Assessing, Managing and Benefiting from Global Interdependent Risks

The Case of Terrorism and Natural Disasters

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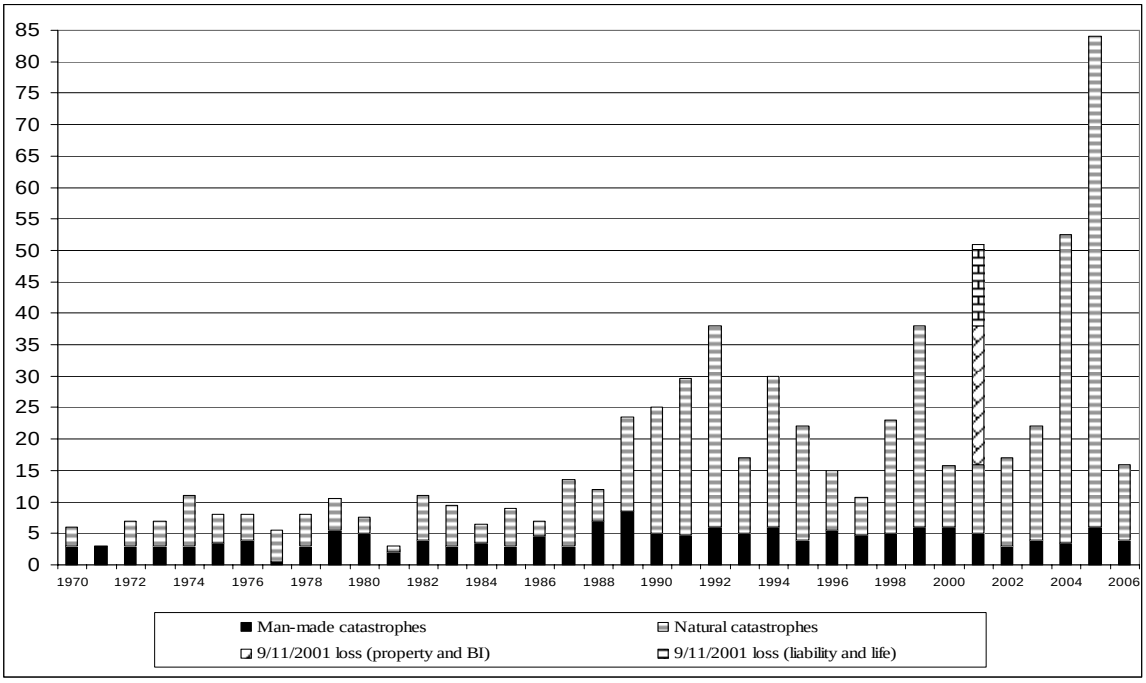
1. INTRODUCTION

With the increasing globalization of economic and social activities, the world has now become so interdependent that actions taken today 5,000 miles away could affect you tomorrow. Conventional wisdom holds that one country or one organization has the capacity and expertise to manage future large-scale risks alone. However, in an increasingly global interdependent world, they have neither.

A hallmark of the 21st century is that we have entered a new era of catastrophic risks, as illustrated by the evolution of economic and insured losses associated with a series of global events that occurred in just the past few years. The increase in insured losses from man-made (including terrorism) and natural disasters worldwide over the past 36 years (see Figure 1) graphically depicts the new era we have entered. From Table 1 we see that the 9/11 terrorist attacks inflicted $35 billion in insured losses[1]. Claims were paid by over 150 insurers and reinsurers worldwide, illustrating how risks are today diversified over global markets. Four major hurricanes hit one of the most populated states in the U.S. (Florida) in 2004, and three major hurricanes hit the Gulf of Mexico the following year. The devastation due to Hurricane Katrina in 2005 has been unprecedented both in terms of human and economic losses. It is the most costly catastrophe in the history of insurance worldwide ($45.5 billion in insured losses) as shown in Table 1. Of the twenty most costly insured catastrophes that occurred in the world over the past 36 years (1970-2006), half of them occurred since 2001.

[1] For a discussion on terrorism insurance markets by the authors, see Kunreuther and Michel-Kerjan (2004, 2007a-and-b) and Michel-Kerjan and Pedell (2006).

Figure 1. Worldwide Evolution of Catastrophe Insured Losses, 1970-2006



(9/11: all lines, including property and business interruption (BI); in U.S.$ billon indexed to 2006)
Sources: Wharton Risk Center with data from Swiss Re and Insurance Information Institute

Table 1. The 20 Most Costly Insured Catastrophes in the World, 1970-2005

Rank	U.S.$ billion (indexed to 2005)	Event	Victims (Dead or missing)	Year	Area of primary damage
1	45.5*	Hurricane Katrina	1,326	2005	USA, Gulf of Mexico, et al
2	35.0	9/11 Attacks	3,025	2001	USA
3	22.3	Hurricane Andrew	43	1992	USA, Bahamas
4	18.5	Northridge Quake	61	1994	USA
5	11.7	Hurricane Ivan	124	2004	USA, Caribbean et al
6	10.3	Hurricane Wilma	35	2005	USA, Gulf of Mexico, et al
7	8.3	Hurricane Charley	24	2004	USA, Caribbean et all
8	8.1	Typhoon Mireille	51	1991	Japan
9	6.9	Winterstorm Daria	95	1990	France, UK, et al
10	6.8	Winterstorm Lothar	110	1999	France, Switzerland, et al
11	6.6	Hurricane Hugo	71	1989	Puerto Rico, USA, et al
12	5.2	Hurricane Frances	38	2004	USA, Bahamas
13	5.2	Storms and floods	22	1987	France, UK, et al
14	5.0*	Hurricane Rita	34	2005	USA, Gulf of Mexico et al
15	4.8	Winterstorm Vivian	64	1990	Western/Central Europe
16	4.7	Typhoon Bart	26	1999	Japan
17	4.2	Hurricane Georges	600	1998	USA, Caribbean
18	4.1	Hurricane Jeanne	3,034	2004	USA, Caribbean, et al
19	3.7	Typhoon Songda	45	2004	Japan, South Korea
20	3.5	Tropical Storm Alison	41	2001	USA

(* Excludes $2-3 billion in offshore energy losses)
Sources: Wharton Risk Center with data from Swiss Re and Insurance Information Institute

There are a number of other large-scale risks which have similar features to terrorism and natural disasters. The trigger for the August 2003 power failures in the northeastern U.S. and Canada, was an event that occurred in Ohio. A disease in one region of the globe can readily spread to other areas through transportation networks, as was the case with the rapid spread of SARS from China to its trading partners, and as may be the case with avian flu (Heal and Kunreuther, 2007). The meltdown of a nuclear reactor in one country can lead to massive radioactive contamination hundreds of miles away, as illustrated by the Chernobyl nuclear plant disaster in 1986. The initial evidence that a major exhaust of radioactive material was affecting other countries came not from Soviet sources, but from Sweden, where on April 27, 1986 workers at the Forsmark Nuclear Power Plant (approximately 1,100 km from the Chernobyl site) were found to have radioactive particles on their clothes (Mould, 2000). These few examples illustrate the existence of important interdependencies between people and organizations hundreds if not thousands of miles apart.

All these risks have the common feature that individuals and firms are interconnected so that any one unit can create negative *security externalities*.[2] People, organizations and/or governments may not realize how their failure to operate can affect a large number of agents, often rippling far beyond their direct influence. If the organization is an industrial firm then there is a trade-off between private efficiency and public vulnerability. This source of market failure is often reinforced if there is no coordination mechanism in place to endogenize these externalities. A challenge for public policy is to find a way for the government to provide incentives for the private sector to invest adequately in security (including both technical designs and management practices). Recent major catastrophes also revealed failure in government preparedness, which negatively impacted on the operation of firms in the private sector. (Michel-Kerjan, 2007).

