughout the world - insurance becomes an institution for

transferring disaster risks over the globe. Not surprisingly, private insurance cover is unevenly distributed. Referring to Table 1, Asia has the highest percent of the disasters (and victims), but only around 13 per cent of worldwide insured losses. In contrast, North America has only about half the number of disasters and 65 per cent of worldwide insured losses, and Europe lies in between. According to Swiss Re (1998) industrialized countries, which have only 20 per cent of the world's population, account for 90 percent of the worldwide premium volume from all types of insurance. Surprisingly, however, the insured losses in relation to per capita GDP of the developing countries are actually higher than in the industrialized world (Swiss Re, 1997b). This high level of insurance in relation to income may be accounted for by the insurance purchases of international firms operating in these countries.

Table 1. Catastrophes and Insured Losses 1995-1998

Region	*Number of catastrophes*	*Insured Losses in million USD*	*Per Cent Insured Losses*
Europe	173	8,926	17
North America	330	33,220	65
(USA)	(170)	(29664)	(58)
Asia	643	6,470	13
(Japan)	(20)	(2,975)	(6)
Africa	139	370	1
Others (inc. space)	37	2,172	4
World Total	1,322	51,158	100%

The numbers represent aggregate Swiss Re data over the years 1995 - 1998

(Swiss Re, *Sigma* No. 2/1996, No. 3/1997, No. 3/1998 and No. 1/1999)

Although considerably higher than in the developing world, the extent of insured losses in the industrialized countries is also quite low, particularly for earthquakes and floods, for which cover usually ranges from 5 to 20 percent. Alternatively, storm damage is considerably better insured, usually in the range of 60 to 95 percent (Swiss Re, 1997b). U.S. corporations carry little insurance on large losses, especially for losses of between $10 million and $500 million, and insurance is virtually non-existent above $500 million (Froot and O'Connell, 1997b).

Throughout the world, public infrastructure is seldom insured, and generally the costs of repairing infrastructure are absorbed by the taxpayers. This is not a financial problem (although it may raise issues of equity) in large countries, such as the U.S., where the federal government absorbs up to 90 per cent of state and local government infrastructure losses from major disasters, thus spreading these losses across the entire U.S. population. However, in small countries, governments may have difficulties raising the funds to repair infrastructure and pay other disaster-response bills. In Poland, the infrastructure losses from the 1997 floods resulted in over 2 per cent of Poland's GDP (Kunreuther and Linnerooth-Bayer, 1999), and it was estimated that due to lack of funds it would be several years before all the roads and bridges were repaired (Swiss Re, 1997c).

In examining the global incidence of natural disaster losses, the question arises who ultimately pays the *insured* losses? In principle, and in the absence of government involvement, the premium payers bear the costs of insured risks over the long run. To the extent that insurers and reinsurers diversify their risks geographically, the risks are spread across the international community of premium payers. However, a unique feature of catastrophic risk insurance is that risk sharing is not possible only through shared premiums among those at risk. The problem is the timing, since a rare catastrophic event can occur before enough premium income has accumulated to cover the claims. To be viable, the private insurance market must match a smooth flow of annual premiums to non-smooth, stochastic annual loss payments (Jaffe and Russell, 1997). Therefore, insurance companies rely on both reinsurance and capital reserves to meet very large, dependent claims.

A great deal of recent attention has been given to the question whether the capital reserves of insurance and reinsurance companies are sufficient to cover large losses. In the U.S., the insurance industry has calculated scenarios for natural catastrophes ranging from US$ 21 to 101 billion of insured losses. With insurance reserves of over US$ 250 billion and access to re-insurance markets, it appears that the U.S. insurance industry can cover even the large, mega-catastrophes. However, the uneven spread of these reserves may render the insurance industry vulnerable to large defaults and insolvencies in the case of a mega-disaster (Cummins and Doherty, 1997). Moreover, studies by both Froot (1997a) and Swiss Re (1997b) show that the overwhelming proportion of large events in the U.S., and world wide, is not covered by reinsurance.[1] In the case of bankruptcies, the losses could be passed on to present and future policy holders (through "pay back" arrangements), other insurance companies and, in some cases, the government and taxpayers. To overcome the finite nature of insurance capital, recent attention has been given to novel risk-transfer or hedging instruments, including catastrophe bonds (Smith, et al, 1997), which transfer the risks to the global capital markets.

