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EVALUATING THE EFFECTIVENESS OF TERRORISM RISK FINANCING SOLUTIONS

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ABSTRACT

The 9/11 attacks in the United States, as well as other attacks in different parts of the world, raise important questions related to the economic impact of terrorism. What are the most effective ways for a country to recover from these economic losses? Who should pay for the costs of future large-scale attacks?

To address these two questions, we propose five principles to evaluate alternative programs. We first discuss how a federal insurance program with mandatory coverage and a laissez faire free-market approach for providing private insurance will fare relative to these principles. We conclude that neither solution is likely to be feasible here in the United States given the millions of firms at risk and the current structure of insurance regulation.

We then evaluate how well the U.S. Terrorism Risk Insurance Act (TRIA), a public-private program to cover commercial enterprises against foreign terrorism on U.S. soil, meets the five principles. In particular, we show that TRIA has had a positive effect on availability of terrorism coverage and also has significantly contributed to reducing insurance premiums.

TRIA is scheduled to terminate at the end of the year, but pending legislation would extend the program for fifteen years after December 31 (HR. 2761). In this paper, we show that such a long-term extension might have important impacts on the market. This could increase the take-up rate, as prices might be even lower than they are today. We show also, however, that if TRIA were extended for a long period of time in its current form, some insurers could "game" the program by collecting ex ante a large amount of premiums for terrorism insurance, while being financially responsible for only a small portion of the claims ex post. The general taxpayer and the general commercial policyholder (whether or not covered against terrorism) would absorb the residual insured losses. This raises major equity issues inherent in the design of the program.

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1. Introduction

The nature of international terrorism has radically changed over the past 20 years and is now well accepted with a large portion of extremist religious and other groups seeking to inflict fear, mass-casualties and maximum disruption to western nations' social and economic continuity and operating internationally (Enders and Sandler, 2006). Quite surprisingly, however, even after the terrorist attack on the World Trade Center in 1993 and the Oklahoma City bombing in 1995, terrorism was still included as an unnamed peril in most commercial policies in the United States. Insurers did not view either international or domestic terrorism as a risk that should be explicitly considered when pricing their commercial insurance policies, principally because losses from terrorism had historically been small and, to a large degree, uncorrelated.

The terrorist attacks of September 11, 2001, killed over 3,000 people from over 90 countries and inflicted insured losses currently estimated at $37 billion (in 2007 prices) that was shared by nearly 150 insurers and reinsurers worldwide. Reinsurers (most of them European) were financially responsible for about two-thirds of these losses. These reinsurance payments came in the wake of outlays triggered by a series of catastrophic natural disasters over the past decade and portfolio losses due to stock market declines. With their capital base severely hit, most reinsurers decided to reduce their terrorism coverage drastically or even stop covering this risk.

Hence, in the immediate aftermath of September 11, 2001, insurers operating in the U.S. found themselves with significant amounts of terrorism exposure in their existing portfolio with limited possibilities of obtaining reinsurance to reduce the losses from a future attack. Most of them decided to stop covering terrorism. By early 2002, 45 states permitted insurance companies to exclude terrorism from their policies, except for workers' compensation insurance policies that cover occupational injuries without regard to the peril that caused the injury (U.S. Congress Joint Economic Committee, 2002). Due to the difficulty in purchasing terrorism insurance, some private sector groups called for federal intervention. Most notably, the construction and real estate industries claimed that the lack of available terrorism coverage delayed or prevented projects from going forward because of concerns by lenders or investors (U.S. GAO, 2002).

Political pressure from these groups led Congress to pass the Terrorism Risk Insurance Act of 2002 (TRIA) (U.S. Congress, 2002), a $100 billion risk-sharing arrangement between the insurance industry, all commercial policyholders and the federal government.[1] One specific feature of TRIA is that the law required insurers to offer coverage to all their clients, who could then accept or refuse to purchase it. TRIA was originally designed as a 3-year program but was extended for two additional years at the end of 2005. Congress is currently discussing a fifteen-year extension of the Act in a form similar to TRIA (HR. 2761)[2].

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[1] The complete version of the Act can be downloaded at: http://www.treas.gov/offices/domestic-finance/financial-institution/terrorism-insurance/claims_process/program.shtml

[2] A recent Congressional Budget Office (CBO) report provides a series of cost estimates for expected federal expenditures under this proposed bill (CBO, 2007-b)

As illustrated by the events of March 11, 2004 in Madrid, and the July 7, 2005 attacks in London and the bomb threats in the United Kingdom at the end of June 2007, the terrorism risk is likely to remain with us for the indefinite future. While a lot of attention, energy and money have been devoted to prevent another attack on U.S. soil, important other questions have to be considered relating to the economic impact of future successful large-scale attacks. What are the roles and responsibilities of the private and public sectors in providing potential victims (people and firms) with adequate coverage against acts of terrorism?[3] What is the best way to assure the economic continuity of a country in the wake of large-scale terrorist attacks? Who will pay for the economic losses associated with future attacks?

This paper discusses the challenges in defining an economically effective, equitable, and sustainable solution to address terrorism risk financing when there is dynamic uncertainty associated with the threat and the potential for devastating losses. Proposed solutions can range from *no insurance* with state and federal funding to victims *ex post*, to an *unfettered insurance market* where prices and risk sharing are determined *ex ante* by the laws of supply and demand. In practice, there are limitations to solutions where either the public or private sector provides coverage alone. In fact, none of the terrorism insurance programs developed or modified after 9/11 in OECD countries has adopted either of these one-sided solutions, nor do they follow the same risk-sharing arrangement, due to differences in the perceived nature of the threat and different cultural and institutional arrangements. (OECD, 2005; Michel-Kerjan and Pedell, 2005 and 2006).

The paper is organized as follows: **Section 2** proposes a set of principles by which to evaluate different national risk-sharing solutions. **Section 3** indicates special features of the terrorism risk that must be considered in applying these principles. **Section 4** examines two proposals for sharing the risks of terrorism at opposite ends of the spectrum: a federal insurance program with mandatory coverage similar to the one currently in place in the U.S. for providing commercial airlines with terrorism third party liability insurance, and a *laissez faire* approach allowing private insurance market to operate without any federal intervention. We also provide a rationale as to why neither of these solutions has emerged in the United States to cover commercial enterprises against terrorism risks. **Section 5** details the loss-sharing process between insurers, policyholders and taxpayers under the current terrorism insurance program, TRIA. **Section 6** evaluates how well TRIA is likely to fare using the above principles, including the potential effect of a long term extension of the program as proposed in pending legislation. The paper concludes with a summary of our key findings and suggestions for future needed research.

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[3] On that question see Sykes and Gron, 2002; Kunreuther and Michel-Kerjan, 2004; Smetters, 2004; Brown, Cummins, Lewis and Wei, 2004; Jaffee, 2005; Kunreuther and Michel-Kerjan, 2005; Jaffee and Russell, 2005; Cummins, 2005; Dixon and Reville, 2006; U.S. Congressional Budget Office, 2007-a.

2. Principles for Guiding Risk-Sharing Arrangements

We propose the following five principles for evaluating insurance and other risk transfer programs for providing financial protection against any specific risk:

Risk-based Premiums: Insurance and other risk transfer programs' premiums should reflect the risk. The premiums will then signal to individuals and firms the hazards they face and encourage them to engage in cost-effective mitigation measures to reduce their vulnerability to catastrophes.

Sufficient Demand for Coverage: The demand by individuals and firms for insurance coverage with risk-based premiums should be sufficiently high so that insurers can cover the fixed costs of introducing a program for providing coverage and spreading the risk broadly through their portfolios.

Minimize Likelihood of Insolvency: Insurers and reinsurers should determine how much coverage to offer, and what premium to charge against the risk, so that the chances of insolvency are below some predefined acceptable threshold level.

Equitability: Insurance and other risk transfer programs should be fair to insurers, reinsurers, policyholders, and the general taxpayer where there is government participation.

Minimize Gaming: There should be no economic incentive for some insurers or policyholders to take advantage of provisions in the insurance or risk transfer program by undertaking strategic behavior.

3. Special Features of Terrorism

These five principles can be used to design risk-sharing contracts for risks where there is considerable historical data and scientific information, such as automobile accidents, fire and life insurance, and even natural hazards. Estimating the risk of terrorism presents special challenges, however, which makes it difficult for private insurers to provide widespread coverage to commercial enterprises. The factors listed below increase the amount of capital that insurers must hold to provide terrorism risk insurance coverage, sometimes to a point where insurers will find it financially unattractive to provide coverage, unless they are required to do so.

Potential for Catastrophic Losses from Terrorism

After the 9/11 events, insurers are concerned that catastrophic losses from future terrorist attacks would have a severe negative impact on their surplus and possibly lead to insolvency. Empirical evidence provided by experts on terrorism threats supports their concerns. Results of simulations of conventional attacks using truck bombs presented in Appendix 2 demonstrate that a large attack against high-rise buildings could inflict losses of about $12-15 billion for a single building. A series of simultaneous attacks could then produce losses far exceeding those of September 11, 2001.

Unconventional attacks using nuclear, biological, chemical and radiological (NBCR) weapons have the potential of inflicting much larger insured losses, especially on workers' compensation and business interruption lines. The bombing of a chlorine tank in Washington, DC could kill and injure hundreds of thousands of people. Plausible scenarios elaborated by Risk Management Solutions, one of the three leading modeling firms examining catastrophe risks, indicate that large-scale anthrax attacks on New York City could cost between $30 and $90 billion in insured losses (Towers Perrin, 2004).

A recent RAND study examined the impact of NBCR attacks on the losses to insurers and other interested parties from different scenarios (Dixon et al., 2007). The report presents the results of simulations for six attack scenarios: two conventional ones (1- and 10-ton truck bombs) and four NBCR scenarios such as a 5-kiloton nuclear bomb and an attack using a radiological device in the same metropolitan area. The report concludes that a 5-kiloton nuclear bomb would inflict losses of $630 billion dollars to commercial property and workers' compensation. A 2006 GAO report, written for the Chairman of the House Committee on Financial Services, concludes that "Given the challenges faced by insurers in providing coverage for, and pricing NBCR risks, any purely market-driven expansion of coverage is highly unlikely in the foreseeable future." (US GAO, 2006).

