Understanding the Economic Costs and Benefits of Catastrophes and Their Aftermath

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Abstract

The number and magnitude of devastating natural and human events makes it imperative that we actively and systematically estimate the costs and benefits of policy decisions in affected regions, states, and nations. Such strategic risk management preparedness efforts should forecast well into the future and include scenarios with and without enhanced engineered structures; with reduced vulnerability through land use planning and design; with the impact of resiliency and mitigation; with evacuation and relocation; and with the costs and benefits of recovery and restoration. We describe different kinds of regional economic models that can be used in these preparedness planning efforts and advocate a shared federal-state strategic planning effort to accomplish the objective.

key words: benefits, costs, disasters, economic impacts, preparedness, mitigation, resilience

1. INTRODUCTION

The deaths, injuries, property and psychological damage from the 9/11 attacks, Hurricane Katrina, and other recent disasters have challenged us to consider how we can contribute to more informed risk management policies and decisions to minimize the overall costs of such catastrophes.[1] This paper focuses on the economic costs and benefits of catastrophic events from the perspective of American, national and state governments. The Committee on Assessing the Costs of Natural Disasters of the National Research Council[2-4] observed that economic losses are not always calculated, despite the substantial costs of hurricanes, floods, drought, earthquakes, blizzards and winter storms. They added that methods used to estimate economic impacts are inconsistent. With regard to so-called "indirect" impacts (defined below) the Committee remarked that estimates are rarely quantified.[2] The group suggested data that should be collected and, moreover, asserted need for standardized data and methods to provide consistency. The Committee underscored the difficulty in advocating for government programs without economic impact data, and they called for the Bureau of Economic Analysis of the U.S. Department of Commerce to assume the responsibility for compiling economic data, in cooperation with FEMA (Federal Emergency Management Agency) and other federal agencies that take part in natural disaster preparedness, response, and mitigation.

Considerable thinking and analysis, examples of which are described below, have been directed at these and similar suggestions.[5-15] While we are pleased to note the abundant energy devoted to this subject, we are concerned that the goals of the work remain unclear, and, therefore, the paths toward achieving them are not well laid out.

Thus, the purposes of this paper are to state an unambiguous set of goals for such a modeling effort, describe why we have chosen them, and suggest what it implies in terms of future research.

The paper is divided into six parts. We state our objective for this paper in part two. Part three motivates this objective and emphasizes the need to look further than the immediate vicinity of impact and period of economic shock. We call for a coordinated local, state and federal effort to anticipate the economic effects of hazardous events across the nation for a decade or more. Part four focuses on five elements of disasters that may be the subjects of post-event criticism: investments and protection of engineered structures; land use and facility planning; resiliency and pre-event mitigation; evacuation and relocation; and levels and stages of restoration. Proactive analyses of these five elements can make the difference between a hazardous event that remains limited to short-term economic implications or to one that generates a major long-term national economic drag. The proposed preparedness program relies upon economic models and the data they require. The fifth section describes simulation models that may be used to estimate the costs and benefits of various kinds of policy-driven actions. The final section reiterates the objective, reviews the associated data, methods, and organization needed to achieve it, and proposes a set of models and organizations to implement the program.

2. OBJECTIVE: ACTIVE PREPAREDNESS POLICY ANALYSIS

The federal government should take the lead in building an economic simulation capacity at the local (county), regional (groups of counties), state (or multiple states if the potential event is sufficiently extensive), and national scales. In some cases, international economic impact analysis capacity is essential; thus, methods for assessing multi-national impacts should also be developed.

To understand life cycle costs and benefits of making investments prior, during, and after events, the federal government should be able to project costs and benefits at least a decade into the future. It should do so systematically, assuming that once an event has started, options to manage impacts are reduced. And this information should be summarized and routinely presented to key political leaders.

This objective is already being partially met by a variety of private companies, universities, and government agencies. We believe that our vision is more aggressive in scope than what is currently done and emphasizes the critical role of the federal government in driving the process with the end goal of enabling its sub-regions to recover more quickly in the aftermath of catastrophes. We acknowledge that achieving our goal implies facing some formidable challenges with regard to data, science and engineering, communications, resource, and, especially, organizational planning. Nevertheless, on balance, we believe that meeting our objective would markedly enhance risk management strategic planning by enabling policy makers to consider the potential consequences of their actions or inactions. It would press them into thinking explicitly about the potential realities of hazardous events.