2. Disaster Losses: The national picture

The first and immediate effects of a natural disaster are to human lives and property damage. As shown on Figure 1, the victims of financial losses can be households (private residential property), small businesses and industries (commercial property), farmers (agricultural) and governments (public infrastructure). These initial and delayed "stock" losses to properties, their contents, crops, etc. are referred to as *direct losses*. By requiring clean-up and other responses from government, and by disrupting business and social activities, these "stock" losses lead to losses in the "flow" of goods and services. In Figure 2, these flow losses are referred to as *indirect losses* from the disaster. Indirect losses from business, agriculture, government and household disruption can be significant, even several times the magnitude of the direct losses.

[1] In 1997, CatXL[1] of US$ 52.9 billion were purchased, the biggest shares bought by US insurers (35%), the UK (11%) and Japan (9%).

Figures 1 and 2 show how the direct and indirect losses from natural disasters can be absorbed by governments and taxpayers, insurance and reinsurance companies, other financial institutions, and the international community of aid givers and investors. Some of these losses are directly reimbursed, for example, by primary insurance companies, of which a portion might be passed on to other persons or institutions, for example, to reinsurance companies or the government. Likewise, some of the non-reimbursed losses might be passed on, for example, the losses of defaulted loans that are absorbed by lending organisations. Indirect losses, which affect economic development and growth, are absorbed by a much wider public in the region, country and internationally.

In a survey of disaster loss sharing, Linnerooth-Bayer and Amendola (forthcoming) conclude that in most countries, the direct victims and their government play the most important role in absorbing the financial losses from natural disasters. Collective loss sharing by the state is usually financed from *ex post* financing instruments, such as public borrowing or from international lending organizations, budget diversions, and, ultimately, taxes. There is little international disaster aid and thus little loss sharing at the global level. Although it varies among countries and types of disaster losses, insurance and reinsurance coverage are also limited as market mechanisms for transferring private and public disaster risks. Finally, governments experience large infrastructure losses from natural disasters. These losses are seldom insured, but are usually financed from *ex post* financing instruments.

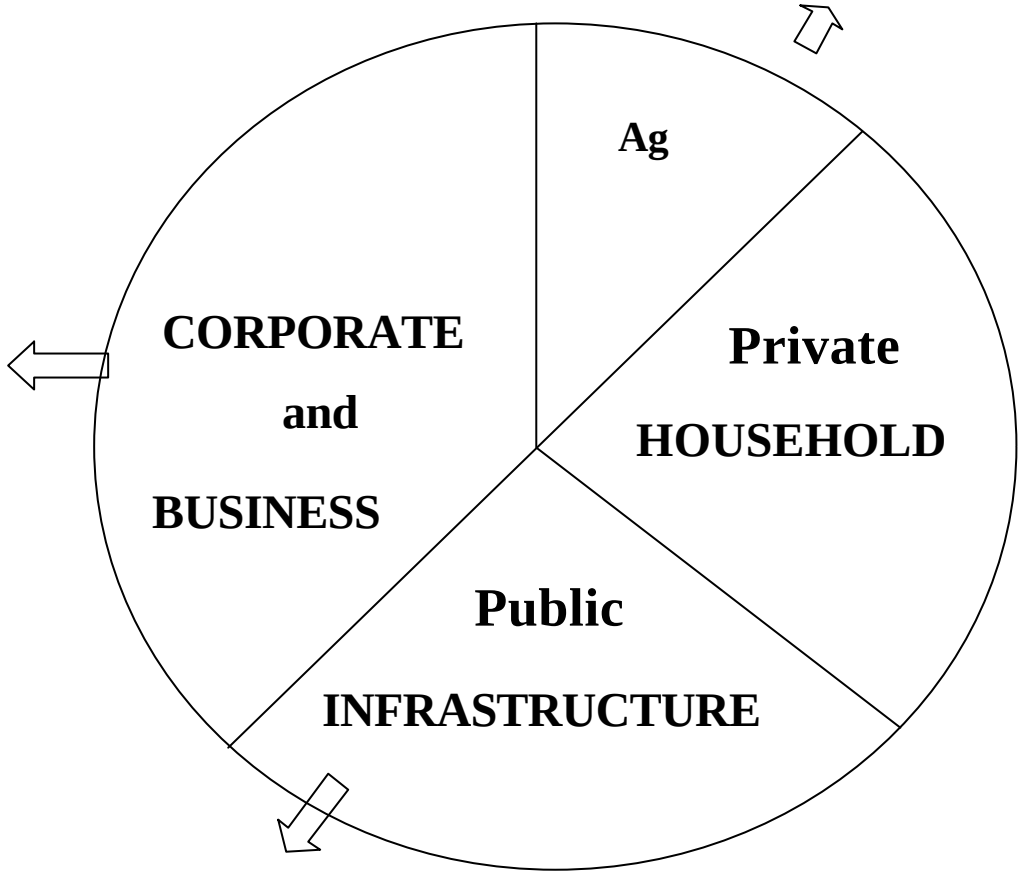
3. Insurability and marketability of the uninsured losses

