

Advances in Economic Consequence Analysis of Terrorism Events

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1. Overview

Progress in these economics analysis projects included the following:

- Further development and application of a comprehensive framework for analyzing the economic consequences of terrorist attacks, with an emphasis on resilience and behavioral linkages. The framework was applied to several types of bioterrorist attacks. A presentation was made at a DHS Workshop on Benefits Estimation for the purpose of helping DHS staff develop a template for benefit-cost analysis of new regulations. A paper was accepted for publication in the *Journal of Homeland Security and Emergency Management*.
- A new initiative was the creation of the CREATE Terrorist Economic Impact Forum, which is a consensus modeling approach to arrive at definitive estimates. The subject of the first TIEMF was the 2001 Terrorist Attacks on the World Trade Center. The project consisted of 8 nationally recognized research teams undertaking this study in parallel using the same assumptions and data but different methodologies. Preliminary findings indicate the impacts on the Gross Domestic Product of the United States were somewhere between \$40 and \$120 billion. Potentially large business interruption losses were reduced by around 75% because of resilience actions, most prominently the rapid relocation of World Trade Center Area tenants to other locations, primarily in the New York Metro Area. The largest impacts, even after adjusting for on-going recessionary trends, were an almost 2-year reduction in air travel and associated tourism due to the general public’s fear of flying in the aftermath of 9/11. Two sessions were organized for the presentation of the results at the North American Regional Science Association meetings, and plans are underway for publication as a special issue of a major journal.
- A conceptual advance was made on a major source of resilience—production rescheduling (recapture factor)—by developing a model that measures its potential based on the extent of business damage

"This research was supported by the United States Department of Homeland Security through the Center for Risk and Economic Analysis of Terrorism Events (CREATE) under grant number 2007-ST-061-000001. However, any opinions, findings, and conclusions or recommendations in this document are those of the authors and do not necessarily reflect views of the United States Department of Homeland Security."

and the speed of recovery. Empirical work included the measurement of reduced business interruption (BI) following 9/11 due to business relocation.

- Advances were made in computable general equilibrium (CGE) modeling by methods to constrain several sectors simultaneously to reflect reduced production capacity resulting from a terrorist attack. The models were applied to estimating the BI impacts of bioterrorism and to the World Trade Center Attacks.
- Research overlapping with an NSF grant developed a base for the economic analysis of risk perception reactions following a terrorist attack. The bounded rationality framework will address behavioral responses, such as the “fear factor.” Modified utility and production functions will be incorporated into a CGE model to determine how these responses cascade throughout the economy.

2. Research Accomplishments

2.1. Development of a Comprehensive Framework for Economic Consequence Analysis: Application to Bioterrorism

CREATE researchers continued to develop and apply a framework for the analysis of the economic consequences of bioterrorist attacks and how it has been made operational. Figure 1 provides an overview. Standard economic loss estimation until recently has begun with Target Specific (Direct) Economic Impacts and Loss of Life. Direct Remediation costs should be inserted into the analysis at this stage, in part because they, along with the two more standard types of direct impacts, are subject to indirect effects (often referred to as multiplier, general equilibrium, or macroeconomic effects at increasingly higher levels of modeling sophistication). Resilience adjustments have the effect of lowering direct business interruption (BI). Extended Linkages have the potential to significantly increase BI; it is also likely to be offset somewhat by Resilience. Both of these new categories of impacts are likely to be enhanced by multiplier effects as well. The sum of all these positive and negative components yields a bottom-line estimate of Total Economic Impacts.

