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Economic Consequences of Terrorism (3 Integrated Proposals)

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Economic Consequences of Terrorism (*3 Integrated Proposals*)

Project Technical Description: This project will continue to enhance, broaden and transition the CREATE Economic Consequence Analysis Framework. I will continue to coordinate and perform research on integrating behavioral considerations and resilience into economic models of an economy impacted by a terrorist attack, and to maintain and upgrade CREATE's suite of economic consequence analysis models. I 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. Also, I will begin a major thrust area on Enterprise Risk Management.

Keywords: Economic Consequences, Behavioral Impacts, Resilience, Cyber-Terrorism, transitioned Models, Enterprise Risk Management

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, Daniel Salazar, Sam Chatterjee, Michael Orosz

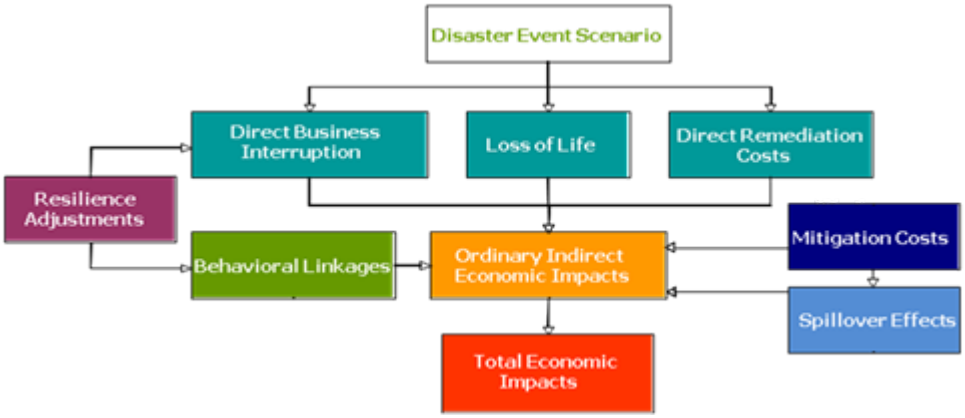

Figure 1. CREATE Economic Consequence Analysis Framework

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 breath and depth of economic consequence analysis, modeling behavioral responses to and recovery from terrorism, and developing a framework for analyzing supply chain aspects of cyber terrorism.
- Accelerate research transition to DHS in several ways, but primarily working with other CREATE modelers to develop "Reduced Form" regression models, based on hundreds of CGE simulations of a typology of terrorist attacks with varying parameters relating to size, locations, target, and residence and behavioral responses.
- Develop the new area of Enterprise Risk Management for national risk assessments and for private sector non-financial services, especially for consequences categories such as brand reputation, quality, market share, profitability, global environmental sustainability, etc.

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 at Monash University, as well as CREATE affiliates in the Risk Perception area. A major application of the framework will be to continue research on compound, or cascading, disasters that have especially large consequences, such as the recent events in Japan and potential terrorist threats on interdependent infrastructure, including cyber, which can lead to major economic disruptions.

B. Modeling Behavioral Responses to Terrorism and Their Economic Impacts. This research will continue the collaboration with CREATE researchers in psychology and decision sciences. Together with economic affiliates at Monash University, we will translate experimental and survey findings on the social amplification of risk and stigma effects into changes in economic behavior. For example, after a terrorist attack using an insidious agent such as radiological, chemical or biological material, workers and investors are likely to require a premium to return to the affected area, while shoppers and tourists are likely to require a discount to return as well. These are incorporated into a CGE model to estimate the direct and indirect economic impacts. In Year 10, we will work closely with Bill Burns and his research team on translating his survey estimates of alterations in risk perceptions into parameters of a CGE model. We will also more closely examine the nature and length of stigma effects. In addition, we will work closely with James Giesecke and Peter Dixon on adapting their approach to modeling the effects of fear on the well-being of a population affected by a terrorist attack. This aspect will be collaborative research with USC and Monash researchers.

C. Modeling Supply-Chain Impacts and Resilience, with special application to cyber threats. The CREATE economic consequence methodology is especially relevant to modeling supply-chain aspects of terrorism. Computable general equilibrium (CGE) analysis essentially portrays the economy as a set of interconnected supply chains. 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). On valuable refinement of the methodology will be geared to the application to analyzing the total economic consequences of a successful cyber attack on a key manufacturing component (e.g., semi-conductors) and a key type of infrastructure (e.g., electricity).