In this report, we distinguish between two concepts of risks: those that are *uninsurable* and those for which insurance is *not profitably marketable*. According to Kunreuther (1998), insurers can offer protection against any risk that they can identify, and for which they can obtain information to estimate the frequency and magnitude of potential losses, as long as they have the freedom to set premiums at any level. Due to problems of ambiguity in estimating very low probability events, adverse selection, moral hazard, and highly correlated losses, insurers may desire to charge premiums that considerably exceed the expected loss. These premiums may be so high as to make insurance ill affordable. If demand is very low, it is not profitable for insurers to incur the costs of operating in the market. Therefore, the risks may be insurable, but the policies are not profitably marketable.

The insurability of natural disaster risks

According to this definition, in an unregulated market the only risks that are uninsurable are those for which it is not possible to estimate the frequency and magnitude of potential losses. Rating agencies typically collect data on all the losses incurred over a period of time for particular risks and exposure units. In the case of earthquakes and floods, if there is sufficient long-term data available on annual damages, say to concrete structures, then it is possible to estimate relevant indicators, such as expected loss and probable maximum loss. However, due to the lack of historical data on extreme floods and earthquakes, as well as a lack of data on damages to insured structures, this type of analysis may not be feasible.

Figure 1: DIRECT LOSSES*



Reimbursed

- Insurance
  - Reinsurance
- Public Loans

Self financed

- Retained earnings,
- Financial institutions

Reimbursed

-
  - Reinsurance
- National + local
- public disaster
- payments
  - Tax-payers (also future) Budget Diversions
- Charitable aid
  - Other charities

Self financed

- Savings
- Banks,
- Financial institutions

Reimbursed (local gov'ts)

