1. Introduction

**Harry W. Richardson, Peter Gordon
and James E. Moore II**

Since 9/11 there has been considerable speculation and research about future potential terrorist attacks on the United States. Interestingly, and perhaps predictably, much of this research has focused on the cost of human lives and psychological effects rather than more direct economic impacts. Yet there is little doubt that both the economic costs of protection and the potential economic damage from certain types of terrorist attacks could be substantial. This book focuses on some of these issues. It is the result of one of the first activities of CREATE (the Center for Risk and Economic Analysis of Terrorism Events) established at the University of Southern California by the US Department of Homeland Security. This was a conference held in August 2004 that brought together economists and planners from around the country who have developed research interests in terrorism and its economic impacts.

There was a spate of studies after 9/11 (for example, Glaeser and Shapiro, 2001) that considered the problem of whether the attack would lead to a reassessment of corporate location decisions with firms choosing sites less visible than downtown (or midtown) Manhattan. It did not happen, mainly because of a widespread and probably justified belief that future terrorist attacks would diversify rather than repeat the same kind of targets.

'Extreme events' are characterized by non-linear responses, low probabilities, high consequences and the potential for systems interaction that may lead to catastrophic losses. Terrorist acts are probably the most serious of these events because they are done deliberately. However, as suggested in several chapters of this book, the research methodologies previously applied to 'natural' extreme events, such as earthquakes and hurricanes, can be helpful. Several scholars have been studying the economics of natural disasters for some time. Economists interested in understanding and achieving the benefits of mitigation are playing a disaster mitigation game against nature. Although the factors leading to natural disasters remain poorly characterized, the parameters are relatively stable. However it makes sense to improve our understanding of

natural hazards. The information acquired will be useful in both natural disaster and terrorism research.

On the other hand, when the source of disaster is cognitive, the process generating adverse events is no longer stationary and the events have minimal predictability. This is why game theory in combination with more, possibly new, analytical tools is so important. But the issues have not yet been resolved and the origins of this book represent only an exploratory, but worthwhile effort.

Also, new approaches may be needed to analyze the often subtle differences between natural and manmade events. For example terrorist attacks are much less predictable in terms of time, place and type of event than natural disasters. Also, even with multiple simultaneous attacks, it is difficult for terrorism to replicate the number of locations that might be impacted by a severe hurricane. On the other hand, certain types of terrorism (for example, the spatial diffusion of epidemics) can affect a larger geographical area and impact many more people.

There may also be many inexpensive cost-effective policies which help to combat terrorism, but also have beneficial societal impacts. A few examples are mentioned in this book, but there must be scores of others. The ones mentioned include: battery-operated traffic signals (Lave et al.; Chapter 4); the wider use of surveillance cameras, especially near bridges and other components of critical infrastructure (Richardson et al.; Chapter 14); and the general public health benefits of bioterrorism defenses (Abt, Chapter 7). The point is that an integrated approach to homeland security issues is required, as well as a public explanation of the more general social benefits, including policies that they come from what appears to be totally unrelated fields.

There is also a strategy and a minimal risk in our endeavors. We recognize that by publishing our views of these problems, we are to some degree providing potential information to knowledgeable terrorists. The risk is minimal because there is almost no specific information in the book that provides significant value added to what is already widely in the public domain. It is to our net benefit to inform each other about the issues and to collaborate on developing our best analytical tools. Advertising the state of information about targets and their vulnerability yields little, because once we recognize our vulnerabilities there will be policies planned and/or implemented to remedy them. In the words of the 9/11 Commission (US National Commission, 2004, p. 391): 'In measuring effectiveness, perfection is unattainable. But terrorists should perceive that potential targets are defended. They may be deterred by a significant chance of failure.'

