INSURABILITY OF (MEGA)-TERRORISM RISK:

CHALLENGES AND PERSPECTIVES

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Howard KUNREUTHER and Erwann MICHEL-KERJAN

The Wharton School
Center for Risk Management and Decision Processes
Jon M. Huntsman Hall, Suite 500
3730 Walnut Street, Philadelphia, PA 19104-6340
United States

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EXECUTIVE SUMMARY

Catastrophic events present special challenges for economics and risk management since they have an immediate impact on a wide range of stakeholders, can have severe long-term economic and social consequences and are difficult to assess quantitatively. As these events normally have a low probability of occurrence, there are limited historical data on which to base estimates of the risks and there is considerable uncertainty associated with experts' risk assessments.

The terrorist attacks of September 11, 2001 are the most costly disaster in the history of insurance and have led both insurers and reinsurers to reevaluate under what conditions they can provide coverage against this risk. We examine the conditions for insurability of risks and conclude that terrorism presents special problems due to the uncertainty of the risk, the possibility of adverse selection and moral hazard as well as correlated losses between different lines of coverage. These factors may explain the unwillingness of private insurers in the United States to offer coverage following 9/11 and why the US Congress passed legislation that provides government protection against catastrophic terrorist losses.

We argue that the special characteristics of terrorism compared with major natural hazards call for government participation in any terrorism insurance program. This need has been recognized by most countries through the creation of national programs for covering (mega)-terrorism. Since the creation of these programs, the level of demand for non-compulsory commercial terrorism coverage has remained low in countries such as the U.S. and Germany. The paper discusses some factors that explain this behavior. If the low level of demand continues, a large-scale terrorist attack will likely have a more devastating effect on business and social continuity today than after 9/11 because losses will not be diversified in the national and international insurance and reinsurance industry. This raises the question as to whether terrorism insurance should be mandatory and, if so, how would such a program be administered?

The report discusses also the most recent developments in quantitative risk modeling. A wide range of stakeholders are likely to find these models useful for evaluating their exposure through alternative scenarios but they currently are not able to predict the likelihood of specific terrorist actions. We conclude that better data are needed to evaluate alternative public-private partnerships for encouraging risk reduction measures and providing insurance against terrorism.

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A. INTRODUCTION

Catastrophic events present special challenges for economics and risk management since they have an immediate impact on a wide range of stakeholders can have severe long-term economic and social consequences and are difficult to assess quantitatively. As these events normally have a low probability of occurrence, there are limited historical data on which to base estimates of the risks and there is considerable uncertainty associated with experts' risk assessment estimates.

An aversion to ambiguity leads insurers to set premiums much higher than they otherwise would if there was agreement among experts as to the likelihood and consequences of future events. (Kunreuther, Hogarth, and Meszaros, 1993). On the demand side, it is well known that potential purchasers may underestimate the risks and consider the insurance premiums as being too expensive, thus refusing to purchase coverage if they have the choice (Kunreuther, 1996).

Because these events are capable of having a debilitating impact on the country, providing adequate financial protection to victims of catastrophes often becomes a national issue. Facing unprecedented large-scale potential damage, the private sector may severely restrict the insurance supply or even refuse to provide coverage. In such cases, the government is likely to intervene by offering insurance at prices that property owners can afford (Moss, 2002).

This report discusses some of the challenges associated with the insurability of (mega)-terrorism today. It is structured around the following four main themes:

Section B discusses new frontiers for dealing with terrorism as an extreme event: September 11, 2001 (9/11) highlighted the radical change in the nature of international terrorism and its consequences thus occurred over the past 20 years.

Section C focuses on the insurability of catastrophic events and on the characteristics of terrorism risk that make it more challenging to deal with than major natural hazards.

Section D analyzes the need for developing public-private partnership to deal with (mega)-terrorism as indicated by the challenges faced by private insurers and reinsurers after 9/11. The paper describes the risk-sharing mechanisms operating in the United Kingdom, France, Germany and the United States.

Section E provides features of the new models developed after 9/11 to help quantify terrorism risks and discusses some of their strengths, limitations and possible applications.

Section F summarizes the arguments for public-private partnership for dealing with catastrophic losses from terrorism and raises some questions for future research.

B. NEW FRONTIERS

B1. INSURING 9/11: A NEW LOSS DIMENSION

Prior to September 11, 2001 terrorism exclusions in commercial property and casualty policies in the U.S. insurance market were extremely rare (outside of ocean marine). The private insurance market had functioned effectively in the U.S. because losses from terrorism had historically been small and, to a large degree, uncorrelated. Attacks of a domestic origin were isolated, carried out by groups or individuals with disparate agendas and did not create major economic disruption nor many casualties.

In fact, insurance losses from terrorism were viewed as so improbable that the risk was not explicitly mentioned in any standard policy and hence the rate for providing such coverage to firs was never calculated. Even the first attack on the World Trade Center (WTC) in 1993 was not seen as being threatening enough for insurers to consider revising their view of terrorism as a peril to be explicitly considered when pricing a commercial insurance policy (Kunreuther and Pauly, 2004).

The 1993 bombing of the WTC killed 6 people and caused $725 million in insured damages (Swiss Re, 2002-a). Prior to Sept. 11th the Oklahoma City bombing of 1995, which killed 168 people, had been the most damaging terrorist attack on domestic soil, but the largest losses were to federal property and employees and were covered by the government. So insurers and reinsurers felt that they did not have to pay close attention to their potential losses from terrorism in the United States.

The terrorist attacks of September 11, 2001 killed nearly 3,100 people[1] from over 90 countries and injured more than inflicted damage currently estimated at nearly $80 billion, about half of which was covered by insurance. (Swiss Re, 2002-a). Over the $40 billion total insured losses, those associated with property damage and business interruption are estimated at $19 billion. Prior to 9/11, most terrorist attacks did not have a major impact on liability coverage[2], most published comparisons were based only on insured property losses. Table 1

[1] This number represents victims of the attacks in New York, Washington, DC and Pennsylvania as well as among teams of those providing emergency service.

[2] An important exception is the terrorist attacks against the Pan American Flight 103, which exploded over Lockerbie, Scotland in December 1988 and inflicted $520 million insured losses under liability coverage (ICAO, 2002).

details the 10 most costly terrorist attacks between 1970 and 2001 in terms of insured property losses (including business interruption and aviation hull losses, but excluding liability and life).

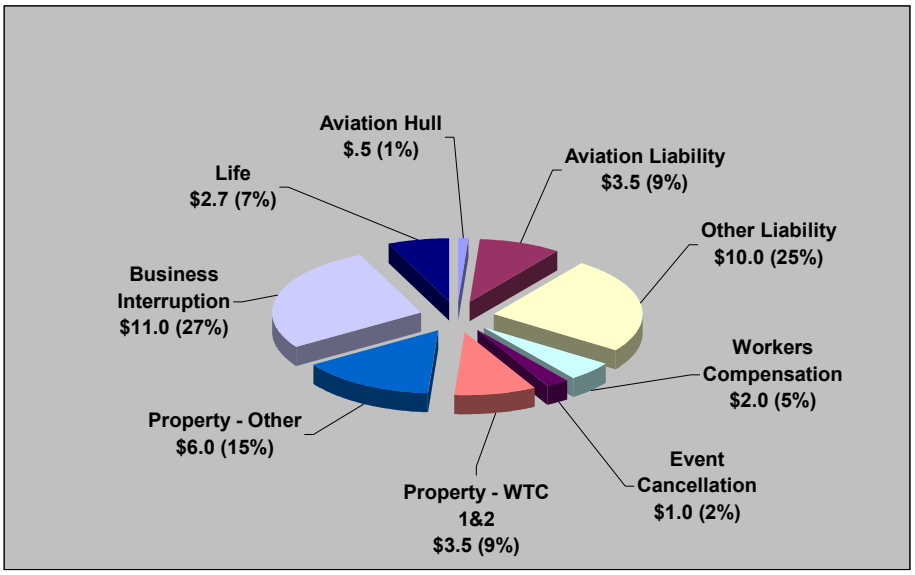
Table 1.
The 10 Most costly terrorist attacks in terms of insured property losses. 1970-2001

Insured property US$ million, indexed to 2001 (excluding liability and life)	Event	Injured	Fatalities	Date	Location
19,000	Terror attacks against WTC, Pentagon and Pennsylvania by hijacked airliners	2 250	3,100	11 Sept. 01	USA (NYC, Wash. DC, PA)
907	Bomb explodes near NatWest tower (City)	54	1	24 Apr. 93	UK (London)
744	Explosion of IRA car bomb near shopping mall	228	0	15 Jun. 96	UK (Manchester)
725	Bomb explodes in garage of World Trade Center	1000	6	26 Feb. 93	USA (New York)
671	Bomb explodes in financial district	91	3	10 Apr. 92	UK (London)
398	Rebels destroy 3 airliners, 8 military aircraft and heavily damage 3 civilian aircraft	15	20	24 Jul. 01	Sri Lanka / Colombo Airport
259	IRA bomb attack in South Key Docklands	100	2	09 Feb. 96	UK (London)
145	Truck bomb attack on government building in Oklahoma City	467	166	19 Apr. 95	USA (Oklahoma City)
138	PanAm Boeing 747 crashes due to bomb	0	270	21 Dec. 88	UK (Lockerbie)
127	Hijacked Swissair DC-8, TWA Boeing 707 and BOAC VC-10 dynamited	0	0	06 Sep.70	Jordan (Zerqa)

Sources: Swiss Re, Economic Research (2002-a).

The insured losses from 9/11 illustrate the high degree of risk correlation between different lines of insurance coverage. Indeed, these attacks not only impacted on commercial property, business interruption and aircraft hull but also led to significant claims from other lines of coverage: workers' compensation, life, health, disability, and general liability insurance. Figure 1 depicts the composition of the $40.2 billion total insured loss estimates due to these terrorist attacks (as of July 2002).

Figure 1.
Composition of 9/11 Loss Estimates, by Line ($ Billions)



Sources: Insurance Information Institute (Hartwig, July 2002).

To more fully understand the losses from 9/11 from an insurability perspective, it is important to compare this event with other types of catastrophic events, such as natural disasters, that have impacted on the (re)insurance industry. Table 2 presents the 10 largest world wide insurance losses due to natural catastrophes and man-made disasters from 1970 to 2003. Prior to 9/11 losses, the mostly insured event was Hurricane Andrew that devastated the coasts of Florida in August 1992 and inflicted $20.5 billion insured losses. The insurance claims from the 9/11 terrorist attacks were almost twice as much as those from Hurricane Andrew.

Table 2.
The 10 most costly insurance losses 1970-2003.

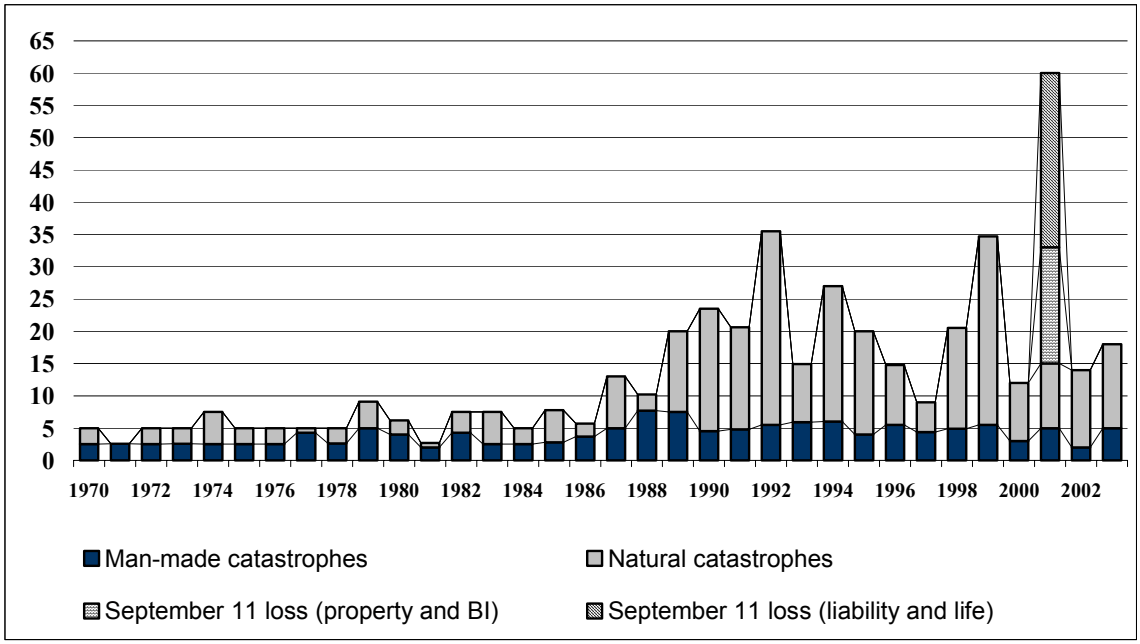
US$ Billion *(indexed to 2002)*	***Event***	***Fatalities***	***Year***	***Country***
40.2	9/11 Attacks	3,050	2001	USA
20.51	Hurricane Andrew	38	1992	USA, Bahamas
16.98	Northridge Earthquake	60	1994	USA
7.45	Typhoon Mireille	51	1991	Japan
6.32	Winterstorm Daria	95	1990	France, UK et al
6.26	Winterstorm Lothar	80	1999	France, Switzerland et a
6.08	Hurricane Hugo	61	1989	Puerto Rico, USA et al
4.74	Storms and floods	22	1987	France, UK et al
4.39	Winterstorm Vivian	64	1990	Western Europe
4.36	Typhoon Bart	26	1999	Japan

Sources: Swiss Re (2003) and Hartwig (2002).