The 9/11 events, as well as the anthrax attacks in the month thereafter, also demonstrated a new kind of vulnerability: the use of networks as "weapons of mass disruption" (Michel-Kerjan, 2003-a). Terrorists can use the capacity of a country's critical networks to have a large-scale impact on the nation. In any given network (e.g., transportation) — every aircraft, every piece of mail, every marine container — can become a potential weapon. The impact of a supply chain disruption on the retail industry could be financially catastrophic should the federal government order a major port to be shut down in the wake of potential or actual threats from contaminated containers. As a point of reference, a 10-kiloton nuclear bomb planted in a shipping container that explodes in the port of Long Beach, California, could inflict total direct costs estimated to exceed $1 trillion, not to mention the ripple effects on trade and global supply chains that could even produce a global recession (Meade and Molander, 2006).

Are these scenarios likely? According to experts in nuclear security and non-proliferation, they might very well be. A 2005 survey of 85 non-proliferation and national security experts led by Senator Richard Lugar put the likelihood of a nuclear attack somewhere in the world within the next ten years at 20 percent and the likelihood of a radiological attack at 40 percent (Lugar, 2005, p. 6). It should be noted, however, that the report does not focus on the likelihood of attacks on any specific country.

Catastrophic risks pose an additional challenge. Because losses can have severe financial impacts on insurers and reinsurers who provide coverage in a very competitive environment, some of them might decide not to cover a risk unless most of the others do so as well. Ibragimov, Jaffee and Walden (forthcoming) propose a model that explains why insurance providers, acting in a non-coordinated fashion, may choose not to offer insurance for catastrophic risks and not to participate in reinsurance markets, even though there is sufficient market capacity to reach full risk-sharing. In particular, they show that nondiversification traps may arise when risk distributions have fat left tails, implying a

relatively high probability of catastrophic losses[4]. There may be a need for some type of coordinative mechanism through a centralized agency (e.g. federal government or trade associations) to ensure that risk sharing takes place.

Interdependent Security

The vulnerability of one organization, critical economic sector and/or nation often depends not only on its own choice of security investments, but also on the actions of other agents. This concept of *interdependent security* implies that failures of a weak link in a connected system could have devastating impacts on all parts of it, and that as a result there may be suboptimal investment in the individual components (Kunreuther and Heal, 2003; Heal and Kunreuther, 2006). Unless there is a monopolistic insurer who then has the ability to internalize these externalities within its entire portfolio, the existence of such interdependencies poses another challenge in determining how much terrorism insurance to offer and what premium to charge.

Interdependencies do not require proximity. In the case of the 9/11 attacks, security failures at Boston's Logan airport led to crashes at the World Trade Center (WTC). The failure was embedded within the security protocols promulgated by the Federal Aviation Administration and not with the application of those protocols, i.e., checking for bombs in passengers' luggage, but not profiling. There was nothing that the Port Authority of New York and New Jersey and firms located in the WTC could have done on their own to prevent these aircrafts from crashing into the Twin Towers. Any protective efforts they might have undertaken would have been rendered useless by the absence of action at a distant site.

Except for very specific coverage (e.g., contingent business income), terrorism insurance normally does not cover losses unless the insured is the direct target of an attack. For example, following the terrorist attacks of 9/11 the Federal Aviation Administration (FAA) banned takeoffs of all civilian aircraft regardless of destination. In March 2004, the city of Chicago was denied insurance compensation for business interruption losses that resulted from the FAA's decision. The specific clause of the insurance contract for business interruption specified that it would cover only losses that were the "direct result of a peril not excluded," thus imposing a limitation that excludes interdependent effects due to the response to an attack (U.S. District Court, 2004).

Shifting Attention to Unprotected Targets

Terrorists may respond to security measures by shifting their attention to more vulnerable targets. Sandler (2003), Keohane and Zeckhauser (2003), Lakdawalla and Zanjani (2005), and Bier (2007) analyze the relationships between the actions of potential victims and the behavior of terrorists. Rather than investing in additional security measures, firms may prefer to move their operations from large cities to less populated

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[4] An insurance portfolio holding equal shares of two risks with fat-tailed distributions might actually be more exposed than if that portfolio contains only one of these two risks. Each catastrophe could be so large that it affects the insurer's or reinsurer's solvency. In this case, catastrophic risk management will differ from traditional portfolio optimization which generally benefits from diversification (Samuelson, 1967).

areas to reduce the likelihood of an attack[5]. Of course, terrorists may choose these less protected regions as targets if there is heightened security in the urban areas. Terrorists also may change the nature of their attacks if there are protective measures in place which would make the likelihood of success of the original option much lower than another course of action (e.g. switching from hijacking to bombing a plane). This *substitution effect* has to be considered when evaluating the effectiveness of specific policies aimed at curbing terrorism (Sandler, Tschirhart and Cauley, 1983). The likelihood and consequences of a terrorist attack are thus determined by a mix of strategies and counterstrategies developed by a range of stakeholders that change over time. This *dynamic uncertainty* makes the likelihood of future terrorist events extremely difficult to predict (Michel-Kerjan, 2003-b).

A factor associated with dynamic uncertainty is the *timing of an attack*. Given the eight years that separated the first World Trade Center bombing in 1993 and the large-scale terrorist attacks during the morning of September 11, 2001, one could conclude that terrorist groups plan their attacks far in advance and perpetrate them when the public's attention and concern with terrorism have receded. This implies that the probability of a very large attack is not necessarily lower than that of smaller ones. Indeed, if terrorists really want to inflict mass casualty and major economic disruption, as several terrorist groups have publicly announced (Central Intelligence Agency, 2003; 9/11 National Commission, 2004), the probability distribution of future attacks could be such that there is an important mass concentrated on the "no attack" and on the "large attack" states of the world, and very little in the middle. In other words, there is a high probability that nothing happens, but if an attack is successful, the losses are likely to be catastrophic.

Distribution of Information

The sharing of information on terrorism is clearly different than the sharing of information regarding other potentially catastrophic events. For example, there are large historical databases and scientific studies in the public domain for natural hazards: insurers, property owners, businesses and public sector agencies all have access to this information. Data on terrorist groups' activities and current threats are normally kept secret by federal agencies for national security purposes. For example, the public still has no idea who manufactured and disseminated anthrax in U.S. mailings during the fall of 2001. Without this information, it is difficult for modelers to make projections about the capability and opportunities of terrorists to undertake similar attacks or other disruptive actions in the future. In the context of terrorism, the distribution of information between insurees and insurers may be identical in that there is a *symmetry of non-information*. If there is any asymmetry of information, it is in favor of government agencies, which affects the optimal risk-sharing arrangements between public and private sectors (Michel-Kerjan and DeMarcellis, 2006).

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[5] Abadie and Dermisi (2007) show that central business districts can be greatly affected by changes in the perceived level of terrorism. Following the 9/11 attacks, there was a pronounced increase in vacancy rates in iconic buildings in Chicago such as the Sears Tower, the Aon Center and the Hancock Center.

Role of Capital Costs[6]

All these elements force insurers to hold a large amount of capital in order to cover potential catastrophic losses from terrorism. An insurer thus needs to charge high premiums relative to its loss expenses to earn a fair rate of return on equity and thereby maintain its credit rating. To illustrate, we construct a somewhat conservative hypothetical example that ignores taxes and regulatory constraints. Consider a portfolio that has $1,000 in expected losses, *E(L)*. Let *k* be the ratio of capital to expected losses for the insurer to maintain its credit rating. For this example *k=1*, a value utilized by many property liability insurers for their combined book of business. (Doherty 2000).

In addition to paying claims, the insurer is assumed to set aside capital for covering additional expenses (*X*) in the form of commissions to agents and brokers and underwriting and claims assessment expenses. For this example *X = $200*. Given the risk characteristics of the portfolio, investors require a return on equity (*ROE*) of 15 percent to compensate for risk. The insurer invests its funds in lower-risk vehicles that yield an expected return, *r*, of 5 percent. What premium *π* would the insurer have to charge its policyholders to cover them against terrorism and to secure a return of 15 percent for its investors? The formula is given by:

$$\pi = \frac{E(L) + X(1+r)}{(1+r) - k(ROE - r)}$$

which yields a value of *π* = $1274 for this hypothetical example.[7]

This calculation is sensitive to the value of *k*. For terrorism risk, the volatility of *E(L)* is high since it is extremely difficult to estimate the probability of a future attack. As a result, *k is* likely to be considerably greater than 1, thus significantly increasing the premium required to generate a fair return on equity. A related issue with respect to terrorism risk is that it can be expensive to underwrite since it requires extensive modeling. Many companies buy commercial models and/or use their own in-house modeling capability. Moreover, since there is a high likelihood that many insurers might experience severe losses at the same time, the demand for capital following a terrorist attack is likely to be quite high, increasing its cost. Insurers want to reflect this cost in the premiums they charge.

If we redo the above premium calculation with *X= $600* and *k= 5*, the required premium is now $2,964, more than twice the value of *π* computed above. There are other considerations that can increase the cost of capital even further, notably the impact of double taxation. Harrington and Niehaus (2001) have shown that tax costs alone can exceed the claim costs, which will lead to further increases in premiums.

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[6] This subsection is based on a recent report on disaster insurance (Wharton Risk Center, 2007). Neil Doherty provided the insights on capital costs on which this example is based. Froot (2007) develops a model of optimal pricing and allocation of risks that also addresses these issues. He applies the model to underwriting the risk and determining the optimal amount of surplus capital held by the firm.