This book is intended as a good first step. Scenario building will remain fundamental to the problem of anticipating and responding to terrorist

threats. Effective protection against terrorist threats is going to take something more, something new. We cannot afford to pick courses of action by exhaustively evaluating every feasible alternative and comparing each one to find the preferred option. We need to be mathematically more sophisticated. We need approaches that allow us to make choices without explicit enumeration of alternatives. It will always be necessary to evaluate some alternatives in detail, and the lessons learned from our research to date will continue to pay off in this dimension. However we need to learn to couple the techniques we have developed with a means to identify third-best alternatives that do not merit intensive evaluation. Becoming systematic about identifying and evaluating scenarios is merely a first step. Also it is important to stress mitigation and recovery because 100 per cent prevention is a fruitless goal.

The chapters employ a wide range of analytical techniques used in other fields of economics and planning. These include cost–benefit analysis, game theory, experimental economics, hedonic pricing models, input–output/transportation network and computable general equilibrium models. Cost–benefit analysis, which features – not unexpectedly – in many chapters, presents especially difficult problems in the field of terrorism because of the extreme uncertainty of the benefits.

What follows is a summary of what we have learned from this experience. Certainly, as Sandler and Enders point out in Chapter 2, both theoretical and empirical techniques can be used to put modern-day terrorism into perspective. Their chapter surveys past contributions, presents updated empirical findings and suggests new directions for research. Because of strategic interactions among terrorists and targeted governments, game theory and economic methods play an important role in identifying novel policy recommendations and behavioral insights. Transnational terrorism and efforts to curtail it involve externalities and market failures. The chapter analyzes how terrorists alter tactics in reaction to government policies and how a no-negotiation hostage policy is difficult to institute in practice.

Heal and Kunreuther explore the problem of interdependent security among agents in Chapter 3. In an interdependent world the risks faced by any one agent depend not only on its choices but also on those of all others. Expectations about others' choices will influence investments in risk management, and the outcome can easily be suboptimal for all. They model this as a Nash equilibrium game and give conditions for a suboptimal equilibrium to be tipped to an optimal one. They also investigate the smallest coalition to tip an equilibrium (the minimum critical coalition) and show that this is also the cheapest critical coalition to move the system from the suboptimal to the optimal equilibrium. The results are examined for a few

case studies: airline security, the control of infectious diseases via vaccination, and investment in research and development.

Several of the chapters deal with the consequences of power failures. In Chapter 4 Lave, Apt, Farrell and Morgan point out that energy, transportation, telecommunications and water infrastructures are potentially attractive targets, because it is impossible to protect some elements of these complex systems, and disruptions could impose large costs and possibly result in thousands of deaths. The electric power system is an especially attractive target because of its ubiquitous importance in both the economy and our personal lives, from heating and cooling, access to drinking water, sewage disposal, access to media outlets, traffic lights – without which emergency services would be paralysed – to most economic production, including the entire information technology sector. Their chapter discusses these issues and recommends changes to lower the number of blackouts, reduce the vulnerability of the system to terrorists, and decrease the social costs of blackouts when they occur.

These problems are similar to those discussed in Chapter 5 by Chang, McDaniels and Reed. Infrastructure service outages can cause broad-ranging disruptions across all sectors of an economy. The problem of infrastructure failure interactions (IFIs) is particularly important. The objectives of the chapter are to characterize IFIs and to identify promising mitigation strategies for effectively containing them. The conceptual base of the chapter includes a new framework for characterizing and identifying important IFIs, as well as approaches for evaluating strategies to mitigate their effects. A case study involves a preliminary assessment of IFIs that occurred in a 63-hour storm beginning on 20 January 1993 in the Pacific Northwest. Although this was a natural event (as are multiple references to earthquakes in the chapter), many of the findings apply to man-made events, especially terrorism.

Schuler in Chapter 6, examines some of the features of the bulk power system that might enhance its capacity to recover from a breakdown. In general it is characterized by robustness because power could be restored quickly even after a major terrorist attack. The only way to avoid this would be a highly coordinated attack on multiple regional facilities, although restocking and repair of equipment might increase delays. Collateral damage may be more of a problem, especially if the attack was in the winter in the north. Low-voltage distribution outages may also be irritating because repair crews have to proceed step by step (compare the bulk power failure in the Northeast in August 2003 and the low-voltage distribution failures of the Florida hurricanes in the late summer of 2004).