7. Interfaces to CREATE Projects:

As coordinator for economics at CREATE, 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, James Giesecke, and Brock Blomberg, 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 Bill Burns (Decision Research), as well as USC researchers, Richard John and Heather Rosoff.

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 major extensions are 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). For example, Direct Remediation costs 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 overall effect on the economy.

During Year 9, I performed an economic consequence analyses for major water service companies in Los Angeles County for a disruption of their major source of water supplies (the California Aqueduct), factoring in several major types of resilience (Rose et al., 2012). I also completed the macroeconomic analysis of cost, benefits, and spillovers of enhanced security for the UCASS Project on the tradeoffs between urban commerce and security (Hora et al., 2013; Rose et al., 2013). I led the study of the macroeconomic consequences of changes in wait times at border inspection crossings for Customs and Border Protection (Roberts et al., 2013). I also contributed to the development of a methodology and its application to the evaluation of the regional and national economic impacts of a major tsunami event that would potentially affect Southern California for the U.S. Geological Survey (Sue Wing et al., 2013), extending recent work on port impacts for the U.S. Coast Guard (Rose and Wei, 2012). Finally, I developed a methodology for analyzing supply chain consequences of terrorist attacks, again factoring in resilience, for application to cyber terrorism (Rose, 2013) and for the purpose of estimating losses for actuarial tables for contingent business interruption insurance (Rose and Huyck, 2012).

Nat Heatwole and I also developed a successful pilot for rapidly estimating the economic losses from natural hazards (Heatwole and Rose, 2012a). A practical and user-friendly software tool was also developed for a FEMA demonstration conference (Heatwole and Rose, 2012b). In year 10, we will explore extending the analysis to terrorism events as well.

9. Major Products and Customers:

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., this past year 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). This past year, we continued to provide CGE technical support to Tony Cheesbrough's group in the Policy Office on the use of our U.S. CGE model, which we transferred to them. We have also encouraged DHS staff to develop a working relationship with Peter Dixon to transition his dynamic CGE Model of the U.S. to his group and to have them take Dixon's short course on the use of the model.

Our reduced form loss estimation model should be of great use to FEMA and state and local emergency management agencies. We intend to pursue external funding to extend it beyond our pilot analysis for earthquakes to other types of natural hazards and to terrorism.

10. Technical Approach:

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., 2013). 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 continue to contribute to larger team efforts, such as PortSec. We will also continue to provide training in the use of these models to DHS staff.

In Year 10, 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 data on supply chains in CGE models stem from exploiting data bases of the U.S. Bureau of the Census and U. S. Bureau of Economic Analysis. The former agency collects detailed information on a semi-decadal basis from all sub-sectors of manufacturing, as well as all firms in several other sectors. This includes data on purchases of inputs for production processes and sales of products to other firms. The latter agency refines and aggregates the data into "input-output tables." Each column of the table represents the direct input to a sector's production process. Various mathematical manipulations (typically matrix inversion or power series expansions in the case of I-O will be used to identify the successive upstream rounds of indirect inputs from other sectors or downstream rounds of indirect supplies to other sectors. These computations are more complicated in a CGE framework, which requires calculation of a Jacobian matrix of first partial derivatives of the equilibrium solution. The non-linear structure stems in part from the use of neoclassical, as opposed to I-O fixed-coefficient, production functions in the CGE model, which allow for substitution between inputs. Thus, the supply chains are transformed into supply "webs" more characteristic of today's concern about flexibility of supply deliveries. We will illustrate the usefulness of this approach in an application a critical material shortage and to cyber terrorism. The former will utilize insurance company data on contingent business interruption (insurance against supplier or customer actions (Rose and Huyck, 2012). 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). 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). More recently, the

research has been expanded to pioneering econometric analysis of key concepts of consequences, such as estimating the likely number of property foreclosures in the aftermath of an anthrax attack (e.g., Dormady, Szelazek, and Rose, 2013) and developing a rapid consequence analysis estimation tool.

CREATE is becoming the "go to place" for high level macro 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.