This paper focuses on mega-terrorism and large-scale natural disasters to highlight the nature of the interdependencies and global nature of the risks. Our particular interest is in examining alternative risk management strategies as well as effective coordination approaches for reducing future losses, and providing adequate protection to potential (direct and indirect) victims of such large-scale disasters.

With respect to *terrorism,* the attacks of September 11, 2001 and the Anthrax crisis have revealed tragically our lack of collective preparedness to deal with such global threats. In the case of 9/11, the security failures at Boston's Logan airport led to the destruction of the World Trade Center (WTC). The failure was embedded within the security protocols promulgated by the Federal Aviation Administration and not with the application of those protocols, i.e., checking for bombs in passengers' luggage but not profiling. There was nothing that the Port Authority of New York and New Jersey and firms located in the WTC could have done on their own to prevent these aircrafts from crashing into the Twin Towers. Any protective efforts they might have undertaken would have been rendered useless by the absence of action at a distant site. The Anthrax crisis likely challenged all the postal services of most developed countries.

[2] The notion of "security externalities" was introduced in Auerswald, Branscomb, LaPorte and Michel-Kerjan (2006); see also Kunreuther and Heal (2003) introducing the concept of "interdependent security".

The possible use of so-called weapons of mass destruction (WMD) is even more threatening. A 10-kiloton nuclear bomb planted in a shipping container that explodes in the Port of Long Beach, California could result in total *direct* costs exceeding $1 trillion with ripple effects on trade and global supply chains that could lead to a global recession (Meade and Molander, 2006)[3].

Turning to *natural disasters*, Hurricanes Katrina, Wilma and Rita had sustainable impacts on energy prices not only throughout the U.S. but also on the energy markets. The growing interdependence of social and economic activities makes it very likely that the next major catastrophe in Florida and/or the Gulf of Mexico would have long term impacts on both the U.S. economy and other nations. Similarly, a major earthquake in one of the world's financial centers like Tokyo, Japan, is very likely to destabilized financial markets worldwide.

In **Section 2,** we will discuss some of the behavioral challenges in managing catastrophes. **Section 3** discusses risk management strategies for promoting cost-effective mitigation measures in the context of these challenges that are likely to be exacerbated when we deal with global risks. **Section 4** discusses additional and challenging features of global risks by developing a simple model that provides an understanding of the nature of interdependencies and how they affect decisions by agents to invest or not invest in security or protection. Specifically, we highlight the coordination challenge: even though each agent's welfare is improved if everyone invests in security measures, there is no economic incentive for anyone to adopt these measures on their own. The launching of an international global reaction capacity in the aftermath of the Anthrax crisis in 2001 illustrates the importance of coordination when developing solutions to tackle global risks. **Section 5** concludes the paper by discussing the World Economic Forum's *Global Risk Network* in which the Wharton Risk Center and several leading companies are currently involved.

2. How Individuals Behave with Respect to Low Probability Events

In designing risk management strategies, one needs to understand how individuals collect and process information with respect to events that occur with relatively low probabilities. Here, we focus on features of behavior that have been well-documented empirically. While not specific to global risks, these features pose challenges for catastrophe risk management in general, which shall be even more pronounced in the case of global risks as discussed in Section 4.

Underestimation or Ignoring Probabilities

Before a disaster, individuals are unlikely to think about the consequences of the event and hence do not consider the trade-offs between the expected benefits and costs of protective measures. Empirical studies indicate that decision makers often use "threshold

[3] Gordon, Moore, Richardson and Pan (2005), Rosoff and von Winterfeldt (2005) also analyze the human and economic impacts on the local economy of a dirty bomb exploding in the twin ports of Los Angeles and Long Beach for different attack scenarios. See also Park, Gordon, Moore II, Richardson and Wang (2007) for a comparison of the cost of similar terrorist attacks of several US ports (including New York/New Jersey and Houston).

models," whereby if the probability of a disaster is below some prespecified level, they believe it will not happen to them. In laboratory experiments on the purchase of insurance, many individuals bid zero for coverage, apparently viewing the probability of a loss as sufficiently small that they were not interested in protecting themselves against it. (McClelland et al 1993). People considering protective measures rarely, if ever, have explicit loss probabilities available to them. Often, loss probability does not seem to play a role in their decisions (Camerer and Kunreuther, 1989; Hogarth and Kunreuther, 1995; Huber, Wider & Huber, 1997). When loss probability is considered, it is derived from experience, not from actuarial tables. For example, most people only purchase earthquake insurance after suffering a loss, even though they indicate that it is less likely than before for such an event to occur again in their neighborhood now that the stress on the fault has been relieved (Kunreuther 2006).

In the U.S., even after the 2004 and 2005 hurricane seasons that considerably raised the level of awareness, a large number of residents did not invest in loss reduction measures with respect to their property or undertaken emergency preparedness measures. In a survey of 1,100 adults living along the Atlantic and Gulf Coasts undertaken in May 2006, 83 percent had taken no steps to fortify their home this year, 68 percent had no hurricane survival kit and 60 percent had no family disaster plan. Goodnough, A. (2006).

Turning to terrorism, it took the events of 9/11 for insurers to consider this risk explicitly in their pricing decisions. To our knowledge, there was not an insurer or reinsurer in the world who had conceived of the possibility that a plane crashing into the World Trade Center could cause the structure to collapse. In this sense, such a risk would be considered unknowable. By writing contracts that promised coverage for perils not excluded, insurers were agreeing to provide coverage against losses from presumably unknowable events. Only after such events occur are they priced or explicitly included or excluded from coverage. This is the process followed by insurers with respect to the terrorism risk associated with 9/11 (Kunreuther and Pauly, in press).

Short Time Horizons (Myopia)

In making decisions that involve cost outlays, individuals are often myopic and hence only take into account the potential benefits from such investments over the next year or two. In one study, subjects indicated the maximum they were willing to pay for protective measures such as investing in a deadbolt lock for their apartment, purchasing a steering wheel lock and strengthening their homes against earthquakes. By varying the number of years that each of the measures provided protection, we could determine how much more the person was willing to invest in the item as a function of time. If a person was willing to pay $50 for a deadbolt lock if he planned to live in his apartment for 1 year, then he should be willing to pay up to $95.45 if he had a two-year lease and an annual discount rate of 10%. Many of the arguments used by respondents suggest that they focused on the cost of the product in determining how much they are willing to pay to invest in a protective measure and do not take into account the expected benefits over more than one year. (Kunreuther, Onculer and Slovic, 1998). These justifications are consistent with experiments by Schkade and Payne (1994) and Baron and Maxwell (1996) which revealed that the willingness to pay for public goods was affected by cost information.

This tendency toward myopia is one of the most widely-documented failings of human decision making. As a rule, we have difficulty considering the future consequences of current actions over long time horizons. Behavioral research by psychologists has lead to the conclusion that most people utilize hyperbolic discount rates (Loewenstein and Prelec, 1992) implying that payoffs several years in the future are not given very much weight in comparison to exponential discounting. As a general rule, we have difficulty considering the future consequences of current actions over long time horizons (Meyer and Hutchinson, 2001).

Budget Constraints

Short-run budget constraints also discourage individuals from investing in protective measures. More specifically if individuals have limited disposable income after purchasing necessities, then they will not even consider purchasing insurance or allocating funds for mitigation measures. In focus group interviews to determine factors influencing decisions on whether to buy flood or earthquake coverage, one uninsured worker responded to the question, "How much does one decide on how much to pay for insurance?" as follows:

> A blue-collar worker doesn't just run up there with $200 [the insurance premium] and buy a policy. The world knows that 90 percent of us live from payday to payday….He can't come up with that much cash all of a sudden and turn around and meet all his other obligations. (Kunreuther, et al 1978.)