[7] Specifically *π= [$1,000+ $200(1+.05)]/ [(1+.05) - 1 (.15-.05)]*

Government Influencing the Risk

Another factor that distinguishes terrorism from other risks is who can influence the likelihood of specific events and their consequences. International terrorism has always been viewed as a matter of national security as well as foreign policy. The government can reduce the probability of a successful attack and the resulting outcome through appropriate counter-terrorism policies and international cooperation as well as through adequate crisis management programs. But some decisions made by a government as part of its foreign policy can also affect the will of terrorist groups to attack this country or its interests abroad (Lapan and Sandler, 1988; Lee, 1988; Pillar, 2001). Government failure to adequately address a large-scale crisis, such as one that would emerge in the aftermath of a large terrorist attack, would have a direct impact on many individuals, commercial enterprises and their insurers. In that sense, the terrorism risk is a public-private good.

4. Applying the Principles to Federal and Private Terrorism Insurance

These special features of the terrorism risk have important implications for designing a risk-sharing arrangement that meets the five principles specified in Section 2. Here we examine how well two specific programs fare on these grounds. We start with the federal government establishing its own insurance program without any private insurer and reinsurer involvement. We then turn to the establishment of a private sector terrorism insurance market with no government intervention. We also discuss the pros and cons and feasibility of these arrangements.

Federal Insurance Program

A federal terrorism insurance program has, in fact, been established in the U.S. to cover third party liability facing airlines (i.e., harm to passengers and crew along with individuals or property on the ground). Seven days after the 9/11 attacks, commercial aviation insurance providers cancelled all third party liability insurance policies worldwide, which created a crisis, because according to international law, an aircraft cannot take off without such liability coverage. A few days later, insurers reinstated the insurance for passengers but imposed minimal coverage for losses to people and property on the ground. For example, the new typical policies offered to the airlines included a $50 million maximum limit for third parties compared to pre-9/11 caps in the $1.5 to $2 billion range.

In most countries, the government stepped in to fill the gap and installed a government program so the commercial aviation could continue to operate. In the United States, the Air Transportation and System Stabilization Act was passed by Congress on September 22, 2001 and extended the Federal Aviation Administration (FAA)'s ability to provide that type of insurance coverage to all U.S. commercial air carriers. This emergency measure was designated as temporary, but the program has been reauthorized several times since its inception and remains in effect today. As of October 1, 2006, policies under this program provide 75 airlines with insurance coverage for potential

losses ranging from $100 million to $4 billion each (White House, 2007). This program presents an ideal case for studying how a federal insurance meets our principles.

Risk-based Premiums Under this program, airlines pay a premium per flight to the Aviation Insurance Revolving Fund managed by the FAA, based on their performance activity (the number of emplacements and revenue passenger per mile or revenue ton miles for freight operation). In this sense, the premium reflects relative risk exposure: the more your aircraft flies in a given year, the higher your risk is and the more you pay for coverage.

But the premium levels charged against airlines remains extremely low by all accounts. In 2003 the FAA reported that its exposure under the program was $113 billion (U.S. GAO, 2003a). Using the Bureau of Transportation Statistics' reported flight operations data for 2003, and FAA projections of flight operations growth[8], it would take from 2001 to 2016 for the Aviation Insurance Revolving Fund to accumulate $1 billion in collected premiums assuming a constant interest rate of 7 percent on invested capital and air traffic operations growth of 3.5 percent if there were no claims during this 15 year period (Straus, 2005).

Sufficient Demand for Coverage All airlines are required to hold third party liability insurance, so they all participate in this subsidized program.

Minimize Likelihood of Insolvency Since insurers are not involved in this program and airlines' liability is limited to $100 million above the losses which will be paid by the government, this program addresses the insolvency issue. The capacity of the government to diversify losses by assessing taxpayers over time gives the public sector an advantage over any private insurer (Gollier, 2001). Furthermore the government does not need to hold excess capital to meet losses should they be catastrophic.

Equitability An important issue with any government program is that it imposes risk on stakeholders other than those it covers. Given the 15 years or so required for this program to build up $1 billion in reserves, the government is likely to finance a major loss from a terrorist attack in the near future with taxpayers' money.

Minimize Gaming Since all airlines are required to purchase this coverage at prices that are fixed, it is difficult to see how any airline could game the system.

Private Market Solution

The other option would be to let the market operate for terrorism risk without any government intervention.

Risk-based Premiums Insurers would decide whether to provide terrorism coverage and if so, what price to charge given their own evaluation of the risk. In that sense, a *laissez-faire* approach satisfies this principle.

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[8] 2003 Aviation Capacity Enhancement Plan, Federal Aviation Administration, http://www.faa.gov/ats/asc/03ACE.html.

Sufficient Demand for Coverage   Given their need to hold significant amounts of capital to cover the potential catastrophic losses from a terrorism attack, insurers would charge very high premiums for limited coverage as illustrated by the case of insuring Chicago's O'Hare Airport. Prior to 9/11 the airport had $750 million of terrorism insurance coverage at an annual premium of $125,000. After the terrorist attacks, insurers offered the airport only $150 million of coverage at an annual premium of $6.9 million (representing an increase in the premium over coverage ratio of over 275 percent!). The airport was forced to purchase this policy since it could not operate without coverage (Jaffee and Russell, 2003). Another example is the Golden Gate Park in San Francisco, which was simply unable to obtain terrorism coverage at any price (Smetters, 2004).

Furthermore, rating agencies' criteria for sound management would lead insurers to limit the concentration of their exposure. Insurers could attempt to transfer portions of their risk to reinsurers, but the amount of available coverage for the U.S. market in 2005 was only in the range of $6-8 billion, (Wharton Risk Center, 2005). Moreover, the cost of capital for reinsurers is also high because of their concern with a catastrophic loss.

In theory, insurers could also transfer part of their terrorism risk to the capital markets through new financial instruments that have been developed over the past decade (e.g., industry loss warranties, catastrophe bonds, or, more recently, sidecars). Since 9/11, however, only three terrorism-related catastrophe bonds have been issued and these were part of multi-event coverage for other risks such as natural disasters and pandemics (Kunreuther and Michel-Kerjan, 2005; U.S. Congressional Budget Office, 2005). Most investors and rating agencies consider terrorism models as too new and untested to be used in conjunction with a catastrophe bond covering terrorism 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 terrorism catastrophe bonds is unlikely (U.S. GAO, 2003b).

These features of terrorism suggest that there will be limited demand by firms for partial coverage, given the very high prices that would be charged by insurers for protecting firms against this risk. As memories of 9/11 fade, many firms are likely to conclude that such insurance is too costly and not necessary. The risk of future losses will be viewed as below their threshold level of concern, thus contributing to a low level of insurance coverage.

Minimize Likelihood of Insolvency   In his study on insurers' decision rules, Stone (1973) develops a model whereby firms maximize expected profits subject to satisfying a constraint related to the survival of the firm.[9] An insurer satisfies its survival constraint by choosing a portfolio of risks with an overall expected probability of total claims payments greater than some predetermined amount (L^*) that is less than some threshold probability, p_1. This threshold probability reflects the trade-off between the expected benefits of issuing another insurance policy and the costs to the firm of a catastrophic loss that reduces the insurer's surplus by L^* or more. The value of L^* is determined by an

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[9] 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.

insurer's concern with insolvency and/or a sufficiently large loss in surplus that will lead a rating agency to downgrade its credit rating. If insurers are free to charge whatever prices they think are appropriate and are not required to cover any specific risk, they are likely to use a survival constraint to determine their portfolio of policies for covering the terrorism risk.

Equitability   In a free market, only those who perceive themselves to be at risk pay for terrorism coverage. In this sense, a private insurance program appears to be equitable. But there are also issues related to *ex post* payments to disaster victims that need to be considered. As noted above, given the high prices charged by insurers to reflect to cost of capital necessary to cover that risk, only a small portion of the firms are likely to be insured. After the next terrorist attack, the government, using general taxpayers' revenue, is likely to compensate the uninsured victims for damage they sustained. This behavior would be viewed as inequitable if one feels that uninsured firms should bear their own costs following a disaster.

Minimize Gaming   If firms believe that the federal government will assist them following a terrorist attack, they may behave strategically by not purchasing insurance and expect to be rescued by federal relief. There is considerable empirical evidence from public sector actions following natural disasters that the government will respond with liberal relief to victims following a catastrophic loss (Kunreuther and Pauly, 2006).

Challenges in Implementing These Programs for Commercial Risks

Federal Terrorism Insurance   While a federal insurance program for third party liability facing airlines satisfies most of the principles, it illustrates the challenges of balancing effective and affordable coverage with equity issues. Moreover, the program cannot be easily extended from 75 airlines to the 31 million commercial enterprises in the United States. Such an enterprise is likely to strain the capacity of the government to assess the risk, market coverage and to deal with the claims process after the next mega attack. Any federal program without the collaboration of the insurance industry excludes the insurers' expertise as well as its financial and operational capacity to provide coverage nationwide.

Private Sector Approach   As pointed out in the Introduction, there was limited interest by private insurers in voluntarily providing terrorism coverage following 9/11. Reinsurers were reluctant to provide coverage and a market for terrorism coverage through insurance-linked securities did not emerge. We also noted that the federal government is likely to come to the rescue of uninsured victims after the next large-scale terrorist attack.

In our description of a free terrorism insurance market, we assumed that insurers were free to decide what risks to cover, and what price to charge. Such a *laissez faire* market for terrorism risk coverage would require a radical change in the current state regulatory system in place in the United States since many insurers are constrained in rates they can charge.[10] They are also required to include any losses from terrorism in

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[10] For instance, at the end of 2002, the Insurance Services Office (ISO) used the estimates provided by AIR Worldwide (one of its subsidiaries) to file advisory loss costs with the insurance commissioner for each state. ISO defined three tiers for the country, placing certain areas within Chicago, New York City,

workers' compensation policies (in every state except Texas) as well as losses from fire following a terrorist attack in approximately one third of all states. The specific features of the terrorism risk and the challenges associated with having either federal insurance or a free market solution led to a call for some type of collaboration between the private and public sectors[11]. In the United States, Congress passed the Terrorism Risk Insurance Act of 2002 (TRIA) to deal with this issue. When TRIA was renewed at the end of 2005, the Act maintained a similar risk-sharing arrangement for 2006-2007 with an increase in the share of the losses covered by the private sector.