3. SPATIAL AND TEMPORAL DIMENSIONS OF ANALYSIS

3.1. Spatial Context

There is no denying that neighborhoods and other localities can be destroyed by earthquakes, bombs, and other natural and human-caused disasters. The direct costs of hazardous events are too often apparent. They include human and animal deaths and injuries, damage to structures and their contents, vehicles, infrastructure, utilities and their delivery systems, landscapes and agriculture, as well as cleanup and response costs.[2-4] People in damaged areas may not be able to go to work, they may not be able to live in their homes, and their children may not be able to go to school. The elderly, physically impaired, and poor are most vulnerable to hazards.[16] Research has spelled out the challenge of capturing local immediate costs.[2] Estimating local impacts is the first priority. If we cannot measure these most obvious impacts, it is difficult to envision credible analyses of the effects outside the immediate impact area.

Non-local impacts cannot be ignored.[2,5,9,14] They can include disruption of communications and natural gas, and electrical power systems; water and sewerage service; interregional petroleum flows; and other private infrastructure systems. They can include traffic congestion due to weakened bridges; severed, washed-out, or collapsed runways and roadways; or flooding and diversion. Non-local impacts also include declines in sales, wages, and profits due to loss of function in the neighborhoods of affected areas. These losses are attributable to reduced supplies and demand from the directly affected area, and slowdowns in transporting products and people. Employees who have lost their jobs may reduce their purchases. Tax collections slide because of business losses and consequent reductions in worker earnings.

Hazardous events produce winners. Producers outside the immediate impact area may benefit by supplying markets previously supplied by the incapacitated businesses in the impact area. Construction workers may experience an increase in the demand for their services and, consequently, wages through the repair and rebuilding effort. Outside money can flow into the affected region that would otherwise have gone elsewhere.

Some individuals, when given the opportunity during the change induced by disasters, may pick up the sword of entrepreneurship and carry their new-found skills forward to induce a new growth paradigm within the affected region.

At the national and international level, costs of a catastrophe depend upon where and when an event occurs. When the affected area is a central place for international trade—particularly when it has refineries and ports that supply fuel, food, and other products across the globe—economic impacts consequent to the event can be felt by millions of people. Overall, we need to be more methodical about tracing the economic impacts across local, state, national and international landscapes.

3.2. Temporal Context

The actual life of a disaster is typically much longer than the period of active economic and political response to the event. For example, immediate repairs to infrastructure may be cheap patches, while the long-term costs may include expensive (and extensive) rebuilding. Investors who watch their facilities crumble or businesses fail may opt not to rebuild or expand business in the region. Firms in the process of relocating undoubtedly immediately question the suitability of a region where an event has occurred. When a major business shrinks its investments in a region, others often follow suit. In short, in some cases the life cycle costs of an event may be incurred over a decade or more. If decision makers are left only with knowledge about short-term economic costs and benefits, they could be misled into making suboptimal choices, especially if the bulk of the costs are incurred in the short term and the benefits accrue over a much longer period of time.

4. FIVE KEY ELEMENTS FOR STRATEGIC ANALYSIS AND MANAGEMENT

Our objective is formulated around repeated post-event criticism that government and private organizations

- have failed to protect engineered systems,
- have not implemented land use planning and design tools to reduce hazards,
- have failed to provide resources that build resiliency into systems and mitigate against disastrous economic outcomes,
- have inadequately considered and planned for evacuation/relocation, and
- have failed to understand the implications of different levels and staging of restoration.

4.1. Engineered Structures

How much would it have cost to build New Orleans' structures to withstand Katrina's flood waters or to build the World Trade Center to withstand the impact of two airplanes? Should we have spent whatever was necessary to allow these structures to survive? What are the opportunity costs involved in building to survive such disasters? If the Corps of Engineers had spent more bolstering levees in New Orleans, it would have had less money to spend on other needed federal projects and programs. An endless series of second-guesses can follow from capital investment prevention decisions. Estimating the costs and benefits ahead of time will not remove second-guessing but such risk-based analyses would at least inform resource allocation discussions and decisions, and perhaps prevent under-spending on useful and needed capital projects.