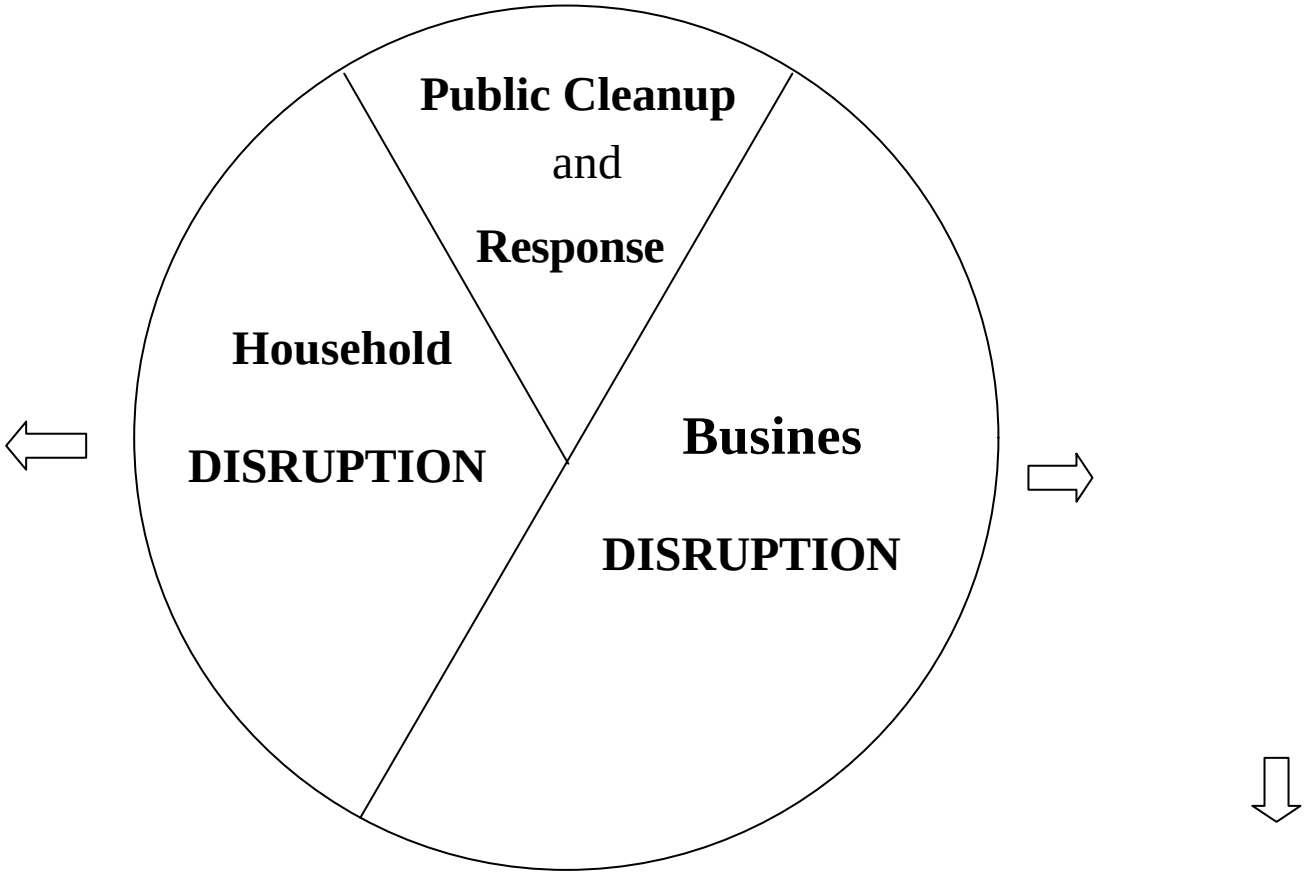
- International disaster aid

Government financed

- Ex - post
  - Taxpayers + future generations
- Taxes
- Budget
- World bank and other financial

* Excluding human losses, injuries, health effects + environmental costs, including primary and secondary losses

Figure 2
INDIRECT ECONOMIC LOSSES



In the past, the lack of historical data on extreme events, and the insurers´ concerns about their risks of capital insufficiency and insolvency, rendered many natural disaster risks, especially the flood hazard, uninsurable. For instance, in Australia, … More recently, insurers have turned to scientific studies by seismologists, geologists, hydrologists and structural engineers to provide more information (in addition to historical loss data) on estimating the frequency of earthquakes and floods and the potential damages. The recent use of geographic information systems (GIS) for incorporating data on the physical risks and the characteristics of the structures in a region has improved estimates of potential insurer losses. New advances in information technology have led to the development of catastrophe models, which provide large-scale simulations of disaster scenarios under various policy options. A catastrophe model combines scientific risk assessments of the hazard with historical records to estimate the probabilities of disasters of different magnitudes and the resulting damage to affected structures and infrastructure. Researchers at IIASA have coupled catastrophe modeling with stochastic optimization techniques to show how insurers can optimally set premiums and diversify their insurance portfolios (Ermolieva, 1997).

Not only must the risks and potential losses be estimable for hazards to be insurable, but also insurers must be able to set premiums for each potential customer or class of customers, which requires knowledge of the customer's risk in relation to others in the population of potential policy holders. If this information is lacking, there is a problem of adverse selection. If the insurer sets a premium based on the average probability of loss, those at highest risk will be the most likely to purchase coverage, and the insurer may take a loss. The problem of adverse selection only occurs if the persons purchasing insurance have better knowledge of their risk exposure than the insurers.