The remainder of this paper evaluates TRIA over the period 2002-2007 using the five principles. As this paper is being completed, proposed legislation for extending TRIA is being considered by Congress. One new feature of the legislation that will be discussed in the next section is that TRIA would be extended for fifteen years, thus creating a situation where some insurers would have an economic incentive to game the system.

5. Terrorism Risk Sharing under TRIA

Eligibility for Coverage

Under the TRIA program, insurers are obligated to offer terrorism coverage to all their commercially insured clients. Firms are not required to purchase this insurance unless mandated by state law, as is the case for workers' compensation lines. The stated coverage limits and deductibles must be the same as for losses from other events covered by the firm's current policy. This implies that if there are restrictions on a standard commercial insurance policy, then terrorism coverage will also exclude losses from these events. Thus the risks related to a terrorist attack using nuclear, biological, chemical, or radiological weapons (NBCR) are covered under TRIA only if the primary policy includes such coverage.

Structure of the Partnership

Under TRIA there is a specific risk-sharing arrangement between the federal government and insurers for a certified event. Figure 1 depicts the public-private loss-sharing for an insurer when total insured losses are less than $100 billion. If the loss suffered by an insurance company i is less than its deductible (ID_i), the insurer does not receive any reimbursement from the federal government. This situation is illustrated by an insured loss of L_1 in Figure 1 where the insurer's payment is represented by the oblique lines. If the insured loss due to a certified terrorist attack is greater than its deductible, as depicted by L_2 in Figure 1, the federal government will initially reimburse the insurer for a portion α of the losses above its deductible. From 2002 to 2006, α was 90 percent and it was reduced to 85 percent in 2007. During the 2002 to 2006 period, the

San Francisco and Washington, DC, in the highest tier, with assigned loss costs of approximately $0.10 per $100 of property value. But ISO's advisory loss costs were challenged by some regulators who felt that such premiums would lead businesses to relocate to other areas. Negotiations ensued and compromises were made, and nowhere did the filed loss costs exceed $0.03 per $100 of property value in the first tier.

[11] See U.S. Congressional Budget Office (2007-a) for a discussion of alternative policy options to TRIA.

insurer was responsible for paying only 10 percent of the losses up front (this figure was increased to 15 percent in 2007). The federal payment is represented by horizontal lines in the figure. This federal backstop provision is equivalent to free up-front reinsurance above the deductible. As will be discussed later, the federal government will recoup part or all of this payment from all commercial policyholders.

The insurer's deductible is determined as a percentage of its total direct commercial property and casualty earned premiums of the preceding year for TRIA lines (that is, lines covered by the Act), and not just the premiums of clients that purchase terrorism coverage. This deductible has significantly increased over time: 7 percent in 2002 and 2003, 10 percent in 2004, 15 percent in 2005, 17.5 percent in 2006, and 20 percent in 2007. That means that if an attack occurs in 2007, insurers will be responsible for losses equal to 20 percent of the direct commercial property and casualty earned premiums in 2006. This deductible plays a very important role in determining loss sharing between insurers and the federal government, and can be very large for many insurers.[12]

Figure 1. Loss-Sharing under TRIA between an Insurer and the Federal Government. 2002-2007
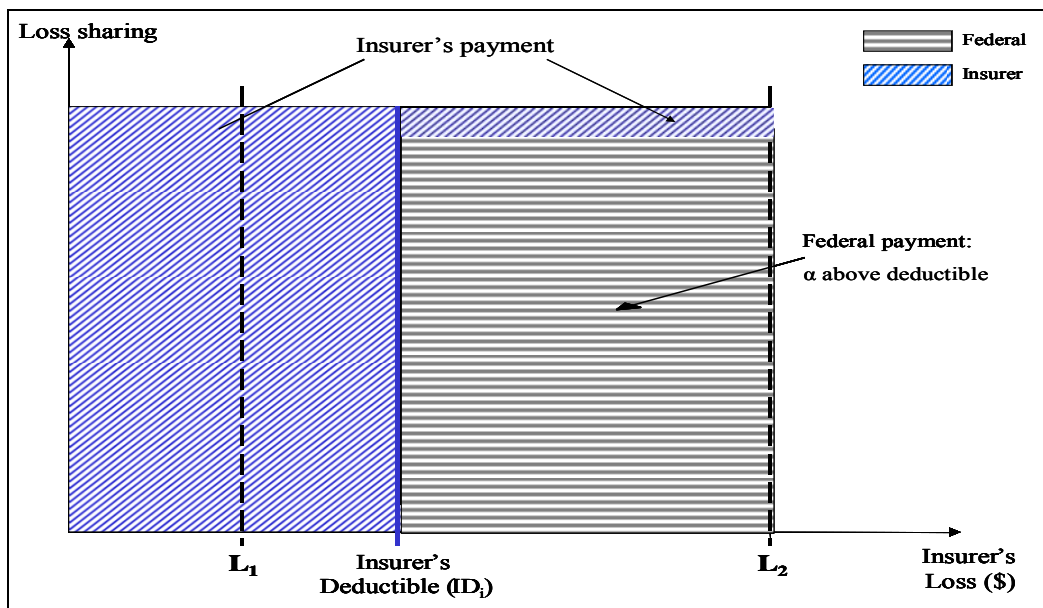
[Note: If the insurance company's *(i)* loss is less than its deductible (ID_i), the insurer is not reimbursed by the government (e.g., for an insured loss of L_1). If the loss is greater than the deductible (L_2), the government reimburses the insurer for α percent of the losses above its deductible, and the insurer pays (1- α)]

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[12] Using data provided by A.M. Best on their estimates of TRIA retentions for major publicly held insurance companies for 2005, we determined this deductible to be $3.6 billion for American International Group (AIG) and $2.5 billion for St. Paul Travelers. Four other companies on the list of top 10 insurers, based on TRIA-line direct-earned premiums had TRIA deductibles between $800 million and $2.1 billion in 2005.

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If the insurance industry suffers terrorism losses that require the government to cover a portion of companies' claims, then these outlays will be fully or partially recouped *ex post*. More specifically, the federal government will recoup the portion of its payment between the total insurers' outlays and an insurance industry aggregate retention amount; called the "mandatory recoupment." The industry aggregate retention, which is defined by law, has been increased over time to transfer more of terrorism risk to the private sector: it was $15 billion in 2005; $25 billion in 2006; $27.5 billion in 2007.

This mandatory recoupment[13] is obtained by levying a surcharge on all commercially insured policyholders, whether they had purchased terrorism insurance or not. If the insured losses exceed $100 billion during the year, then the U.S. Treasury will determine how the losses above this amount will be covered[14].

This federal recoupment surcharge "may not exceed, on an annual basis, the amount equal to 3 percent of the premium charged for property and casualty insurance coverage under the policy."[15] Insurers play the role of intermediaries by levying this surcharge against all their property and casualty policyholders[16], whether or not they had purchased terrorism insurance, and transfer the collected funds to the Department of Treasury. In other words, taxpayers would have paid insured losses between $15 and $100 billion if a large attack had occurred in 2005; they would pay insured losses between $27.5 and $100 billion if a large attack occurred in 2007.

The law indicates that the federal government could also recoup part of that payment (so-called "discretionary recoupment") but is not clear on the process; in this paper we assume that this does not exist.

Figure 2 depicts the repayment schedule, under TRIA, between the insurers, all commercial policyholders and the taxpayers after the federal government has reimbursed all insurers for 90 percent (85 percent in 2007) of their claims payments above their deductible level (for those suffering loss above their TRIA deductible).

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[13] The law is ambiguous as to what will happen if the total insurers' outlays are above this market aggregate retention.

[14] The TRIA legislation states that "If the aggregate insured losses exceed $100,000,000,000, (i) the Secretary shall not make any payment under this title for any portion of the amount of such losses that exceeds $100,000,000,000; and (ii) no insurer that has met its insurer deductible shall be liable for the payment of any portion of that amount that exceeds $100,000,000,000. Congress shall determine the procedures for and the source of any payments for such excess insured losses." §103(e)(2)(A). The 2005 extension of TRIA does not modify this.

[15] TRIA, Section 103(e)(8)(C).

[16] There is no statement in the legislation or its interpretation that specifically indicates that only the commercial policyholders are taxed. We have discussed this point with insurers and reinsurers. They have assumed that because TRIA applies only to commercial enterprises, the Department of Treasury will tax only commercial entities after a terrorist attack.