4.2. Land Use and Facility Planning

Location is a major determinant of the vulnerability of people's lives and health as well as the riskiness of capital investments. Hence, insurance premiums are adjusted by location to provide sufficient financial protection against many catastrophic events. The rising costs of these events, the spatial fixity of much physical capital, and the concomitant inability of insurance companies to make payouts makes buying coverage a problematic decision.

In the United States, the Federal Emergency Management Agency (FEMA) is responsible for disaster planning and response. FEMA has already undertaken programs to protect against disasters by buying properties that have demonstrated persistent vulnerability to some types of disasters—taking them permanently off of the market. For example, Pattonsburg, Missouri, a town of 500 people, was inundated by floods 30 to 40 times during the last half of the twentieth century.[17] Finally in 1993, FEMA refused to pay to rebuild it. Instead it opted to relocate the town two miles from its former site and out of harms way. Some, but not all, of New Pattonsburg's residents believe the cost of the relocation was justified. But assuming it is justified in the long run, how far can and should such a policy be extended? To larger areas? The cost of implementing such a policy in metropolitan areas could be high. But whatever the cost, it is undoubtedly measurable. For example, should such a policy have been extended to all residents of New Orleans or at least to the residents of some of its most vulnerable neighborhoods? How about at least to government buildings that do not meet reasonable siting guidelines, since FEMA funds their rebuilding at 100 percent of their value? This is clearly a value-laden question. Before making decisions to refuse to rebuild areas or to move towns, some realistic estimates of the costs and benefits of repeated restoration projects certainly should be calculated.

4.3. Resilience and Mitigation

Resilience can be defined as the adaptations within an economy that speed recovery from a shock and avoid some losses. Thus, resilience is people, governments, and organizations responding to problems by conserving, substituting, and rescheduling their activities. For instance, in the event of an electric power outage, the adaptations would draw electricity from non-grid sources, would convert to using non-electric forms of energy, and would minimize tasks that use a good deal of electric power. The need for resilience is reduced in the face of improved mitigation against shocks. So, these two possible policy responses go hand in hand. For example, restaurants that own generators can stay open during a power outage, albeit perhaps with fewer customers, when other restaurants cannot.[5,13-15]

Despite their importance to how an economy reacts consequent to a catastrophe, with a few exceptions, we know remarkably little about how and when resilient behavior is applied and the extent to which mitigation can be undertaken.[5,13-15] More needs to be learned, and tested. That is, if, after a disaster, 80 percent of the public potable water a region needs is restored in two days instead of in a longer period predicted by experts, researchers should follow up to discover what the resilient behavior was and who or what specifically induced it. They should find out what equipment and training could support this resilient solution in other disaster areas. They should also study the results to discover how to make an even speedier response in a cost-effective manner. Finally, these costs and benefits should be factored into regional economic modeling.

4.4. Evacuation and Relocation

Engineering, planning, and resiliency know-how will never be sufficient to buffer certain locales from disasters. Hence, political leaders need credible evacuation plans for people and crucial capital when disasters are deemed both certain and imminent. Unfortunately such mobilization planning is costly, difficult to configure, and, like insurance, the effort taken to develop the plans may never yield a payoff. A lack of historical precedent with regard to identified potential threats as well as high accrual costs may cause populations to be complacent, recalcitrant, or even belligerent when faced with evacuation or relocation. As a result such preparations can create political problems for elected officials. The political losses, of course, are greater yet when the allocation of emergency workers and equipment is insufficient to facilitate an orderly evacuation of people and mobile capital.

Our point is that evacuation and relocations plans can be evaluated. Costs of various evacuation and relocation scenarios (based on different amounts of people and capital goods moved) can be estimated and compared to the costs and benefits of not evacuating.

