

**Extended White Paper FY15****Project Title: Economic Consequences of Terroism (3 Integrated Proposals)****Adam Rose (CREATE/USC)**

8/31/14

**Summary description:** This project will continue to enhance, broaden and transition the CREATE Economic Consequence Analysis Framework. It will place a greater emphasis on transforming CREATE’s sophisticated/high performance computing CGE models to “reduced form” regression equations that can readily be used in-house by DHS staff, beginning with the Office of Policy / Strategy, Planning, Analysis and Risk (SPAR). I will continue to explore refinements of the framework to application to cyber threats. Also, I will work with DHS to develop a CREATE capability in Security Economics more broadly.

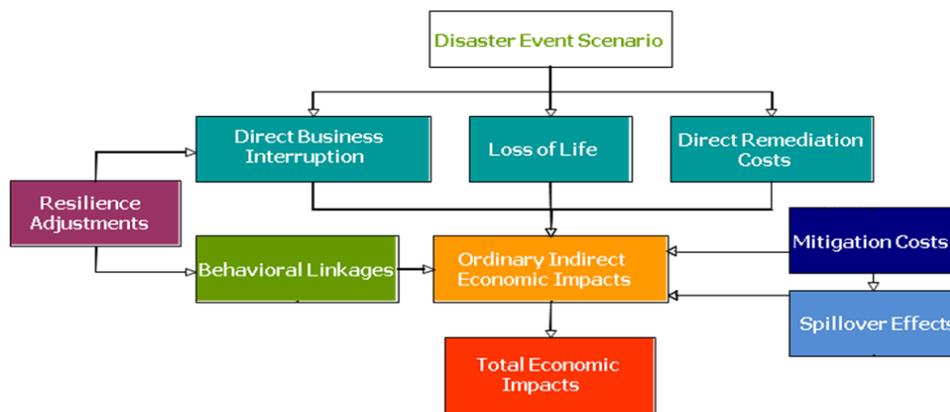
**Keywords:** Economic Consequences, Behavioral Impacts, Resilience, Cyber-Terrorism, Transitioned Models, Enterprise Risk Management, Security Economics

**1. Theme Area:** Economic Consequences Analysis

**2. Principal Investigator:** Adam Rose

**3. Institution:** USC

**4. Co-Investigators:** Peter Dixon, James Giesecke, Dan Wei, Fynn Prager, Nathaniel Heatwole, Zhenhua Chen, Michael Orosz, Sam Chatterjee



**Figure 1. CREATE Economic Consequence Analysis Framework**

### 5. Brief Description: (1 paragraph description)

I propose to continue an integrated body of research on the economic consequences of terrorism and natural hazards. Its objectives are: to advance the state of the art of basic understanding and modeling of key features of the topics, to build operational models, to apply the models to key issues and case studies (including those at the request of DHS), and to help transition the models and findings for use by DHS and others. The research involves 3 sub-projects:

- Advancing the breadth and depth of economic consequence analysis, modeling behavioral responses to and recovery from terrorism events.

- Accelerate research and transition to DHS of E-CAT (Economic Consequence Analysis Tool), a rapidly deployable methodology for obtaining approximate estimates of the consequences major threats. To the economy of the U.S.
- Help develop the new area of National Security Economics for more active CREATE involvement.

## **6. Objectives: (Clear expression of purpose and goals.)**

A. Advance the breadth and depth of economic consequence analysis. This involves the further incorporation into the CREATE economic consequence analysis framework of behavioral responses to terrorism (arising from such factors as risk amplification and stigma) and of resilience (inherent and adaptive ways to build resilience capacity and to mute losses following a disaster). These will be further integrated into various economic models, most notably computable general equilibrium (CGE). Much of this research will be done in collaboration with CREATE affiliates Peter Dixon, Maureen Rimmer, and James Giesecke at Monash University, as well as CREATE affiliates in the Risk Perception area. Another extension of the framework will be to continue research on compound, or cascading, disasters that have especially large consequences, such as the recent earthquake/tsunami/nuclear reactor accident in Japan and potential terrorist threats on interdependent infrastructure, including cyber, which can lead to major economic disruptions in the U.S.