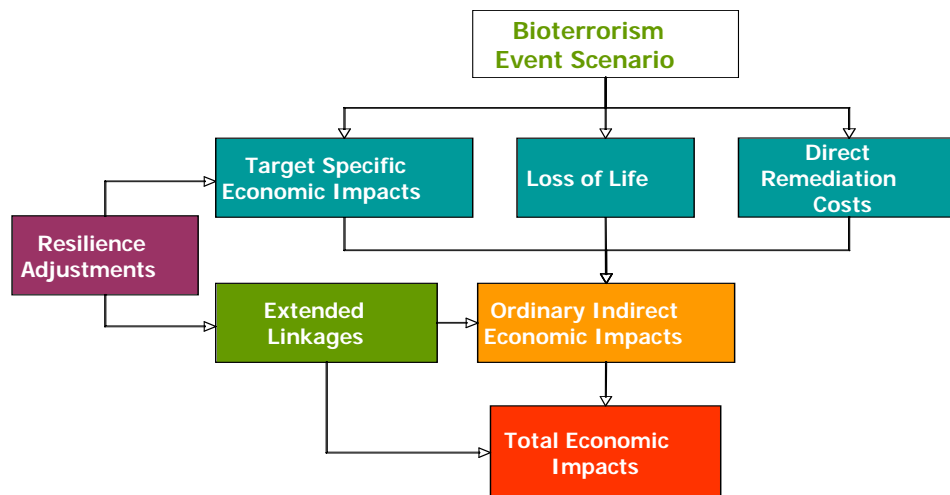


Figure 1. Analytical Framework Overview

CREATE continues to lead in developing the capability to estimate the aggregate and spatial economic impacts of terrorist attacks. The results for the application of the framework to 6 types of terrorist attacks

are summarized in Table 1. The first four results of the table were estimated with an input-output (I-O) model by the team of Gordon, Richardson and Moore, and the latter two with a computable general equilibrium (CGE) model by our research team. Losses are divided according to major impact categories. The influence of remediation of the attack is not included, since it is likely to be highly variable even within an individual attack category, given the bioterrorist agent, as well as being highly dependent on public policy decisions regarding timing and safety levels.

TABLE 1. SUMMARY OF ECONOMIC CONSEQUENCES OF BIOTERRORIST ATTACKS EXPRESSED IN TERMS OF GROSS OUTPUT (SALES REVENUE) LOSSES (in billions of 2007 dollars)

Type of Attack	Loss of Life	Ordinary BI	Extended Linkage	Resilience	Total ^a
Stadium	-57.2	-0.5	-16.2	8.5	-65.4
Urban Center	-2.2	-8.2	^b	4.4	6.0
Airport	-1.0	^c	-440.0	119.5 ^c	-321.5
Lettuce	-.054	-.024 ^e	^b	^e	-.078
Foot & Mouth	^c	-46.2	^b	4.2	-42.0
Water Service	^b	-27.3	-2.6	26.7	3.2

^aTotal does not include stimulus from remediation.

^bNot measured

^cLess than \$100 million.

^dRecent estimate added to the analysis.

^eResilience is considered to offset domestic consumption, such that ordinary BI estimates represent only the decrease in export sales.

In examining these results, one is immediately struck by huge variability across targets and impact categories. A brief summary of the results indicates:

- Stadium Attack. This results in limited property damage, but a potentially huge loss of life because of the crowding of people in a confined location. BI is small because it involves loss of activity in a single venue. Future sporting events can be moved to other locations. Extended linkages are large because fear of similar attacks reduces attendance elsewhere. At the same time, resilience is significant, as people substitute other leisure activities for sporting events.
- Urban Center Attack. This is less likely to have a concentrated impact on people as the previous case, but will have a relatively larger impact on ordinary BI, though this effect is significantly offset by business relocation and other resilience measures.
- Airport Attack. This would result in a limited loss of life and property damage, as well as BI in terms of lost flights for a short duration. However, as in the case of the September 11 attacks, it could lead to a fear factor that causes people to avoid air travel and hence related tourist or business-trip activity (the airline industry did not recover after 9/11 for almost two years).
- An Attack on the Lettuce Crop. This would cause a minimal loss of life because the population would be much less concentrated than in the other cases and because health warnings would be quickly issued. Also, there are ready substitutes for lettuce.