4.5. Recovery and Restoration

Contrary to intuition, experience to date has demonstrated that regions that suffer natural disasters can benefit economically in the long run.[6-8,18] In the case of natural disasters, damaged older regional infrastructure and equipment is replaced with newer, more-efficient technologies in the wake of such disasters. Moreover, the regional reconstruction effort itself appears to provide some of the economic impetus necessary for regions to begin to pull themselves up by their bootstraps. Terrorist attacks and other human-caused disasters, such as hazardous waste sites and spills, may leave residual anger, fears and stigma, and recovery from them may not be speedy or complete.[19-21]

Estimates of the economic implications of redeveloping places in the wake of disasters need to be developed systematically. Economic winners and losers of proposed restoration programs must be identified a priori. Which regions, neighborhoods, and populations benefit the most from such efforts, and which are most adversely affected?

Using the presentation in sections 3 and 4, Table I summarizes the key attributes required to meet our overall objective.

Table I about here

5. TOOLS FOR ESTIMATING LOCAL, STATE, REGIONAL AND NATIONAL IMPACTS

Our objective depends on the availability of data and statistical tools that can be used to estimate the economic costs and benefits of catastrophic events in the United States. Some of the models have been widely used for many economic impact studies; others are less widely used, but are potentially important contributors to long-term multiregional modeling. Please note that the purpose of this section is to summarize the models, focusing on their strengths and weaknesses with regard to the paper's stated objectives. It is not to provide a detailed review of the models, which is beyond the scope of this paper. These models are described in the accompanying references.

5.1. Input-Output and Econometric Models

Input-output (I-O) models are built around a matrix that describes how the sectors of an economy interact with one another.[22-23] For example, for the construction industry, the model shows the "production recipe" for the goods and/or services that the construction industry sells as well as the shares of its revenues that are consumed by other industries in the economy. Given the purposes of disaster forecasting, an I-O model such as the one the authors have developed, which uses 517 economic sectors, would be appropriate. For example, this model has separate categories for bricks (SIC 3251), glass (SIC 3210), and gypsum board (SIC 3275). Different amounts of these materials and equipment are needed to construct new schools, and repair highways and bridges. While our I-O model provides results in terms of indirect output (akin to business revenues), it also yields results in terms of jobs, earnings, gross state product, and federal, state, and local taxes.

A clear advantage of I-O models is that the heart of the model is a set of economic transactions that are readily viewed and understood. Indeed, of the models, the I-O model is the easiest to understand. Another advantage is that it is relatively easy to capture engineering changes in an I-O model.

I-O models have limitations. They assume that technology and productivity are fixed. The analyst assumes that the patterns of future transactions are identical to today's patterns. Thus, while we can find out how much it will cost to rebuild a highway, we have to assume fixed wages and prices in a standard I-O model, at least until the federal government updates the data base, which occurs every five years. Leontief[22,24] proposed a dynamic model, which is reviewed below under IIM.

HAZUS (Hazards.US) is the best example of the application of an input-output model to hazards. HAZUS includes not only an economic module but also risk analysis components.[25-30] Developed for FEMA by the National Institute of Building Sciences (NIBS), HAZUS allows organizations to estimate the potential losses from floods, hurricane winds and earthquakes. It allows users with varying levels of knowledge of the disaster to enter data. Economic results spilling out of the model center on business interruptions, repair costs, and new construction costs. Given general estimates of the direct costs of the damage to structures and transportation systems, it provides detailed estimates of their composition and also estimated costs of repair, cleanup, and indirect effects from declines in sales, supply shortages, and other disaster-related problems.

In essence, HAZUS combines scientific models, engineering, and geographic information systems data. FEMA began working on HAZUS in 1992 and released a model for earthquakes in 1997. Since then it has expanded to other natural hazards. FEMA and seven southwestern Florida Counties used HAZUS during the 2004 hurricane season to estimate potential wind damage to hospitals, schools, buildings and other structures.[26] They plan to fine tune their data and continue to use the model. FEMA[27] reports a rapid increase in users, training for potential users, and more user applications. It expects close to 20,000 users by 2008. Schneider,[28] director of the multi-hazard loss estimation program of NIBS, noted that the economic element that estimates indirect impacts has not been as widely used as had been anticipated.