The budget constraint for investing in protective measures may extend to higher income individuals if they set up separate *mental accounts* that limit how much they will spend on certain items. . Dividing spending into budget categories facilitates rational trade-offs between competing uses of funds and acts as a self-control device. Poorer families tend to have budgets defined over periods of a week or a month, while wealthier families are likely to use annual budgets (Thaler,1999). Heath and Soll (1996) provide further evidence on the role of budget categories by showing how actual expenses are tracked against these budgets.

Impact of Local Interdependencies

Suppose a family was considering elevating their house on piles so as to reduce flood losses from a future hurricane. If none of their neighbors have taken this step, their house would look like an oddity in a large group of homes at ground level. If the family choose to move, they would be concerned that the resale value of their home would be lower because the house was different from all the others. Given that there is a tendency not to think about a disaster until after it happens, the family may reason that it would be difficult to convince potential buyers that elevating the house should increase its property value.

The question as to how actions of others impact one's own decisions relates to the broader question of interdependencies which is a theme of this paper. If all homes in the neighborhood were elevated, then this family would very likely want to follow suit; if none of them had taken this step, then they would not have an interest in doing so. It is conceivable that if a few leaders in the community elevated their houses then others would do the same. This type of tipping behavior is common in many situations and has been studied extensively by Schelling (1978) and popularized by Gladwell (2000).

Disaster Assistance

One of the arguments that has been advanced as to why individuals do not adopt protective measures is that they assume generous relief will be forthcoming from the government should they suffer losses from a disaster. Under the current system of disaster assistance, the Governor of the State(s) can request that the President declare a "major disaster" and offer special assistance if the damage is severe enough. However, neither the Governor nor the President decide the level of federal aid, Congress does.

Federal disaster assistance may create a type of Samaritan's dilemma: providing assistance *ex post* (after hardship) reduces parties' incentives to manage risk *ex ante* (before hardship occurs). If a family residing in a hazard-prone area expects to receive government assistance after a loss, it will have less of an economic incentive to invest in mitigation measures and purchase insurance prior to a disaster. Should a large number of individuals behave in this way, the increased losses from a disaster due to the widespread lack of protection makes it more likely that the public sector will come to the rescue after a disaster.

In fact, the empirical evidence suggests that individuals or communities have **not** based their decisions on whether or not to invest in mitigation measures by focusing on the expectation of future disaster relief. This behavior seems counter-intuitive and the reasons for it are not fully understood. It will be interesting to see whether Hurricane Katrina changes this view, given the highly publicized commitment by the Bush administration to provide billions of dollars in disaster relief to victims.

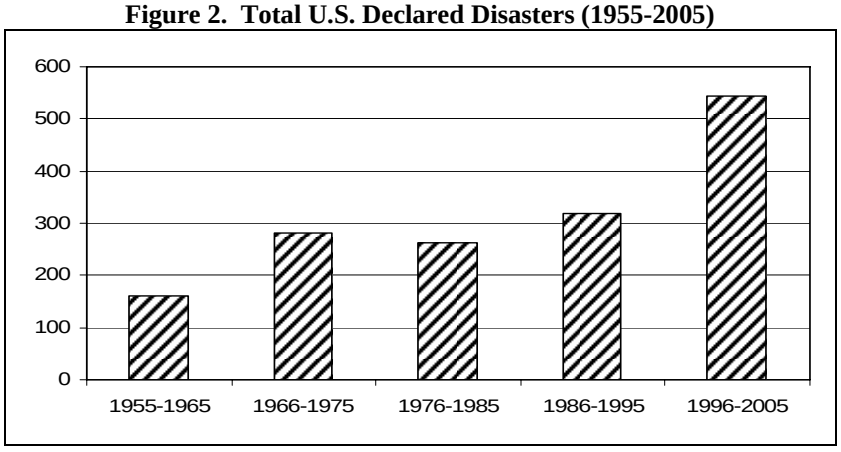
Whether or not individuals incorporate an expectation of disaster assistance in their pre-disaster planning process, a driving force with respect to the actual provision of government relief is the occurrence of disasters where the losses are large. If the disaster occurs at a critical time in the political process, it is almost certain that liberal relief will be forthcoming. One has only to look back at earlier disasters, such as the Alaskan earthquake of March 1964 and Tropical Storm Agnes of June 1972, both of which occurred during a Presidential election year, to remind oneself of the type of aid the Federal government is capable of giving. Following the Alaskan earthquake where relatively few homes and businesses had earthquake resistant measures and insurance protection, the U.S. Small Business Administration (SBA) provided 1 percent loans for rebuilding structures and refinancing mortgages to those who required funds through its disaster loan program. Hence, the uninsured victims in Alaska were financially better off after the earthquake than their insured counterparts. After the Rapid City, South Dakota floods and Tropical Storm Agnes in June 1972, the SBA offered homeowners forgiveness grants for the first $5,000 of their losses (in 1972 prices) and then provided interest rates for the remaining portion of the loan (Kunreuther 1973).

Overall, the number of Presidential declarations has dramatically increased over the past 50 years, as indicated in Figure 2 (Michel-Kerjan, in press). In the case of Hurricane Katrina, which triggered the largest amount of federal aid in the aftermath of a disaster ever, the President declared a "major disaster" on August 29th, allotting more federal funds to aid in rescue and recovery. By September 8th, Congress had approved $52 billion in aid to victims of Hurricane Katrina. As of August 2006, over $120 billion

of federal aid had been approved for victims and rebuilding infrastructures destroyed by the 2005 hurricanes.

The SBA received more than 422,000 applications for disaster loans following Hurricane Katrina and the other Gulf Coast hurricanes in 2005, of which 364,000 were for homes and more than 58,000 were for businesses. The volume of applications, however, overwhelmed the SBA, and many Gulf Coast homeowners and businesses had to wait months to receive money from the agency. As of May 2006, it took the SBA an average of 74 days to process disaster loan applications, compared with the agency's goal of 21 days. This demand surge needs to be taken into consideration when dealing with large-scale disasters. Through the Accelerated Disaster Response Initiative (ADRI), SBA reduced the backlog of approved loans in the system from 120,000 in the summer of 2006 to under 28,000 by year end. As of July 2007, nearly 85% of the $6.9 billion in approved SBA disaster loans has been allocated to victims of the 2005 hurricanes. (PR Newswire, 2007).

Figure 2. Total U.S. Declared Disasters (1955-2005)



Sources: Data from the U.S. Department of Homeland Security (FEMA) (2006)

3. PROMOTING COST-EFFECTIVE MITIGATION MEASURES

If individuals or firms are reluctant to adopt protective measures to reduce the chances of catastrophic losses due to the interdependent links, the private and public sectors may have a role to play in addressing this problem. In this section we illustrate ways these issues could be addressed in the context of natural disasters and terrorism.

Reducing Losses from Natural Disasters

One of the principal reasons that individuals in hazard-prone areas do not adopt mitigation measures is that they only consider the short-run returns of the investment even though it promises to yield benefits over a much longer time horizon. Take the case of a homeowner or firm residing in a hazard-prone area considering whether to invest in some type of mitigation measure to protect its property. For example, a homeowner could be considering strengthening its roof to reduce the chances of it being blown off in a future hurricane. Suppose the expected annual benefit from this investment (B) occurs at the beginning of each year. If the firm only considers the expected benefits from such an investment over the next two years, then if it undertakes this truncated benefit-cost

analysis, it will only undertake this investment as attractive if the upfront cost of mitigation (*C)* is less than *[B + B/(1+d)]* where *d* is the firm or individual's annual discount rate. An investment viewed as unattractive based on this short-term horizon, may actually pass the benefit-cost test if one extended the time horizon.