Taking an even broader perspective, Figure 2 depicts the trend in world wide insurance losses due to natural catastrophes and man-made disasters from 1970 to 2003 showing how insured losses have increased in recent years. Among the 40 most costly events over this period of time, 75% of them occurred between 1990 and 2003 (in constant prices).

In particular, the insured losses from Hurricane Andrew and the Northridge Earthquake led insurers and reinsurers to pay much more attention to the catastrophic potential of natural disasters. Some of the smaller insurers were forced to declare insolvency due to these events. Those that survived began to rethink what is meant by an insurable risk and the roles catastrophic models to estimate the likelihood and consequences from specific hazards that might cause damage in specific locations (Grossi and Kunreuther, in press).

Figure 2.
Worldwide Evolution of Insured Losses, 1970-2003
(Property and business interruption (BI); in US$ billon indexed to 2003)



Source: Swiss Re, Economic Research (2002-b; 2003).

The events of September 11th confronted the insurance and reinsurance industries with an entirely new loss dimension. Reinsurers (most of them European) will be responsible for a large portion of the $40 billion claims. The 9/11 terrorist attacks came on top of a series of catastrophic natural disasters over the past decade and portfolio losses due to stock market declines. Having their capital base severely hit, most of them decided to drastically reduce their exposure to terrorism, or even stopped covering this risk. The few who marketed policies

charged extremely high rates for very limited protection. This directly affected insurance supply and most insurers stopped covering terrorism.

While the prices of commercial property-liability insurance were beginning to rise prior to September 11, 2001[3], the terrorist attacks appeared to have hardened the general liability market even further. Take the case of insuring Chicago's O'Hare airport. Prior to 9/11, the airport had $750 million of terrorist insurance coverage at an annual premium of $125,000. After the terrorist attacks insurers only offered the airport $150 million of coverage at an annual premium of $6.9 million. The airport purchased this coverage and could not obtain any more (Jaffee and Russell, 2003). The Golden Gate Park was unable to obtain terrorism coverage and its non-terrorism coverage was reduced from $125 million to $25 million. Yet the premiums for this reduced amount of protection increased from $500,000 in 2001 to $1.1 million in 2002.

By early 2002, 45 states in the U.S. permitted insurance companies to exclude terrorism from their policies, leading to a call for some type of federal intervention (Brown, Kroszner and Jenn, 2002). In other countries, similar reactions were observed. Deprived of reinsurance capacity at an affordable price, most insurers decided to stop covering terrorism risk and turned to the government to fill the gap.

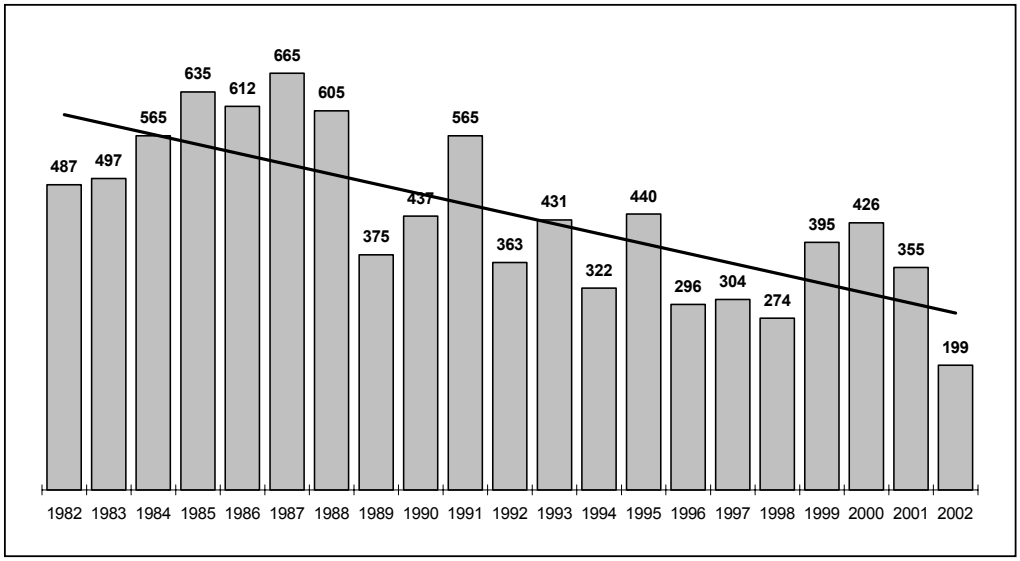
B2. EMPIRICAL EVIDENCE ON CHANGE IN THE NATURE OF TERRORISM RISK

There is evidence collected by Enders and Sandler (2000) that the terrorism risk has changed radically over the past two decades. On the one hand, the total number of international terrorist attacks worldwide has been decreasing on average in the 1990s compared with the 1980s, as shown in Figure 3. (U.S. Department of State, 2003). This decrease is mostly due to the end of the East/West conflict that led to the reduction in activities of several political terrorist groups. (Pillar, 2001).

On the other hand, there has been a significant change towards attacks that create more injuries and fatalities. When we consider the 15 worst terrorist attacks in terms of the number of casualties (Table 3), all of them occurred after 1982. Moreover, 80% of these large-scale attacks occurred between 1993 and 2004, including the latest attacks in Spain that killed 201 persons and injured more than 1000 others on March 11, 2004.

[3] See the evolution of the catastrophe reinsurance price index, Figure 6 of the report.

Figure 3
Total International Terrorist Attacks and Trend, 1982-2002.



Sources: U.S. Department of State (2003)

In this context, as pointed out by Sandler and Enders (in press), "the events of 11 September with their massive casualties of innocent people of all ages came as no surprise to those of us who study terrorism and warned of an ominous changing nature of transnational terrorism." The question today is not really whether other terrorist attacks will be perpetrated but rather who, where and with what type of weapons.

Dealing with this new spectrum of terrorism risk, the use of non-conventional chemical, biological, radiological and nuclear weapons (CBRN) has to be also considered. Although the use of such weapons requires higher level of technical skill and the WMD capability of active terrorist organizations is low, the intent of several of them to acquire such a capability is beyond doubt. (Woo, 2004). For example, Al Qaeda clearly expressed interest in acquiring and deploying these weapons of mass destruction. (Central Intelligence Agency, 2003).

In this regard, the 9/11 events and the anthrax attacks during the fall of 2001 demonstrated a new kind of vulnerability. Attackers can use the diffusion capacity of our large critical networks and turn them against the target population so that each element of the network (e.g. every aircraft, every piece of mail) now becomes a potential weapon (Michel-Kerjan, 2003-a).

Table 3.
The 15 worst terrorist acts in terms of causalities [4]

Date	*Location*	*Event*	*Fatalities*	*Injured*
11 Sep 2001	USA	Terror attack	3 100	2 250
23 Oct 83	Lebanon/ Beirut	Bomb attack on US Marine barracks and French paratrooper base	300	100
12 March 93	India/ Bombay	Series of 13 bomb attacks	300	1 100
12 Oct 2002	Indonesia/Bali	Bomb attack in a night club	190	300
11 March 04	Madrid, Spain	Bomb attacks on trains	202	>1400
21 Dec 88	UK/ Lockerbie	PanAm B-747 explodes mid-air	270	0
07 Aug 98	Kenya/ Nairobi	Bomb attacks on US embassy complex	253	5 075
12 Oct 02	Indonesia	Nightclub bombing	190	300
19 Apr 95	USA/ Oklahoma City	Truck bomb attack on government building	166	467
23 Nov 96	Comoros/ Indian Ocean	Hijacked Ethiopian Airliner B-767 ditched at sea	127	0
13 Sep 99	Russia/ Moscow	Bomb destroys apartment building	118	0
04 Jun 91	Ethiopia/ Addis Ababa	Arson in arms warehouse	100	0
31 Jan 96	Sri Lanka/ Colombo	Bomb attack on Ceylinco House	100	1 500
18 Jul 94	Argentina/ Buenos Aires	Bomb attack	95	147
26 Feb 93	USA New York	Bomb explodes in garage of world Trade Center	6	1000

[4] Multi-Sources: US Department of States (2003), Swiss Re (2002, updated March 2003), Press releases.

During the anthrax episode, for example, the attacks were not turned against a specific postal office. Rather the attackers used the whole United States Postal Service network to spread threats throughout the country and abroad. Any envelope could have been considered as contaminated by anthrax so that the whole postal service was potentially at risk (Boin, Lagadec, Michel-Kerjan and Overdijk, 2003). Less than one hour after the first aircraft crashed against the North WTC Tower, the U.S. Federal Aviation Administration (FAA) ordered all private and commercial flights grounded and suspended. It was on September 12th 2001 that they were authorized to resume their flights, as the number of hijacked planes on 9/11 was not known and each flying aircraft was a potential danger. It was the first time and only time that the FAA has ever shut down the airline system.

These examples demonstrate that a small but carefully targeted attack can cause large-scale economic consequences because they impact on interdependent and large-scale operating networks. In 1998, U.S. Presidential Decision Directive 63 classified those sectors, among others (e.g. aviation, transportation, water supply, electricity[5], telecommunications, banking and finance, energy), as "critical infrastructure sectors" for the social and economic continuity of the country. (White House, 2003). Since then, new programs have been launched in other countries also to understand this source of mega-terrorism and undertake actions to manage this new type of vulnerability. (OECD, 2003).[6]

The growing globalization of economic activities, combined with increasing interdependencies and terrorist threats, make the question of protection (physical and financial) even more crucial as a the malevolent use if these network can inflict mega-terrorism. A single event can be sufficient to destabilize the insurance industry and perhaps the economy. The antecedents to catastrophes can be quite distinct and distant from the actual disaster, as in the case of the 9/11/01 attacks when security failures at Boston's Logan airport led to crashes at the WTC and Pentagon. The same was true in the case of recent power failures in the northeastern US and Canada, where the initiating event occurred in Ohio but the worst consequences were felt hundreds of miles away.

[5] This is illustrated by the August 14, 2003 power failure in the U.S. and the September 27, 2003 one in Italy.
[6] See also, for example, the large conference organized by the Geneva Center of Security Policy on "Critical Infrastructures and Continuity of Services in an Increasingly Interdependent World" (October 2003, Geneva).

C. INSURABILITY OF EXTREME EVENTS: WHY IS TERRORISM DIFFERENT?

We first consider the conditions for a risk to be insurable by focusing on natural hazards and then turn to terrorism. There are some crucial differences between these two types of events which make terrorism a more challenging risk to be insured by the private sector alone.

C1. INSURABILITY OF CATASTROPHE RISKS

In most developed countries, insurance is one of the principal mechanisms used by individuals and organizations for managing risk. Insurance allows the payment of a relatively small premium for protection against a potentially large loss in the future. In the United States, some property insurance coverage is required by law or by the lending institution. For example, homeowners normally have to purchase fire coverage as a condition for a mortgage. Automobile liability insurance is also required in most states as a condition for licensing a car. However, earthquake insurance is usually not required by lenders on property even in seismically active regions of the country such as California.

Insurance pricing can be a signal as to how risky certain activities are for a particular individual. To illustrate, consider automobile insurance. For cars that are the same price, younger, inexperienced drivers of sporty vehicles pay more in premiums than older drivers of more conservative cars. For life and health insurance**,** smokers pay more for coverage than nonsmokers. This allocation of risk seems appropriate since it is tied to the likelihood of outcomes resulting from the nature of an individual's lifestyle. If one individual is more susceptible to a specific risk, then the cost for coverage against a loss from that risk is greater. Of course, since insurance rates are subject to regulation, the price of the policy may not fully reflect the underlying risk.

The key challenge is how to allocate catastrophe risk among stakeholders in a manner similar to what is done for the more frequent events where there is a large historical database to estimate insurance premiums for individuals with different risk characteristics. For example, for automobile coverage the large number of data points and the absence of correlation between accidents allow the use of actuarial-based models to estimate risk.

Conditions for Insurability of a Risk

Consider a standard insurance policy whereby premiums are paid at the start of a given time period to cover losses during this interval. Two conditions must be met before insurance providers are willing to offer coverage against an uncertain event. The first is the ability to identify and quantify, or estimate at least partially, the chances of the event occurring and the extent of losses likely to be incurred. The second condition is the ability to set premiums for each potential customer or class of customers.