Recent scientific advances in estimating the frequency, magnitude and damages from floods and earthquakes are thus improving the insurability of these hazards. However, these advanced techniques require extensive data on the physical characteristics of the hazards, the frequency of the disasters, and the property structures in an exposed region. This data is often lacking or expensive to collect, and insurance companies and consulting firms are making large investments in data collection efforts. Since information is a public good, a more efficient strategy would be for the government to collect this data and make it widely available to insurers, regulators, academics and others interested in assessing the risks and losses of natural disasters. This is the case, for instance, in the United States, where the Federal Emergency Management Agency (FEMA) has made flood risk maps publicly available.

The marketability of natural disaster insurance

Even with adverse selection, the hazard may still be insurable if the premium is set high enough above the average risk. However, demand for insurance cover offered at premiums above the actuarially fair value will likely be low or non-existent. Thus, the insurance may not be marketable.

Adverse selection is not the only factor that may prevent the marketability of insurance. An inherent problem with low-probability and high-consequence risks is that the estimates of

potential losses are uncertain or ambiguous. Despite advanced techniques for estimating the probability of catastrophic events and improved data on the possible damages, the probabilistic loss estimates are still considerably more ambiguous than for low-probability risks with a long history of data. Because the law of large numbers does not apply to very low-probability events, the variance of the probability estimates is greater. The higher the uncertainty regarding the probability of a specific loss and its magnitude, the higher the premium will be. Kunreuther, et al. (1995) showed that actuaries and underwriters are so averse to ambiguity and variance that they tend to charge much higher premiums than if the risk were well specified.

A related problem with catastrophic risks is that the risks are correlated in the sense that one event results in simultaneous losses. Since insurers are risk averse, that is, they place a high value on avoiding a catastrophic loss to their balance sheet (and possible insolvency), they will want to set a high enough premium not only to cover expected losses, but also to protect themselves against the possibility of bankruptcy. Another problem that will increase the price of insurance is *moral hazard*. If insurance leads to careless behavior that increases the expected losses, then insurers will necessarily have to charge higher premiums than those calculated from data that does not account for this moral hazard.

A countervailing force that actually may result in premiums lower than actuarially fair value is the investment opportunities for insurers. Insurers usually invest the cumulating premiums, and since equity markets have been increasing dramatically in value, many insurers have been willing to take a loss on their book of business to have access to investment capital.

In theory, therefore, insurers can offer insurance against any risk that they can identify, and for which they can obtain information to estimate the frequency and magnitude of the potential losses. However, due to problems of ambiguity, adverse selection, moral hazard, and highly correlated losses, they may want to charge premiums that considerably exceed expected losses and brokerage fees (although this may be counterbalanced by investment opportunities). On the demand side, studies show that many persons are not willing to purchase insurance at, or even below, the actuarially fair value. It appears that many persons are myopic, or have an attitude that very infrequent events “can’t happen to me”.

Palm (1998) argues that, despite the intuitive appeal of the axioms associated with normative models of choice, the plain fact is that few individuals behave according to expected utility theory when deciding whether to purchase insurance. The author explores a number of explanations for „irrational“ insurance choices, including „anchoring“ and other behavioral heuristics and the notion that individuals construct their choices in a way that supports their cultural biases or preferred way of life. Although the demand for insurance against natural hazards is low, surveys show that it increases after disasters that receive media attention. Following the Northridge earthquake and the increased seismic activity in California, there was a significant increase in the demand for earthquake insurance. This actually appeared to be motivated by „rational“ considerations, including anticipated losses, a fear that governmental aid would be unavailable or insufficient, and an estimate of likely damages as opposed to the cost of premiums.

In sum, even if the risks of natural disasters are insurable, there are often significant obstacles for the successful marketing of insurance. The most fundamental problem is that insurers are only willing to offer policies at a premium that protects them against insolvency by correcting the variance of the estimated expected losses. In addition, if these estimates do not take account of adverse selection and moral hazard, the premium will also be increased above the actuarial value. Since this premium may be significantly above expected losses, the demand may be small or non-existent.