Long-term Loans

The insurance industry could partner with banks and financial institutions to encourage investments which are cost-effective when viewed over the long-run but are not deemed attractive when evaluated using a short time horizon. Suppose the homeowner at risk had purchased an insurance policy to protect itself against the loss. In fact, banks often normally require some insurance against damage from hurricanes, tornados, and floods as a condition for mortgage. The insurer could provide an annual premium reduction to those who undertake the mitigation measure and the bank could provide a 20-year loan for undertaking this measure that could be tied to the mortgage. The annual premium reduction would not be viewed as financially attractive to justify the upfront investment cost if one was only considering the next two years; however, the bank loan now converts this investment cost into an annual payment which now is likely to be lower than the annual premium reduction, assuming that insurers are basing their rates on risk.

To illustrate with an example, suppose the roof mitigation measure considered by a homeowner residing in a hurricane-prone area cost $1,500. A 20-year loan of $1,500 at an annual interest rate of 10% would result in payments of $145 per year. If the annual probability of a hurricane damaging the homeowner's house was 1/100 and the mitigation measure would reduce insured losses by $30,000, then the reduction in the annual insurance premium to reflect these lower claims costs would be $300, which is greater than the annual loan cost. Without the bank loan, the homeowner would never have adopted the mitigation measure had he focused on a two-year time horizon.

A bank should have a financial incentive to provide this type of loan. By linking the expenditure in mitigation to the structure, rather than to the property owner, the annual payments are lower and this would be a selling point to mortgagees. The bank will also feel that it is now better protected against a catastrophic loss to the property and the insurer knows that its potential loss from a major disaster is reduced. These mitigation loans would constitute a new financial product. Moreover, the general public will now be less likely to have large amounts of their tax dollars used for disaster relief. A win-win-win-win situation for all!

Long-Term Insurance

Today, banks and financial institutions do not routinely provide long-term loans to property owners for undertaking mitigation measures. One way to encourage them to do so would be for insurers to market long-term insurance contracts on properties where the purchase of insurance is a condition for a mortgage. For such a long-term policy to be feasible, insurers would need to charge a rate based on their best estimate of the risk over a 10 to 25 year period. The uncertainty surrounding these estimates could be reflected in the premium as a function of the length of the insurance contract, in much the same way that the interest rate on fixed-rate mortgages varies between 15, 25 and 30 year loans.

The obvious advantage of a long-term insurance contract from the point of view of policyholders is that it provides them with stability and an assurance that their property is protected for as long as they own it. This has been a major concern in hazard-prone areas where insurers have cancelled policies following severe disasters such as those that occurred during the 2005 hurricane season. One reason that insurers do not renew policies after these events is that state regulators force them to charge premiums in hazard-prone areas that are below the actuarially-based estimates.

If insurers were free to charge risk-based rates they might be favorably disposed toward a long-term insurance contract. A key principle guiding a current study by the Wharton Risk Center in conjunction with Georgia State University and the Insurance Information Institute is that premiums must reflect the risk (Wharton Risk Center 2007). The rationale for this principle is that risk-based premiums provide signals to individuals as to the hazards they face, and this encourages them to engage in cost-effective measures to reduce their vulnerability to catastrophes.

Under current insurance contracts, property owners do not have an economic incentive for spending money to guard their home more effectively from hazards. For example, homeowners might be reluctant to incur the $1,500 investment cost because they would only get $300 in return the next year, with no guarantees of future reductions. In addition, they might not know how long they will reside in the area and/or whether their insurer would reward them again when their policy is renewed. With a 20-year insurance contract required as a condition for a mortgage, the premium reduction would be viewed as a certainty.

Of course, there are many issues that have to be addressed if one is to develop long-term property insurance contracts:

- Could one offer adjustable rate insurance policies similar to these types of mortgage contracts?
- Could a property owner change his or her insurance policy over time in a manner similar to refinancing a mortgage?
- What role would the modeling companies and the scientific community studying climate science play in providing estimates for developing risk-based premiums, and for suggesting a rationale for changes over time as new information becomes available from the scientific community?
- What types of risk transfer instruments would emerge from the reinsurance market as well as from the capital markets to protect insurers against catastrophic losses?
- What role would the federal government play in providing such protection?
- Should property owners be required to purchase insurance or would this be at the discretion of the banks issuing a mortgage?

Although these issues will have to be resolved before such policies are marketed, we feel that the idea should be introduced as a way of dealing with the issue of myopia that often discourages individuals and firms from investing in cost-effective mitigation measures.

4. CHALLENGES RELATED TO GLOBAL INTERDEPENDENT RISKS

The complexity of world and its evolutionary, adaptive character mean that no *definitive* list of global risks can be constructed. Every list will be the product of its time and of those who constructed it. Here, we highlight some criteria a risk must meet to be considered a global risk with the understanding that it might be challenging to define very clearly the frontier between a global risk and a non-global risk. Moreover, there is often a lot of uncertainty surrounding these global risks.

Defining Global Risks

We use the following criteria proposed by the World Economic Forum's Global Risk Initiative for defining global risks (World Economic Forum, 2006):

- *Global scope:* A global risk has global scope if it has the potential of having primary and/or secondary economic impacts in at least three world regions in at least two continents.
- *Cross-industry impact:* A global risk has **cross-industry impact**, potentially affecting three or more industries, and which typically results from interdependent actions and/or generates interdependent consequences globally.
- *Economic and social impac*t: **A** global risk has a major **economic impact** (e.g., exceeding $10 billion) **and/or** a major **social impact** in terms of human suffering and loss of life, triggering public pressure to respond. There is uncertainty as to how the risk will manifest itself over ten years, and the severity of its impact.
- *Multistakeholder approach:* The risk demands the involvement of a number of interested parties because cooperation is required between the public and private sectors to understand the drivers of the risk, to assess its interdependencies with other risks and its impacts on different industries or countries. In addition, concerted endeavors by governments, multilateral organizations, businesses and civil society institutions are likely to be needed to address the causes or mitigate the effects.

Nature of Global Interdependencies

The nature of the interdependencies needs to be well understood in order to develop risk management strategies. In the case of natural disasters, the interdependencies are primarily a function of the interactions between the individuals who are at risk in hazard-prone areas. As pointed out above, a person may be reluctant to invest in a protective measure, such as elevating one's house, if others do not take similar measures. Even if one has taken steps to protect one's house against a future disaster, the structure could be damaged because a neighboring house was unprotected. An unstrapped water heater could be toppled by an earthquake, causing a fire that spreads to other homes in the neighborhood.

Terrorism differs from natural disaster since the threat can come from far away. The existence of growing interdependent systems translates also into levels of security of

those systems that strongly depend on the weakest link within a constellation of complex interactions. For example, the crash of Pan America's flight 103 over Lockerbie, Scotland in December 1988 which killed 259 people on board and 11 others on the ground illustrates this point. The explosion was caused by a bomb loaded at Gozo, Malta on Malta Airlines where there were poor security systems, transferred at Frankfort Airport to a Pan Am feeder and then loaded onto Pan Am 103 at London's Heathrow Airport. The bomb was designed to explode only when the aircraft flew higher than 28,000 feet, which would normally not occur until the plane started crossing the Atlantic to its final destination, New York. There was not a thing that Pan Am could do to prevent this tragedy unless they inspected all transferred bags, which is both a costly and time-consuming process. The terrorists who placed the bomb knew exactly where to check the bag. They put it on Malta Airlines, which had minimum-security measures, and Pan Am was helpless. Hence, the terrorists took advantage of the weakest link in a chain of interdependencies (Lockerbie, 2001).

While most airlines now check all incoming bags (including those coming from another airline), a similar weak link exists for cargo marine containers. For instance the port of Hong Kong does not screen any container coming from other ports. Terrorists could load a bomb in a container in Karachi, Indonesia where security is very poor; the bomb would them be transferred from Hong Kong to the port of Los Angeles with a very low probability of being inspected, much lower than if the shipment had come directly from Karachi[4].