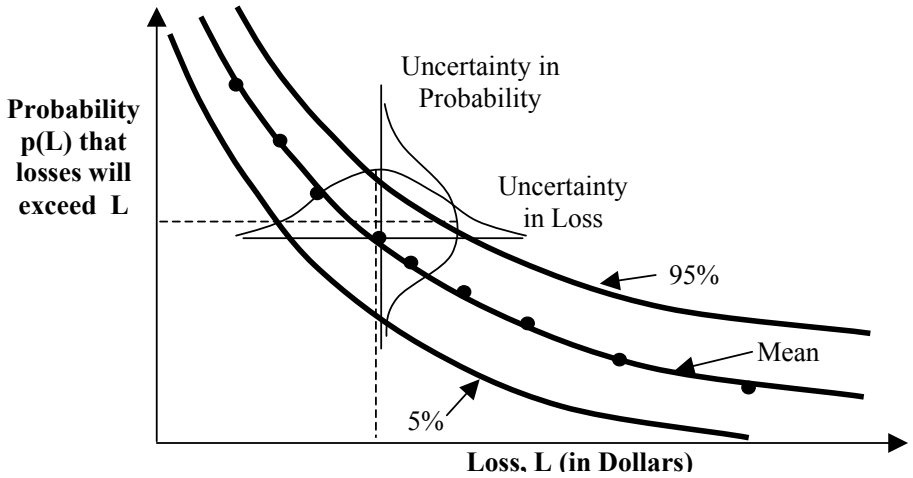
If both conditions are satisfied, a risk is considered to be insurable. But it still may not be profitable. In other words, it may be impossible to specify a rate for which there is sufficient demand and incoming revenue to cover the development, marketing, operating, and claims processing costs of the insurance and yield a net positive profit over a prespecified time horizon. In such cases, the insurer will opt not to offer coverage against this risk.

To satisfy the first condition, estimates must be made of the frequency of specific events and the likely extent of losses. Such estimates can be based on past data coupled with data on what experts know about a particular risk. The insurer can then construct an expedience probability (EP) curve that depicts the probability that a certain level of loss will be exceeded on an annual basis[7].

To illustrate with a specific example, suppose one was interested in constructing an EP curve for dollar losses to homes in Los Angeles from an earthquake. Using probabilistic risk assessment, one combines the set of events that could produce a given dollar loss and then determines the resulting probabilities of exceeding losses of different magnitudes. Based on these estimates, one can construct the mean EP depicted in Figure 4. By its nature, the EP curve inherently incorporates uncertainty associated with the probability of an event occurring and the magnitude of dollar losses. This uncertainty is reflected in the 5% and 95% confidence interval curves in the figure.

[7] It is not necessary to have a precise estimate of the probability for a risk to be covered by insurance (Eeckhoudt and Gollier, 1999). For example, the first U.S. satellite launch was covered (Explorer I in 1958) despite the lack of historical data and the difficulty of calculating the risk of failure. There are also some anecdotal cases: for example, Lloyd's covered the discovery of the Loch Ness monster in 1973. In 2001, potential attacks by the Yeti for travelers in the Himalaya Mountains have been covered too (Godard et al., 2002).

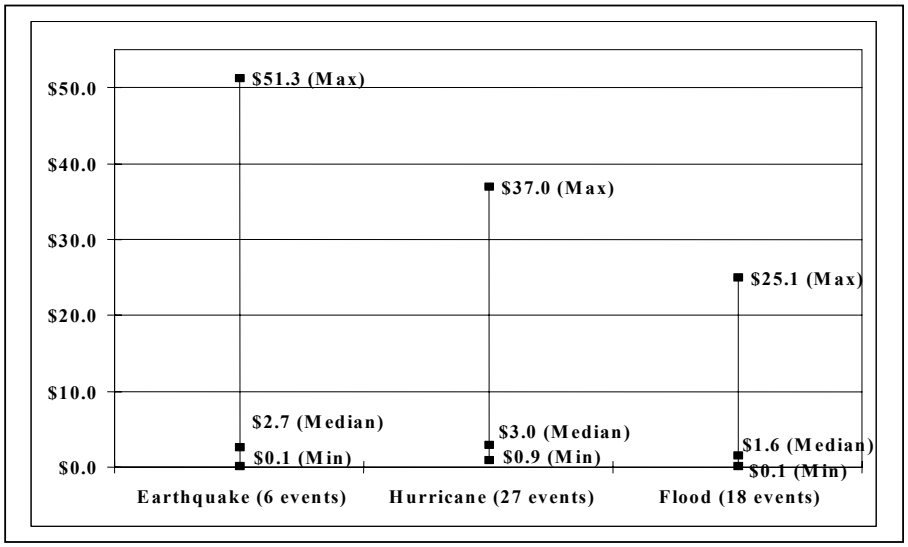
Figure 4.
Example of Exceedance Probability (EP) Curves



A key question that needs to be addressed in constructing an EP curve is the degree of uncertainty regarding both probability and outcomes. It is a lot easier to construct such a curve for natural disasters and chemical accidents than it is for terrorist activities. But even for these more predictable accidents or disasters, there may be considerable uncertainty regarding both the likelihood of the occurrence of certain risks and the resulting damage. For low probability-high consequence risks, the spread between the three curves depicted in Figure 4 shows the degree of indeterminacy of these events. Providing information on the degree of uncertainty associated with risk assessments should increase the credibility of the experts producing these figures.

Extreme events, such as natural disasters or large-scale terrorism, pose a set of challenging problems for insurers because they involve potentially high losses that are extremely uncertain. In the case of natural disasters, Figure 5 illustrates the total number of loss events from 1950 to 2000 in the United States for three prevalent hazards: earthquakes, floods, and hurricanes. Events were selected that had at least $1 billion of economic damage and/or over 50 deaths (American Re, 2002). Looking across all the disasters of a particular type (earthquake, hurricane or flood), for this 50-year period, the median loss is low while the maximum loss is very high. Given this wide variation in loss distribution, it is not surprising that insurers are concerned about the uncertainty of the loss in estimating premiums. With respect to terrorism, the events of 9/11 were totally unexpected by insurers based on past experience. As shown in Table 1 there was considerable variation in the losses from the top 10 terrorist events over these past 31 years.

Figure 5.
Historical economic losses in $ millions versus type of significant U.S. natural disaster



With respect to the second condition, if there is considerable ambiguity or uncertainty associated with the risk, insurers may wish to charge a much higher premium than if they had more precise estimates of the risk (Kunreuther et al. 1993, 1995). Moreover, if the capacity of the insurance industry is reduced due to recent large losses, then premiums will rise due to a shortage in supply. The situation will be exacerbated if the recent losses trigger an increase in demand for coverage, as was the case after Hurricane Andrew in 1992 and the Northridge earthquake in 1994 (Kunreuther and Roth, Sr., 1998) as well as after the terrorist attacks of 9/11.

Once the risk is estimated, the insurer needs to determine a premium that yields a profit and avoids an unacceptable level of loss. State regulations often limit insurers in their rate-setting process, and competition can play a role in what may be charged in a given marketplace. Even in the absence of these influences, there are two other issues that an insurer must consider in setting premiums: problems associated with asymmetry of information (adverse selection and moral hazard) and the risk of highly correlated losses.

Adverse Selection

If the insurer sets a premium based on the average probability of a loss, using the entire population as a basis for this estimate, those at the highest risk for a certain hazard will be the most likely to purchase coverage for that hazard. In an extreme case, the poor risks

will be the only purchasers of coverage, and the insurer will lose money on each policy sold. This situation, referred to as *adverse selection*, occurs when the insurer cannot distinguish between the probabilities of a loss for good- and poor-risk categories[8].

The assumption underlying adverse selection is that purchasers of insurance have an informational advantage by knowing their *risk type*. Insurers, on the other hand, must invest considerable expense to collect information to distinguish between risks. For example, suppose some homes have a low probability of suffering damage, (the good risks), and others have a higher probability (the poor risks). The good risks stand a 1 in 1000 probability of loss and the poor risks, a 3 in 1000 probability. For simplicity, assume that the loss is $100,000 for both groups and that there are an equal number of potentially insurable individuals in each risk class.

Since there is an equal number in both risk classes, the expected loss for a random individual in the population is $200[9]. If the insurer charges an actuarially fair premium across the entire population, only those in the poor-risk class would normally purchase coverage, since their expected loss is $300 (i.e., .003x$100,000), and they would be pleased to pay only $200 for the insurance. The good risks have an expected loss of $10,000 (i.e., .001x$100,000), so they would have to be extremely risk averse to be interested in paying $200 for coverage. If only the poor risks purchase coverage, the insurer will suffer an expected loss of -$100 on every policy it sells.

It is important to remember that the problem of adverse selection only emerges if the persons considering the purchase of insurance have more accurate information on the probability of a loss than the firms selling coverage. If the policyholders have no better data than the insurers, both sides are on an equal footing. Coverage will be offered at a single premium based on the average risk, and both good and poor risks will want to purchase policies.

[8] For a survey on adverse selection issues, see Dionne and Doherty (1992)
[9]This expected loss is calculated as follows: [50(.001x$100,000) + 50(003x$100,000)]/100 = $200.

Moral Hazard

Providing insurance protection to an individual may lead that person to behave more carelessly than before he or she had coverage. If the insurer cannot predict this behavior and relies on past loss data from uninsured individuals to estimate rates, the resulting premium is likely to be too low to cover losses.

Moral hazard refers to an increase in the probability of loss caused by the behavior of the policyholder. Obviously, it is extremely difficult to monitor and control behavior once a person is insured. How do you monitor carelessness? Is it possible to determine if a person will decide to collect more on a policy than he or she deserves by making false claims (so called "ex post moral hazard")?

Highly Correlated Risks

Correlated risk refers to the simultaneous occurrence of many losses from a single event. In general, insurance markets flourish when companies can issue a large number of policies whose losses are spatially and otherwise independent. The statistics for this type of portfolio illustrate the theory of the *law of large numbers,* introduced by Bernoulli (1738). This law states that for a series of independent and identically distributed random variables, the variance around the mean of the random variables decreases as the number of variables increases.

Fire is an example of a risk that satisfies the law of large numbers since losses from this type of event are normally independent of one another. Of course, there are exceptions to this rule, such as the Oakland conflagration fire of October 20, 1991 where 3,000 structures were damaged for a total insured loss of $1.7 billion. More recently, the fires in Southern California between October 23 and November 6 of 2003, destroyed over 700,000 acres of land and approximately 3,600 residential properties.

To illustrate this law's application to spatially independent events, suppose that an insurer wants to determine the probability of losses from fire for 1,000 identical homes valued at $100,000, each of which has a 1/1000 chance of being completely destroyed by fire; otherwise the house will be unscathed. Since there are 1000 homes in the risk pool, the fire will destroy on average one structure per year. The average annual loss (AAL) for each home

would be $100, or the product of the probability, p, and the value of the home, L, or 1/1000 x $100,000.

If the insurer issued only a single policy rather than 1000, then a variance of approximately $100 would be associated with its AAL.[10] As the number of policies issued increases, the variance of the AAL per policy will decrease in proportion to the number of policies, n. Thus, if n = 10, the variance of the mean will be approximately $10. When n = 100 the variance decreases to $1, and with n = 1,000 the variance is only $0.10. This clearly demonstrates that it is not necessary to issue a large number of policies to reduce the variability of expected annual losses to a relatively small value if the risks are independent.

However, losses from natural hazards or terrorism attacks do not follow the law of large numbers, as they are not independent. Catastrophic risks involve spatially correlated losses or the simultaneous occurrence of many losses from a single event. For example, due to their high concentration of homeowners' policies in the Miami/Dade County area of Florida, State Farm and Allstate Insurance paid $3.6 billion and $2.3 billion in claims respectively in the wake of Hurricane Andrew in 1992. Given this unexpectedly high loss, both companies began to reassess their strategies of providing coverage against wind damage in hurricane-prone areas (Lecomte and Gahagan, 1998).

The terrorism attacks of 9/11 caused significant losses from different lines of an insurers' portfolio, another form of correlated risk, as shown in Figure 1. Due to their high concentration of policies in the World Trade Center, Lloyd's, Munich Re and Swiss Re would pay $2.9 billion, $2.4 billion and $2.4 billion in claims respectively in the wake of 9/11. Among the important number of insurers that suffered losses, Allianz, AIG and AXA paid $1,300 million, $820 million and $550 million, respectively. (Hartwig, 2002).

C2. DETERMINING WHETHER TO PROVIDE COVERAGE

If an insurer's portfolio leaves them vulnerable to the possibility of extremely large losses from a given disaster, then the insurer will want to reduce the number of policies in force for these hazards, decide not to offer this type of coverage at all or increase the capital available to for dealing with future catastrophic events.