Figure 2. Loss Sharing under TRIA Between Insurance Industry, All Policyholders and Taxpayers. 2002-2007
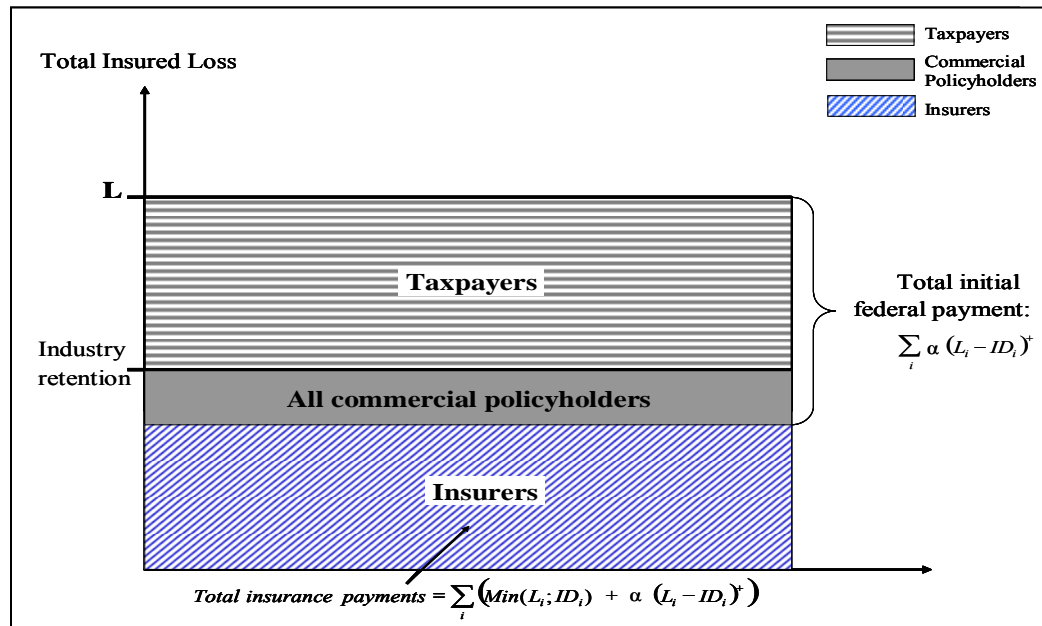
6. Applying the Five Principles to TRIA

We now examine how well the principles developed in Section 2 apply to TRIA by focusing on data we collected for the period 2002-2006. For two of the principles, *Equitability* and *Minimize Gaming,* we consider the impact of the proposed 2007 legislation on insurers' behavior and its possible consequences on the market.

Risk-based Premiums

It should be clear from the discussion in the previous sections, however, that there are limited data for estimating the likelihood of a terrorist attack and its resulting consequences, so it is difficult to know whether premiums are risk-based. Experts utilize a *scenario-based approach* to estimate direct consequences (e.g,. physical damage, lives lost) as well as indirect impacts (e.g., losses due to business interruption) from a range of terrorism-related events that vary by location and mode of attack[17]. However, few insurers consider the likelihood of these scenarios occurring in determining their exposure[18].

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[17] When asked, "Does your company consider scenarios in its catastrophe/exposure management process?" 92 percent of the insurers who responded to the Wharton questionnaire answered "Yes." One company responded to the above question by noting: *"Our company uses deterministic terrorist attack scenarios, and the associated Probable Maximum Loss (PML) estimates of these scenarios, to establish and manage exposure concentrations within major metropolitan areas and/or surrounding landmark properties."* (Wharton Risk Center, 2005).

[18] This is illustrated by the following responses by insurers to the question: "Do you take estimates of the likelihood of the various known scenarios into account when making underwriting decisions?": *"Not really. There is little historical data to predict future events;" "Likelihood is very unpredictable for terrorist acts." "Our company does not believe that estimates of the frequency of terrorist attacks are credible at a country, regional or specific property level."* (Wharton Risk Center, 2005).

TRIA's most important success was to significantly reduce and stabilize the price of terrorism insurance compared to premiums charged between 9/11 and the enactment of this legislation. Surveys undertaken on a regular basis since the inception of TRIA by Marsh and Aon, the two largest insurance brokers operating in the U.S., provide a good representation of the market for medium and large accounts. A recent Marsh survey of over 1,600 client firms in the U.S. that covers the past 11 quarters revealed that the cost of property terrorism insurance decreased significantly in 2005. The median terrorism price, which is calculated as the ratio of premium to total insured value (and is the figure used by most of the surveys of the U.S. market), fell from $57 per million dollars of total insured value in 2004 to $42 in 2005, a decline in the average cost of terrorism coverage by over 25 percent (Marsh, 2006). These rates increased in 2006 in most regions except for the Midwest where prices remained stable and were much lower than the three other regions, as shown in Figure 3.

Figure 3. Terrorism Pricing (Premiums per $ million of Total Insured Value)
Median Rates by Region
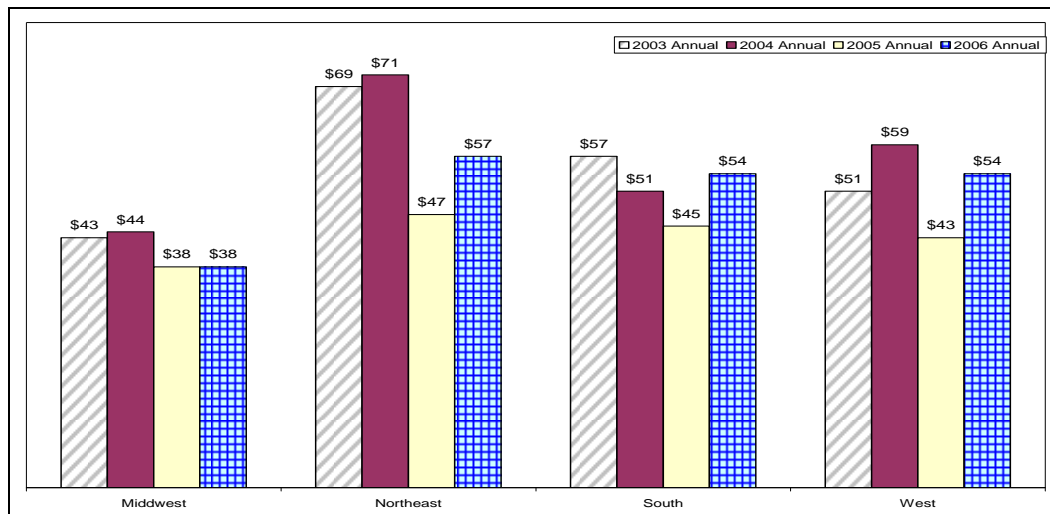
Source: Authors' calculations with data from Marsh.

International comparisons are also helpful, even though they should be taken with caution since programs and type of coverage differ from one country to another. Recent results are somewhat puzzling, though. For instance, Michel-Kerjan and Pedell (2007) analyze terrorism insurance costs for a total of 2,600 large companies in the U.S. and Germany that decided to purchase that coverage in 2006, and conclude that terrorism insurance prices (defined as premiums over quantity of insurance purchased) in Germany are on average 2 to 4 times *higher* than in the U.S.

Even though it may be difficult to achieve risk-based premiums for terrorism, state insurance regulators should not restrict rates unduly to the extent that insurers will *not* want to provide coverage. Currently, some states limit the premiums that insurers can charge for terrorism coverage. These restrictions may lead insurers **not** to offer property insurance to certain firms if they feel that such coverage will be unprofitable in the long-run.

Sufficient Demand for Coverage

The requirement under TRIA that insurers offer terrorism coverage, coupled with the relatively low premiums, has significantly contributed to increase take-up rate. Data provided by Marsh that we summarize in Figure 4 show a significant and fairly continuous increase of the take-up rate, from 23 percent in the second quarter of 2003 to 62 percent in the fourth quarter of 2006. These data suggest that most of the surveyed companies that wanted such coverage have now purchased it. The remaining companies are self-insured, except for terrorist losses that would be covered by workers' compensation or by fire due to terrorism.

Many of the large companies surveyed by Marsh may self-insure through the use of structured debt (e.g., warrants, convertible and forgivable debt) and contingent capital (i.e., financing that is contingent on the occurrence of specified events) (Doherty, 2000). Another reason why some firms might not consider insurance to be a good risk financing alternative in the case of terrorism is that the default risk might seem too high to make insurance a viable option to protect their assets[19].

Figure 4. Terrorism Insurance Take-up Rates in the U.S. 2003-2006 (weighted nationwide)
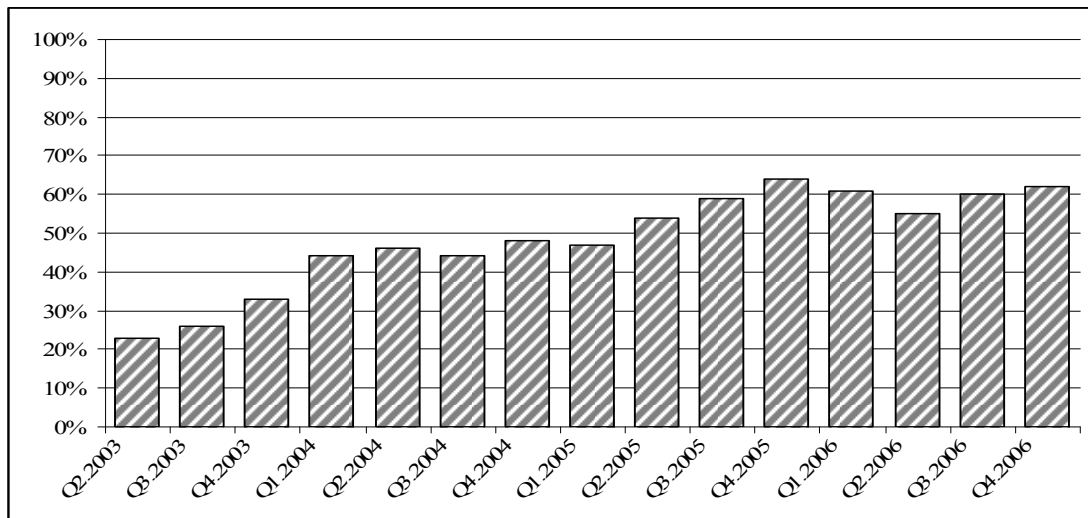
Source: Authors' calculation with data from Marsh (Based on a sample of 1,600 large companies).