I-O models have the capacity to draw intricate portraits of economic impacts. As designed, HAZUS seems remarkably suitable to building local, state, and regional impact results. The clear limitation is its inability to estimate the effects of price changes, in particular prices rises that may result from commodity shortages in the wake of a disaster.

Inoperability input-output models (IIM) overcome one limitations of the standard input-output model formulation.[10-12] As in the case of standard regional input-output models, analysts reduce demand in the sectors most directly affected during the event. In turn, suppliers and customers of these industries are affected and the impact spreads through the economy. So, for example, the events of 9/11 produced a significant decline in air travel and tourism. Industries that supplied these industries and benefited from them were also negatively affected, although less substantially. Assuming no further disruptions, much of the demand reduction is scheduled during the first year, then the economy gradually establishes a new equilibrium. In addition to the actual estimates, the authors developed a graphical method that policy makers can use to identify the most vulnerable businesses.

The combination of a large I-O model supplemented by a dynamic element and adaptable to local, state and national needs is appealing. Like the econometric model example described below, this form of an I-O model could alert officials to the implications of actions that they might consider.

Econometric time series models are a second broad category of widely used simulation tools[31] and a set that can be used to measure the effects of shortages that are within historical magnitudes. The one the authors use for New Jersey, for example, is a system of close to 300 equations each of which is based on historical data for New Jersey and the nation. Historical data used in building such models are typically available for 25 to 30 years. National forecasts of employment, wages, and prices drive the model's state forecasts, and the business sector detail is at the three-digit industrial codes level (e.g., food production, chemicals).

The strength of econometric time series models is their sensitivity to historical trends in the economy. Assuming equations have been or can be easily developed to measure it, another major advantage of this kind of economic model that you can estimate the economy's temporal reaction from the time of an investment to through its full yield of economic benefits. This is done by comparing the model's baseline forecast to another forecast that accounts for the investment. The difference between the results for any one equation in the two modeling scenarios provides a measure of the economic impact of the investment.

The strength of the systems econometric time-series model, its entrenchment in historical trends, is also one of its weaknesses. That is, the model is constrained by the nature of past economic relationships, which cannot always inform us about the complete manner in which certain economic events or activities will unfold within an economy. Thus, unless severe shortages are part of a region's history, econometric time series models may not respond appropriately to such impacts of catastrophic events without a lot of "manhandling." A second limitation is that full historical data by industrial sectors for employment and gross product are not available in as much business sector detail as they are for I-O models.

An econometric model was used to study the economic impact of a terrorist attack on the New Jersey electrical power system during the summer of 2005.[9] The authors created three economic scenarios the varied in the manner in which the largest electric utility was affected by an outage. This utility provides power to the state's industrial core, which hosts about three-quarters of the state's population and economic activity (over 1.7 million residential and close to 300,000 nonresidential customers). The three scenarios assumed that a terrorist attack knocked out 90 percent of the electrical delivery capacity. After two days, 25 percent of capacity was restored. After a week, 50 percent was restored. All the electrical supply was restored after a fortnight.

One clear advantage of econometric models over input-output models is that they estimate a schedule for economic impacts. The median simulation in the case discussed above leads to reductions in all the major indicators of the state's economy during the year of the attack. When power is fully restored, personal income, gross state product, and tax revenues rebound. Five years after the attack, the model shows the few detectable impacts remain. Those that persist are limited to minor perturbations of four business sectors that spend large shares of their revenues on electric power and, hence, are industries that are particularly sensitive to electricity rates.

Some results are counterintuitive in the sense that returning to "business as usual" after a disaster implies that a region was unaffected by a disaster. Indeed, time-series studies of the economic consequences of natural hazards show that, for short periods of time, regional economies can be made better off than was expected prior to the event.[6-8,18] This is because after most natural disasters major efforts are made to rebuild damaged regional infrastructure and to replace destroyed equipment in the immediate wake of the event. Thus natural hazards can induce some regions to update their capital stock and adopt newer technologies, which enable productivity improvements in affected industries. In fact it would seem that a region's production of replacement materials and equipment and of labor service to affect the repairs provides sufficient economic impetus for the region to pull itself up by its bootstraps.