[10] The variance for a single loss L with probability p is Lp (1-p). If L = $100,000 and p = 1/1,000, then Lp(1-p) = $100,000(1/1,000)(999/1,000) or $99.90.

Capital Constraints

Cummins Doherty and Lo (2002) have undertaken a series of analyses in the context of natural catastrophes that indicate that U.S. property-liability insurance industry could withstand a loss of $40 billion with minimal disruption of insurance markets. According to their model, a $100 billion loss would create major problems for the insurance industry by causing 60 insolvencies and leading to significant premium increases and supply side shortage.

In the aftermath of the terrorism attacks of September 11th, there was a severe shortage of capital provided to insurers, as the reinsurers were reluctant to provide protection against this risk except at very high prices. Hence for insurers to provide their clients with the same coverage they were offered in the past, they had to find capital from other sources. Most insurers were unable to do this so they either excluded terrorism from the standard commercial property coverage or reduced the amount of protection they were willing to offer while at the same time raising premiums. The experience of O'Hare Airport in obtaining coverage after September 11th discussed in Section B1 illustrates the latter strategy by insurers.

Survival Constraints

In his study on insurers' decision rules as to when they would market coverage for a specific risk, Stone (1973) develops a model whereby firms maximize expected profits subject to satisfying a constraint related to the survival of the firm.[11] Following the series of natural disasters that occurred end of 1980's and in the 1990s, insurers focused on the survival constraint in determining the amount of catastrophe coverage they were willing to provide. In particular, insurers were caught off guard with respect to the magnitude of the losses from Hurricane Andrew in 1992 and the Northridge earthquake in 1994. Insurers only marketed coverage against wind damage in Florida because they were required to do so and state insurance pools were formed to limit their risk. In California insurers refused to renew homeowners' earthquake policies after the 1994 Northridge earthquake and the California Earthquake Authority was formed by the State of California in 1996 with funds from insurers and reinsurers. (Roth, Jr., 1998).

[11] Stone also introduces a constraint regarding the stability of the insurer's operation. However, insurers have traditionally not focused on this constraint in dealing with catastrophic risks.

An insurer satisfies the survival constraint by choosing a portfolio of risks with an overall expected probability of insolvency less than some threshold, p_1. A simple example illustrates how an insurer would utilize the survival constraint to determine whether the earthquake risk is insurable. Assume that all homes in an earthquake-prone area are equally resistant to damage such that the insurance premium, z, is the same for each structure. Further assume that an insurer has $A dollars in current surplus and wants to determine the number of policies it can write and still satisfy its survival constraint. Then, the maximum number of policies, n, satisfying the survival constraint is:

$$\text{Probability [Total Loss} > (n \cdot z + A)] < p_1$$

Whether the company will view the earthquake risk as insurable depends on whether the fixed cost of marketing and issuing policies is sufficiently low to make a positive expected profit. This, in turn, depends on how large the value of n is for any given premium, z. Note that the company also has some freedom to change its premium. A larger z will increase the values of n but will lower the demand for coverage. The insurer will decide not to offer earthquake coverage if it believes it cannot attract enough demand at any premium structure to make a positive expected profit. The company will use the survival constraint to determine the maximum number of policies it is willing to offer, with possibly an adjustment of the amount of coverage and premiums and/or a transfer of some of the risk to others (larger insurers, reinsurers or capital markets).

C3. WHY IS TERRORISM DIFFERENT?

Although terrorist activities and natural disasters can be both characterized as extreme events, there are crucial differences between them. These include: availability of historical data, dynamic uncertainty, shifting attention to unprotected targets, existence of negative externalities and government influencing the risk.

Availability of Historical Data

There are large historical databases on losses from natural hazards that are in the public domain. These data have been utilized by modeling firms in conjunction with estimates by scientists and engineers on the likelihood and consequences of future disasters in specific locations. Data on terrorist groups' activities and current threats are normally kept secret for national security reasons. Moreover, while some time series data on terrorist acts over the past

years are in the public domain, they may not reflect the changing expectations of planned activities of terrorist groups today. As discussed above, the nature of terrorist activities and targets has radically changed in the last 20 years and may do so again over the next 20 years.

Dynamic Uncertainty

Since terrorists are likely to design their strategy as a function of their own resources and their knowledge of the vulnerability of the entity they want to attack, the nature of the risk is continuously evolving. The likelihood and consequences of a terrorist attack is determined by a mix of strategies and counterstrategies developed by a range of stakeholders and changing over time. This leads to *dynamic uncertainty*. (Michel-Kerjan, 2003-b).

More formally, the analyst is confronted with a dynamic game where the actions of the terrorist groups in period *t* are dependant on the actions taken by those threatened by the terrorists (i.e. the defenders) in period *t-1*. Hence terrorism risk will change depending on at least two complementary strategies by the defenders. The first entails protective measures adopted by those at risk. The second consists of actions taken by governments to enhance general security and reduce the probability that attacks will occur. In this sense, terrorism is a mixed public-private good. From the terrorists' point of view, they must determine what targets to attack and the commitment of resources to specific activities.

In contrast, actions can be taken to reduce damage from future natural disasters with the knowledge that the probability associated with the hazard will not be affected by the adoption of these protective measures. In other words, the likelihood of an earthquake of a given intensity in a specific location will not change if property owners design more quake-resistant structures. For example, damage due to a future large-scale earthquake in Los Angeles, Tokyo or Monaco can be reduced through adoption of mitigation measures; however, it is currently not possible to influence the occurrence of the earthquake itself.

The firms that have modeled the risks from natural disasters have attempted to develop estimates of terrorist risk, but they are the first to acknowledge that there is considerable uncertainty in their projections. Moreover, the models do not provide distributions of expected loss from terrorism, in the statistical sense, but rather estimate potential losses associated with specific scenarios. (Kunreuther, Michel-Kerjan and Porter, in press). Section E of this report discusses in more detail new developments in terrorism risk models and how they can be used to price the risk.

Shifting Attention to Unprotected Targets

Terrorists may respond to security measures by shifting their attention to more vulnerable targets. Keohane and Zeckhauser (2003) analyze the relationships between the actions of potential victims and the behavior of terrorists. Establishing publicly observable protective measures against a given mode of attack on a specific building should reduce the probability of an attack against it because the marginal benefit of the attack (i.e., the likelihood of success) as perceived by the terrorist group decreases. However, shielding that building makes an attack on an unprotected structure more likely[12].

Rather than investing in additional security measures, firms may prefer to move their locations 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. They also may change the nature of their attack if protective measures in place make its 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, Cauley, 1983). CIA director, George Tenet, suggested this behavior in his prophetic unclassified testimony of February 7, 2001, (prior to 9/11) when he said: "As we have increased security around government and military facilities, terrorists are seeking out "softer" targets that provide opportunities for mass casualties". (CIA, 2001). Khalid Sheikh Mohammed, the Al Qaeda chief of military operations, arrested in March 2003 has since explicitly admitted such a soft target strategy (Woo, 2004).

Information Sharing

The sharing of information on the terrorism risk is clearly different than the sharing of information regarding natural hazard risk. In the latter case, new scientific studies normally are common knowledge so that insurers, individuals or businesses at risk, as well as public sector agencies, all have access to these findings. With respect to terrorism, information on terrorist groups' activities, possible attacks or current threats is kept secret by government agencies for national security reasons.

One justification for government intervention in insurance markets relates to the asymmetry of information between buyers and sellers and the problems this may cause, such as

[12] One exception would be if terrorist groups attack trophy buildings to prove that they can inflict damage to well-protected structures.

adverse selection. In the case of terrorism, there is a very peculiar case of *symmetry of non-information* on the risk between those insured and insurers, where government is the most informed party.

Interdependent Security

Another type of negative externality that affects the decision to invest in protective measures relates to problems of *interdependent security*. Kunreuther and Heal (2003) and Heal and Kunreuther (2003) have addressed this issue by asking the following question: What economic incentives do residents, firms or governments have for undertaking protection if they know that others are not taking these measures and that their failure to do so could cause damage to them?

Investing in airline security illustrates the nature of the interdependency problem. Suppose Airline A is considering whether to institute a sophisticated and costly passenger security system knowing that some passengers who transfer from other airlines to their planes may not have gone through a similar screening procedure. The more airlines that do not invest in these measures, the less incentive Airline A has to incur this cost. The interdependent risks across firms may lead all of them to decide not to invest in protection.

The crash of Pan America's flight 103 over Lockerbie, Scotland in December 1988 that 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). Similarly, the collapse of the World Trade Center on September 11, 2001 could be attributed in part to the failure of security at Logan airport in Boston where terrorists were able to board planes that flew into the twin towers.

Internalizing these externalities can be particularly challenging for insurers. Their pricing may adequately reflect the risk of an insured party being contaminated by others

particularly if they are some distance away, as was the case in the airline example. We will return to this issue in discussing the need for public-private partnerships for terrorism insurance.

Government Influencing the Risk

Finally, there are also more fundamental differences between catastrophic natural hazards and mega-terrorism. International terrorism is a matter of national security as well as foreign policy. It is obvious that the government can influence the level of risk of future attacks through appropriate counter-terrorism policies and international cooperation.

Some decisions made by a government as part of their foreign policy can also affect the will of terrorist groups to attack this country or its interest abroad (Lapan and Sandler, 1988; Lee, 1988; Pillar, 2001). Governments can also devote part of their budget to the development of specific measures on national soil to protect the country. The creation of the new U.S. Department of Homeland Security in 2002 confirms the importance of this role in managing the terrorist risk.

Summary

Both terrorist activities and natural disasters have the potential to cause catastrophic losses, thereby posing limitations for the insurability of the risk. Terrorism has additional challenges due to the lack of current data on terrorist activities, the dynamic uncertainty due to the ability of these groups to purposefully adapt their strategy in reaction to new security measures and the existence of interdependencies that could reduce firms' incentives to adequately invest in security measures. Moreover, the risk of terrorist attacks is partly under the government's control. These features of terrorism make this risk very different than catastrophic risks associated with natural hazards.

D. COVERING MEGA-TERRORISM: THE NEED FOR PUBLIC-PRIVATE PARTNERSHIPS

These characteristics of terrorism, along with the difficulty insurers face in finding new capital for covering potential losses from future events, raise the question as to how the government and the insurance industry can work together in providing protection against terrorist risks. As this section discusses, the need for public-private partnerships was actually recognized in most countries in the aftermath of 9/11.

D1. PRIVATE MARKET RESPONSES TO 9/11

Given the challenges in estimating the likelihood of specific terrorist attacks and their consequences, a question that is being posed today is whether the private insurance market can offer coverage without some public sector involvement. As discussed above, if there are limited data on which to estimate the risk and there is the potential for catastrophic losses, then insurers will want to charge premiums reflecting their aversion to ambiguity and restrict coverage to reduce the possibility of insolvency. If, in addition there are negative externalities associated with the risk, then the private insurer will not be able to encourage risk-reducing measures through premium reductions, as it would be able to do without these interdependencies. The insurer knows that even if a firm undertakes security measures to reduce its own risk, other firms that have not been as prudent can still affect it, thus increasing the risk from what it would otherwise be. (Kunreuther and Heal, 2003).

This section examines the demand and supply for terrorism insurance after the terrorist attacks of 9/11. For obvious reasons, most available data and publications relate to the US insurance market[13]. We show that there was a very thin market for protection and explore why private sector solutions, such as a mutual pool and a sustained market for terrorist catastrophe bonds did not emerge.

We conclude that the failure of the insurance industry to satisfy the unsatisfied demand for coverage during the year following September 11th was the principal reason that the U.S. Federal government to pass new legislation requiring insurers to provide terrorism coverage.

[13] For a macroeconomic study of the economic consequences of the attacks of 9/11, see Lelain, Bonturi and Koen. (OECD, 2002).

Market Reactions to 9/11

The response by the insurance industry to the terrorist attacks could have been predicted by the literature on insurance firm behavior following catastrophic events.[14] In the short run, large losses from a specific disaster reduce surplus and hence capacity to provide coverage. Given the high transaction costs of raising outside capital to replenish surplus and the relatively high interest rates associated with these funds, firms reduce the amount of coverage they offer and increase the price of insurance for the particular risk that caused the losses.

Consider the impact that 9/11 had on the supply of terrorism coverage. Insurers were unable to obtain reinsurance for these events except at very high prices and felt that losses from another terrorist attack of comparable magnitude could do irreparable damage to the industry[15]. As a result, many insurers refused to offer coverage to their clients. The few that did provide insurance charged very high prices so only organizations that were required to have this coverage actually purchased it.