We will also continue to update our suite of economic consequence tools. A priority this year will be to update the USCGE Model from a year 2006 to a year 2013 base.

B. Accelerate development and transition of a rapidly deployable methodology for obtaining approximate estimates of the economic consequences from events listed in the Homeland Security National Risk Characterization (HSNRC) Risk Register. The tool is intended for use by the DHS SPAR, but will likely also be useful to other DHS Components and Offices. CREATE will develop a simple reduced form quick-turn scalable economic modeling analysis tool programmed in Excel and VBA. This tool, E-CAT (Economic Consequence Analysis Tool) will account for the cumulative direct and indirect residual impacts (taking into account resilience and behavioral factors that significantly affect base estimates, as well as risk reduction efforts) to the national economy, businesses, and households from risk events including terrorism, intentional acts, natural disasters, and technological accidents. This will be based on hundreds of CGE simulations of a typology of terrorist attacks with varying parameters relating to size, locations, target, and resilience and behavioral responses. This leverages research being completed for projects for DNDO and NBIC.

An additional area of study will be on developing an economic consequence analysis framework for analyzing supply-chain aspects of cyber terrorism. This will be coordinated with Tony Cheesebrough, chief economist at NPPD.

C. Extend outreach to fellow broader range of economists and potential customers. Help develop the new area of National Security Economics for more active CREATE involvement. This will entail active participation in the new Economics of National Security Association, participation in its conferences at the ASSA meetings and at the NBER and the identification of economists that can become affiliated with CREATE in this area

**7. Interfaces to CREATE Projects: (How will your project integrate with others.)**

I work closely with other researchers in the economic consequence area, as well as coordinating efforts with Howard Kunreuther in the behavioral economics area. Specifically, I work with other CREATE researchers, Peter Dixon, Maureen Rimmer, and James Giesecke to maintain and enhance our suite of economic consequence analysis models, primarily computable general equilibrium and various types of econometric models (including time series and macroeconometric packages such as REMI). The proposed research also interfaces with projects in psychology and decision sciences by USC researchers, Richard John and Heather Rosoff, as well as by Bill Burns (Decision Research).

**8. Previous or current work relevant to the proposed project.**

CREATE researchers continue to develop and apply a framework for the analysis of the economic consequences of terrorist attacks (see Figure 1). The first major extensions were Resilience and Extended Linkages, which greatly affect economic consequences (Rose, 2009a). Resilience adjustments refer to actions that mute the initial shock and that hasten recovery. They have the effect of lowering direct business interruption, a major component of target-specific impacts (Rose, 2009b; Cox et al., 2011). One form of Extended Linkages, Behavioral Linkages refer to extreme behavioral reactions, such as fear of working or shopping in a high risk area, which have can increase impacts by more than order of magnitude (Giesecke et al., 2012; Burns et al., 2013). Current work is being done on the inclusion of Direct Remediation costs, which are likely to be immense for insidious attack agents such as nuke/rad/chem/bio and should be inserted into the analysis at an early stage, in part, because they, along with the two more standard features, are subject to indirect effects (often referred to as multiplier, general equilibrium, or macroeconomic effects). Moreover, we will continue to work on new ways of integrating the implications of mitigation into the framework in conjunction with the Urban Security and Economic Activity Project (Rose and Chatterjee, 2011; Rose et al., 2013). This involves inclusion of direct capital and operating costs of security measures against terrorism. It also includes modeling various spillover effects that might arise, such as delays, inconvenience, and changes in the business environment. These represent increases in costs of business and household activity and will be incorporated into a CGE model as additional input requirements of relevant sectors to determine the overall macro effects. See also progress report below.

The proposed research also leverages advances made on two recent projects by the PI. First is work on reduced-form economic consequence analysis, performed in conjunction with Peter Dixon's team, funded this past year by the Domestic Nuclear Detection Office (DNDO). Second is the development of a Check-List of economic consequence analysis categories and initial estimates for the National Bioterrorism Integration Center (NBIC).