- A Foot and Mouth Disease Attack. This would lead to minimal loss of life, but sizeable BI reductions from the slaughtering of animals and decrease of exports sales. Resilience would be significant in terms of the increase in consumption of chicken and fish as substitutes.
- Municipal Water System Attack. This would likely cause minimal loss of life (except perhaps in an anthrax case). BI would be sizeable and extensive linkages would be significant through the shutdown of neighboring water systems for testing. Resilience would be especially large because of the likely short duration of the event and the strength of the resilient actions, such as production rescheduling. The fear factor would be small because it would likely only include the very brief shutdown of facilities in adjacent areas.

The variations in the results can be summarized in the following categories of explanations:

- Strength of the attack agent
- Concentration of people and their ability to escape
- Vulnerability/security of the target
- Duration of the event
- Fear of replication on this or related targets
- Perceived ability to mitigate future attacks
- Resilience (relocation, substitution, rescheduling, etc.)

The case studies yield some insight into the relative economic severity of various types of bioterrorism attacks. It helps demonstrate that several components of the impacts having the greatest influence are behavioral rather than technical. This should help policymakers pinpoint strategies for reducing losses from bioterrorism.

2.2. Terrorist Economic Impact Modeling Forum

CREATE began a new initiative in 2008 called the Economic Impact Modeling Forum (EIMF). Its objective is to improve economic modeling in the terrorist field and to generate reliable estimates of the consequences of actual or potential terrorist attacks. EIMF is patterned after the twenty-five year successful experience of the Stanford Energy Modeling Forum (EMF). It convenes several modeling teams to analyze a common topic, with the intent of arriving at a narrow bound of estimates.

At the request of DHS, CREATE chose as its topic for 2008, the economic impact of the 2001 terrorists attacks on the World Trade Center. We identified the following leading analysts and modelers:

- Federal Reserve Bank of New York, which performed some of the earliest research on 9/11.
- Regional Economic Models, Inc. (REMI), which has developed the leading off-the-shelf econometric models at the local, state and regional levels.
- Risk Management Solutions (RMS), Inc., which is a leader in risk analysis and in casualty and loss estimation.
- University of Maryland Inforum, a leading provider of economic forecasts using a combination of input-output and econometric models.
- Brock Blomberg of Claremont University, a leading macroeconomist and terrorist expert (and CREATE affiliate), who has developed a unique time series approach to measuring the economic impacts of terrorism.
- Bryan Roberts of DHS, who is developing a consensus of forecasts approach.
- Peter Gordon, Harry Richardson, and James Moore and their research team, of CREATE and USC, who are developing both time series and input-output modeling approaches.

- Adam Rose and his research team, of USC and CREATE, who developed a computable general equilibrium (CGE) modeling approach.

The project involves a research process and the following steps:

1. Convene the group to agree on the topic, scope, data and assumptions.
2. Meet to discuss preliminary results and examine consistency of scope, data and assumptions, as well as to suggest modeling improvements.
3. Meet to narrow the range of estimates and to discuss further refinements.
4. Present the results at professional meetings to obtain feedback.
5. Publish the results to disseminate the findings to professional and lay audiences.

The 2008 EIMF completed the first three steps by September and presented the initial findings at the North American Regional Council Meetings in November in New York City. This organization is a leader in research and practice on economic impact analysis. Preliminary findings indicate the impacts on the Gross Domestic Product of the United States were somewhere between \$40 and \$120 billion. Potentially large business interruption losses were reduced by around 75% because of resilience actions, most prominently the rapid relocation of World Trade Center Area tenants to other locations, primarily in the New York Metro Area. The largest impacts, even after adjusting for on-going recessionary trends, were do to an almost 2-year reduction in air travel and associated tourism due to the general public's fear of flying in the aftermath of 9/11.