Minimize Likelihood of Insolvency

Due to the uncertainty in the likelihood of terrorism losses, insurers use a survival constraint to determine the extent of coverage that they are willing to offer. The essence of the survival constraint is to write coverage so that an insurer's aggregate exposure (E)

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[19] The presence of default risk has received little attention in the theoretical literature on insurance even though that risk exists in many insurance situations. Doherty and Schlesinger (1990) and Mahul and Wright (2004) examine the effect of risk of default on rational insurance purchases. The first study concludes that because of default risk less-than-full insurance coverage optimal, even if the contract is sold at an actuarially fair price. The second study concludes that the optimal insurance contract under rational expectations is a disappearing deductible under full performance (no default) and coinsurance above a deductible under partial default. These results differ from Arrow (1971) which establishes that for a premium depending only on the policy's actuarial value, a risk-averse firm would prefer full (marginal) insurance coverage above a deductible, and that the optimal deductible is zero.

under an assumed scenario will not exceed a certain percentage of its policyholders' surplus (*S*). Although the insurers' exact terrorism exposure is not publicly available, we can assume that insurers with large deductibles (*D*) relative to their surplus (*S*) are the ones most at risk if they are providing terrorism coverage to most of their policyholders. Using a data set provided to us by A.M. Best for the top 470 insurers in the U.S. (ranked by the volume of TRIA-line insurance sold), we determined the evolution of the *D/S* ratio for our sample of 451 insurers for 2003-2005.

294 insurance companies providing terrorism insurance in the U.S. had a *D/S* ratio lower than 10 percent in 2003 compared with only 139 insurers in 2005. Only 36 insurers in the sample had a *D/S* ratio above 20 percent in 2003, while there were 80 such insurers in 2004 and 162 in 2005 (including 8 of the 30 largest insurers) as depicted in Figure 5. Rating agencies are likely to view such high ratios with some concern.

Figure 5. 451 Largest Insurers' Exposure to Terrorism under TRIA (2003-2005): Change in Their *D/S* Ratios.
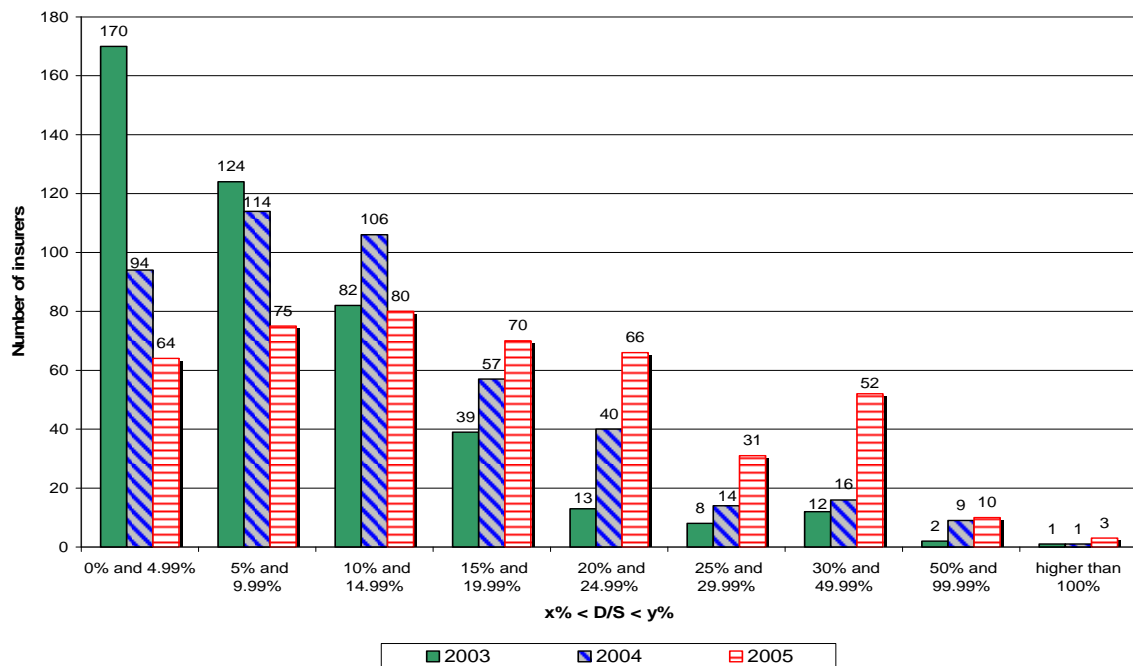
[Note: The analysis is conducted for the Top 451 insurers in the U.S. Each year, we plot the number of insurers whose D/S ratio lies between different percentage ranges in increments of 5 percent (e.g., [0% and 4.99%]; [5% and 9.99%], etc.).]

We also computed the *D/S* ratios for 2006 and 2007 for the top 30 insurers using extrapolated figures from 2003-2005. Figure 6 depicts the number of insurers (y-axis) whose *D/S* exceeds pre-specified values of *x* percent (x-axis) from 2003-2007. We see that 13 of the top 30 insurers would have a TRIA-deductible higher than 20 percent of their surplus in 2007. While none of these 30 insurers had a D/S ratio higher than 50 percent in 2005, three insurers had D/S ratios above this percentage in 2006 and 2007.

In states such as California and New York, where only a few companies insure the largest portion of the workers' compensation market, these insurers are likely to bear the largest portion of the losses from a large-scale terrorist attack that inflicts mass casualties. For instance, in California, the State Compensation Insurance Fund represents half of the workers' compensation market in the state. Under TRIA today, 85 percent of the losses above their deductibles would initially be covered by the federal government and eventually be paid by all policyholders and taxpayers. Since workers' compensation providers are not able to exclude terrorism from their policies, in the absence of federal backstop some of these insurers are likely to become insolvent after a large terrorist attack unless they were to be able to obtain protection against catastrophic losses from the private sector and/or reduce their exposure to such losses by downsizing their portfolios.

Figure 6. Number of the Top 30 Insurers Whose *D/S* Exceeds Pre-specified Values
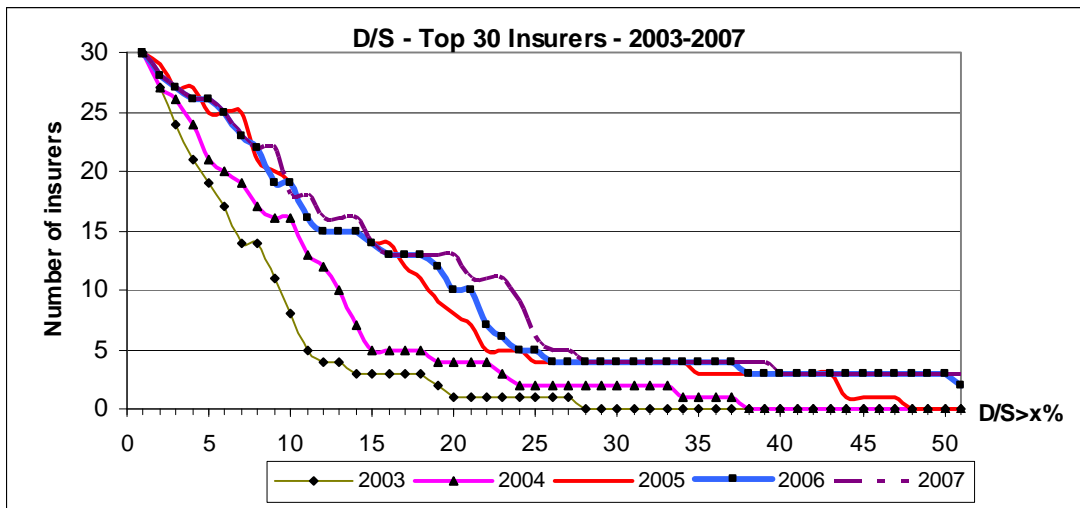
Equitability

Under TRIA, an "act of terrorism" is defined as one "committed by an individual or individuals acting on behalf of any foreign person or foreign interest, as part of an effort to coerce the civilian population of the U.S. or to influence the policy or to affect the conduct of the U.S. Government by coercion," and one in which aggregate insured losses are at least $100 million. The proposed legislation to extend TRIA removes the "foreign person or interest" restriction and reduces the total insured loss trigger to $50 million.

An attack like the Oklahoma City bombing of 1995 that killed 168 people and was the most damaging attack on domestic soil prior to 9/11, would not be a certified event under TRIA because it would be considered domestic terrorism. It makes good sense to include all "acts of terrorism" as certified events. In fact, the distinction between what would be a "certified" event and a so-called "domestic" terrorist event may be difficult to establish. For example, are attacks on the U.S. soil similar to the ones perpetrated in London on July 7, 2005 considered domestic or international? We know today that some of the terrorists were British citizens who were trained to kill in Pakistan.

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By providing financial protection to those who suffer losses from any terrorist attack, whether by a foreigner or someone from this country, the insurance program is more equitable.

The rationale for a decrease in the loss trigger is that small insurers could suffer severe losses from a terrorist attack, losses that might severely deplete their surpluses or that might lead to insolvency if the current $100 million trigger level were maintained. This proposed reduction to $50 million in total insured losses would thus satisfy the principle of equitability by helping small firms to stay in business, assuming that they would have difficulty obtaining affordable reinsurance premiums to protect themselves from losses between $50 million and $100 million.

A third area of equitability relates to who should pay for the losses following a terrorist attack. TRIA holds that if the insurance industry suffers terrorism losses that require the government to cover a portion of their claims, then these outlays shall be fully or partially recouped *ex post* by levying a surcharge on all commercially insured policyholders, not just the policyholders who had purchased terrorism coverage. This implies that if losses are sufficiently high, the responsibility for recouping these payments rests with all firms who have purchased insurance in any of the TRIA-covered lines.

Using data collected on the top 451 insurers operating in the United States which comprise 97 percent of the market with respect to 2004 TRIA-line direct earned premiums (DEP)[20], Kunreuther and Michel-Kerjan (2006) examined the impact of the 2006 TRIA design on loss-sharing between the key stakeholders: victims, insurers and their policyholders, and the taxpayers. By simulating the explosion of a 5-ton truck bomb in one of the 447 tallest high-rises in major cities in the United States (see Appendix 2), we conclude that under the current program, taxpayers are *not* likely to pay anything for losses below $25 billion. For a $40 billion loss, insurers and policyholders would handle between 75 percent and 95 percent of the loss depending on the proportion of policyholders who purchased some type of terrorism insurance (i.e., the property take-up rate). In one $40 billion loss scenario, all commercial policyholders would end up paying $6.3 billion as the result of the mandatory recoupment, whether or not they had purchased terrorism insurance. More generally, what is clear is that insurers and all commercial policyholders will pay a much greater loss share in 2006 and 2007 than under the 2005-attack scenario, due to the higher deductible and higher market retention. Hence, the general taxpayer incurs a smaller portion of the loss.