Such rebuilding was not expected in the power-outage scenarios in Greenberg et al.[9] Instead, the simulations suggest that a terrorist attack could hasten the movement of businesses that are uncertain about staying in region that is perceived to be risky for business; that is, the departure of weakly tied industries could speed up the arrival of expected industry declines. A third related possibility is that existing businesses stay, but now opt to allocate planned expansions outside the study area. Overall, in the short run, it is plausible to assume that some businesses and residents would relocate in the aftermath of a disaster that does not damage infrastructure and that net economic impacts would take on a net negative dimension not typically observed after natural disasters.

To recognize this possibility, we reran the three simulations, but this time we did not assume that all the jobs in place when the summer 2005 quarter began would be restored in the winter. Instead, only half of the jobs were restored so that the state is down 20,300 jobs at the end of the fourth quarter of 2005. But the difference jumps substantially in 2006 when 84,000 fewer jobs exist than were expected from the baseline forecast. This job gap persists in the longer run, as it closed only slightly to 67,000 by 2010. The story is the much the same when read using other economic measures, e.g., wages and salaries as well as gross state product.

The point of providing the details in this paper is to show that a standard econometric model can be used to test a variety of scenarios featuring differences in a variety of assumptions about the severity of the disaster, the amount of pre-disaster mitigation effort undertaken with the economy, and the extent to which actors in the economy undertake resilient behavior. Most important, studies such as this in New Jersey invite policy makers to think about the benefits of pre-event preparedness planning versus the costs of taking no action or only limited action.

5.2. Other models and extensions

Input-output and systems econometric time-series models are the most commonly used economic models. But hazard researchers have explored other options.

Computable General Equilibrium (CGE) Models. CGE models assume optimal decisions by consumers and producers in response to markets and prices subject to labor, resource, and capital constraints. CGE models, in essence, have blocks of equations that represent key actors in the economy (e.g., consumers, producers, government) and equations that make sure that the different blocks are consistent. The heart of the model is usually a slightly modified I-O model. The models can be built to explicitly consider resilience in the equation structure, which is a major advantage, if, in fact, the elasticities in the models reflect resilience and other changes.

Adam Rose has been a leader in developing and testing these models in hazards research.[5,13-14] For example, he built a CGE model to test the impact of an earthquake on the water supply and in turn the economy of the Portland, Oregon region.[5] The model included equations for improving the system of pipes and rest of the network, altering the schedule of water use and other options. Improving the network of pipes had a major impact on economic losses. Rose, Oladosu, and Liao[32] simulated the economic impacts of a terrorist attack on the Los Angeles power system. Without resilience, they estimated a loss of $20.5 billion in two weeks. With several forms of resilience (conservation, on-site electricity generation, rescheduling of production), the loss was reduced to $2.8 billion. CGE models have some of the same limitations of I-O models. In addition, the assumption that consumers and producers optimize is debatable. But CGE models theoretically should be an improvement because of their capacity to explicitly include resiliency.

A chief criticism leveled at CGE models is that they rely on external sources for some of the elasticity values required during their calibration.[33] This is especially the case for region-specific models where studies that derive the elasticities are scant. As a result, regional CGE models tend to reply upon elasticities from national or international studies, which are likely not to be comparable. In some cases this may not be damning in that the analyst can perform sensitivity analyses on various values of certain key elasticities. But in some cases, particularly for dynamic CGE models, which conceptually could substitute for time-series econometric systems models, the data are lacking to econometrically estimate some key components equations.[34]

The absence of estimated production functions also has led to the use of a class of production functions (constant elasticity of substitution) that may not accurately portray economic processes in a nation or region. And while, this may not be a major issue when trying to get general qualitative and quantitative insight through a CGE simulation, it is an attribute of current CGE modeling practice that Partridge and Rickman[33] argue could be readily remedied. Such research has since been undertaken by Adkins, Rickman, and Hameed,[35] who estimate the desired parameters using a translog Bayesian approach to production functions.

The dynamic stochastic general equilibrium model (DSGE), put forward by Smets and Wouters[36] and originally developed in early version of a paper by Christiano et al.[37], also uses Bayesian generalized production functions. To date, the DSGE approach has largely been applied at the national level and applied to analyses of macroeconomic monetary shocks.[38-40] Nonetheless, it would seem to hold some promise for the economic analysis of disasters.