Interdependencies are even more pronounced and critical for terrorism since terrorists are likely to take into account the actions of their adversaries when planning an attack strategy. For example, they may respond to security measures undertaken by some of those at risk by shifting their attention to more vulnerable targets. This game theoretic view of behavior has been studied by Sandler (2003), Keohane and Zeckhauser (2003) and Bier (2007) in determining what costs should be incurred by individuals and firms who are potential victims of a terrorist attack. Rather than investing in additional security measures, firms may prefer to move their operations from large cities to less populated areas to reduce the likelihood of an attack. Of course, terrorists may choose these less protected regions as targets if there is heightened security in the urban areas. Terrorists also may change the nature of their attacks if there are protective measures in places which would make the likelihood of success of the original option much lower than another course of action (e.g., switching from hijacking to bombing a plane). This *substitution effect* has to be considered when evaluating the effectiveness of specific policies aimed at curbing terrorism (Sandler, Tschirhart and Cauley, 1983). The likelihood and consequences of a terrorist attack are thus determined by a mix of strategies and counterstrategies developed by a range of stakeholders that change over time. This *dynamic uncertainty* makes the likelihood of future terrorist events extremely difficult to predict (Michel-Kerjan, 2003).

[4] There currently is a debate in the U.S. as to whether the federal government should require a 100 percent inspection of incoming cargo containers (the current screening rate is nearly 5 percent). See Martonosi, Ortiz and Willis (2005) for a discussion of the feasibility and cost effectiveness of a 100 percent container inspection policy.

There is an additional challenge related to global risks: the interdependencies exist not only across regions but also across *time*. People tend to look for local causes to explain events. There is generally little discussion of the numerous actions taken before, far away from, or with little apparent connection to a disaster that can increase risk levels or damages from a given disaster. Kousky and Zeckhauser (2006) introduce the concept of *JARring* actions: those actions that Jeopardize Assets that are Remote. JARring actions impose a particular type of negative externality – one in which the cost is imposed on people who are spatially or temporally distant. Unless there is a system in place that allows victims to hold the responsible parties accountable, internalizing such externalities will be a challenge. This is particularly true if the actions occurred thousands of miles away, or thirty years ago. Greenhouse gas (GHG) emissions illustrate this point, as they typically remain in the atmosphere for decades, and it does not matter whether the emission comes from the U.S., Europe or China: regardless of their origin, they will have the same marginal impacts on global warming. Unless there is coordination over time and between nations, the incentive for those who reduce their emissions will be reduced, as their actions will have limited effect on the whole system. This raises the question as to how one can provide economic incentives to individuals, organizations and countries so they will want to invest in protection when they are connected to and dependent on others whose failures may compromise others in the network.

The Coordination Challenge

The vulnerability of one organization, critical economic sector and/or country often depends not only on its own choice of protection/security investments, but also on the actions of other agents. This concept of *interdependent security* implies that failures of a weak link in a connected system could have devastating impacts on all parts of it, and that as a result there may be suboptimal investment in the individual components (Kunreuther and Heal, 2003; Heal and Kunreuther, 2006).

Consider the problem facing an industrial plant which is part of a global supply chain. Interdependencies exist across supply chains in every industry, and the complexity of these has been growing by leaps and bounds as industry has become more globalized through outsourcing and off-shore activities. The result is that global supply chains that utilize sources from one country for manufacturing, or retailing operations in another country, now dominate many of the major economic sectors, from the automotive industry to semiconductors to the huge retail industry represented by giants like Wal-Mart and the Home Depot. The effects of supply chain disruptions (whether from natural disasters, terrorism or other unexpected events) on the profitability of supply chain participants are now recognized as being potentially very large[5]. Coping with the management challenges of such disruptions is, however, a very difficult matter, as the interdependencies involved require cooperative activity and monitoring across the supply

[5] See Sheffi (2005) for an analysis of how enterprises can develop protection and coordination mechanisms so their supply chains are likely to be more resilient to major disruptions such as those discussed in this paper.

chain in ways that are not captured in the traditional intra-supply-chain metrics of price, cycle time, and product quality.[6]

To highlight the need for coordination in the context of a supply chain, consider a two-firm example where Firm 1 (F_1) with assets A_1 has outsourced part of its production process to Firm 2 (F_2) with assets A_2. Each firm could invest in measures to protect their operations against damage from some event (e.g., a terrorist attack, a natural disaster) that will occur at either one firm or the other but not at both. The cost of a protective measures for each firm i is c_i $i=1,2$. To keep the analysis simple, assume that if both firms undertake this action, the chances of experiencing a loss from this event is zero. If F_1 does not protect itself and F_2 does, then there is a probability p_1 that F_1 will experience a loss L_{11} and will create a loss to F_2 of L_{12}. For example, L_{12} represents the lost profits to F_2 if F_1 experiences damage from an event so that it has reduced its outsourcing activity with F_2. Similarly, if F_2 does not invest in protection but F_1 does, then it has a probability p_2 of experiencing a loss of L_{22}, which will create problems for F_1 who has lost profits from not being able to outsource to F_2 is L_{21}. If both firms do not invest in protection, then there is the possibility that either of the firms will experience a loss with probabilities p_i $i=1,2$ and have a negative impact on the other firm. We assume throughout that the damages that result from multiple security failures are no more severe than those resulting from a single failure. In other words, damages are non-additive[7]. The key issue is actually whether or not there is a failure, not how many failures there are. The loss matrix for the different outcomes is shown by Table 1:

Table 1: Expected Costs Associated with Investing and Not Investing in Protection

		Firm 2 (F_2)	
		S	N
Firm 1 (F_1)	S	$A_1-c_1,\ A_2-c_2$	$A_1- c_1 - p_2 L_{21},\ A_2- -p_2 L_{22}$
	N	$A_1-p_1 L_{11},\ A_2-c_2 - p_1 L_{12}$	$A_1-[p_1 L_{11} + (1-p_1) p_2 L_{21}]$, $A_2- [p_2 L_{22} + (1-p_2) p_1 L_{12}]$

In this two-agent game there can be two Nash equilibria ***(S,S)*** or ***(N, N)*** with it being more profitable for both firms to invest in protection. This may require the two firms to decide together that it would be in each of their best interests for each to incur these upfront costs to avoid the potential consequences of a disaster to one of the firms. Without such coordination there may be economic incentives for each of the firms not to incur this investment cost. Why? Because even after protecting itself, each firm knows that it can suffer an additional loss should the other firm not follow suit. The possibility of experiencing this negative externality may make it more profitable for each firm to **not** invest in security and expend these resources in other ways. As one expands the number of firms in the supply chain, the likelihood of incurring losses from others due to interdependencies in the system increases, and the importance of coordination becomes

[6] For more details on the nature of the risk and interdependencies in global supply chain see Heal et al (2006).

[7] We recognize that there are lots of scenarios of attack that could inflict additive damage or where the presence of several protection barriers makes a system more unlikely to suffer terrorist attack.

even greater. We now extend this simple model to the case where *n* agents make decision in a global interdependent environment[8].

Consider A interdependent risk-neutral agents indexed by i. Each is characterized by parameters p_i, L_i, c_i and Y_i. Here p_i is the probability that agent $i's$ actions lead to a direct loss L_i. A direct loss can be avoided with certainty by investing in loss-prevention at a cost of c_i. Initial income before any losses are incurred or before expenditure on loss-prevention is Y_i. Each agent i has a discrete strategy, X_i, that takes as values either S or N representing investing and not investing respectively. If i incurs a direct loss, then this may also affect other agents' outcomes. We call the loss to them in this case "an indirect impact." More specifically, $q_i(K, X_i)$ is the expected indirect loss to agent i when it follows strategy X_i and the agents in the set $\{K\}$ are the only ones investing in loss-prevention.