While the increase in insurers' deductible had an important impact on the distribution of potential losses and equity issues, the major change when TRIA was renewed at the end of 2005 was certainly the increase of insurance industry retention from $15 to $25 billion in 2006. Kunreuther and Michel-Kerjan (2006) show that this change will shift a significant portion of the losses that would have been paid by taxpayers to all commercial policyholders for terrorist attack scenarios where losses are $25 billion and $40 billion.[21]

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[20] Since data are not available on individual insurers' terrorism exposure, market share appears to be the most reasonable proxy for analyzing loss sharing across the affected parties.

[21] For a terrorist attack scenario where the loss is $100 billion there is no difference between the two retention limits because our analysis for 2006 reveals that insurers already pay $34.1 billion in claims,

Minimize Gaming

We now turn to our fifth principle and to an aspect of TRIA that has not been considered by those who have designed the program. If TRIA is made permanent or extended for a long period of time without being reviewed on a regular basis, very large insurers with low deductible/surplus ratios could strategize by significantly increasing their terrorism underwriting. Any insurer with a low deductible/surplus (*D/S*) ratio would have an economic incentive to write a large number of policies in a concentrated area subject to a terrorist attack (e.g. Times Square, Wall Street area) due to the positive correlation in these losses. In other words, the insurer knows that if one of these buildings is damaged or destroyed, the surrounding ones are also likely to suffer severe damage. They would then collect large amounts of premiums for terrorism insurance but would be financially responsible for only a small portion of the claims. Commercial policyholders (whether or not they are covered against terrorism) and the federal government would absorb the residual insured losses.

Determining Terrorism Coverage Using an "E* Gaming Strategy"
To examine how the aggregate exposure/surplus ratio affects the amount of coverage an insurer will want to provide if TRIA is extended indefinitely, we propose a simple model with the following notation:

E^* = maximum insured terrorism exposure (i.e. worst case scenario)

E = actual dollar claims incurred by an insurer from a worst case scenario

DEP = direct earned premiums written for TRIA lines of coverage

$D = a.DEP$ = TRIA deductible determined by the percentage a
   (e.g. a = 20% in 2007)

S = current surplus

$X = E/S$ = aggregate exposure for terrorism/surplus ratio

$Y = D/S$ = deductible/surplus ratio

Given the difficulties in estimating the probability of a terrorist attack, rating agencies focus on deterministic scenarios in evaluating an insurer's credit rating. We focus our estimates on insured losses from a five-to-six ton truck bomb scenario in determining the maximum exposure an insurer will be willing to accept. If an insurer experiences insured losses of E^*, it determines its dollar claims (E) using one of two equations:

$$E = E^* \quad \text{if } E^* \leq D \tag{1}$$

$$E = D + .15 (E^* - D) \quad \text{if } E^* > D \tag{2}$$

which is above the $25 billion retention. In this case there is no mandatory recoupment by the federal government.

We define an *E* gaming strategy* as the decision by an insurer to increase significantly the amount of coverage it provides in order to take advantage of the 85 percent risk-sharing arrangement with the government in 2007, and at the same time to collect a significant amount of terrorism insurance premiums.

For each insurer, we can determine its aggregate terrorism coverage in urban areas. We assume that each insurer is concerned with maintaining an aggregate exposure from deterministic scenarios at 10 percent of its surplus (*S*). Insurers with a *D/S* ratio greater than 10 percent will limit their exposure to 10 percent of their surplus ($E^* = E$). Those with *D/S* less than 10 percent could offer much more coverage than under TRIA, particularly those with very small *D/S* due to a large surplus ($E^* > E$).

Figure 7 depicts the difference that fixing a threshold of *E/S* = 10 percent would have on insurers' decisions regarding how much terrorism coverage to offer, depending on whether the insurer had a *D/S* ration higher than 10 percent (Insurer (a); left part of the graph) and those with *D/S* less than 10 percent (Insurer (b); right part of the graph). In both cases, there are two bars. The solid gray bar on the left indicates the *D/S* ratio of the insurer in 2005, the one made up of oblique lines on the right indicates exposure based on the constraint that *E/S* = 10 percent.

Figure 7. Insurer's Exposure Limited to 10 percent of Its Surplus
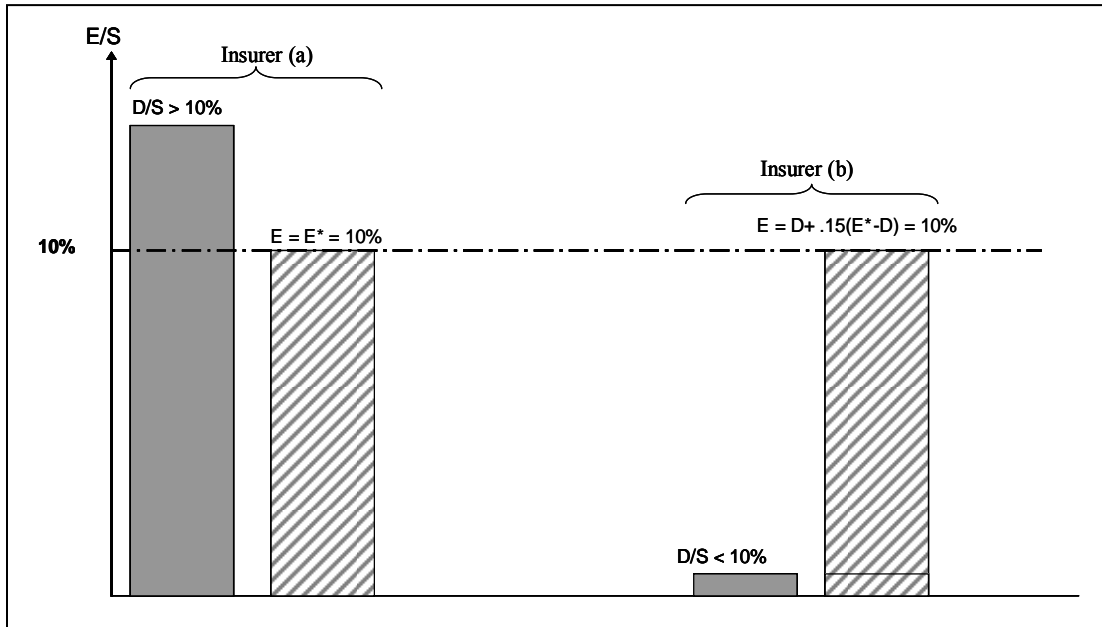
The aggregate exposure for each of these two types of insurer is depicted in Figure 8. An insurer with considerable business in non-TRIA lines such that its surplus is high but its deductible is quite low will take advantage of the structure of TRIA's program (if it is made permanent) by increasing its aggregate exposure considerably from the current level, up to *E**.

**Figure 8. Gaming TRIA. Aggregate Exposure of Insured Losses;
Additional Capacity Provided by Insurers with D/S<10%**
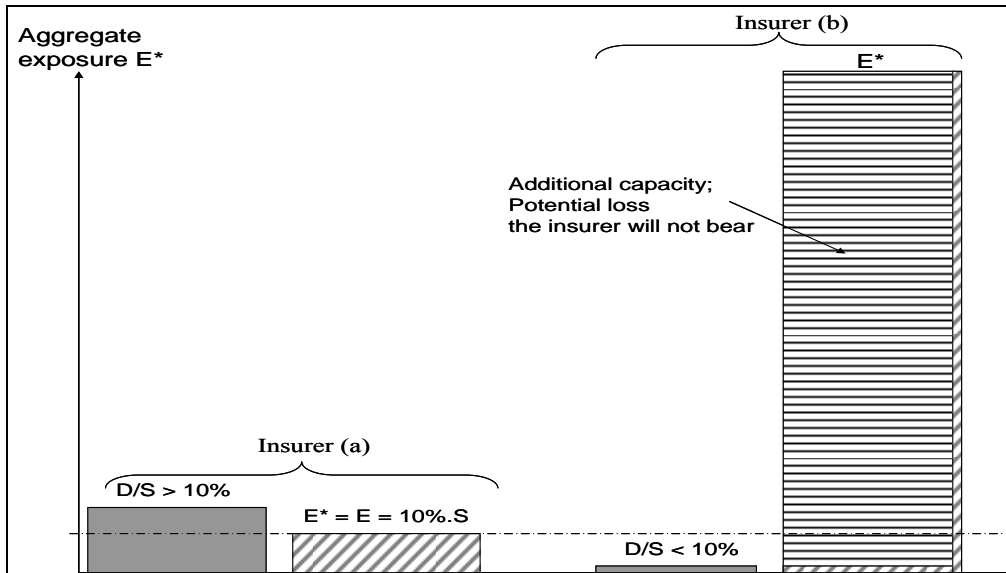
Using E^*, one can then determine how the coverage from a terrorist attack would be spread across insurers and compare it with what would have happened under TRIA. Because insurers with low *D/S* ratios are willing to write considerably more property coverage at relatively low prices in metropolitan areas if TRIA is extended indefinitely, all commercial enterprises will expect to be insured against property losses (we assume a 100 percent take-up rate)[22].

In order to measure that behavior empirically, we focus on the locations where a large terrorism loss is more likely. To make the data analysis manageable, we have limited our sample of insurers to those who already provide the largest terrorism coverage in urban areas. We have undertaken the analysis here for the year 2005. We selected the top 30 insurers based on TRIA-line direct earned premiums in 2004 and then eliminated the 7 companies who are small business and personal lines insurers This group of 23 large insurers actually accounted for about two-thirds of the TRIA-lines direct earned premiums in that year[23]. For the sake of simplicity, we then make the assumption that these 23 insurers cover 100 percent of the insured losses in the city we consider. We then analyze how losses would be shared under TRIA and compare this with a design of a "permanent" TRIA.