Unlike reinsurers, primary insurers must obtain approval from state regulatory agencies when implementing new coverage restrictions. In October 2001, the Insurance Services Office (ISO), on behalf of insurance companies, filed a request in every state for permission to exclude terrorism from all commercial insurance coverage. (U.S. General Accounting Office, 2002). In the US, as of February 2002, 45 states, the District of Columbia and Puerto Rico had approved the insurance industry's applications for terrorism exclusion language. The states that had not approved the new exclusion were California, Florida, Georgia, New York and Texas accounting for about 35 percent of the commercial insurance market (U.S. Congress, Joint Economic Committee, 2002).[16]

Potential Role for Mutual Insurance

One way the private market might have developed a larger market for terrorism insurance without governmental participation would have been to create mutual insurance, such as risk retention groups. A risk retention group (RRG) is an entity that provides liability

[14] See Winter (1988, 1991), Gron (1994); Doherty and Posey (1997), Cummins and Danzon (1997); Froot and O'Connell (1997, 1999).
[15] Maurice Greenberg, CEO of AIG made this point by saying "The industry is going to pay its loss in the World Trade Center events. What we're saying is that if terrorist events continue, this is an industry with finite capital", (Hamburger and Oster, 2001).
[16] There is no reliable information, however, on the share of the commercial property and casualty insurance market in the 5 states that did not approve the exclusion. (U.S. General Accounting Office, 2002).

insurance to its owner-members. Traditionally, it is created when insurance is not available or premiums are so high that few buyers feel they can afford coverage.

The airline industry considered forming such a mutual company when coverage for third party liability for terrorism and war risks was withdrawn within 10 days after 9/11. New policies offered by insurers limited their aggregate third party liability to $50 million, falling far short of the $3.5billion of aviation liability losses from 9/11 (Hartwig, 2002). For airlines, the question of adequate third party liability coverage became vital for the continuity of their activities. As a temporary measure, the federal government provided this protection for U.S. airlines, as did other governments worldwide. When first warned that government coverage was going to cease, the U.S. airlines created their own RRG, *Equitime* in June 2002.

However, this group never became operational.[17] A principal reason for the failure of this RRG has been the continued subsidized financial protection of airlines by the federal government, crowding out the emergence of private solutions at a competitive price. Indeed, a temporary FAA (Federal Aviation Administration) terrorism insurance program, which covers approximately 75 U.S. air carriers, had been in effect since September 2001 for a six-month period. It was then extended to the end of 2004 and more recently to December 31 2007 (U.S. House of Representatives, 2003).

Potential Role for Terrorism Catastrophe Bonds

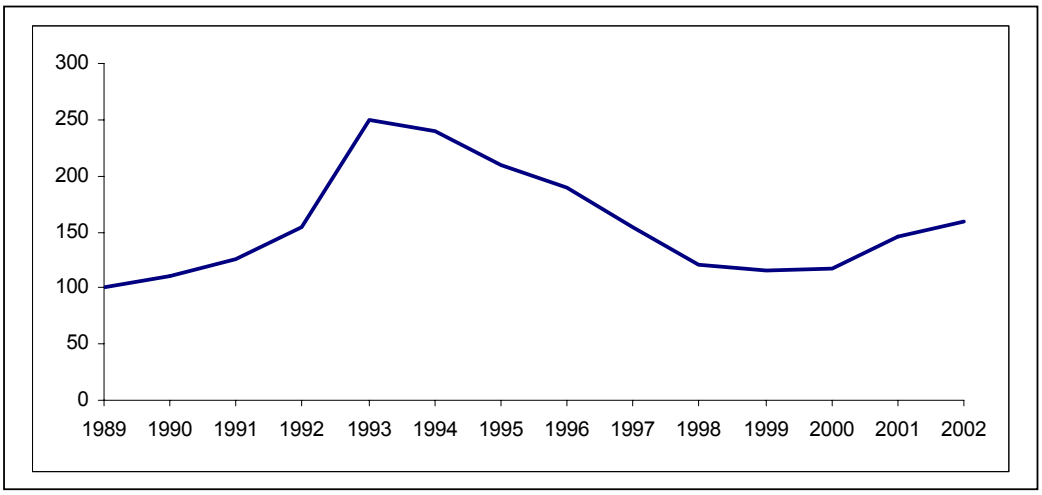
Since another report for the *OECD Task Force on Terrorism Insurance* will discuss the role of new financial instruments, we will not provide a detailed analysis of this new asset and the potential for using these instruments as a complement for insurance and reinsurance in the coming months or years.[18] Rather, we provide some explanation as so why no sustained market for terrorist cat bonds has emerged to date.

In the aftermath of Hurricane Andrew and the Northridge Earthquake in the early 1990s, property catastrophe reinsurance was in short supply and the price of reinsurance more than doubled in the U.S. compared with late 1980s, as illustrated by Figure 6. For insurers to provide their clients with the same amount of coverage they offered prior to these events they had to find capital from other sources. They collaborated with the investment banking community to develop new classes of financial instruments. Alternative risk transfers, such as

[17] European airlines planned also to create their own RGG, *Eurotime,* which never became operational either.
[18] The readers interested in these new developments as well as risk financing for catastrophic risks can turn to several other publications: Godard, Henry, Lagadec, and Michel-Kerjan (2002), Lane (2002), Grossi and Kunreuther (in press).

options and catastrophe bonds, emerged to cover these losses by transferring part of the risks to the capital markets. Though the market for risk-linked securities is still in its early stages, insurers and reinsurers have over $4.3 billion in catastrophe bonds outstanding at the end of 2003, an increase in more than 50% over 2002. The total amount of risk-linked securities since its inception is over $9.5 billion (Swiss Re 2004). However, this market is still considerably below the expectations of insurers, reinsurers and investment bankers accounting in 2002 for less than 3% of worldwide catastrophe reinsurance coverage. (U.S. General Accounting Office, 2003).

Figure 6.
Catastrophe Reinsurance Price Index, 1989-2002. (1989 = 100)



Sources: U.S. General Accounting Office (2003)

A market for catastrophe bonds to cover losses from terrorist attacks has ***not*** emerged since 9/11. To date, only two terrorism-related cat bonds have been issued. None of them is actually a pure terrorism cat bond issued for a specific type of attack only but multi-event cat bonds associated with the risk of natural disasters or pandemics.[19]

[19] The first bond was issued in Europe in August 2003. The world governing organization of association football (soccer), the FIFA, which organizes the 2006 World Cup in Germany, developed a $262 million bond to protect its investment. The bond is actually not a terrorist bond per se, but a multi-event bond. Under very specific conditions, the catastrophe bond covers against *both* natural and terrorist extreme events that would result in the cancellation of the World Cup game without the possibility of it being re-scheduled to 2007 (U.S. General Accounting Office, 2003). The second terrorist-related bond is a securitization of catastrophe mortality risk that has been undertaken in 2003 by Swiss Re, the world largest life reinsurer. Mortality is measured with respect to a mortality risk index, weighted according to Swiss Re's exposure in several countries. The trigger threshold for the mortality index is 30% higher than expected up to the end of 2006, based on 2002 mortality in these countries. This may represent 750,000 deaths. According to Woo (2004), the trigger threshold might be attainable before the end of 2006 only if pessimistic lethality estimates are made for both a pandemic *and* a terrorist attack using weapons of mass destruction killing several hundred thousand people.

Bantwal and Kunreuther (2000) specified a set of factors that might account for the relatively thin market in catastrophe bonds for natural hazard risks that may partially explain the lack of interest in terrorist catastrophe bonds. In their paper the authors conjecture that the reluctance of institutional investors to enter this market is due to a combination of ambiguity aversion, myopic loss aversion, and fixed costs of education on a new type of asset.

Four additional elements may explain the lack of interest in new financial instruments for covering the terrorist risk. Unlike investments in traditional high yield debt, money invested in a natural or terrorist catastrophe bond can disappear instantly and with no warning. Those marketing these new financial instruments may be concerned that if they suffer a large loss on the catastrophe bond, they will receive a lower annual bonus from their firm and have a harder time generating business in the future.

More specifically, investment managers may fear the repercussions on their reputation of losing money by investing in an unusual and newly developed asset or making money based on loss of human life. The short-term incentives facing investment managers differ from the long-term incentives facing their employers. If this is a major problem in marketing catastrophe bonds, then there is a need to develop strategies for bringing the principal (employer and its shareholders) and its agents (investment managers) into alignment.

Second, there may be a moral hazard problem associated with issuing such bonds if terrorist groups are connected with financial institutions having an interest in the U.S. For example, the recent aborted DARPA terrorism futures market experimented by the Pentagon, suffered from moral hazard: a terrorist group supported by specific investors might have an obvious financial interest to perpetrate and benefit from a terrorist attack against a public figure on whose life odds were placed. (Woo, 2004).

A third reason why there has been no market for terrorist catastrophe bonds was the reluctance of reinsurers to provide protection against this risk following the World Trade Center attacks of September 11th. Financial investors perceive reinsurers as experts in this market. Upon learning that the reinsurance industry required high premiums to provide protection against terrorism, investors were only willing to provide funds to cover losses from terrorism if they received a sufficiently high interest rate. (Kunreuther, 2002).

Finally most investors and rating agencies consider terrorism models recently developed (see Section E) as too new and untested to be used in conjunction with a catastrophe bond covering risks. The models are viewed as providing useful information on the potential severity of the attacks but not on their frequency. Without the acceptance of

these models by major rating agencies, the development of a large market for terrorist catastrophe bonds are unlikely (U.S. General Accounting Office, 2003).

D2. TERRORISM RISK COVERAGE: NEED FOR GOVERNMENT INTERVENTION

When the private insurance market fails there is normally a response from the public sector. Let's consider first two examples related to natural disasters, one in France and the other in the United States.

At the end of the 1970s, the French government asked insurers to study ways to create a private insurance market against earthquakes and floods. The French private insurers studied the possibility of insuring these risks without any governmental intervention and concluded that these events were uninsurable because of the uncertainty associated with these risks and their concerns of insolvency. Amid growing public pressure by the French public for some type of insurance following major floods in the Rhône, Saône and Garonne valleys at the end of 1981, France created a new and so far unique system the following year. The "Cat.Nat. System" is based on a public-private partnership, which covers all major natural hazards except storms, with unlimited state-guaranteed public reinsurance. The system has been operating for 22 years now. (Michel-Kerjan, 2001).

In the U.S., insurers were prepared to cancel windstorm coverage in hurricane-prone areas of Florida following Hurricane Andrew in 1992. The state legislature passed a law the next year that individual insurers could not cancel more than 10 percent of their homeowners' policies in any county in any one year and that they could not cancel more than 5 percent of their property owners' policies statewide. At the same time the Florida Hurricane Catastrophe Fund was created to relieve pressure on insurers should there be a catastrophic loss from a future disaster. (Lecomte and Gahagan, 1998).

In the same spirit, government protection against catastrophic losses associated with mega-terrorism is particularly important, as such events pose severe problems of liquidity and possible insolvency to insurers and reinsurers. Government has the capacity to provide this type of coverage, as it can diversify the risks over the entire population and spread past losses to future generations of taxpayers, a form of cross-time diversification that the private market cannot achieve because of the incompleteness of inter-generational private markets. (Gollier, 2001). Government participation in any insurance program to cover against terrorism is even more crucial since the risk of terrorist attacks is partly in the government's control, as discussed in Section C.

The need for government intervention was recognized in most countries as they develop national program to cover the risk associated with terrorism. Below we provide some features of programs operating in three European countries (U.K., France, and Germany) and United States as chronologically launched.

United Kingdom

In the wake of the two terrorist bomb explosions in the City of London in April 1992 and an announcement seven months later by British insurers that they would exclude terrorism coverage from their commercial policies, the UK established a mutual insurance organization (Pool Re) to accommodate claims following terrorist activities. Pool Re charges a separate, optional premium for terrorism coverage that can be calculated as a percentage of the total sum insured under a fire and accident policy and mainly depends on the location of the property. The four different rates established by Pool Re are based on the risks, with the highest rate in Central London and the second highest in the rest of the city. The Treasury backs Pool Re as the reinsurer of last resort

Until September 11, 2001 terrorism exclusions within insurance policies in the UK were limited to property policies. They were based on the Terrorism Act of 1993 and designed to deal with the IRA bombing campaign on mainland Britain. Fire and explosion were excluded by insurance companies, but were covered under Pool Re. The scale of the 9/11 attacks in the US led to the need for extending protection under Pool Re to "all risks" (including damage caused by chemical and biological as well as nuclear contamination). As of January 1, 2003 the Pool Re policy cover all these risks which has resulted in doubling of the pre September 11th 2001 premiums. Moreover, insurers are now free to set the premiums for underlying terrorism policies, thereby introducing competition into the terrorist insurance market[20].

Michel-Kerjan and Pedell (2004) provide a comparative analysis relative to each country's market of the current terrorism insurance programs developed after 9/11 in France, Germany and the U.S. Below we briefly discuss key features associated with risk sharing between the public and private sectors in each of these three programs. The Appendix of this report provides a comparison of the main features of these three public-private partnerships.