In discussing the question of the design and coordination of the bulk power system, Schuler adopts a simulation approach that examines the

number of agents and whether they act collectively or individually in response to external random shocks. His results suggest three general conclusions. First, it is desirable to have a larger group size as the frequency of potential external shocks increases to facilitate the impact on only a subgroup. Second, risking collapse of the whole system may be worthwhile if restoration can be speeded up. Third, a 'hotchpotch' system may have benefits provided that there is coordination.

In Chapter 7, Abt makes three key points: (1) under current conditions of inadequate US biodefenses, a single catastrophic bioterrorist attack can kill more people than any single nuclear terrorist attack; (2) catastrophic bioterrorism attacks are difficult to deter or defend against, but their risks of massive potential fatalities can be prevented and mitigated by scientifically feasible, economically affordable and politically acceptable means; and (3) cost-benefit assessment of improved biodefenses reap a dual net benefit of at least an order-of-magnitude reduction in deaths and damages and additional peacetime public health benefits to protect against natural deadly epidemics, for an annual investment of less than the \$10 billion. This compares with the amount currently invested in ballistic missile defense, a much smaller and less likely threat.

Cost-benefit assessments are considered for improved biodefenses against three catastrophic bioterrorist attacks on the most valuable and vulnerable urban transport centers (New York, Washington, DC and Los Angeles). Potential economic and loss-of-life costs of the three most catastrophic types of bioterrorist attacks (smallpox, plague and anthrax) are estimated from realistic scenarios for current and near-future improved biodefenses. Deaths from a current potential mass bioattack on US cities range from 500 000 to 30 million people; economic damage ranges from \$200 billion into trillions. The median and the range of deaths and damages of a catastrophic bioterrorist attack on any large city exceed those from a single nuclear terrorist attack.

Ganderton, Brookshire and Bernknopf report in Chapter 8 on the application of an innovative web-based tool to investigate aspects of the Homeland Security Advisory System (HSAS). The system's high profile has attracted serious criticism for failure to provide relevant threat information, in particular the nature, location and timing of the threat. Their experiments provide a mechanism for analyzing the current system's weaknesses and should aid in the search to improve its value as a risk communication mechanism. Employing the interactive and graphical features of the Internet, experiments are conducted in which subjects faced with potential security threats can purchase more detailed (more spatially accurate) alert information and concurrently choose appropriate preparation and response actions. Empirical analysis of the responses suggest that more

geographically detailed threat warnings have value that increases with the level of the threat, and that people base their intended responses on the information and the level of the threat. This research supports the case for more spatially detailed terrorist threat information, made easier with the use of maps. The methodology relies heavily on the principles of experimental economics, a now widely accepted approach, but still controversial (especially with human subjects).

Redfearn's Chapter 9 addresses the market's perception of risk from terrorism by examining the prices of single-family homes before and after the 9/11 terrorist attacks. In the wake of the attacks, government officials responded by raising security at sites considered to be likely targets of future attacks. In the greater Los Angeles metropolitan area, these included the ports of Long Beach and Los Angeles, Los Angeles International Airport and several local civic centers, among others. The skyscrapers of downtown Los Angeles were also thought to be potential targets. It is clear that some markets internalized these actions as representative of the real risk of repeat attacks (for example a pronounced increase in terrorism insurance premiums for commercial properties and 'trophy' properties). It is not clear however that the consumers have similarly altered their behavior. Where surveys indicate that terrorism is seen as a genuine risk, the actions of home buyers in the LA Basin indicate otherwise: the effects of 9/11 on residential markets have been insignificant in the areas surrounding potential targets. Of course many houses sold are too far away from potential targets at least for certain types of attack (for example conventional bombs), because of natural barriers around certain types of facility (for example the ports and the airports). Nevertheless results suggest that the perceived risk of harm from terrorism is in fact unchanged since 9/11.