Table 1 provides the aggregate results of the analysis comparing loss sharing among all commercial policyholders under TRIA and U.S. taxpayers with loss sharing

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[22] It is unclear how terrorism insurance will be priced under this scenario. Insurers with low *D/S* ratios competing for business in urban areas will have an economic incentive to reduce their price as they expand their coverage, because they know they will be only responsible for 10 percent of any loss greater than D – something an insurer with a more limited surplus cannot do. As a result, the major providers of coverage will be winnowed down to only a few insurers.

[23] In 2005, insurers were responsible for only 10 percent of the insured losses above their deductible, not 15 percent as is the case today.

under an *E** strategy if an attack in New York City inflicted $25 billion of total losses in 2005. Because the total loss will increase from $17.5 billion (with a 50 percent take-up rate) to $25 billion (with a 100 percent take-up rate), the general taxpayer's share of the loss will increase from $2.5 billion to $10 billion – that is a 300 percent increase from what taxpayers would have paid under the TRIA program in 2005.

The difference between the $15 billion insurance industry retention in 2005 and insurers' payments of $13.3 billion will be charged against all commercial policyholders who will experience a 288 percent increase in payments. The difference in market share by the insurers playing an *E** strategy would result in a 37 percent decrease in insurance industry payments, even if all losses caused by the attacks are now covered. The very large insurers with low *D/S* ratios will provide most of the coverage and pay very little after a terrorist attack compared with their aggregate exposure. They would keep all their premiums and transfer the loss to all commercial policyholders and taxpayers. This points to an inequity in this system, because the policyholders of those insurers who do not suffer any loss are responsible for the same amount of repayment to the government in the form of a surcharge as are policyholders in companies that suffered large losses and were subsidized by the government.

Table 1. Distribution of Losses under TRIA-2005, and if TRIA is Made Permanent
($25 billion loss in New York City)

	Non-insured	**Insured Loss Sharing**			
		Total insured	**Insurers' Payments**	**All Commercial Policyholders**	**U.S. Taxpayers**
SCENARIOS					
TRIA-2005 – 50% take-up rate on Property Insurance – 23 insurers					
Total: $25bn Property: $15bn WC: $10bn	**$7.5bn**	*$17.5bn*	*$13.3bn*	*$1.7bn*	*$2.5bn*
Insured loss sharing			*76%*	*9.8%*	*14.2%*
TRIA Extended Indefinitely – 100% take-up rate – 23 insurers					
Total: $25bn Property: $15bn WC: $10bn	**$0**	**$25bn**	**$8.4bn**	**$6.6bn**	**$10bn**
Insured loss sharing			*46%*	*14%*	*40%*
Change in final payments			**-37%**	**+288%**	**+300%**

Minimize Gaming: There are several reasons why insurers may not be willing to assume the large aggregate exposure implied by an *E** gaming strategy.

First, a larger *E** increases the likelihood that an insurer will experience medium to large losses below its TRIA deductible by insuring more structures in high-risk areas. In this sense, insurers may decide to limit their aggregate exposure by estimating the likelihood of different terrorist attack scenarios. Insurers may then reduce their aggregate exposure by utilizing their survival constraint in a manner similar to the processes they follow for

other catastrophic risks. Second, when an insurer provides coverage against terrorism it also provides insurance against all other events that could cause damage or losses to their property and/or claims from their workers' compensation coverage. When an insurer decides whether to write more terrorism coverage, it needs to consider its aggregate exposure from a much broader set of risks (e.g., fire, theft, work injury).

Insurers may be also concerned that Congress will amend a long term/permanent TRIA-like program if legislators observe the type of strategizing described above. Consider, for example, insurers who expanded their coverage by focusing on E^* because they thought they would benefit from TRIA for the indefinite future. If new legislation now makes them responsible for 50 percent of their losses above their TRIA deductible, these insurers will very likely want to cancel some of their commercial policies for fear of incurring large claim costs after a terrorist attack. One reason why *no* insurer has followed an E^* gaming strategy to date is because the initial period of the program (three years) and the first renewal period (two years) were not long enough to merit a major change in their terrorism risk coverage strategy.

7. Conclusion and Future Research

Covering commercial enterprises against terrorism risk constitutes a new insurance market in the United States. Given that millions of companies are now covered, that market has become a more substantive one within just a few years. This paper has discussed some key features of terrorism which make the risk difficult to analyze using optimal risk sharing models. For this reason, we proposed five principles to guide the evaluation of programs designed to provide financial protection to potential victims of major disasters. We applied these principles to the case of mega-terrorism but they should have broad applicability in the field of catastrophe risk management.

The series of disasters that occurred at an accelerated rate in the last few years demonstrate that we have entered a new era of large-scale risks and mega-catastrophes. Consider the 20 most costly insured catastrophes in the world between 1970 and 2006. Half of them occurred since 2001, nine in the United States.[24] These data suggest that catastrophes should no longer be considered low-probability events. Given the increase in globalization of economic and social activities worldwide, future catastrophes will have both devastating impacts on victims who directly suffer from them and indirectly affect many others located hundreds if not thousands of miles away. This raises important questions such as the implication of fat tails on risk diversification, optimal risk sharing and price arrangements when the risk is highly uncertain, and the appropriate roles and responsibilities of the public and private sectors. Future research is also needed to provide better understanding of the pricing and availability of terrorism insurance coverage under TRIA and how this impacts on demand by firms at risk in this public-private collaborative arrangement.

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[24] This may be one reason that the White House Council of Economic Advisors (2007) devoted an entire chapter of its Economic Report of the President to Catastrophe Risk Insurance.

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Brief side-by-side comparison between TRIA 2005 and TRIA 2006-2007

|	TRIA	Extension of TRIA	
	2005	2006	2007
Program trigger (« per event » in 06-07)	$5 million	$50 million	$100 million
Insurer's deductible (% DEP previous year)	15%	17.5%	20%
Federal share (% above insurers' deductible)	90%	90%	85%
Industry aggregate retention/recoupment threshold	$15 billion	$25 billion	$27.5 billion
Annual Program Cap	$100 billion	$100 billion	$100 billion

**Impact on two scenarios of attacks (five-ton truck bomb and 9/11 type)
on workers' compensation and P&C lines
Simulations on the United States' 447 largest commercial high-rise buildings**

This appendix provides the results of a series of simulations quantifying the effect on property damage and workers' compensation losses of a five-ton truck bomb exploding in each of the United States' 447 largest commercial high-rise buildings (Figure A1), along with the of a large commercial aircraft crashing against each of these buildings (A, B, C, etc) (Figure A2)[25]. One reason for this focus is that A.M. Best uses the 5-ton truck bomb of scenario in analyzing the impact of a terrorist attack on insurers' balance sheets.

**Figure A1. Projected Property Losses and Workers' Compensation Losses from
        Five-Ton Bomb Attacks to 447 High-Rise Buildings in the United States
        (in $ billion)**
        [Each triangle represents one specific high-rise building used in the simulation;
        For example, triangles A, B, and C are three distinct buildings]

_____
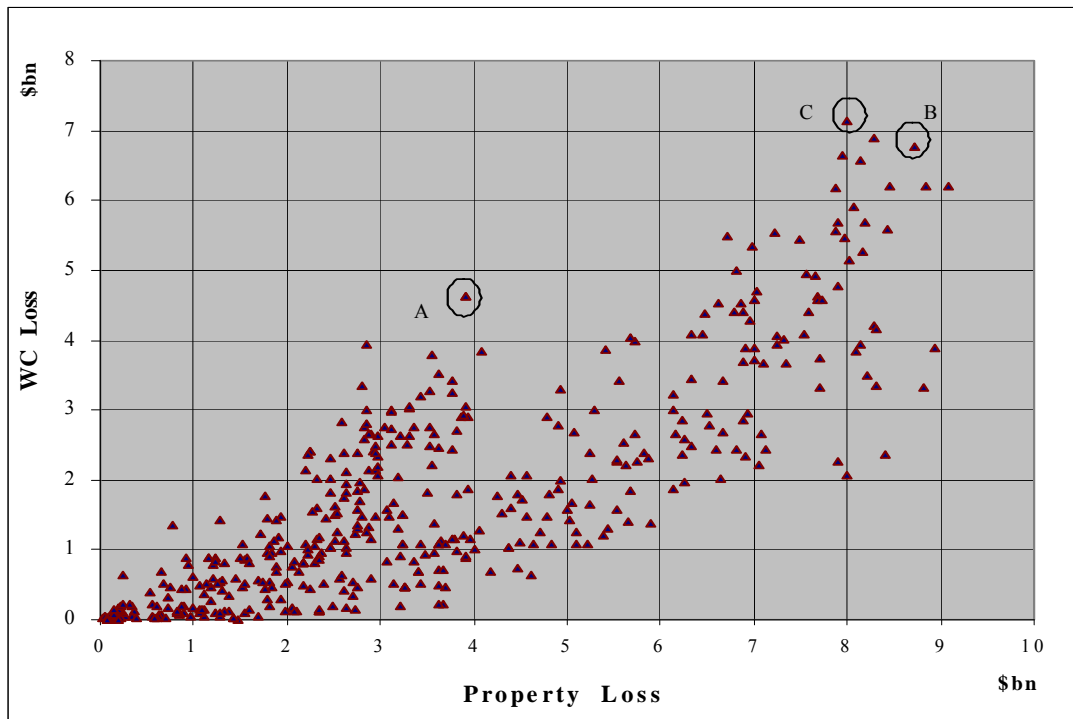
[25] We are grateful to Andrew Coburn from Risk Management Solutions who provided us with these data.

Figure A2. Projected Property Losses and Workers' Compensation (WC) Losses from Aircraft Attacks to 447 High-Rise Buildings in the United States (in $ billion)
[Each triangle represents one specific high-rise building used in the simulation]