2.3. Measuring Economic Resilience to Terrorism

Economic resilience refers to the ability to reduce the negative economic consequences of terrorism after the event takes place by utilizing remaining resources as efficiently as possible and speeding the time to recovery. CREATE researchers have pioneered the conceptual and empirical advances in this field. This year we made progress on several conceptual and empirical fronts.

We developed a formal model of production rescheduling, which refers to the ability of businesses to make up lost production by running their operations over time after recovery has begun. Previous studies have indicated that production rescheduling can reduce these losses by more than 90 percent in many sectors for short-term terrorist disruptions. This response has significantly more potential in cases of terrorism than in natural disasters when the former are targeted to one segment of the economy (e.g., electricity or communication systems) because the remainder of the economy is unscathed, and readily start up after the target is repaired or restored. The model takes into account the type of shock to the system, business, extent of loss, duration of outage and special factors affecting the ability to make up lost production (see Figure 2).

We began research on developing an economy-wide model of supply chain management. Thus far, supply chain analysis has been confined to a narrow set of sectors, but this approach attempts to analyze interactions across the entire economy to identify all of the potential bottlenecks, as well as the opportunities for inventory pooling, substitution and other ways to overcome them.

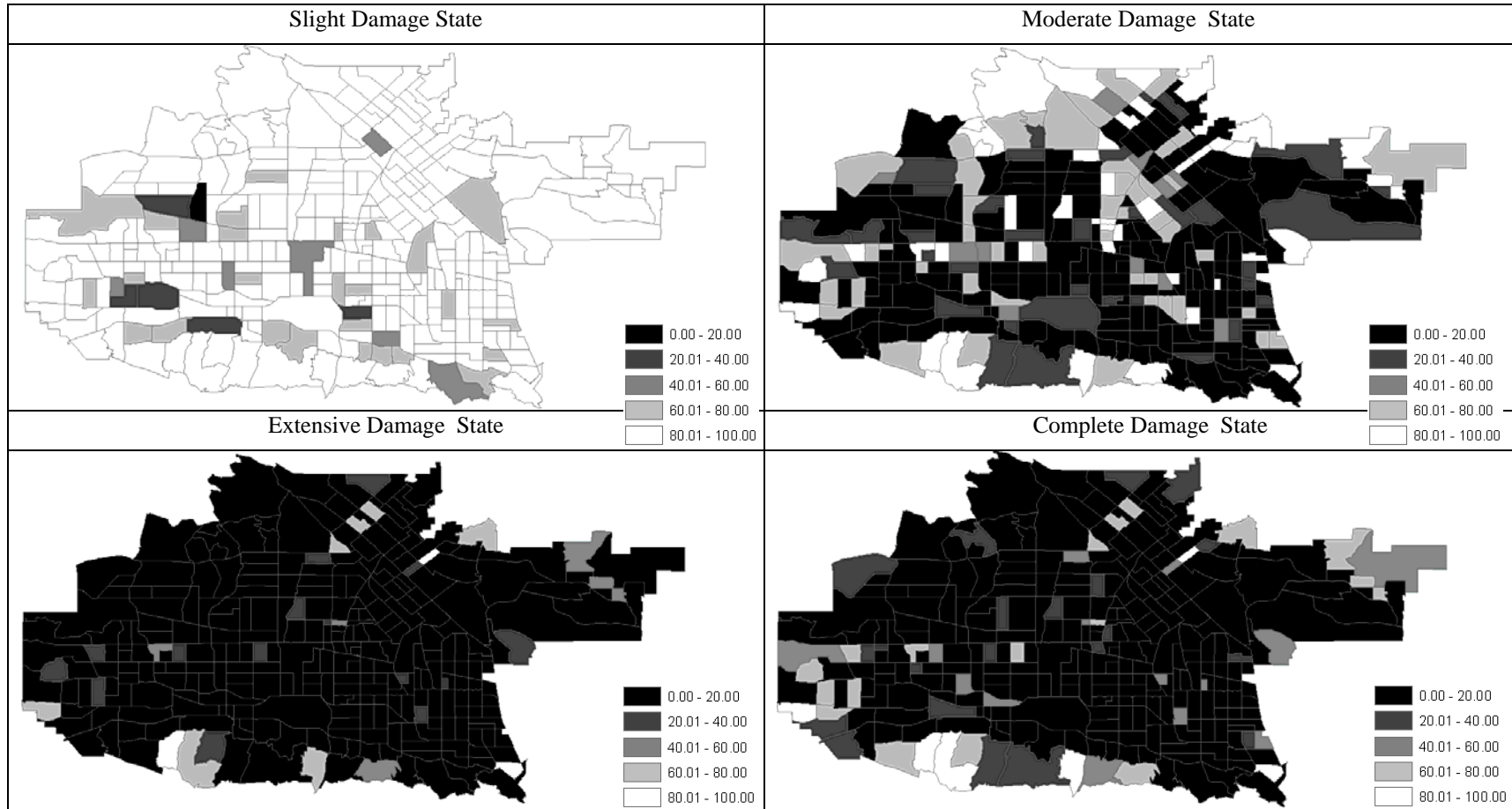


Figure 2. Regional Distribution of Recapture Factor by Damage State for the Retail Trade Sector of the Los Angeles Economy: Estimates from General Recapture Factor Model (percent production recapture per census tract)

We analyzed the ability of relocation to reduce losses in the case of the September 11 attacks on the World Trade Center. Less than 2 percent of the businesses in the area failed, and the remainder relocated within the U.S., the vast majority in the New York Metro Area. Business interruption still ensued because the relocation was not immediate. A sampling of firms, however, indicated that all of them were relocated within eight months. Adjustments for the lag in relocation resulted in business being interrupted by 28 percent of its annual potential in the aftermath of 9/11.