4. Institutional arrangements to improve insurability and marketability

Many of the conditions resulting in high premiums (and low demand) have been or can be corrected with private institutional arrangements. For instance, insurers can reduce moral hazard problems with deductibles or co-insurance. The adverse selection problem can be reduced with improved information on risks if insurers operate in a regulatory environment where they are free to set premiums consistent with the customer's risks. The problem of capital insufficiency and bankruptcy risk can be improved with strategies of diversification, reinsurance, and the use of newly developing capital market instruments, such as catastrophe bonds, for transferring risks to the capital markets.

However, even taking account of these measures, insurers are reluctant to enter many catastrophic risk markets with premiums low enough to attract customers. For this and other reasons, the public authorities in many countries are heavily involved in insuring natural disaster risks. This intervention can take the form of governments acting directly or indirectly as primary insurers. In the U.S., the unwillingness of private insurers to cover flood risks (and the desire of the federal government to require mitigation measures at the local level) led to the National Flood Insurance Program (NFIP), where the federal government underwrites flood risks. This intervention can also take the form of public compensation from a general pool of taxes. In countries such as Poland and Hungary, where there is only a small private insurance industry, the government traditionally compensates the victims of natural disasters.

Public compensation to the uninsured victims of natural catastrophes is substantial throughout the world. In the United States, the average annual expenditure by the federal government for disaster assistance from 1977 to 1993 was more than USD 7 billion. On an annual basis, this is significantly greater than the loss borne by reinsurers on U.S. catastrophe coverage (Froot, 1997a). In Europe, there is an established tradition of collective loss sharing or solidarity for natural disaster losses. In Poland, for example, the central government responded to the 1997 flood with more than a half billion U.S. dollars in flood relief covering about 16 per cent of the estimated, direct losses.

Opponents of government compensation to uninsured victims point out the inefficiencies of this policy (Kunreuther, 1998). For example, if uninsured disaster victims are guaranteed grants and low-interest loans that enable them to continue to locate their property in hazard-prone areas, and more people build in those areas, taxpayers will be subject to increasingly larger expenditures for bailing out victims of future disasters. On the other hand, many feel

that this inefficiency is offset by the promotion of an equity principle of social solidarity in the community or country. According to this principle, a share of the losses from natural disasters should be borne by those not directly at risk from the hazard. Even in the United States, most households, businesses and local governments have little or no insurance to protect themselves from earthquakes, floods and other major disasters (with the exception of damages from windstorms). One reason for this is that uninsured victims can expect substantial aid from the federal government, which offers grants and low-interest loans to private victims and covers up to 75 percent of local government expenditures to repair damaged infrastructure.

On the other extreme are countries, such as the U.K., where nearly 100 per cent of those living in flood risk areas are insured, and the government hardly compensates uninsured victims. However, it is not clear that the British solution will work for other countries. Insurers appear to be more willing to cover flood risks in the U.K. than in other countries, perhaps because there is little recent experience with very high-consequence (or "mega") floods and the public appears willing to accept relatively high premium payments (and also willing to accept the implied cross subsidies of the all-peril policies). In many countries there is an increasing recognition that a program must be developed that will effectively and fairly link private and public responsibility, insurance and loss mitigation.

From the insurers´ perspective, the government can most usefully pursue this goal by improving conditions for the private insurance market to operate effectively. This means that the government should intervene to enhance the insurability and marketability of natural disaster insurance. The following measures might be considered for this purpose:

<u>To improve the insurability of natural disaster risks, the public authorities can:</u>

- Collect and provide data on hazards to improve risk assessments (e.g., the flood risk maps provided by the U.S. government);
- Collect and provide data on natural disaster losses (e.g., the Polish statistical office collects detailed loss data);

<u>To improve the marketability of natural disaster insurance, the public authorities can take the following selected measures to increase private and commercial demand for private insurance:</u>

- Natural disaster insurance can be made conditionally or fully compulsory (e.g., flood insurance in the U.S. is a mandatory condition for a mortgage);
- Public compensation after a disaster can be reduced or made conditional on the victims having insurance (e.g., pending legislation in Italy);
- Public information campaigns can be instituted to make households and businesses more aware of natural disaster risks;
- Other?