**9. Major Products and Customers: (What are the major products of this effort, and who are the primary clients that are interested in the results.)**

We develop and enhance major economic models, primarily at the macroeconomic level. These models, especially CGE, are complex, as they now include extensive behavioral, dynamic, and interregional elements. These models are used for both in-depth research and quick-response

projects requested by DHS (e.g., on the UCASS and CBP Wait Times projects). They have been found to yield reasonably accurate results (see, e.g., Rose and Blomberg, 2010; Dixon et al., 2011). Our major customers are the 4 agencies listed below for which we began 4 major studies last year and for which continuations are either in place or expected:

- Customs and Border Protection (CBP) Border Wait Times Phases II and III
- CBP Centers of Excellence and Expertise (CEEs) Phases I and II
- Domestic Nuclear Detection Office (DNDO) Modeling the Temporal and Spatial Consequences of Nuclear and Radiological Terrorism Events
- National Biosurveillance Integration Center (NBIC) Develop the Value-of-Information for Biosurveillance Project

The proposed research will put us in a better position to serve agencies like the above and others, such as NPPD. For one, it will enable us to complement our capabilities in macroeconomics with those in micro (individual business and market) level economics.

## **10. Technical Approach: (Detail the technical approach to achieve research objectives.)**

### **A. CGE Modeling.**

We will continue to place a major emphasis on the refinement and application of computable general equilibrium (CGE) analysis. A CGE model is based on the behavioral responses of individual producers and consumers to price signals, subject to constraints on capital, labor, and natural resources. CGE is superior to other multi-sector modeling approaches in numerous ways, including the incorporation of behavioral content, the explicit role of prices and markets, and the flexibility of production technology. In addition, CGE acts as an excellent organizing framework for incorporation of numerous features of the behavior of individual economic agents, the role of mitigation and resilience, and the workings of the overall economy (see, e.g., Dixon et al. 2011; Rose et al., 2014). We will continue to translate changes in risk perceptions measured by other CREATE researchers into changes in CGE model parameters to gauge their economic consequences. We will also continue to develop a bounded rationality framework to facilitate the inclusion of a broader range of behaviors.

The USC team will continue to stand ready to use our suite of tools (CGE, I-O, simulation, and econometrics) to provide DHS with rapid turnaround estimates of economic consequences for special requests. . We will also continue to provide training in the use of these models to DHS staff.

In FY15, we will refine the framework of CGE analysis to analyze supply-chains disruptions. Each sector is modeled both in terms of its own set of direct inputs, as well as its role as an input into other sectors, but the successive rounds of forward and backward supply chain connections can be computed as part of the general equilibrium solution (economy-wide quantity and price interactions). CGE models can also model the acceleration of the recent trend to decrease vulnerability by broadening the supply chain in terms of the alternative suppliers and the use of input substitutes. The work on cyber terrorism, in conjunction with Mike Orosz, will explore how this type of attack cascades throughout the economy.

The proposed research continues a tradition of state of path-breaking work on macroeconomic modeling of terrorism and natural hazards by the PI. This includes the pioneering work on defining economic resilience, deriving operational metrics and incorporating it into CGE models (e.g., Rose, 2009; Rose and Krausmann, 2013). It also includes the measurement of and incorporation of key behavioral considerations such as the social amplification of risk and stigma effects into these models (e.g., Giesecke et al., 2012).

CREATE is the “go-to place” for high-level macroeconomic consequence analyses. We have also transitioned several products, both practical tools such as a RAMCAP economic consequence module for water system disruptions, and complex tools for high level accurate analyses, such as our U.S. CGE model. We have more in the pipeline. Moreover, we have provided tech support in the use of these models and are in the process of expanding our broader training efforts.

## **B. Reduced Form Modeling.**

CREATE will analyze terrorism scenario sets to identify a small number of spanning scenarios that address the important dimensions of economic consequences. Several paradigms will be identified to classify thousands of scenarios into a manageable number of cases. Characteristics used to distinguish cases will be identified as part of this analysis and may include type of attack, size of attack, size of population affected, timing of quarantine and remediation, and other major factors. We will first identify planned sensitivity or uncertainty analyses that will be performed on the paradigm cases. Sensitivity analyses may involve critical input parameters (e.g., type and magnitude of attack, location) or CGE parameters (e.g., temporal length, spatial extent, or effectiveness of resilience). We will then develop a methodology for running hundreds of CGE simulations for the paradigm cases and developing reduced form estimating equations for major attack types that DHS can apply to the larger scenario sets to estimate time profiles and/or cascading consequences for the individual scenarios.