The market system represents a major source of resilience. Prices provide signals about the value of goods, and this becomes especially important when critical inputs are in short supply in the aftermath of a terrorist event or natural disaster. Simulations were undertaken for a disruption to the Los Angeles County water supply to determine what price increases would clear the market. Results indicate that only small price increases would be needed for low levels of disruption, but that a significant price rise would be needed for a major disruption.

2.4. Economic Impact and Resilience Modeling and Analysis with Computable General Equilibrium (CGE) Models

This past year CREATE economists advanced the CGE methodology for application to bioterrorism. This included creating templates for the identification of key variables and parameters that would be affected by such attacks, and the development of algorithms to incorporate multiple constraints into the model to reflect damage to the capital stock of multiple sectors, as in the case of an urban center attack. The team also applied an enhanced methodology to three case studies to illustrate the workings of the modeling approach and the relative influence of several types of resilience and major types of extended linkages.

2.5. Behavioral Impacts of Terrorist Attacks: Bounded Rationality Analysis of the Fear Factor

This research develops a bounded rationality framework to analyze extreme behavioral reactions to catastrophic risk, calibrate production and utility functions to data collected by other CREATE researchers, generate estimates of the range of behavioral linkages such as the “fear factor,” apply the model to various case studies, and transfer the modeling capability to other researchers and DHS staff. The economic impacts of many terrorist attacks extend far beyond the usual direct and indirect impacts. One area of negative impacts that can be as many as two or three orders of magnitude greater than the direct effects is *behavioral linkages*, such as the “fear factor.” This stems from the social amplification of risk, where media attention and individual and social psychological responses cause people to over-react to an event. This study will translate the research by others at CREATE, as well as data and insights collected by DHS staff, into a formal economic modeling framework. It begins with individual decision functions of producers and consumers in the context of bounded rationality. These utility and production functions will then be inserted into a computable general equilibrium model in order to ascertain indirect market effects.