To improve the marketability of natural disaster insurance, the public authorities can take the following selected measures to increase the supply of private insurance at lowered premiums*:

- The government can improve the reinsurance opportunities and expenses for private insurers by acting as reinsurer for very high losses and passing these costs on to:
  - A pool of primary insurers and their premium payers (e.g., the California Earthquake Authority),
  - The premium payers of other perils (e.g., the French system),
  - The taxpayers (e.g., the U.S. Flood Insurance Program)
- The government can actively promote the pooling of risks across primary insurers, or organize a reinsurance pool (e.g., the Japanese program)
- The government can promote, finance, or mandate mitigation measures, such as zoning and building requirements (e.g., in France);
- The government can take a pro-active stand on issues like climate warming or population policy that may reduce the medium-term losses from natural disasters;
- Other???

* Note that the government can promote the supply of insurance at lowered premiums with measures that will not increase the marketability of private insurance, for example, by: providing insurance below what private insurers will charge (e.g., the U.S. flood insurance program in its early stages); requiring uniform premiums and thus promoting the cross-subsidization of premiums across low- and high-risk insureds (which may lower premiums more for high-risk customers than it raises premiums for low-risk customers); setting premium rates below what the insurers wish to charge; and, restricting exit from the market (e.g., in Florida);

Finally, to improve the marketability of sovereign insurance to cover public infrastructure losses, the public authorities can take the following measures:

- The central government can placing more responsibility on local governments to finance the repair of public infrastructure damages (e.g., proposed by new U.S. legislation);
- The authorities can make it more difficult for local and central governments to borrow as a way of financing infrastructure repair after a disaster (e.g., the U.S. Congress now requires FEMA appropriations to the states to be taken from diversions from other US government budgets; in Europe, many countries face borrowing constraints to meet the Maestricht requirements); and,
- Central governments can directly purchase insurance or hedge their risks through alternative risk-transfer mechanisms, e.g., catastrophe bonds.

In addition, it should be pointed out that international lending organizations, such as the World Bank, may also have an influence on the demand for insurance by central and local

governments. The World Bank is considering measures to promote sovereign insurance in developing and emerging economy countries, where a large percentage of its loans for infrastructure development is diverted to finance disaster relief.

5. The case studies

The roles of the public and private sectors in compensating the losses from natural disasters are illustrated in the reported seven case studies of flood and earthquake disasters in Europe, North America and Europe. The most notable aspect of these cases is their diversity. The disasters have affected the people and economies of the countries in very different ways. In only one case, the Kobe earthquake, were fatalities high, and the financial losses affected different sectors of the economies. Agricultural losses were high, for example, in Mississippi following the 1993 and 1995 mid-west floods; public infrastructure was strongly affected during the 1997 Polish floods; the commercial sector suffered very large losses from the 1995 Kobe earthquake; and, damages to churches and other buildings of high cultural value distinguished the 1997 Umbria earthquake. The concluding chapter of this report gives a comparison of the losses, and how the victims were compensated, in each of the seven cases.

The institutional arrangements of the case study countries are also remarkably different, and are compared in the concluding chapter. The role of the public sector ranges from the public flood insurance system in the U.S., the high involvement of the public authorities in compensating risks in Poland, to the almost fully private system in the U.K. Not surprisingly, the market opportunities for private insurance depend importantly on the types of losses and the institutional arrangements in the countries involved. While the private market is near saturation in the U.K., there are ample opportunities in the other case-study countries for insuring natural disaster risks. The institutional arrangements that encourage or discourage the insurability and marketability of flood and earthquake insurance are compared in the concluding chapter.

Finally, this report concludes with a list of possible research topics for further investigation of the insurability and marketability of natural disaster insurance.

References

Changnon, Stanley A., David Changnon, E. Ray Fosse, Donald C. Hoganson, Richard J. Roth Sr., and James M. Totsch (1997). Effects of Recent Weather Extremes on the Insurance Industry: Major Implications for the Atmospheric Sciences, *Bulletin of the American Meteorological Society*, 78:425-435.