This work will leverage the on-going CREATE research for DNDO on analyzing the duration and time-path of rad/nuke events and for OHA/NBIC on broadening its range of impacts. It builds upon prior work on developing a reduced form model to predict the economic consequences of earthquakes and reduced form modeling for DNDO. It will also build on the UCASS Project, where CREATE developed a user-friendly spreadsheet program to facilitate the performance of ECA (Rose et al., 2014). CREATE’s E-CAT will provide probability distributions, belief functions, or interval estimates for economic consequence estimates. CREATE will also offer a four-hour short course for DHS staff (ideally onsite with DHS personnel) and help advance the process of harmonization of modeling of economic impacts for various risk assessments. PLCY/SPAR and S&T Office of University Programs (OUP) will help tailor and shape the course materials for offering to a broader DHS risk analyst community.

We will also explore computational science approaches that could combine state of the art in economics / CGE + computer science / high performance computing & big data analytics. This might lead to a fielded tool / web portal (open source) tool for shared high performance computing of rapid approximate CGE models. We will explore the use of the COIN-OR (2013) business model. This work will be done in conjunction with Peter Dixon’s CoPS team, which has pioneered many computational advances in CGE modeling.

**C. Extended Outreach to Customers and National Security Economics**

I will work with CREATE Economics Coordinator, Scott Farrow, to help develop the new area of National Security Economics for more active CREATE involvement. This will entail active participation in the new Economics of National Security Association and the identification of economists that can become affiliated with CREATE in this area. Potential topic areas include: the terrorist production function and supply chain, financial market implications of terrorism, and economic causes of terrorism.

Outreach will be enhanced by working with NPPD and the new resilience group in S&T. A kick-off event and orientation for potential customers will be held in DC with the coordinating help of CREATE's Dr. Isaac Maya, CREATE Program Manager Gia Harrigan, Economics Coordinator, Scott Farrow.

**References:**

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Rose, A. 2009b. *Economic Resilience to Disasters*, Community and Regional Resilience Institute Report No. 8, Oak Ridge, TN, 2009.

Rose, A. and S. B. Blomberg. 2010. "Total Economic Impacts of a Terrorist Attack: Insights from 9/11," *Peace Economics, Peace Science, and Public Policy* 16(1): Article 2.

Rose, A. and E. Krausmann. 2013. "An Economic Framework for the Development of a Resilience Index for Business Recovery," *International Journal of Disaster Risk Reduction*, 5 (October): 73-83.

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Rose, A., M. Avetisyan and Samrat Chatterjee. 2014. "A Framework for Analyzing the Economic Tradeoffs between Urban Commerce and Security Against Terrorism," *Risk Analysis*, forthcoming.

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## 11. Major Milestones and Dates: (Key progress management steps and schedule)

### Economic Consequence Modeling:

- Milestone 1: Establish a work plan in conjunction with SPAR and S&T OUP by August 15<sup>th</sup>, 2014.
- Milestone 2: Develop a refined checklist of economic consequences integrated across the set of risks DHS faces (e.g., the set of risks covering terrorism, intentional acts, natural disasters, and industrial accidents as described in the HSNRC Risk Register); to include both the HSNRC consequence categories shown in Figure 1, and the NBIC bio-consequences shown in Figure 2 by November 15<sup>th</sup>, 2014.
- Milestone 3: Explore alternative approaches: Check-list populated by entries and bounds from the literature CGE modeling simulations to yield “data” for regression analysis (Date TBD)
- Milestone 4: Incorporate uncertainty into the analysis
- Milestone 5: Develop and finalize a spreadsheet capability by March 31<sup>st</sup>, 2015.
- Milestone 6: Offer a 4-hour short-course (ideally onsite at DHS) on the use of the model, model features, and options for future research and capability development leveraging higher-end approaches by May 30<sup>th</sup>, 2015.

### National Security Economics

Work with DHS and members of Association of National Security Economists to develop this area for CREATE on an on-going basis.