[20] There was also an intention to set the *maximum* insurance retention for the next four years, with individual insurers' retentions being based on market share. It is now set at £30 million (43 million euros) per event and £60 million (86 million euros) per annum for 2003; it will increase up to £100 million (144 million euros) per event and £200 million (288 million euros) per annum for 2006.

France

France suffered several terrorist attacks during the 1980's. A law enacted in September 1986 requires the French insurers to provide terrorism coverage up to the overall limits of a standard commercial property insurance policy. To avoid problems of adverse selection and low demand for insurance that may result in large uncovered losses, terrorism insurance is mandatory in France. After 9/11 French insurers were forced to renew terrorist coverage and retain most of the risk, as most reinsurers refused to cover acts of terrorism in their policies. Discussions between FFSA, GEMA[21] and the French government led to the creation of the first post 9/11 State-backed reinsurance pool for terrorism worldwide, the GAREAT (for Group of Insurance and Reinsurance against Terrorism, in French), on January 1, 2002[22]. A scale of premiums charged by the pool is established nationwide. Those premiums only depend on the sum insured[23] and not on the location at risk. All insurers must be members of the pool. (Godard et al., 2002).

As of 2004, the current partnership between the government and the insurance industry is a four-layer scheme. Private insurers retain the first portion of losses up to 400 million euros; the next layer is placed in the international insurance and reinsurance market up to 1.65 billion euros (a 1.25 billion euros trench). A third layer is comprised of reinsurance covering losses between 1.65 and 2.0 billion euros. Losses greater than 2.0 billion euros are

[21] The French Federation of Insurance Companies and the French Group of Mutual Insurance Firms, respectively; the two major representative institutions from the French insurance market.

[22] The reaction has been swift in this country for several reasons. First, the situation in France was really acute because the law did not allow commercial property insurers to dissociate terrorism coverage from commercial property. Indeed, the law of September 9, 1986 obliges insurers to provide terrorism coverage up to the overall limits of a property policy. As the law does not requires reinsurers to do that, most of them declined to cover acts of terrorism after 9/11. So French insurers that would not like to continue to cover against terrorism had not other choice than simply not offering any property policy at the 2001 renewals. Many businesses considered as potential targets for terrorist attacks would have been left not only without coverage against terrorism but also without commercial property damage and business interruption protection. Another factor accelerated those negotiations: the expectation of possible new terrorist attacks on the French soil. The explosion of the chemical factory AZF (owned by the oil company TOTAL) that occurred on September 21, 2001 in a high densely populated area as the city of Toulouse in the south of France contributed to increase these threats. While the event occurred only 10 days after 9/11, its origin was still not officially recognized 16 months after (a terrorist attack was still discussed by French media in January 2003). This chemical explosion constitutes one of the most important industrial catastrophes ever in Europe.

[23] For sums insured higher than €6 million and lower than €20 million, the insurer pays to the pool a premium equal to 6% of the commercial property and business insurance premium paid by the insured. The insurers continue to cover lower risks without the possibility for them to be reinsured by the pool. In particular, the insurance contracts of individuals are not modified. For sum insured higher than €20 million but lower than 50, the applied percentage is 12%. When sum insured is higher than €50 million, the insurer pays a premium equal to 18% of her basic insurance premium. The French decree dated December 31, 2002 allows insureds with sum insured higher than €20 million to limit their cover for acts of terrorism to 20% of the property damage guarantee. Finally, for "special risks" (nuclear, captives or property over 750 million euros, nuclear or captives) the rate is quoted individually (25 policies entered into this category in 2003).

covered by the government (unlimited guarantee for which the pool pays an annual premium), and managed by the Caisse Centrale de Réassurance, a public-owned reinsurer.

Germany

Discussions between the German federal government and the insurance industry led to the creation of a special insurer for terrorism risks, Extremus AG. The company has been operating since November 2002. Extremus, a corporation whose shareholders are essentially private insurers and reinsurers operating in Germany, directly insures terrorism risk through the participating companies. As in France, a premium scale is established nationwide that depends on the sum insured and not on the location at risk. Coverage by Extremus is non-compulsory and is only offered if the total insured value per policy is at least 25 million euros.

As of 2004, the annual reinsurance capacity is limited to 10 billion euros and is provided in three layers. The shareholders of Extremus provide the first layer of 1.5 billion euros. International reinsurers led by Berkshire Hathaway provide the second layer of €0.5 billion. The Federal Government of Germany would provide an additional capacity of 8 billion euros if needed. It is interesting to note that the second layer was reduced from €1.5 billion in 2003 to €0.5 billion at the beginning of 2004 in order to enable Extremus to cover its operating costs (Frankfurter Allgemeine Zeitung, 2004). The third layer was reduced from €10 billion to €8 billion at the beginning of 2004.

United States

No state or federal insurance legislation was enacted during the year following 9/11 in the United States. As a result many firms remained largely uncovered at the time of the first anniversary of the 9/11 attacks (Hale, 2002). The lack of available terrorist coverage at an affordable price delayed or prevented certain projects from going forward due to concerns by lenders or investors in providing financing for these efforts. These concerns led to the passage of the Terrorism Risk Insurance Act of 2002 (TRIA) on November 26, 2002.

While TRIA may have been welcome news for commercial enterprises,[24] it appears to have been a mixed blessing for insurers, as TRIA requires that insurers offer a policy covering against terrorism to all their clients who can decline the offer.

[24] According to a study by the U.S. Council of Insurance Agents and Brokers (CIAB), 85% of insurance brokers who responded, estimated that terrorism was more available in the market in June 2003 than it was in January 2003 (CIAB, July 2003).

Under TRIA's three-year term –the act expires on December 31, 2005–, insured commercial property and casualty losses from terrorism are covered only if the U.S. Treasury Secretary certifies the event as an "act of terrorism" carried out by foreign persons or interests[25] and only for losses above $5 million.

There is a specific risk-sharing arrangement between the federal government and insurers that operates in the following manner. First, each insurer is responsible for an annual deductible based on a percentage of its prior year direct earned premium. The percentage varies over the three-year operation of TRIA: 7% in 2003, 10% in 2004 and 15% in 2005. Once an insurer has met its backstop deductible, the federal government is responsible for paying 90% of the insurer's losses above that amount. The insurance industry's and federal government's share of losses is capped to a combined annual amount of $100 billion. Should this amount ever be reached, the Act contemplates that Congress will reconvene to determine a mechanism for further funding.

Second, the Act contemplates that Treasury may recoup the entire federal share of losses through a post-event policyholder surcharge administered by insurers. That surcharge is applied to all property and casualty insurance policies whether or not the insured has purchased terrorist coverage, with a maximum of 3% of the premium charged under that policy per year.

An important element of this program is that the federal government does not receive any premium for providing this coverage. Although the overall effect on the crowding-out of private solutions is not clear a priori, this limits the role of reinsurance companies to covering the deductible portion of the insurer's potential liability from a terrorist attack. With respect to catastrophic losses, there is no way reinsurers can compete with a zero cost federal terrorism reinsurance program.

Currently it is unclear what type of terrorism insurance program will emerge in the United States after 2005. One possibility is that TRIA will be renewed with the same or a new risk-sharing arrangement between the insurance industry and the federal government. However, if the program is terminated on December 31, 2005, alternative solutions will need to be found. The challenge is to develop an efficient program that will satisfy the different interested parties, each of whom has their own set of values and concerns. In addition to insurance coverage, there are ways of encourage investment in loss-reduction measures before an event so as to reduce the need for the public sector to provide financial aid following a disaster. (Kunreuther, Michel-Kerjan and Porter, 2003).

[25] An event like the Oklahoma City bombings would not be covered under TRIA.

D4. A LOW DEGREE OF MARKET PENETRATION

Empirical Evidence

As the U.S. TRIA and the German Extremus have been operating for only 15 months, it is too early to get a robust analysis on the market penetration of terrorism insurance in these countries, although the limited available data presents an interesting picture of the demand for terrorism coverage two years after the 9/11 attacks.

In the US, when Congress passed the Terrorist Risk Insurance Act (TRIA) in November 2002, the expectation was that it would ease insurers concerns about providing coverage and enable buyers at risk to purchase coverage at reasonable prices. Although insurance is now available nationwide, there have been few takers (Treaster, 2003). The Council of Insurance Agents and Brokers (CIAB)[26] undertook the first national survey on the level of demand for terrorist coverage (CIAB, March 2003). At that time, 48% of its members that handle the largest accounts (customers who pay more than $100,000 annually in commission and fees to the broker) indicated that less than 1 in 5 of their customers had purchased terrorism insurance.

The low demand was even more pronounced for smaller companies (less than $25,000 in commission and fees to the broker): 65% of the brokers indicated that less than 1 in 5 customers were purchasing insurance against terrorism. According to another national survey by the CIAB a few months later, 72% of the brokers indicated that their commercial customers are still not purchasing terrorism insurance coverage (CIAB, July 2003).

Even in locations like New York City, the level of demand remains low. During the autumn of 2003, the New York-based insurance brokerage firm Kaye Insurance Associates surveyed 100 of its clients at middle market real estate, retail and manufacturing in the New York area on a series of insurance-related issues, including terrorism insurance. Only 36% of the companies indicated that they had purchased terrorism insurance (Kaye, 2003).

In Germany, the demand for terrorism insurance is even lower than in the United States.[27] By the end of October 2003, there were only 1,100 contracts managed by Extremus with a total annual premium income of €105 Million, aggregate coverage insured of €650 billion and maximum annual compensation of €65 billion. In Germany there exist approximately 40,000 firms exposed to risks over €25 million. The 1,100 policies thus

[26] The council represents the top tier of the nation's insurance brokers who collectively write 80 percent of the commercial property/casualty premiums annually.
[27] The following data have been provided by members of Extremus, AG (personal communication).

represent only 2.75% of the market that would be eligible for terrorism coverage.[28] If one focuses on just the largest German companies, the level of demand is higher. According to a survey published in 2003, 40% of the DAX100 companies[29] and 13 of the 100 DAX30 companies had insurance contracts with Extremus. (Frankfurter Allgemeine Zeitung, 2003).

Risk Perception and Other Factors

Since most businesses have little or no information on terrorism risk and no new attack has occurred on U.S. soil since 9/11, US firms may perceive the chances of another event to be extremely low. A few years after 9/11, concern with damage from terrorism appears to have taken a back seat. In 2003, most firms believed that if a terrorist attack occurs, it would not affect them, whereas in the first few months after 9/11, they had the opposite belief. The aforementioned CIAB study indicated that more than 90% of the brokers said that their customers eschew terrorism insurance because they think they don't need it (CIAB, 2003b). The Kay survey also asked those who had not yet purchased terrorism coverage why they had not done so. The top reason was that the company was not a target (66%), followed by high cost (17%). (Kaye, 2003).

This behavior has been well documented for natural hazards where many individuals buy insurance after a disaster occurs and cancel their policies several years later if they have not suffered a loss. It is difficult to convince these individuals that the best return on an insurance policy is no return at all. In other words, there is a tendency for most people to view insurance as an investment rather than as a form of protection (Kunreuther, 2002). These firms consider insurance, even at relatively low premiums, to be a bad investment.

The expectation that government may financially aid affected businesses whether or not they are covered by insurance, as illustrated by the airline industry following 9/11, may also contribute to limiting interest in spending money on coverage. Finally, the definition of terrorism coverage can also be problematic. More specifically, the distinction between an *act of terrorism* that would be covered and an *act of war* that would be excluded is not always very clear.

[28] This estimate has to be dealt with carefully as the size of the contracts is not accounted for, but according to expert opinion of members of Extremus, it gives a fairly realistic picture and underlines the prevailing very low dimension of market penetration. Unfortunately, it is impossible to get more precise information for the time being.

[29] The DAX100 (DAX30) comprises the 100 (respectively 30) largest listed companies in terms of market capitalization of the free float.

In conclusion, if the low level of demand continues, a mega-terrorist attack will likely have a more devastating effect on business continuity and social activity today than after 9/11 because losses will not be diversified in the national and international insurance and reinsurance industry, but mainly incurred by those at risk unless the government intervenes again. This may be partially alleviated by introducing some degree of mandatory coverage, as currently is done in France. Such a program leads to a high degree of risk mutualization and hence lower prices of terrorism insurance in large cities. Whether terrorism coverage should be required in other countries by private institutions (e.g. banks as a condition of mortgage) or even by the government remains, however, an open question.

The U.S. Treasury Department is required by Congress to study the supply and demand for terrorism coverage as inputs to the process of determining whether TRIA should be renewed in 2005 may be made. Those studies, launched in December 2003, should contribute to a better understanding of the current level of demand for terrorism insurance.

Finally, it seems difficult –if not impossible– to measure the real degree of efficiency of each terrorism insurance program and to make a quantitative comparison between them. For instance, most Europeans programs have defined rates that depend on simple variables such as the level of sum insured, and do not result explicitly from quantification of risk exposure. Without the ability to estimate terrorist risks and potential damages associated with a wide range of scenarios of attacks, any economic evaluation of these programs remains impossible.