Work on the project overlaps with that of an NSF Human Social Dynamics grant to Burns, Slovic, and Rose, co-PIs; Asay, co-investigator. Progress has been made on both projects in terms of the development of conceptual framework for decision-making by producers and consumers in light of factors influencing their perceptions in the face of disasters (e.g., changes in risk aversion and decision time horizons). A questionnaire has been circulated by Burns and Asay to test hypotheses about behavioral responses. CREATE post-docs and graduate assistants have been trained to construct computable general equilibrium (CGE) models to be used to estimate the total economic impacts of risk amplification.

3. Practical Relevance

3.1. CREATE Economic Impact Modeling Forum

The CREATE EIMF 9/11 project will provide a definitive estimate of the economic impacts of the September 11 attacks on the World Trade Center. This will be key to calibrating benefits of terrorism mitigation strategies, since estimates of avoided economic losses represent the benefits side of the ledger. The EIMF estimates a broad range of impacts, including direct and indirect business interruption, adjustments for resilience, and adjustments for behavioral linkages such as the "fear factor." Omission of these latter two considerations is likely to greatly influence the consequences of major terrorism events. For example, we found that more than 95 percent of the businesses in the World Trade Center area did not fail, but relocated in the New York Metropolitan Region, thereby significantly muting the direct impacts. On the other hand, the significant reduction in airline travel and related tourism for nearly two years following the 9/11 attacks generated losses in the tens of billions of dollars, and turned out to be the major influence on the bottom line. The results indicate that there is significant inherent and adaptive resilience potential in the U.S. economy on the one hand, but that DHS steps to quell fears in the aftermath of an event can have the potential to avoid sizeable losses.

3.2. Measuring Economic Resilience to Terrorism

Resilience represents a relatively low cost approach to reducing losses of terrorism. For example, conservation can more than pay for itself, and production rescheduling usually only requires payment of overtime wages. Measuring the effectiveness of resilience can be combined with assessments of its cost in order to perform benefit-cost analyses of this strategy, as is typically done for mitigation. In fact, the ideal approach is to combine both strategies in the analysis and to determine the optimal mix.

3.3. Behavioral Impacts of Terrorist Attacks: Bounded Rationality Analysis of the Fear Factor

This research links the analysis of risk perception, experimental methods, microeconomic analysis, and economy-wide modeling in a system to measure the economic consequences of the social amplification of risk. It thus will enable researchers and practitioners to improve their estimation of a major source of economic losses that is most unique to terrorism. In contrast to natural hazards, and technological accidents, terrorism is perceived as being spawned by an active, evil enemy that is more likely to strike sooner than later.

4. Collaborative Projects

Adam Rose coordinated the DHS Integrated Network of Centers (INC) Project on Advances in Economic Resilience. This involved his own research, that of the Gordon/Richardson/Moore team, and teams at 4 other University Centers and TSA. Conceptual and empirical advances of the group will be integrated into an overall modeling framework

Adam Rose, in collaboration with Peter Gordon, Jim Moore and a research team at Battelle Memorial Institute, as well as post-doc Bumsoo Lee, were involved in a collaborative research project for the National Bioterrorism and Countermeasure Center (NBACC), which was completed in 2008. This research involved assisting NBACC in developing a broad conceptual framework for economic consequence analysis and then implementing a portion of it in a computerized system. Advances were also made in developing a state of the art approach using computable general equilibrium analysis.

Adam Rose performed the economic impact analysis for the U.S. Geological Survey scenario of a 7.8 magnitude Southern California earthquake for the Great Southern California ShakeOut Exercise, a combined research and role playing exercise. The results were used to highlight the potential threat of such an event, as well as to help develop strategies to reduce losses through resilience.

Adam Rose and Bumsoo Lee performed the economic loss estimation for a project led by Vicki Bier and funded by the Wisconsin Department of Health and Family Services. This is part of a decision support system for pandemic planning focusing on aggregate and socioeconomic impacts.

