

**A Review of:** *The Economic Impacts of Terrorist Attacks*.  
Harry W. Richardson, Peter Gordon and James E. Moore, III,  
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*The Economic Impacts of Terrorist Attacks* reports on the activities of the initial meeting of the Center for Risk and Economic Analysis of Terrorist Events (CREATE), the first university research center funded by the U.S. Department of Homeland Security. The center is tasked with exploring how economics can inform the design of terrorism prevention policy.

The book does not aim to be comprehensive. Nevertheless, it covers quite a bit of ground. Early chapters focus on theoretical contributions based on the theory of public goods games. Subsequent chapters identify a series of specific vulnerabilities that the country faces in its electricity distribution systems, biodefenses, ports and transportation infrastructures.

This review focuses on one theme that runs through much of the book: the ways in which the resiliency of a system to a terrorist attack can be evaluated to inform the design of public terrorism policy. I consider the degree to which the book successfully addresses this issue. The book was not designed with this specific objective in mind, but the theme emerges nonetheless. Furthermore, the concept of designing systems to manage resiliency has broad application to a number of aspects of public policy, including the management of natural ecosystems, global warming, the design of computer networks, and international trade policy and the impacts of globalization.

The editors suggest at the outset that there are two defining characteristics of terrorist attacks: They occur with low frequency, and they have catastrophic consequences. People have difficulty processing risk information with low probabilities and this poses conceptual problems

for economic models. At a broad level, it is not obvious how one measures willingness to pay to avoid low-probability, catastrophic events. Nor is it clear how to model behavioral responses of individuals to changes in information about the risk of such events.

Developing sensible social policy to combat the effects of these events is also difficult. The economist's knee-jerk response is to tell policymakers that the clear policy choice is the one that maximizes the expected net benefits of protection. When we think carefully about the demands that this framework places on consumer sovereignty, and when we realize that the consequences of being wrong are catastrophic and irreversible, the answer becomes less clear. The authors in this volume often look to the impacts of natural disasters as their model of terrorist attacks. Few citizens of New Orleans would argue that they accurately perceived the risks they faced before hurricane Katrina, and fewer still believe that they will be returning to a city that can ever resemble the one they left.

Resiliency captures the idea that complex systems — either natural or man-made — have some capacity to carry on their mission in the wake of a damaging external shock. Once this capacity is exceeded, however, further damage can have catastrophic consequences. And, importantly, this capacity of the system to right itself is something that humans can manage. The implicit assumption throughout much of the book is that a sensible response to the possibility of catastrophic terrorist attacks is to design key systems to be resilient, with the likely penalty being that these systems function somewhat less well when not under attack. In other words, do not buy a Maserati if you expect a few potholes in your future. Beyond this, the concept of resiliency acknowledges the idea that fully insulating ourselves and our social infrastructure from terrorist attack is unrealistic. The variety of potential targets makes defending each, at a level that will prevent damage, prohibitively expensive. Resilient systems allow individual components of a system to fail without sacrificing the viability of completing the system-wide mission.

These ideas are borrowed from the study of natural ecosystems, and key among them is the notion that resilient systems exhibit redundancies. The genetic diversity embodied in species-rich ecosystems is like a set of backstop technologies. Certain species may currently play a

relative minor role in supporting the basic functions of an ecosystem. But when external shocks such as pests or diseases knock out key species, these “backstop” species may fill an important niche in the community and become dominant players in the ecosystem.

Three chapters, by Lave et al, Chang et al and Schuler, all focus on characterizing the vulnerability of electricity generation and distribution systems to terrorist attacks. In this context, a redundancy can be as simple as having spare parts on hand in the event of an attack on the bulk power system. Alternatively, the grid could be designed to allow for quick re-routing of power to affected areas. In both cases, the focus is on the design of the physical system involved, and this is usually what these authors mean when they write of designing of a resilient power system.

If one takes a slightly broader view of the system involved, however, building redundancy into a system could also mean something like encouraging the procurement of backstop technologies, portable power generators, for example, which are not actively in use at present but which can come on line with relative ease when the need arises. Similarly, encouraging people to develop lifestyles that are less sensitive to power outages might also be a possibility. In other words, policies that acknowledge the behavioral responses of consumers might usefully be included in this discussion. These authors (sensibly) view these types of responses as outside of the scope of their analyses, but the possibilities are intriguing.

The biggest change to the existing electricity system that is proposed in these chapters comes from Lave et al. The centralized nature of the bulk power system in the U.S. makes it inherently vulnerable. The authors propose a switch to a system of distributed power generation in which local fuel-cell plants service the majority of the country’s demand for electricity. They also acknowledge real difficulties in implementing this approach — both in the cost of shifting the nation’s infrastructure and in taking on powerful lobbyists working in the interest of maintaining the status quo.

Another key determinant of resiliency is connectedness, or some measure of the speed and intensity with which an attack on one part of a system is translated to other parts of the system. The typical computer network that has been hacked into has a high degree of connectedness in

the sense that once the hacker has gained access to one computer on the network, she has the potential to do great harm to all computers on the network.