The purpose of Smith and Hallstrom's Chapter 10 is to outline most of the major methodological and empirical issues associated with developing cost-benefit analyses for homeland security policies. Their starting point is that the post-9/11 environment is irreversible, so that the net benefits of these policies should not be treated as an effort to restore a pre-9/11 baseline. They also suggest that in discussing the links between policies and risk reductions, the limited information base relating to national security implies drawing from the research on large-scale natural hazards would be helpful, especially in the context of individual responses. Hence they refer to research results relating to Hurricane Andrew, using home sales in Lee County, Florida (which Hurricane Andrew narrowly missed) to estimate how new information about the risk of severe storms is capitalized in housing prices for areas recognized to have potential for damage. Lee County residents in flood hazard areas with significant risk of damage from

future storms received new information about the severity of these storms but no actual damage. The results confirmed the *a priori* hypothesis, in that the risk information conveyed by Hurricane Andrew reduced the property values for homes in the area prone to coastal hazards. The measured effects of the information conveyed by Andrew implied a 19 per cent reduction in the rate of change of the property values. Smith and Hallstram conclude with an important implication for cost–benefit analysis: the strategic induced responses to terrorist (or natural disaster) risks convert the standard aggregate cost–benefit analysis into a type of general equilibrium problem that needs to be addressed in future research.

To estimate the economic losses from terrorism, Rose argues in Chapter 11 that it is necessary to deploy a comprehensive and sophisticated model. Faced with two alternative strategies, one approach is to adapt existing models from related areas such as impact analysis and the economics of natural hazards. The other approach is to begin from square one and develop an entirely new modeling approach for the purpose at hand. Rose suggests that the best strategy would be to enhance the existing approach of computable general equilibrium (CGE) analysis, which has proven successful in recent applications to related areas. At the same time, there is an acknowledgement of limitations of the approach, although most of them are not insurmountable.

The purpose of the chapter is to assess the capability of CGE analysis to estimate the production-related losses of a terrorist attack. The assessment includes a discussion of advantages and disadvantages of CGE in general and in the context of the economics of terrorism. It also deals with attempts to overcome CGE model limitations with respect to disequilibria, parameter specifications and behavior. It further emphasizes the ability of CGE modeling to address two aspects of loss estimation that have typically been neglected (at least quantitatively) in almost all studies of disasters, both man-made and natural. The first of these is the full range of indirect or general equilibrium impacts, which have the potential to increase substantially the size of loss estimates. The second is individual business and market resilience, or the inherent ability of businesses and markets to cushion themselves against shocks, which have the potential to lower these loss estimates.

Martonosi, Ortiz and Willis in Chapter 12 use the example of port container scrutiny to suggest that the goal of transportation security initiatives be cost-effective risk reduction and to argue that all policies should be subject to rigorous cost–benefit analysis. The chapter provides a case study for a specific proposal: 100 per cent inspection of containers at US ports. Container scanning and inspection is a key element in ensuring a secure containerized shipping system. Complete primary inspection is not wholly

infeasible, although the percentage of containers currently scanned remains very low. The chapter presents a cost–benefit analysis of implementing a policy of scanning 100 per cent (or less) of incoming containers at US ports, exploring issues of technological improvement, the impacts of different scanning rates (which could vary from port to port) on cost and effectiveness, the uncertainty of the consequences, and the probabilities of an attack.

A policy of 100 per cent scanning is not feasible with current technology and constraints relating to personnel and port space. A \$10 billion event would make 100 per cent scanning cost-effective, leaving aside the personnel and land constraints. A \$1 billion event would not justify 100 per cent scanning unless its probability was very high (say 80 per cent per year). Improved scanning technology and more resources (both human and non-human) could increase cost-effectiveness, especially if it reduced the false positive rate and had a deterrent effect (on both terrorists and smugglers). Making do with less than 100 per cent scanning would require a targeting strategy superior to random selection.