The next phase of the research will identify the major components of the economic consequence methodology to be developed for the analysis of terrorist attacks:

- Direct property damage, death, injury, quarantine, remediation: work with DHS
- Direct business interruption: use CREATE method for translating direct physical effects into changes in business operations (Rose, 2013).
- Direct Behavioral effects: in conjunction with DHS, use CREATE methodology for estimating increased wage and investor rate of return demand, shopper discounts and aversion behavior in general (Giesecke et al., 2012)
- Indirect business interruption over time and space: Use Monash computable general equilibrium (CGE) models (e.g., Dixon et al., 2010; Dixon et al., 2013):
  - USAGE (dynamic U.S. CGE model)
  - Multi-Region USAGE (50-state CGE Model)
- Incorporation of resilience: (Rose, 2009b; Rose et al., 2013)

We will also continue to develop a rapid economic impact analysis tool for natural hazards (Heatwole and Rose, 2013). This involves applying regression techniques to refinements of Cutter and Mileti's SHELDUS data base and a set of supplementary variables on hazard characteristics and economic background. The major challenge will be to fill in data on the physical characteristics of individual natural hazard types. This work will primarily be undertaken by a graduate research assistant.

We will work with DHS operating agencies to develop a tool for national risk assessments and for private sector non-financial services, especially for consequences categories such as brand reputation, quality, market share, profitability, global environmental sustainability, etc. The basis of analysis will be the standard Pro-Forma Income Statement analysis commonly used in business valuation Revsine et al., 2009). It utilizes a firm's financial statements from the most recent years of operation to project a

baseline revenue growth rate and a percentage of sales approach to project baseline expenses. Economic conditions from a terrorist attack, such as the extent and duration of the regional economic downturn, are entered into the model to estimate the negative impacts on the firm's revenue, and the model proceeds to project the impact on the firm's bottom line.

C. Enterprise Risk Management.

We will work with DHS operating agencies to develop a tool for national risk assessments and for private sector non-financial services, especially for consequences categories such as brand reputation, quality, market share, profitability, global environmental sustainability, etc. The basis of analysis will be the standard Pro-Forma Income Statement analysis commonly used in business valuation (Revsine et al., 2009). It utilizes a firm's financial statements from the most recent years of operation to project a baseline revenue growth rate and a percentage of sales approach to project baseline expenses. Economic conditions from a terrorist attack, such as the extent and duration of the regional economic downturn, are entered into the model to estimate the negative impacts on the firm's revenue, and the model proceeds to project the impact on the firm's bottom line.

To use this model for private businesses without readily available public financial statements, industry averages can be used for the key parameters. The model can accommodate any changes in economic conditions from the disaster. Ideally we would obtain data for individual firms directly from them, or from the working relationship the PI has developed with Dun and Bradstreet.

The model will be developed in a spreadsheet format to facilitate its use, with Microsoft Excel as the platform. The model predicts impacts on the rate of return stemming from changes in business conditions caused by a disaster. Based on the likely affects from a terrorist attack, such as the release of anthrax, the key variables adjusted in this the following analysis include:

- Projected Decline in Demand
- Duration of Demand Decline
- Duration of Facility Closing
- Decontamination Costs
- Operating Leverage

Other variables included in the analysis are:

- Baseline Growth Rate
- Pre-Disaster Assets
- Pre-Disaster Equity
- Facility Size
- Tax Rate

Additional qualitative variables will be incorporated into the analysis, such as product quality and reputation. The effect of these on the firm's bottom line will be assessed as well. The analysis will be expanded to the industry to examine effects on market share of firms incurring a terrorist attack. Dun and Bradstreet data on will be used that highlights areas that represent potential concern from both an underwriting and actuarial perspective, as well as potential negative brand impact. The PI has developed a special working relationship with Jeff Howard, Director, Homeland Security, in the Government Solutions Branch.