Adam Rose served as a co-leader on a new initiative at USC on Megacities. This refers to population centers of unprecedented size that may collapse under their own weight of crowding, congestion, contagion, and pollution, as well as their high vulnerability to external shocks like terrorist attacks and natural hazards. He was co-organizer of a major Workshop that included presentations on these threats.

We established a working relationship with the Center for Policy Studies (CoPS) at Monash University in Australia. This is one of the world’s leading research centers on computable general equilibrium analysis. Its director, Peter Dixon, has recently been funded by DHS and other U.S. government agencies to apply these models to issues relating to terrorism. The collaboration will enhance CREATE’s capabilities in this modeling area.

5. Research Products

Research Products (Please detail below)		#
5a	# of peer-reviewed journal reports published	1
5a	# of peer-reviewed journal reports accepted for publication	2
5a	# of non-peer reviewed publications and reports	4
5a	# of scholarly journal citations of published reports	
5b	# of scholarly presentations (conferences, workshops, seminars)	9
5b	# of outreach presentations (non-technical groups, general public)	2
5c	# of products delivered to DHS, other Federal agencies, or State/Local	
5c	# of patents filed	
5c	# of patents issued	
5c	# of products in commercialization pipeline (products not yet to market)	
5c	# of products introduced to market	

5.1. Publications and Reports

	Ref	Not Ref
1. Rose, A., Asay, G., Wei, D., Leung, B., “Economic Impacts of a Complete Border Shut-Down in Response to a Terrorist Attack,” <i>International Business and Terrorism</i> , Richardson, H., Gordon, P., Moore, J. (eds.) Cheltenham, UK: Edward Elgar, forthcoming 2009		x
2. Rose, A., “A Framework for Analyzing and Estimating the Total Economic Impacts of Natural Disasters and Terrorist Attacks,” accepted for publication in the <i>Journal of Homeland Security and Emergency Management</i>	x	
3. Godschalk, D., Rose, A., Mittler, E., Porter, K., West, C., “Estimating the Value of Foresight: Aggregate Analysis of Natural Hazard Benefits and Costs,” <i>Journal of</i>	x	

	<i>Environmental Planning and Management</i> , forthcoming		
4.	Wein, A., Rose, A., "Regional Economic Consequences," Chapter 7 in Jones, L. et al, <i>The Shake Out Earthquake Scenario</i> , U.S. Geological Survey Circular, 2008		x
5.	Rose, A., Oladosu, G., "Regional Economic Impacts of Natural and Man-Made Hazards: Disrupting Utility Lifeline Services to Households," <i>Natural Disaster Analysis after Hurricane Katrina: Risk Assessment, Economic Impacts and Social Implications</i> , Richardson, H., Gordon, P., Moore II, J. (eds.) Cheltenham, UK: Edward Elga, 2008		x
6.	Rose, A., "Macroeconomic Modeling Impacts of Catastrophic Events," <i>Risking Housing and Home: Disasters, Cities, Public Policy</i> , Quigley, J., Rosenthal, L. (eds.) Berkeley Public Policy Press, 151-75, 2008		x
7.	Rose, A., "Regional Economic Analysis of Earthquake Losses, Mitigation, and Resilience," <i>5th American Waterworks Association Water System Seismic Conference</i> , AWWA, 2007		x
8.	Rose, A., Oladosu, G., Liao, S., "Regional Economic Impacts of a Terrorist Attack on the Water System of Los Angeles: A Computable General Disequilibrium Analysis," <i>Economic Costs and Consequences of a Terrorist Attack</i> , Richardson, H., Gordon, P., Moore II, J. (eds.) Cheltenham, UK: Edward Elgar, 291-316, 2007		x