Cummins, J. David and Neil A. Doherty (1997). Can Insurers Pay for the "Big One"? Measuring the Capacity of an Insurance Market to respond to Catastrophic Losses, Paper presented at the at the Public Private Partnership 2000 Conference on *The Uncertainty of Managing Catastrophic Risks*, Wash. D.C., Dec. 11.

Ermolieva T. Y. (1997). The Design of Optimal Insurance Decisions in the Presence of Catastrophic Risks. IIASA, Interim report: IR-97-068.

Freeman, Paul (1999). Natural Catastrophe Risk Transfer and Developing Countries, Draft Paper, International Institute of Applied Systems Analysis, Laxenburg, Austria.

Froot, Kenneth A. (1997a). The Limited Financing of Catastrophe Risk: An Overview, Harvard University Working Paper, Harvard Business School and National Bureau of Economic Research.

Froot, Kenneth A. and Paul G. J. O'Connell (1997b). The Pricing of U.S. Catastrophe Reinsurance, Paper presented at the NBER conference on the Financing of Property/Casualty Risks, Palm Beach Fl., Nov. 21-23.

International Federation of Red Cross and Red Crescent Societies (1998). *World Disasters Report 1998* (N. Cater and P. Walker, eds.), Oxford: Oxford University Press.

Jaffee, Dwight M. and Thomas Russell (1997). Catastrophe Insurance, Capital Markets, and Uninsurable Risks, *The Journal of Risk and Insurance*, 64:205-230.

Kunreuther, Howard, Jacqueline Meszaros, Robin Hogarth and Mark Spranca (1995). Ambiguity and Underwriter Decision Processes, J*ournal of Economic Behavior and Organization*, 26:337-352.

Kunreuther, Howard and Roth, Richard, Sr. (1998). *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States***,** Washington, D.C: Joseph Henry Press.

Kunreuther, Howard (1998). Insurability Conciditons and the Supply of Coverage, *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States***,** Washington, D.C: Joseph Henry Press, 17-50.

Kunreuther, Howard and Joanne Linnerooth-Bayer (1999). The Financial Management of Catastrophic Flood Risks in Emerging Economy Countries, Paper Presented at Conference on Global Change and Catastrophic Risk Management, IIASA, Laxenburg, Austria, June 6-9.

Linnerooth-Bayer, J. and A. Amendola (forthcoming). Global Change, Natural Disasters and Loss Sharing: Issues of Efficiency and Equity, *Geneva Papers on Risk and Insurance*. Geneva.

MacDonald, G. (1998). Climate and Catastrophic Weather Events, Paper presented at the Engineering Academy of Japan, 17 Apr. 1998. International Institute of Applied Systems Analysis, Laxenburg, Austria.

Munich Re. (1998). *World Map of Natural Hazards*, Munich Reinsurance Co., Munich.

Munich Re (1999). Climate Change and Increase in Loss Trend Persist, Press Release, Munich Re., 15.3.1999.

Palm, Risa (1998). Demand for Disaster Insurance: Residential Coverage, *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States*, Washington, D.C: Joseph Henry Press, 51-66.

Smith, Richard E., Emily A. Canelo and Anthony M. Di Dio (1997). Reinvinting Reinsurance Using the Capital Markets, *The Geneva Papers on Risk and Insurance*, 22:26-37.

Swiss Re (1997a). Natural Catastrophes and Major Losses in 1996: High losses from Man-Made Disasters, but no extremely costly Losses from Natural Catastrophes, *Sigma* No. 3, 1997, Swiss Reinsurance Co., Zurich.

Swiss Re (1997b). Too Little Reinsurance of Natural Disasters in many Markets, *Sigma* No. 7, 1997, Swiss Reinsurance Co., Zurich.

Swiss Re (1997c). Learning from Disaster: The Floods in the Czech Republic, Poland and Germany in the Summer of 1997, Zurich: Swiss Reinsurance Company.

Swiss Re (1998). Natural Catastrophes and Major Losses in 1997: Exceptionally few high Losses, *Sigma* No. 3/1998, Swiss Reinsurance Co., Zurich.

Swiss Re (1999). Natural Catastrophes and Man-made Disaster 1998: Storms, Hail and Ice Cause Billion-Dollar Losses, *Sigma* No. 1, Swiss Reinsurance Co., Zurich.