X. Response to Initial Reviewers:

Reviewers of the Year 10 proposed research posed several questions. Below is my response:

1. *This is a core element which seems to have been a solid contributor and productive although not apparently game changing in either its publications nor its implementation with DHS. On the other hand, the researcher makes the statement that CREATE's CGE model is the "go to" macro model for DHS modeling and cites two applications this year while also saying it has been "transitioned" to DHS. After this many years of development it would be useful to do some stock-taking:*

We believe the CGE models and their new ability to incorporate resilience and behavioral linkages in relation to consequence analysis have been game changers at DHS and the profession at large. Recently, my team in collaboration with one of Dixon's team members, did the pioneering study of translating fear associated with the social amplification of risk into direct and indirect economic costs (Giesecke et al., 2012). This helped us land a contract with TSA to do an analogous study for attacks on the airline system, and we have had expressions of interest from other DHS units. Inclusion of behavioral factors enables consequence estimates to be more complete and accurate, and thus help Congress and DHS make better resource allocation decisions.

a. *Is this a tool that can be transitioned to a think tank or Gov't or is CREATE the right place?*

CGE modeling is specialized area, in part because of its complexity. Very few if any think tanks or Gov't agencies have the capability to make advances in the methodology, and none are as adept at applying it to terrorism and natural hazards. At the same time, we will continue to turn over our models to DHS and assist DHS in using them. We will move forward more actively to transition these models, including making them more accessible to DHS staff bit developing "reduced form versions." However, major methodological advances likely can only emanate from CREATE and Monash affiliates.

b. *Is there feedback on what aspects of the model are most useful?*

- TSA is most interested in the behavioral aspects of the model and its ability to link disruption of the airline industry to the rest of the economy.

- CBP is most interested in CGE for its competiveness and trade capabilities.

- NBIC is interested in it as a comprehensive consequence analysis framework.

- DNDO is interested in having us develop reduced form economic consequence analysis models for them.

- Several units of DHS have expressed an interest in the model for its supply-chain analysis capabilities.

2. *How did wait times at the border lead to a macro-model?*

CBP requested that we estimate the macroeconomic impacts of changes in wait times at border crossings associated with changes in its staffing. These changes affect freight transportation costs, and therefore affect the relative competiveness of U.S. imports and exports. The GTAP CGE model, developed by the ITC and WTO, is well suited to this application because it is especially developed to deal with topics such as this, and provides separate models for the U.S. and each of its major trading partners.

3. *Is there a strategy to get the research work ahead of the curve, such as work on macro cyber disruptions?*

We have submitted a proposal to DHS on cyber security in which CGE played a major role. We stand ready to have a CGE component in any CREATE proposal that will be submitted for additional funding.

4. *There is overlap with the CGE model proposal of Monash, and these should be coordinated.*

While both my research team and Dixon's at Monash/Australia work on CGE modeling, there are some major differences. Dixon's group has long led in dynamics and more recently in multi-regional model development, while my team has led in incorporating resilience. Until recently, Monash did not have a facile regional modeling capability, so my team developed models for NYC and LA, and applied them to major issues such as the impacts of 9/11 and catastrophic earthquakes. The work on the models and applications by CREATE students and post-docs will enable us to continue to train the next generation of CGE modelers in the U.S. Finally, Dixon's models cannot be transitioned to DHS because of strictures against using computer code developed outside of the U.S.

5. *The references to Hora 2013 and Rose 2013 on commerce and security did not seem to be included.*

Hora et al. is now included. The Rose et al. reference has been corrected to read 2013.

Y. Relation to NISAC

The question has been raised as to the relationship between the CREATE line of research and the work of NISAC. They complement each other nicely. The CREATE research represents more basic research on the conceptual side, and more definitive work on the empirical side. For example, when NISAC affiliated researchers at Sandia began their work on resilience, this PI was asked to guide it. NISAC has done a great job in developing consequence modeling systems for widespread use, but they are not up to the state of the art in macroeconomic consequence analysis of the CREATE efforts. Our models have enabled the Rose research team to do the definitive estimates of such major actual and potential events as the September 11 World Trade Center attacks, a dirty bomb attack, an anthrax attack, an H1N1 epidemic, and the Shakeout catastrophic Southern California earthquake scenario.

Z. Response to FCC

We have added the two projects requested by the FCC to the Year 10 SOW:

- Accelerate research transition to DHS in several ways, but primarily working with other CREATE modelers to develop "Reduced Form" regression models, based on hundreds of CGE simulations of a typology of terrorist attacks with varying parameters relating to size, locations, target, and residence and behavioral responses.
- Develop the new area of Enterprise Risk Management work for national risk assessments and for private sector non-financial services, especially for consequences categories such as brand reputation, quality, market share, profitability, global environmental sustainability, etc.

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