In Chapter 13 Haveman, Shatz and Vilchis take a somewhat broader look at maritime security than container screening. Despite the rapid speed of passage for the Maritime Transportation Security Act (MTSA), the legislation lacks a comprehensive view of maritime security issues, especially the maritime transportation supply chain. The CBP (US Customs and Border Patrol), via its initiatives – Customs–Trade Partnership against Terrorism (C-TPAT) and the Container Security Initiative (CSI) – is in the process of shifting the security of container protection from foreign to domestic shores and in encouraging maritime shipping participants to develop their own security plans. However the resources to implement federally mandated measures are not yet in place and there are gaps in the coverage of some programs (such as the lack of inspectors in some ports and concerns about the effectiveness and continuing implementation of supply chain security plans). Until these gaps are remedied, the maritime transportation network remains vulnerable to a terrorist event and the capacity to respond to it.

Chapter 14 by Gordon, Moore, Richardson and Pan examines the impact of an attack on the twin ports of Los Angeles and Long Beach via radiological bombs supplemented by the destruction of overpasses on access freeways. They distinguish between ‘local effects’ (that is shutting down port and port-related activities in the vicinity of the ports) and ‘regional effects’ (more accurately, including national and international consequences) associated with the interruption of international trade. Their estimates cover a wide range, depending on whether the ports are shut down by very small bombs alone for 15 days, or whether the access bridges

are also taken out which would imply a minimum of 120 days to rebuild. In the minimum case, the direct, indirect and induced damages would only be \$138.5m of output and 1258 person-years of employment, with two-thirds of the impacts confined within the region. In the 120-day case, the damages could rise to more than \$34 billion of output and 212 165 person-years of employment, with two-thirds of the impacts felt outside the region. These impacts might be modified by deferred purchases, diversion of trade to other ports (probably minimal), and more use of the newly built separated rail line (the Alameda Corridor, although this is also subject to terrorist attack).

Bae, Blain and Bassok in Chapter 15 also address a transportation network problem in their assessment of what might happen if terrorists blew up to the bridges across Lake Washington in the Seattle region that link downtown with the edge cities on the Eastside; in addition, scenarios are examined where a bomb cuts the critical I-5 Interstate North–South link by blowing up the area under the Convention Center. The lake, the hills and other aspects of the unusual topography plus the chronic underinvestment in highways make the Seattle recovery model problematic. Currently there is no model in Seattle with the capacity to evaluate the economic impacts (the well-known UrbanSim model is much more oriented to land-use impacts), so the results of this study are confined to transportation impacts. Because commuters (and others) would have to go around the lake by relatively narrow surface roads, trip times could almost triple and total regional travel times (by hours and value, for both commuting and freight) could increase by up to 16 per cent. Temporary or partial bridge restoration costs would probably be about \$200 million. These consequences might be moderated by trip deterrence, and the provision of more and superior bus services, especially if the circumstances could induce an even temporary two-thirds increase in the transit share.

This book does not pretend to offer a comprehensive approach to all the issues relating to the economic consequences of terrorist attacks. That would take many books. To take merely a few examples, there are no chapters relating to airports (other than airline baggage-checking security), tourism, attacks on nuclear power stations, border controls or protecting US homeland security abroad. To briefly mention the first, it would not be very difficult to explode a moderately sized conventional bomb in the pre-security area of an airline terminal in a large airport at a busy time of day. This raises a more conceptual issue that has been addressed in the economics of crime literature, the so-called ‘displacement effect’. There are always too many targets that need protecting, and terrorists (and other criminals) can always seek out those unprotected or very lightly protected. An exploded bomb in a busy terminal could do at least as much damage as

on a plane in flight. However the purpose of this Introduction is to discuss the current book, not a menu for future research.

REFERENCES

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