Schuler takes on the question of how cooperation between individual managers on same the electricity grid makes a system more or less resilient. He takes an agent-based approach to modeling the vulnerability of the electricity distribution system. A critical consideration in his analysis is the geographical extent of the cooperation, both in its effect on the size of the cooperating network in terms of number of cooperating managers and the terms of the connectedness of the cooperating systems on the grid. He finds that the interaction between connectedness and cooperation is complicated, with more cooperation among operators leading to better outcomes in isolation of other cooperative groups on the grid, but a potentially more unstable outcome if large collectives are tightly connected and working in an uncoordinated fashion across these collectives.

From the perspective of microeconomic theory, terrorist attacks are most readily characterized by the fact that they operate outside of markets. This puts their analysis in the natural province of public economics and environmental economics as the sub-fields of the economics most directly concerned with external effects. More specifically, acts to prevent or mitigate the consequences of terrorist attacks can be viewed as private or public decisions to provide public goods and correct externalities.

Heal and Kunreuther, building off of the theory of public goods games, address some of the strategic dimensions of terrorism prevention. The generic structure of their model looks much like attempts to model the provision of international environmental goods. Global warming prevention, for example, is widely acknowledged to fit the mold of a classic prisoner's dilemma problem. Heal and Kunreuther highlight a key difference however. Whereas the marginal effectiveness of one country's efforts to reduce greenhouse gas emissions are essentially independent of the emission control levels in other countries, many security problems exhibit a higher degree of interdependency. This assumption transforms the game from a prisoner's dilemma to an "interdependent security" game.

When the degree to which other agents in the model take security measures to avoid the

damages of terrorism increase the marginal effectiveness of one's own measures, then equilibria in which all agents fully invest in security are possible. This is a valuable insight, as the authors point out, when one recognizes the "shape" of the connectedness between different agents. For example, in the case of airline baggage security, a couple of key airlines are responsible for a large fraction of the baggage transfers between airlines that lead to interdependency. Government intervention that somehow induced one or more of these key players to invest in security could have the effect of "tipping" the model in toward the favorable, high-security equilibrium, at modest costs to society.

The contribution from Heal and Kunreuther highlights the fact that, in addition to physical systems, the idea of resiliency can be applied to the behavioral responses of humans and economic institutions. Even in the simple model that they describe, individual choices lead to surprising, system-wide consequences. The chapter also foreshadows some of the challenges that await researchers aiming to develop operational models of these types of responses.

The chapter authored by Adam Rose focuses on the prospects for developing quantitative models of the general equilibrium implications of terrorist attacks via computable general equilibrium (CGE) techniques. Rose also explicitly invokes the idea of resiliency. In his framework, the substitution possibilities embedded in the sectoral production technologies described by typical CGE models embody one type of resiliency. The more substitutable factors of production are, the less severe the consequences of an exogenous shock to the supply of any one of these factors.

A bolder proposition is Rose's idea to measure the implications of "adaptive resiliency," the idea being that the technology of production changes *in response* to a disaster. Firms and consumers become more resourceful in the wake of a terrorist attack. Rose proposes using differences between the activity levels in various sectors of the economy predicted by the CGE model in response to a disaster event, and empirical estimates of output reductions collected after the fact, to recalibrate the parameters of CGE model. If actual gaps are smaller than predicted gaps, the author designates this as the impact of adaptive resiliency.

There is a simple but important difficulty with this approach that the author only briefly ac-

knowledges. Defining adaptive resiliency as the residual error on the predictions of CGE model scenarios makes resiliency indistinguishable from simple measurement or model-specification error. This alone calls into question the viability of the technique. Nevertheless, the focus on developing operational models that depict responses richer than those described by the substitution implications of nested-CES production functions is well placed. The search for a technique that is both satisfying to economic intuition and implementable continues.

Along these lines, a consistent treatment for characterizing public goods within CGE models is also a pressing need. As the Heal and Kunreuther chapter illustrates, both terrorism prevention measures and the impacts of attacks exhibit aspects of nonrivalry and nonexcludability. These outcomes are undoubtedly connected to the markets that are the focus of general equilibrium analysis but describing the connections between public and private goods has not been a priority of CGE models to date.

More generally, the interaction between public policies designed to improve resiliency and the scope of individuals to take measures to self-protect must be considered a key factor in the evaluation of proposed policies. How does the equilibrium level of resilience respond to public measures to increase protection from terrorist attacks? How do we, as economic modelers, describe the availability of backstop technologies? And how does government intervention promote the availability of these goods?

Designing resiliency into the physical system upon which society relies and into the economic system itself as an operational objective seems sensible if the impacts of terrorist attacks are truly catastrophic in the sense that they should be avoided at all cost. But if there is a sense in which we can weigh the costs and benefits of an attack, then resiliency as a policy objective becomes more problematic. Is designing New Orleans to be resilient to flood events a good idea when maintaining it unnecessarily exposes us to danger? Perhaps not. And is the death of a city really catastrophic in the terms described above? Perhaps not. Hurricane Katrina could be viewed as an opportunity — a clean slate on which to start again.

*The Economic Impacts of Terrorist Attacks* exposes the reader to a healthy sampling of the current approaches that researchers have taken in addressing a challenging set of economic prob-

lems. Terrorism fits into the theory of public economics in some respects, but its catastrophic consequences combined with layers of uncertainty make it an area of research with no shortage of unprobed questions.