E. MODELING TERRORISM RISK[30]

This section presents some key features of the new models developed after 9/11 to quantify the risk associated with terrorism. Loss estimates generated by terrorism models are of interest to all parties. The insureds would like a better understanding of their exposure to potential terrorist attacks in order to determine whether to purchase coverage. Insurers and reinsurers can use model output to develop their pricing, reinsurance needs and fashion policy conditions such as deductibles, exclusions and coverage limits. They can also use the output of these models to determine their implication in a particular national program of terrorism risk coverage based on a public-private partnership. Governments can establish their program with rates reflecting at least partially the exposure of the insureds.

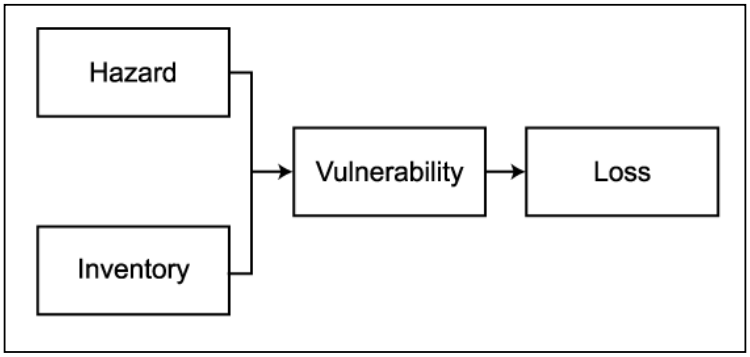
[30] This section builds on Kunreuther, Michel-Kerjan and Porter (2003; in press).

Insurance markets function best when losses are relatively small, random and uncorrelated, and when there is an abundance of historical loss data to which statistical techniques can be applied to predict future losses. As has been discussed throughout this report, when it comes to natural disasters or terrorism, losses can be of catastrophic proportion and are often highly correlated. Furthermore, because such natural disasters occur infrequently, loss data are relatively scarce, making reliance on traditional actuarial techniques dubious at best.

As limited as the data is for nature catastrophes, there is much less information available on terrorist attacks for risk estimation purposes. To the extent that data do exist and are available from government sources, they may not be representative of current threats. Even more important, unlike earthquakes and other natural disasters, whose occurrence has a physical basis that can be understood by scientists, terrorist attacks are a function of the malicious intent of groups of individuals of varying size and varying agendas. The groups themselves come and go and their ability to attract resources in terms of both financial and human capital waxes and wanes as the larger political and/or economic climate changes over time. As discussed in Section C, it is clear that the uncertainty surrounding the frequency, location and severity of future terrorist activity is much higher than for natural hazards, making the task of modeling much more complex. In the absence of historical data to which probability distributions can be fit, the models are by necessity more subjective in nature.

To explore the alternative approaches that modelers have used to overcome the challenges of quantifying terrorism risk, it is useful to begin with a simple modeling framework as illustrated by Figure 7.

Figure 7.
Terrorism Catastrophe model components



E1. TERRORISM HAZARD

A terrorism model must first address three basic issues regarding the hazard itself: frequency of occurrence, the most likely locations of future terrorist attacks, and their severity in terms of insured loss. In undertaking this analysis, the different potential targets plus the interdependencies among networks and systems must be taken into account. For example, the loss of electric power or contamination of the water supply could create long-term business interruption risks and require residents in the affected areas to relocate.

The management of international terrorism risks has traditionally relied upon the experience and judgment of a specialist underwriter. For certain individual risks, recourse might be made on the advice of security professionals. For a portfolio, maximum loss would be carefully capped, but the overall risk assessment procedure would remain essentially qualitative and subjective. The most basic terrorism risk model is thus one encoded within the working experience of an underwriter and dependent on his personal expert judgment. To cover rare catastrophic acts of terrorism, beyond the experience of even the most seasoned underwriter, the judgment of external terrorism experts might be invoked.

Terrorism risk management would still be firmly judgment-based, but the underwriter would be supported by the greater knowledge and perception of terrorism experts. Recognizing that experts' risk estimates are based on their own set of assumptions and may reflect a set of biases, the challenge is to evaluate these figures carefully in modeling terrorism risk. Terrorism models incorporate the judgment of teams of experts familiar both with limited available historical data and current trends. These experts have operational experience in counter-terrorism at the highest national and international levels, with many specializing in terrorism threat assessment. Because each expert is privy to his own sources of intelligence and has his own security clearances, there is no common database of information upon which all experts can form their judgments. In fact, much of the crucial information is confidential.

Determining Likelihood of Attacks

To elicit expert opinion on the likelihood of attacks several different approaches have been utilized. Some modeling firms employ the Delphi method while others convene a conference of experts to capture and statistically combine various opinions into a useful and cohesive form that can be used to generate probabilities. For complex problems not governed

by scientific laws, the judgment and intuition of experts in their field is not only an appropriate ingredient in any model, but a critical one.

The Delphi Method is a well-known and accepted approach developed by the RAND Corporation at the start of the Cold War. Among its first applications was the forecasting of inter-continental warfare and technological change. The Delphi method comprises a series of repeated interrogations, usually administered by questionnaire where the responses are anonymous. Direct interaction between the participants is precluded to eliminate the natural bias to follow the leader. After an initial round of interrogation, individuals are encouraged to reconsider and, when appropriate, to change their views in light of the replies of others in the group that are shared with everyone (Adler and Ziglio, 1996). While the methodology is highly structured, the final estimates by each participant still only represent opinions, informed by other members of the group.

Experts are asked to weigh in on several aspects of event frequency and intensity: the number of attacks per year, the type of target, the attack mode or weapon type, and finally the specific target of each potential attack. Each of these issues depends in part on the nature of the terrorist organization originating the attack. Critical to the results is the team's operational understanding of the likely terrorist actions in the context of the current state of security countermeasures. Targets and attack methods that were once undefended may now be more vigorously protected by federal homeland security, state and local policy, and private security resources.

An alternative to the Delphi method is using a conference of experts where participants can exchange views. The agenda can be topics, such as the kind of weapons a specific terrorist group is more likely to use or what areas/countries are more susceptible to attack. When some experts are unable to attend the conference, their judgment can be elicited separately and fed back to others using the Delphi method.

The lack of historical data makes the use of experts the only way for modelers to determine the likelihood of new attacks. However, experts have their own limitations in forecasting future behavior, as each of them has specialized knowledge. Some are much more focused on a given terrorist group and disregard dangers from others. Others are specialized on a given type of weapon or on a very specific kind of biological or chemical agent. In other words, each expert can be accurate within his or her small window of expertise, but the whole group of experts can be wrong about the reality of the global threats -- a kind of illusory expertise (Linstone and Turoff, 1975).

Another pitfall is the possible optimism/pessimism bias of experts. For instance, if a terrorist attack recently occurred, a natural trend would be to overestimate the likelihood of new attacks in the short run. Conversely, if a governmental agency arrested leaders of a terrorist group, a natural bias could be to concentrate only on that group and overlook other terrorists, resulting in misconceptions of the likelihood of other attacks.

Identifying Likely Targets and Attack Modes

Target types vary depending on the nature and goals of the individual terrorist groups or organizations. For example, the targets that the Animal Liberation Front is likely to find attractive will differ from those chosen by Al Qaeda, not only because of differences in the resources at this group's disposal, but because of its different political agenda.

Once the target types are identified, databases of individual potential targets are developed. In the case of terrorism, targets within the U.S. might include high profile skyscrapers, government buildings, airports, chemical plants, nuclear power plants, dams, major tunnels and bridges, large sports stadiums, major corporate headquarters and marine terminals. Trophy targets normally represent a higher value to the terrorists due to the publicity associated with them, and they therefore have a higher probability of attack, other things being equal. Target databases can comprise tens of thousands or even hundreds of thousands of structures. (White House, 2003).

In the simulations developed by modelers, the terrorist group receives value or utility from the damage inflicted on its adversaries. The expected loss is determined by the probability of success in carrying out the attack and the economic and psychological value of the target. In turn, the probability of success is determined not only by the amount of resources the terrorist group allocates to the attack but also by the resources its opponent allocates to detecting terrorist activity and defending the target. Both parties are constrained by the funds and person power at their disposal and the game becomes one of strategic decisions as to how to deploy those resources, i.e. which targets to attack and with what weapons, and which to defend. Therefore, game theory can be used to analyze likely targets and attack modes.

The severity of the attack is a function of the weapon type. Modeled weapon types include so-called conventional weapons, such as package, car and truck bombs, as well as aviation crash. In light of Al Qaeda's clearly expressed interest in acquiring and deploying weapons of mass destruction, models also account for the possibility of non-conventional

weapon attacks including chemical, biological, radiological and nuclear (CBRN). (Central Intelligence Agency, 2003).

E2. INVENTORY

The 9/11 attacks revealed that not only are the terrorist targets themselves at risk, but so are the surrounding buildings. Nevertheless, the effects of terrorist attacks with conventional weapons are likely to be highly localized compared to natural disasters such as hurricanes and earthquakes. The resulting damage depends on such things as the kind explosive material used, the amount of material, and the density and verticality of the surrounding buildings. For non-conventional weapons, the spatial extent of damage depends on the delivery mechanism and on external factors such as wind speed and wind direction.

Terrorism models can estimate total losses as well as aggregate insured or insurable losses for individual buildings, insurance company portfolios and/or the entire insurance industry. While the large losses resulting from natural catastrophes have historically been to property, terrorist attacks can affect multiple insurance lines that include life, liability, workers' compensation, accident and health. They can also result in severe stress on the psyche of a nation under siege.

The databases that are utilized in natural catastrophe models are also relevant for terrorism models. Modelers have developed industry databases of employees by building occupancy and construction type at the ZIP code level. These can be supplemented with state payroll and benefit information, generally available to insurance companies, to create an inventory at risk. Since 9/11, modelers are emphasizing to insurers the importance of gathering detailed data on the buildings they insure and the employees who work in them. (Insurance Accounting, 2003).

E3. VULNERABILITY

Research on the impact of explosives on structures has been ongoing since the 1950s. The Department of Defense and the Department of State have examined blast loading in the course of developing anti-terrorism designs for U.S. embassies. In addition, research activity has surged since the bombing of the Alfred P. Murrah Federal Office Building in Oklahoma City (1995) and the U.S. military housing facilities in Dhahran, Saudi Arabia (1996). (Olatidoye et al., 1998).

Modelers have developed damage functions that incorporate historical data from actual events combined with the results of experimental and analytical studies of how different building types respond to such attacks. In the case of a terrorist attack using conventional and nuclear weapons, buildings sustain damage as a result of a variety of assaults on their structural integrity and their non-structural components. In the case of non-conventional weapons, the structure of the building is likely to be unaffected but the resulting contamination may render it unusable for long periods and result in extensive cleanup costs. In either case, the damage functions determine loss to building, contents and loss of use.

Conventional Weapons

In terrorism modeling, damage is a function of the attack type and building type. The type of attack, whether package, car or truck bomb, can be expressed as a TNT-equivalent. The size of this charge can be thought of as the intensity of the event. Damage to the target building results from the resulting shock wave, the subsequent pressure wave, and fire.

The target building may sustain total damage from the point of view of insured loss even if it remains standing. If the building collapses, however, it will increase the number of fatalities. Furthermore, different modes of collapse, such as an overturn versus a pancake collapse, will affect the degree of damage to surrounding buildings and thus the total area affected by the event. The buildings surrounding the target building are also likely to be damaged by the resulting shock and pressure waves and/or by falling or flying debris.

Non-conventional Weapons

The effects of nuclear weapons on both structures and populations have been subjects of extensive research for decades. (Glasstone and Dolan, 1977). Chemical, biological and radiological (CBR or "dirty bomb") attacks are more problematical. Accidental releases of chemical agents, such as the one that occurred at the Union Carbide chemical plant in Bhopal, India (1984) have been analyzed, as has the 1986 accident at the Chernobyl nuclear power plant. Other events include the 1995 sarin attack in the Tokyo subway and the more recent distribution of weaponized anthrax through the mail in autumn 2001 in the U.S. (U.S. Department of State, 2003). These examples provide data for empirical analysis and research. Fortunately, those attacks have been extremely rare so there is limited historical data.