When we use a letter to refer to a set, we will designate it $\{K\}$, except when it is an argument of a function, in which case we omit the brackets. A feature of the IDS problem described above is that an agent who has invested in prevention cannot cause an indirect impact on others, so if everyone other than i invests in prevention, then i cannot suffer indirect impacts. That is, if $\{K\} = \{1, 2, ..i-1, i+1, ..A\}$ then $q_i(K, X_i) = 0$ whether $X_i = S$ or N.

If agent i invests in prevention and agents in the set $\{K\}$ are also investing then the expected cost from this is $c_i + q_i(K, S)$ where the first term is the direct cost of investing in prevention and the second is the expected cost (or benefit if negative) of indirect impacts imposed by others who do not invest.

The expected cost of not investing is given by $p_i L + (1 - \alpha p_i) q_i(K, N)$. Here, the first term is just the expected direct loss and the second is the expected indirect impact. In this second term, the parameter $\alpha \in [0,1]$ indicates the extent to which damages are non-additive. If $\alpha = 0$ then this second term is $p_i L_i + q_i(K, N)$, so that the total expected damage sustained by agent i in the case of non-investment is the sum of the direct and indirect effects.

If however $\alpha = 1$ then we have $p_i L + (1 - p_i) q_i(K, N)$, which means that the indirect effects are conditional on the direct loss not occurring. In this case, the damages from harmful events are non-additive (i.e., you only die once). A second plane crashing into one of the towers of the World Trade Center would not have increased the damage from 9/11 significantly, since the two towers entirely collapsed anyway, and a second bomb placed on Pan Am 103 would likewise have inflicted no extra damage.

[8] This model is based on Heal and Kunreuther (2007).

The agent is indifferent between investing and not investing when

$$c_i + q_i(K,S) = p_i L_i + (1-\alpha p_i) q_i(K,N) \quad (1)$$

or

$$c_i(K) = p_i L_i + (1-\alpha p_i) q_i(K,N) - q_i(K,S) \quad (2)$$

where $c_i(K)$ in equation (2) is the cost of investment at which i is just indifferent between investing and not investing: if $c_i < c_i(K)$ then she will invest and vice versa.

The coordination problem associated with global supply chain security that we discussed above is a case where $q_i(K,N) = q_i(K,S)$ and $\alpha = 1$

so that

$$c_i(K) = p_i\left(L_i - q_i(K,N)\right) \quad (3)$$

It follows in this case that $c_i(K)$ increases in K: as more agents invest, the expected indirect loss falls and the cost threshold for investment rises, with $c_i(\varnothing) < c_i(A-i)$ where c_i *(A-i)* is defined as the critical cost when all agents other than i are investing. In this case the game is supermodular (see Milgrom and Roberts, 1994).

In that context, a Nash equilibrium is a set of strategies $X_1,....X_A$ such that (a) $X_i = S$ for all $i \in \{K\}$ (which may be empty), (b) if $X_i = S$ then $c_i(K) > c_i$ and (c) if $X_i = N$ then $c_i(K) < c_i$ and (d) if $c_i(k) = c_i$ then i is indifferent between S and N. It is possible to show that should the above four conditions hold , a Nash equilibrium in pure strategies exists. There may be equilibria where all agents invest in loss-prevention, those where none do, and asymmetric pure strategy equilibria where some invest and others do not. It is also possible that for some parameter values there is more than one equilibrium.

It is also possible to show that there are Nash equilibria at which all agents invest and also Nash equilibria at which none invest if and only if $c_i(\varnothing) < c_i < c_i(A-i)\forall i$. Also, if both $(N,N,..,N)$ and $(S,S,...,S)$ are Nash equilibria, then $(S,S,,..,S)$ Pareto dominates $(N,N,...,N)$ (Heal and Kunreuther, 2007). If there are two equilibria, one with all not investing and the other with everyone investing in protection, then it is obviously interesting to know how we might tip the inefficient $(N,N.....N)$ equilibrium to an efficient $(S,S,.....S)$ equilibrium. Let's now look into the possibility of tipping the non-investment equilibrium.

Tipping

Let $X_i = N\forall i$ be a Nash equilibrium. A critical coalition CC for this equilibrium is a set $\{M\}$ of agents such that if $X_i = S\forall i \in \{M\}$ then $c_j(M) \geq c_j \forall j \notin \{M\}$.

Let minimum critical coalition MCC be a critical coalition of which no subset is also a critical coalition and let a smallest critical coalition SCC be a minimum critical coalition with the property that no other critical coalition contains fewer members.

Define $q_i^j(K,N) = q_i(K-j,N) - q_i(K,N) \geq 0$ (4)

This is the change in the expected indirect loss to agent i, who does not invest in loss-prevention, when agent j joins the set $\{K\}$ of agents who are already investing in loss-prevention. For the remainder of this section we make the following assumption:

*Assumption A*1: $q_i^j(K,N)$ is independent of i: $q_i^j(K,N) = q^j(K,N) \forall i$

This implies that indirect effects are symmetrically distributed across agents. Also define $q_i^j(\varnothing,S) = q_i(\varnothing,S) - q_i(j,S)$ and $q_i^j(\varnothing,N) = q_i(\varnothing,N) - q_i(j,N)$ and make the additional assumption that:

*Assumption A*2: $q_i^j(\varnothing,S) = q_i^j(\varnothing,N) = q_i^j(\varnothing) = q^j(\varnothing)$ (5)

This indicates that the indirect impact of a change of strategy by agent j on another agent does not depend on the other agent's strategy.

Finally, we shall need the following assumption:

*Assumption A*3: The ranking of agents by $q^j(K)$ is independent of $\{K\}$ (6)

This says in intuitive terms that if agent k creates the largest negative externalities when agents in the set $\{K\}$ are investing in loss-prevention, then agent k creates more externalities than any other agent whatever the set investing in loss prevention.

Theorem. *Let $X_i = N \forall i$ be a Nash equilibrium. If a smallest critical coalition exists for this equilibrium then for some integer K it consist of the first K agents when agents are ranked in decreasing order of $q^j(\varnothing)$*[9].

What are the policy and strategy implications of these results on critical coalitions in the context of global risks? Clearly one is that an equilibrium with no investment in security may be converted to one with full investment by persuading a subset of the agents to change their policies. Leadership, either through trade associations and/or through influential firms that take the lead, may convince others of the need to adopt adequate mitigation measures. A trade association can play a coordinating role by stipulating that any member must follow certain rules and regulations and has the right of refusal if they are asked to do business with an agent that is not a member of the association and/or has not subscribed to the ruling. Even without such a formal mechanism, if a few organizations voluntarily take actions, they could convince others to follow suit and induce "tipping" in the spirit of Schelling (1978).

There may also be a role for well-enforced government standards and regulations coupled with third-party inspections and insurance [10] For example, third-party inspections

[9] Note that these results on tipping apply only to the type of problems we introduce here, as these are the ones that have equilibria where all invest and where none invest, so that tipping from the latter to the former is of interest.

[10] For a more detailed discussion as to who can use third party inspections and insurance to enforce a regulation, see the Kunreuther, McNulty and Kang (2002). They propose this type of public-private partnership as a way of enforcing Sect. 112r of the Clean Air Act Amendments that requires chemical companies and other firms to adopt risk management strategies.

coupled with insurance protection could encourage individuals or organizations to reduce their risks from accidents and disasters that could spill over to others. Such a management-based regulatory strategy would shift the locus of decision making from the regulator to individual firms. The firms would then be required to do their own planning as to how they would meet a set of standards or regulations. If these individuals or organizations take preventive action, they can encourage the remaining ones to comply with the regulations to avoid being caught and fined. This is another form of tipping behavior. Without some type of inspection, low-risk divisions that have adopted risk-reducing measures cannot credibly distinguish themselves from the high-risk ones that have not.