## 13. Budget: One page maximum, summary-level by major categories per your organization’s format.

This research will continue to serve as the major basis of my salary to cover my 50% appointment in CREATE. It will also be used in part to fund, CREATE faculty affiliate Dr. Dan Wei (25% time), a portion of Economics Post-Docs, Fynn Prager, Zhenhua Chen and Nat Heatwole’s time, as well as a graduate research assistant.

## 14. CV: One page maximum

### Current Positions

Research Professor, School of Policy, Planning, and Development, USC	2007-
Faculty Affiliate, Center for Risk and Economic Analysis of Terrorism Events, USC	2005-

### Education

Ph.D. (Economics)	Cornell University	1974
M.A. (Economics)	Cornell University	1972
B.A. (Economics)	University of Utah	1970

### Summary

Dr. Rose’s main research interest is the economics of terrorism and natural disasters, with an emphasis on economic consequence modeling, resilience, and behavioral responses. He has pioneered the refinement of computable general equilibrium analysis for application to these areas. He is working on DHS-sponsored studies on economic consequence analysis of radiological and biological threats, and on the economic impacts of U.S Customs and Border Protection institutions and policies. He recently completed studies sponsored by NSF and DHS analyzing the economic consequences of behavioral reactions to terrorism. He has served on a National Research Council panel on Earthquake Resilience, was the lead researcher on the Multi-Hazard Mitigation Council report to the U.S. Congress on the net benefits of FEMA hazard mitigation grants, coordinated 8 studies to arrive at a definitive estimate of the economic consequences of 9/11, and performed the economic consequence analyses for the USGS major disaster scenarios, including the ShakeOut Earthquake. He was commissioned to write the Community and Regional Resilience Institute Report on Economic Resilience. He also served as a consultant on the original development of HAZUS and on its extension to flood hazard. He serves on the Advisory Board of the National Institute of Building Sciences Multi-Hazard Mitigation Council and as an advisor on disaster resilience to the United Nations Development Programme. Dr. Rose’s other major research area is energy and climate change. He serves on the editorial boards of the *Journal of Integrated Disaster Risk Management*, *Energy Journal*, *Energy Policy*, and *Journal of Regional Science*.

### Sample Publications:

Rose, A., M. Avetisyan and Samrat Chatterjee. 2014. "A Framework for Analyzing the Economic Tradeoffs between Urban Commerce and Security Against Terrorism," *Risk Analysis*, forthcoming.

Heatwole, N., and A. Rose. 2013. "CREATE Reduced Form Economic Consequence Estimating Model: An Application to Property Damage from U.S. Earthquakes," *International Journal of Disaster Risk Science* 4(1): 20-32.

Giesecke, J., W. Burns, A. Barrett, E. Bayrak, A. Rose, P. Slovic and M. Suher. 2012. "Assessment of the Regional Economic Impacts of Catastrophic Events: A CGE Analysis of Resource Loss and Behavioral Effects of a Radiological Dispersion Device Attack Scenario," *Risk Analysis*, 33(4): 583-600.

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Rose, A. 2009. "A Framework for Analyzing and Estimating the Total Economic Impacts of a Terrorist Attack and Natural Disaster," *Journal of Homeland Security and Emergency Management* 6(1): Article 4.

Rose, A. *Economic Resilience to Disasters*. 2009b. Community and Regional Resilience Institute (CARRI) Report #8.

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**Additional Requirement for Current CREATE Projects:  
Please provide a 1-2 page Progress Report according to the format below.**

### **1. Research Accomplishments**

Progress continues on an integrated body of research on the economic consequences of terrorism and natural hazards. Its purposes are to advance the state of the art of basic understanding and modeling of key features of the topics, to build operational models, to apply them to key issues and case studies, and to help transition the models and findings for use by DHS and others.

Progress summarized above and in papers and presentations below.

### **2. Applied Relevance**

CREATE's research during Year 9 has demonstrated our ability to utilize a broad suite of tools to accurately estimate the economic consequences of terrorist attacks and major natural disasters. Our studies have ranged from short turnaround responses to federal government requests for important input to policy decisions, state and local government policy assessments, and contributions to the professional literature. Moreover, these tools are being disseminated broadly, including helping DHS and other government officials understand their usefulness. We look forward to transitioning more of our models to DHS in-house use.