Some modelers have developed relationships between the use of non-conventional weapons and potential damage; others employ models developed for various government

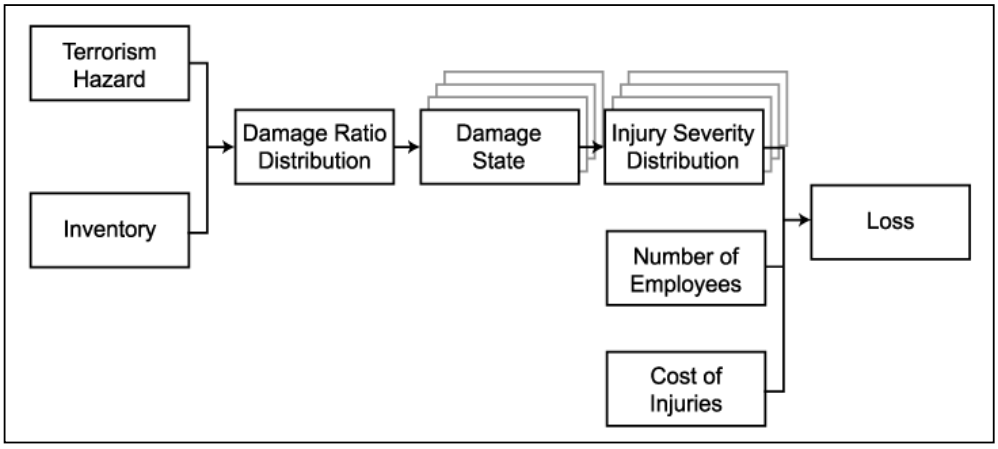
agencies that follow what is known as a source/transport/effects approach. The *source* refers to how a hazard agent originates, including the type, yield, effectiveness, and other properties of the agent. Various attack types are simulated, including chemical agents such as sarin, VX, tabun, biological agents such as anthrax and smallpox. Nuclear and radiological agents such as cesium, cobalt and plutonium are also simulated. (Central Intelligence Agency, 2003).

Transport refers to the means by which the agent disperses or moves from the source to the people, or facilities presumed to be the targets. A full range of mechanisms is considered ranging from mail-borne dispersal to wide area dissemination via aerosol spraying and conventional bomb blast. *Effects* refer to the physical, performance, and psychological impacts of the attack on humans as well as on the environment. While even a small suitcase nuclear device can cause extensive physical damage to buildings over a relatively large geographical area, the primary effects of other non-conventional weapons is contamination, which may render the structures unusable for long periods of time. In fact, in some cases, the most cost-effective way of dealing with badly contaminated buildings may be demolition under very cautious and well-defined procedures.

E4. WORKERS' COMPENSATION LOSS

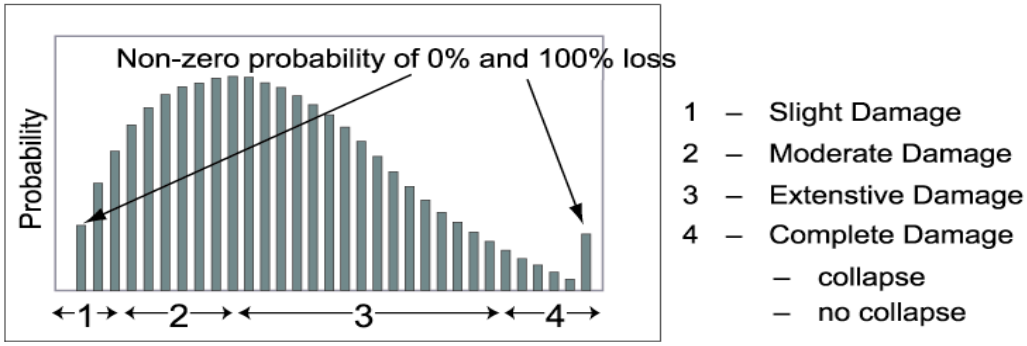
In addition to property damage, terrorism models estimate fatalities under both workers' compensation and life insurance policies, as well as losses from injuries arising from workers' compensation, personal accident and other casualty lines. The number of injuries and fatalities, as well as the severity of injuries, is a function of the nature of damage sustained by the structural and non-structural components of buildings and their contents. Figure 8 illustrates the process for computing workers' compensation loss.

Figure 8.
Modeling workers' compensation loss



In estimating workers' compensation loss, models account for variability in damage to individual buildings so that one can estimate the extent of injuries and fatalities. For each level of severity, a mean damage ratio is calculated along with a probability distribution of damage. Because different structural types will experience different degrees of damage, the damage functions vary according to construction materials and occupancy. A distribution of damage for each structure type is mapped to different damage states. These may be, for example, slight, moderate, extensive and complete, as shown in Figure 9 for a specific building.

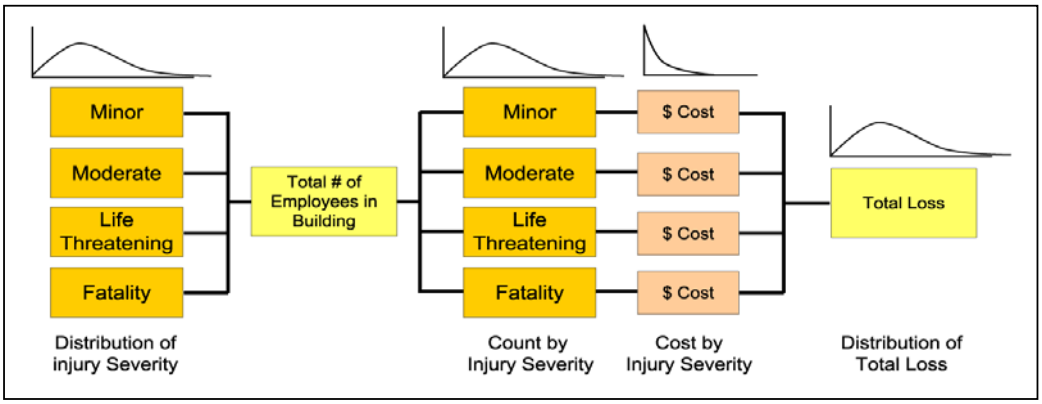
Figure 9.
Building damage distribution mapped to different damage states



At the level of complete damage, the building may or may not have collapsed. Complete damage means that the building is not recoverable. Collapse will typically result in more severe injuries and larger numbers of fatalities than if the building is still standing. Estimates of workers' compensation (and other casualty lines) loss are based not only upon the number of people injured, but also on the severity of the injuries, such as minor, moderate, life threatening and fatality. Distributions of injury severity are then developed for each damage state for each building and occupancy type.

By combining information on the number of employees in each damaged building and the cost of injuries, the model generates the total loss distribution for a particular structure. Losses are calculated based on the number of employees in each injury severity level and on the cost of the injury as shown in Figure 10. To calculate losses arising from life insurance and personal accident claims, potential losses are calculated for both residential and commercial buildings using assumptions about the distribution of the population between these two types of structures at the time of the attack.

Figure 10.
Calculation of workers' compensation loss for an individual building



E5. National Programs of Risk Coverage: the Use of Terrorism Models

Since these terrorism models have been applied to thousands of potential targets, they can provide a picture of the relative risk by state, city, zip code and even by individual location. The Insurance Services Office (ISO) used the estimates provided by one of its subsidiaries, Applied Insurance Research, to file advisory loss costs with the insurance commissioner for each state at the beginning of 2002.[31] ISO defined three tiers for the country, listing Washington, DC, New York, Chicago and San Francisco in the highest tier with recommended loss costs in those cities of $0.10 per $100 of property value. A second tier consisted of Boston, Houston, Los Angeles, Philadelphia and Seattle; the rest of the country fell into the third tier. ISO's recommendations were not, however, well received by cities in the first tier who felt they were being treated unfairly. There were complaints that such premiums would lead businesses to relocate to other areas (Hsu, 2003). Negotiations ensued and compromises were made. ISO filed revised loss costs for first-tier cities based on zip code level model results, which differentiated between the higher risk of downtown city centers and the lower risk of properties on the outskirts. But nowhere did the new loss costs exceed $0.03 per $100 of property value.[32] Thus, while the new official advisory loss costs no longer adequately reflected the risk in the eyes of the modelers, they became more palatable to other stakeholders. The Departments of Insurance in all 50 states eventually approved these ISO advisory loss costs that covered the years 2003, 2004, and 2005.

[31] A "loss cost" is defined by ISO as the long-term average annual expected loss (as generated by the Applied Insurance Research model) per $100 of insured property value. It is used to set insurance rates, or premiums, after the addition of an expense-loading factor to cover administrative fees and a profit margin. Once an ISO advisory loss cost has been approved by a state, any insurance company can adopt it without having to undertake its own often lengthy and expensive rate filing process.
[32] The second tier settled at $0.018 and the third tier at $0.001 per $100 of property value

F. CONCLUSION AND OPEN QUESTIONS

This report focuses on the question as to how to provide adequate financial protection through insurance to firms who may be victims of terrorism. It discusses the question as to whether (mega)-terrorism can be covered by private insurance alone. We argue that the specific characteristics of terrorism make the risk difficult to quantify and hence not insurable by the private sector alone.

The development of terrorism models assists in the risk assessment process but it is difficult to estimate the likelihood of future terrorist attacks given our current state of knowledge. Although none of the terrorist models currently provides well-specified distributions of expected loss in the statistical sense, they can be helpful in enabling insurers to understand the degree of their exposure under specific attack scenarios.

Our report concludes that it is necessary for the government to participate in any terrorism insurance program to cover extreme losses that could result from large-scale attacks. This need has already been recognized in most industrialized countries and has led to the creation of risk-sharing partnerships between the public and private sectors. However, in countries such as Germany and the United States where purchase is voluntary, the demand for terrorism coverage is currently quite low. A large-scale attack could be debilitating if the market for insurance protection in these countries continues to be thin.

There are no easy answers as to what type of public-private partnerships should evolve in the future but there are lots of questions that can be posed in this regard such as:

- Should terrorism coverage be mandatory?
- What role can the private sector institutions play in encouraging firms to purchase coverage? Will financial institutions require terrorism insurance as a condition for a mortgage as they have done with other types of coverage?
- What role should the government play with respect to requiring terrorism insurance?
- How does one deal with issues of interdependency and the challenges of linking risk mitigation measures with insurance?

The answer to these questions will vary across countries and will be partially be determined by addressing the question as to who should pay for terrorism prevention and coverage of victims of attack.

We also need to recognize that insurance needs to be incorporated as part of a risk management strategy that requires a wide range of policy tools ranging from information provision to regulations and standards. These policies need to be informed by risk assessments and an understanding of risk perception in order to implement a strategy for dealing with terrorism that is likely to be politically viable and cost-effective.

Finally, as terrorist groups are much more likely today to try and inflict casualties on the population, there are sets of related questions that need to be analyzed, although they go beyond this report. For example, what financial protection is currently provided to individuals who may be victims of attacks in OECD member countries? How could these programs be improved in the future?

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Appendix A.

TERRORISM RISK COVERAGE AFTER 9/11: COMPARISON OF THE PUBLIC-PRIVATE PARTNERSHIPS IN FRANCE, GERMANY AND THE UNITED STATES

(Sources: *Michel-Kerjan and Pedell, 2004*)

	GAREAT (France)	Extremus (Germany)	TRIA (US)
Basic structure of the partnership for annual aggregate losses	Co-reinsurance pool with unlimited state guarantee for losses higher than €1.75 billion	Insurance pool with federal reinsurance of last resort for losses higher than €2 (3) and less than €10 (13) billion in 2004 (respectively in 2002, 2003)	Risk-sharing arrangement between the federal government and insurers, up to $100 billion
Temporary governmental involvement	Yes. Agreement with the government limited to end of 2003 ; renewed to the end of 2006.	Yes. Agreement with the federal government limited to end of 2005	Yes. Agreement with the federal government limited to end of 2005
Gratuity of governmental coverage	No. Government receives premiums for its unlimited guarantee	No. Government receives premiums for its guarantee	Yes
Compulsory insurance	Yes	No	Insurers are required to offer terrorist coverage Clients can turn down the coverage; compulsory for worker compensation
Minimum sum insured	€6 million	€25 million	No minimum sum insured, but a minimum of $5 million insured losses
Limited exposure of the private sector	€1.5 billion (2002) €1.75 billion (2003) €2 billion (2004)	€3 billion in 2003 €2 billion in 2004 (end of 2002-2005)	Market retention as defined by TRIA $10 billion (2003) $12.5 billion (2004) $15 billion (2005)
National Rate Scale	Yes	Yes	No (only advisory loss cost scale by ISO)
Insurance price depends on risk location	No	No	Yes
Risk segmentation by sum insured	Yes	Yes	No

CONTACT INFORMATION

Dr. Howard Kunreuther
The Wharton School
Risk Management and Decision Processes Center
Jon M. Huntsman Hall, Suite 500
3730 Walnut Street
Philadelphia, PA 19104-6340, USA
Phone: 215 898-4589
Fax: 215 573-2130
E-Mail: Kunreuther@Wharton.upenn.edu

Dr. Erwann Michel-Kerjan
The Wharton School
Risk Management and Decision Processes Center
Jon M. Huntsman Hall, Suite 500
3730 Walnut Street
Philadelphia, PA 19104-6340, USA
Phone: 215 573-0515
Fax: 215 573-2130
E-Mail: Erwannmk@Wharton.upenn.edu