Application: The Anthrax and Beyond Initiative[11]

The Anthrax crisis in the fall of 2001 provides an opportunity to discuss a concrete initiative for addressing the global risk problem in the context of the interdependent environment we described above. Although only four Anthrax-contaminated letters were ultimately found in the U.S. postal network, the uncertainty regarding the nature and degree of contamination lasted for weeks. During the crisis, hundreds of false alerts occurred daily in the United States and in many postal services worldwide. The decision to shut down the whole U.S. Postal Service had been seriously considered, but the service handles about 700 million pieces of mail everyday and shutting it down for just a week, to better measure the scale of the contamination, would have meant that one billion pieces of mail would have to be inspected the following week.

Launching an International Debriefing

The Anthrax crisis raised a set of fundamental questions about postal security worldwide and how interdependencies affect global postal operations. The "Anthrax and Beyond" initiative that Lagadec[12] and Michel-Kerjan designed and implemented, began in the winter of 2002. They suggested an international debriefing process to gather ideas and then launch concrete initiatives that would let postal operators better handle future contingencies. This initiative had three objectives: 1) learn about others' experiences and lessons from the Anthrax crisis; 2) share ideas and proposals to improve the collective reaction to emerging threats (a *(S, S, …, S)* strategy); and 3) establish a platform for crisis management that would link Europe and the United States, so postal operators could connect immediately with their counterparts and with other international organizations.

In order to achieve this goal, it was important to adopt a different posture than simply organizing "another" conference. The initiative involved people at the highest level in their organizations and academic experts who clearly understood not only the emerging risks and crises but also possible conflicts of interest in launching the partnership. These *neutral* experts play a key role in linking the stakeholders and fostering collective thinking and innovation.

[11] This section relies heavily on Lagadec, Michel-Kerjan and Ellis (2006).

[12] Patrick Lagadec is with the Ecole Polytechnique in Paris and a founding member of the European Academy of Crisis Management.

Initially, the initiative was to bring together only a few postal operators from France (LaPoste who took a leading role in this initiative), Germany (Deutsch Post), the Netherlands, and the United Kingdom (Royal Mail). But as the word spread that a core team had undertaken the initiative, postal operators and external stakeholders from a few additional countries joined in, and after a few months nearly 30 countries across Europe and the United States participated in this initiative; a concrete demonstration of the aforementioned tipping effect.

Since emerging crises in interdependent networks would require high-level involvement, international organizations such as the Universal Postal Union and the Comité Européen de Régulation Postale (European Committee for Postal Regulation) also sent representatives to the two-day conference that took place in Paris in November 2002, one year after the height of the international postal crisis. Postal sector executives shared their experiences, suggested new avenues for management, and launched a debate on new operational capabilities.[13].

Immediate Measurable Output – Capacity for a Global Reaction

The "Anthrax and Beyond" initiative produced more than just an opportunity for participants to share experiences. It constituted the first steps in improving the overall reaction among postal networks in case of a new transnational threat. A new international partnership among postal operators was developed to create a global crisis-management network to help allow executives of all the European and U.S. operators to connect instantly. The global information sharing platform was launched at the start of 2003 so executives could exchange information about the solutions each country is implementing and work out a concerted strategy.

That new capacity for global reaction had its first test on January 15, 2003, the day it became operational. PostEurop had received an advisory from the U.S. Postal Service about a possible Anthrax contamination in the Washington, DC area. The network provided postal services across Europe with accurate and timely information on this potential incident, enabling them to assess the scope of the risk. This was a significant improvement over the situation following the Anthrax scare of November 2001 when the chairman of a large postal operator could not talk on the phone with two of his counterparts. The 2003 threat eventually proved to be a false alarm, but it was a dramatic kick-off for the network. This capacity for global reaction is still present today.

The beginning of a crisis is not the time exchange business cards. The improvised responses during a crisis will be incomplete, if not destructive. Efforts are required in advance of any event to make the institutions flexible enough to allow the interdependent concerned parties to coordinate their actions quickly. The above initiative illustrates successful collective actions because they enable information to be shared, strategy to be coordinated and most important, the establishment of relationships that can function smoothly after a disturbing event begins. In the process, they produce measurable benefits for all stakeholders in the form of better preparation or cost-sharing. It would have been extremely costly for any operator to launch such a solution alone. The lessons of this initiative are relevant to managing global risks in other interdependent networks

[13] See Journal of Contingencies and Crisis Management Special Issue, 4 (2003), for a detailed description.

such as pandemics which could be spread through transportation networks, global supply chains disrupted by a series of major natural disasters, or terrorist attacks.

Mitigating Global Risks: A Methodology Framework

We conclude this subsection by proposing a framework for decision makers to start thinking about global risks, and suggest how to mitigate them while at the same time benefiting from these measures. First, it is important to develop criteria for determining risks and act upon them throughout a well specified initiative. The stakeholders impacted by these risks also must be well specified. One must then specify the available scientific data by characterizing the nature of the uncertainties and the existing interdependencies. In most cases, it may be easier to specify a limited number of scenarios and case studies so the nature of potential public-private collaboration emerges more clearly. Finally, one shall determine the feasible strategies for forming *winning coalition* that have a fair/good chance of being implemented.

Here are some of the open questions to consider in this regard:

1. What are the relevant principles to approach our list of global risks?
   General principles
   Principles specific to a given risk
2. What are the elements of uncertainty for a given risk?
   Characterizing probability distribution, ambiguities surrounding these estimates or even ignorance in some cases
   Specifying losses and their distribution, and uncertainty associated with them
3. What is the ultimate goal of our efforts at a local, national or international level?
   Who are the key stakeholders, their agenda and the set of options which they are considering? What are measures of success?
4. What types of programs should be evaluated?
   Role of private and public sectors
   Maintaining status quo
5. What types of scenarios should be developed?
   Nature of interdependencies
   Single period scenarios
   Multi period scenarios
6. What types of cost- and loss-sharing analyses should be undertaken?
   Impact on different stakeholders
   Reconciling differences between key stakeholders

To implement this strategy we recommend selecting one pilot study (e.g., one industry and several major players from different countries, as was done for the Anthrax and Beyond Initiative) to illustrate in a concrete way what can be done, by whom, how, at what costs, what are the potential benefits, and over what period of time.