CREATE has clearly demonstrated its ability to measure resilience in a number of contexts. The concept of resilience is in jeopardy of being overused and becoming a vacuous buzzword that will undercut its effectiveness. Our careful analyses and measurement in cases like 9/11 and the London Subway bombings, as well as in several simulation studies, has given it meaning and specificity. Our research results have helped identify it as a very cost-effective approach to reducing losses from terrorism. Moreover, we have been able to fine-tune our analyses to determine the relative potential of various resilience tactics. This will also serve as a solid basis for developing resilience indicators.

### **3. Collaborative Projects**

Continued to stimulate the working relationship CREATE has established with leaders in CGE modeling at Center for Policy Analysis, Victoria University, Australia. This included achieving an agreement on collaboration between CoPS and other CREATE affiliates, and co-authoring papers and reports on such topics as the economic consequences of RDD and chlorine-based terrorist attacks.

PI of CBP contract on the Macroeconomic Impacts of Reduced Wait Times at Border Inspection Stations, in which we worked closely with CBP. Results led to citation of the study in the (successful) CBP appropriations request to Congress.

PI of Domestic Nuclear Detection Office (DNDO) Modeling project on Temporal and Spatial Consequences of Nuclear and Radiological Terrorism Events.

PI of National Biosurveillance Integration Center (NBIC) project to Develop the Value-of-Information for Biosurveillance Project

#### **4. Research Products**

##### **4a. Publications and Reports—Year 10**

Rose, A., M. Avetisyan, and S. Chatterjee. 2014. “A Framework for Analyzing the Economic Tradeoffs between Urban Commerce and Security,” *Risk Analysis*, forthcoming.

Sue Wing, I., A. Rose and A. Wein. “Impacts of the USGS ARkStorm Scenario on the California Economy,” *Natural Hazards Review*, forthcoming.

Roberts, B. A. Rose, N. Heatwole, M. Avetisyan, D. Wei, O. Chan, and I. Maya. “The Impact on the U.S. Economy of Changes in Wait Times at Ports of Entry,” *Transport Policy* 35(2): 162-75.

Rose, A. and E. Krausmann. 2013. “An Economic Framework for the Development of a Resilience Index for Business Recovery,” *International Journal of Disaster Risk Reduction* 5 (October): 73-83.

##### **4b. Conference Presentations—Year 10:**

Avetisyan, M., A. Rose, N. Heatwole, D. Wei and B. Roberts, “The Macroeconomic Impact on the U.S. Economy of Changes in Wait Times at Ports of Entry,” presented at the GTAP Meetings, June 2014.

Rose, A. “Resilient Responses to Catastrophes Impacting Critical Urban Infrastructure,” presented at the Federal Reserve Bank of New York Conference on Managing the Risk of Catastrophes: Protecting Critical Infrastructure in Urban Areas, November 2013.

Rose, A., I. Sue Wing, D. Wei, and A. Wein. “Economic Impacts of a Tsunami Scenario for The California Economy, presented at the North American Regional Science Council Meetings, November 2013.

#### **5. Education and Outreach Products**

**Students sponsored: 7**

**Post-Docs supervised: 3**

**New Course Developed:** Economic Impact Analysis: 24 students (maximum room capacity signed up for Spring 2014).

#### **6. Outreach:**

- Appointed to the National Institute of Building Sciences Multihazard Mitigation Council. The MMC is the guiding organization for the original development and subsequent advances in the FEMA's HAZUS loss estimation tool. Member of its organizing committee for its annual symposium in 2014.

- Served on the Board of Directors of the International Society for Integrated Disaster Risk Management; served on the organizing committee for the Fourth Annual Meeting in the UK in September 2012.
- Developed a working relationship with the Natural Hazards Center at the University of Colorado at Boulder. Its director, Kathleen Tierney and I recently received a major grant from NSF on "Measuring Dynamic Economic Resilience to Disasters."
- Completed a report for the U.S. Geological Survey on the economic impacts of its third major disaster scenario—CA Tsunami
- Served on the board of the Center for Sustainable Cities at USC, which has a major emphasis on disaster research.
- Served on the editorial board of the new *Journal of Integrated Disaster Risk Management*, *Energy Journal*, and *Journal of Regional Science*.

**6. Current Expenditures:** Budget spending is on track.