5.2. Presentations

Conferences

- Rose, A., Wei, D., "Regional Economic Impacts of the Shake Out Earthquake Scenario," invited seminar presentation, School of Policy, Planning, and Development, USC, Los Angeles, CA, October 2008
- Rose, A., "Economic Consequences of Terrorism: Behavioral Considerations in a Computable General Equilibrium Framework," invited presentation for CREATE workshop, *Behavioral Economics and Terrorism*, August 2008, USC, Los Angeles, CA
- Rose, A., "Social Economic Impacts of Terrorism," invited presentation at the DHS Workshop on community resilience, Arlington, VA, June 2008
- Rose, A., "Bounded Rationality Analysis of the Fear Factor," invited presentation at the DHS Workshop on community resilience, Arlington, VA, June 2008
- Rose, A., "Measuring Economic Resilience," invited presentation at the DHS Workshop on community resilience, Arlington, VA, June 2008
- Rose, A., "Assessing Economic Consequences of Bioterrorist Event," invited presentation at the *Department of Homeland Security University Centers Summit*, Washington, DC, March 2008
- Rose, A., Asay, G., Wei, D., Leung, B., "Economic Impacts of Shutting Down the U.S. Borders in Response to a Security or Health Threat," invited paper presented at the *Western Regional Science Association Conference*, Kona HI, February 2008
- Burns, W., Slovic, B., Asay, G., Rose, A., "Modeling Community Response and Economic Impacts of Risk Amplification Following a Terrorist Strike," contributed paper presented at the *Society for Risk Analysis Annual Meetings*, San Antonio, TX, December 2007
- Rose, A., Asay, G., Wei, D., Leung, B., "Economic Impacts of Shutting Down the U.S. Borders in Response to a Security or Health Threat," contributed paper presented at the *North American Regional Science Council Meeting*, Savannah, GA, November 2007
- Rose, A., "A Framework for Analyzing and Estimating the Total Economic Impacts of a Terrorist Attack," invited paper presented at the DHS Workshop on the quantification of security benefits and regulatory analysis, Washington DC, October 2007

Outreach:

- Rose, A., "Regional Economic Impacts of the Shake Out Earthquake Scenario," invited presentation at the Southern California Association of Governments, Los Angeles, CA, April 2008
- Rose, A., Liao, S., Bonneau, A., "Regional Economic Impacts from Water Service Disruptions in LA: The Verdugo Earthquake Scenario," invited paper presented at the *LADWP/MCEER Workshop on Decision-Support Systems for Risk Management*, Los Angeles, CA, December 2007

5.3. Models, Databases, and Software Tools and Products

The research team has constructed CGE models for the United States, the New York Metropolitan Area, and Los Angeles County that are available to DHS staff. The models can be run using the General Algebraic Modeling System (GAMS) software.

6. Education and Outreach Products

CREATE economists participated in a presentation of their preliminary findings on the EIMF 9/11 project at a workshop at the Homeland Security Institute in July 2008. The workshop was attended by a broad range of DHS staff and consultants. The methods and findings should prove useful in undertaking benefit-cost analysis of mitigation and resilience in other areas.

Detlof von Winterfeldt, Kerry Smith and Adam Rose participated in a Workshop on the Quantification of Security Benefits and Regulatory Analysis, held by the DHS General Counsels Office in October 2007. They presented their work in various areas of risk and consequence analysis. This included an extended framework for economic consequence analysis that includes resilience and economic linkages, as well as the specification of a broad range of economic impact indicators.

Adam Rose made several presentations on economic consequence analysis in general and the regional economic impacts of the 7.8 magnitude Southern California Earthquake to organizations such as the Southern California Association of Governments, Socal First (an organization of local business leaders) and the U.S. Geological Service.

He is assisting the USGS in developing guidelines to improve business resilience to disasters.

Education and Outreach Initiatives (Please detail below)	#
# of students supported (funded by CREATE)	3
# of students involved (funded by CREATE + any other programs)	7
# of students graduated	
# of contacts with DHS, other Federal agencies, or State/Local (committees)	2
# of existing courses modified with new material	1
# of new courses developed	1
# of new certificate programs developed	
# of new degree programs developed	