5. CONCLUSIONS

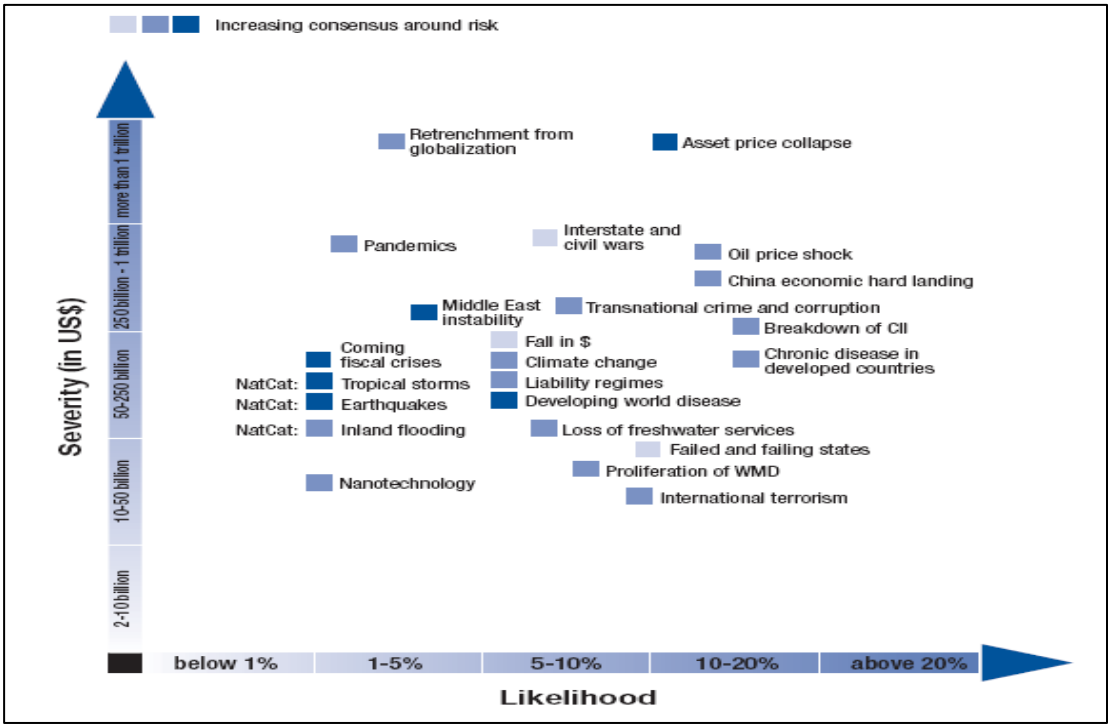
More and more decision makers confront situations that are global in scale, of uncertain importance or consequence, influenced by several different players, and temporally unstable. This increasing globalization of economic and social activities worldwide is reshaping the risk landscape, from the more traditional local and relatively well-defined risks to global and often highly uncertain situations where the impacts can be devastating. The leitmotiv becomes *interdependency* on a large scale. That will require a paradigm shift from the way that most of the risk management literature has been focused. We believe the research community, working in collaboration with leaders in the private and public sectors, has a lot to offer to help better understand this new environment.

In this spirit, we briefly discuss a new initiative recently launched by the World Economic Forum – the *Global Risk Network Initiative*. This network was founded by the World Economic Forum in 2004 in response to a concern that the international community and global businesses were not able to respond adequately to a changing global risk landscape. The initiative became the Global Risk Network at the Annual Meeting 2006 in Davos, Switzerland in partnership with Citigroup, Marsh & McLennan, Merrill Lynch, Swiss Re and the Wharton Risk Management and Decision Processes Center at the University of Pennsylvania. One of its main goals is to better aggregate information about global risks and to act as a clearinghouse for future risk mitigation and risk financing solutions. In this sense, this initiative is a work in progress (World Economic Forum, 2006 and 2007).

The Global Risk Network methodology selected 23 risks ranging from international terrorism, climate change, natural disasters and pandemics to asset price collapse, liability regimes, and critical infrastructure disruption. A survey of experts estimated a range of likelihood and potential losses associated with these risks as depicted in Figure 3. The correlation between each of these risks was then estimated through consultations with a number of risk experts. This correlation matrix, which reflects how one risk can affect another risk which in turn affects another, is displayed as Figure 4.

Figure 4 provides decision makers with some perspective on other issues that could affect their core business which they may not have considered in their strategic planning process. The large-scale destabilization from events such as the Anthrax scare and the SARS epidemic came as a surprise to many managers, signaling that the interdependencies associated with global risks need to be more fully understood and internalized in risk management strategies by firms and governmental organizations.

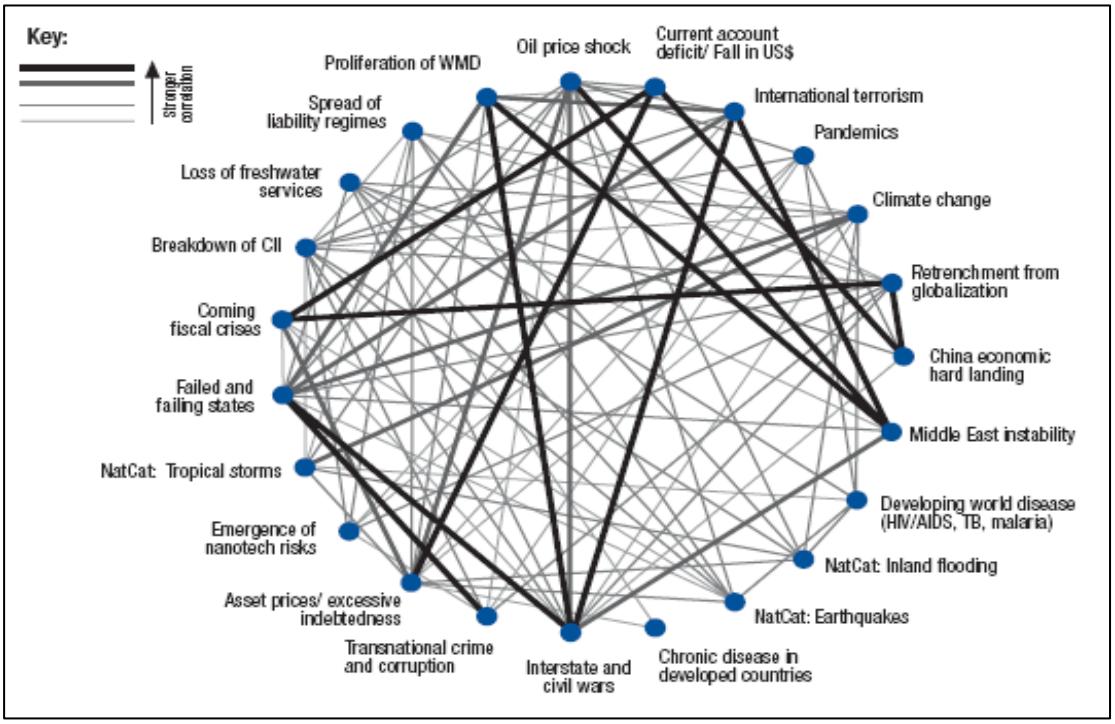
Figure 3: The 23 Core Global Risks



Sources: Global Risk Report 2007 (World Economic Forum, 2007)

[Note: We adopt here the usual approach: Likelihood/severity for each risk – no interdependencies]

Figure 4: New Approach to Deal with Global Risks: Correlation Matrix



In fact, it is not yet clear how many key decision makers in organizations share the view that the above risks are critical ones to consider. For the past ten years the consulting firm *PricewaterhouseCoopers* (PwC) has undertaken a survey of thousands of CEOs worldwide to analyze and understand their concerns regarding the risks that are shaping global business. The *PricewaterhouseCoopers* Global CEO Surveys are launched annually at the World Economic Forum's Annual Meeting in Davos and the results are widely disseminated. For the 10th edition of the CEO survey in 2007, the Wharton Risk Center collaborated with the firm by including a series of questions related to global risks.

Out of the nearly 1,000 CEOs who responded to the survey, more than half indicated they were not very concerned or not concerned at all by many global risks we discussed above. For instance, 62 percent of them were not very concerned or not concerned at all by the risk of a large pandemics; that proportion was 59 percent in the case of global warming and 51 percent for terrorism risk (PwC, 2007). Whether these responders are focused on their core business and/or whether the experts are overestimating these risks are open questions for future research. If one finds that the first explanation has merit, then what can be done to convince CEOs throughout the world that the risks is real and induce them to act upon them collectively?

For many companies, these global risks also constitute opportunities to create value by reaching out to new markets and developing new products. Those firms that are capable of developing innovative risk management and risk financing strategies are likely to be the ones to benefit the most from the change in the global risk landscape that is the basis of this article. As we point out, proactive cooperation may be a necessary ingredient for understanding the interdependencies associated with global risks and for developing necessary partnerships within a specific industry, across industries, and between the private and public sectors. As national boundaries assume less importance, firms need to take into account interactions at an international level when developing their strategic plans. As is normally the case, proactive leaders will be the ones to glean the benefits from initiatives that reduce the potential impacts of future catastrophic events on their activity and those of other affected stakeholders.

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