By taking a Bayesian approach researchers assume model equations represent stochastic processes. Thus, the models provide a range for simulation results, including a most likely alternative (the mode) and confidence intervals. The explicit stochastic element of this modeling approach is consistent with the practices of many risk analysts who estimate with associated probabilities rather than single point estimates. In fact, researchers have applied Bayesian approaches to regional input-output models to derive stochastic interindustry-based results.[41-44] Of course, results from systems econometric time-series models can be interpreted in a stochastic vein as well, albeit their stochastic character is implicit and requires substantially more time-series data.

Regional Economic Modeling, Inc. (REMI). The REMI model is a systems econometric times-series econometric model developed from panel data on U.S. states.[45-47] Hence, like standard systems econometric time-series models, it includes estimates of the relationships among employment, wages, income, populations, and prices. Unlike most such models, however, it also includes equations for interregional trade by industry, and in- and out-migration of labor and households for each region. As a default option it uses a modified national forecast based from the U.S. Bureau of Labor Statistics.[45-47]

Since it is based in cross-sectional as well as time series data, the model can readily consider multiregional perspectives, just as multiregional input-output models can. That is, it can enable the user to determine how an economic change in one region spills over into other regions and subsequently creates feedback effects to the originating region. Of course, both CGE and systems econometric time series models can perform such functions as well, but the time and effort taken to develop such multiregional models make them quite rare. It provides a national perspective as well. Like regional I-O models, regions in the REMI model can be as small as a single county and as large as any group of counties or states.[45-47] We were unable to readily uncover an application of REMI to natural or human hazard events, but the model could clearly be used toward this end.

6. DISCUSSION

We have described a collaborative strategic analysis and planning objective for federal and state government. That objective is to test systematically the economic impact of hazardous events on the U.S. at the local, state, and national scales, and in some cases international scale out at least a decade after the event. We suggest the following combination of activities as a challenge to researchers as a start toward achieving the objective we have proposed. First, hazard-prone states should apply HAZUS to produce the county, multi-county, and state results for a period of up to five years. Frankly, we would suggest that each state produce its own CGE model, but we realize that this would be impractical since it would undoubtedly require an exorbitant amount of upfront as well as ongoing resources for many states to maintain such a model. It would be enough for FEMA to make sure the underlying data and software for HAZUS are updated annually. States specifically should be charged with using the model to measure the costs and benefits for a set of plausible natural and human-made hazard events. For example, using HAZUS one state might select as possible scenarios a massive forest fires, an airplane crash into a densely packed urban area, and a flood of a major river; another might select a hurricane, a terrorist attack, and an oil spill. State governments are best postured to select disasters mostly likely or at least of most concern in their jurisdiction. Similarly, states should be charged with putting together the data on the nature of the hazards needed to enter into HAZUS and the logic to justify the potential severity of the event.

Second, the federal government would take the county, multi-county, and state results from HAZUS and use them in a multiregional economic models to assess longer term impacts. Specifically, the federal government should take each scenario developed by the state governments, enter them into a 50-state model, and examine how its economic effects spread across the United States. In other words, Pennsylvania's results are input into the national model and followed to determine the impacts on Ohio, New Jersey, New York, and other nearby and distant states. For now, a standard multi-state econometric model like that produced by REMI is logical choice for the national model, We would hope that the REMI model also would soon be joined by a well-articulated and developed multiregional CGE model, perhaps one that relies upon functional economic areas rather than states and then splits the results for these functional economic areas along state boundaries.

We have suggested that the states undertake the exercise of applying their data to HAZUS because delays between the state and federal applications of the data are inevitable. Moreover, we suggest that undertaking the exercise will facilitate the data collection and preparation process. That is, the states will understand why the federal government is requesting such data and why it is requesting the data be in a specific layout and format.

The results of the combined modeling exercise by the state and federal governments should be integrated and reported to key federal and state officials. As such it will be a well-organized, unified document of what locals perceive as highest-risk hazards, complete with an estimated accounting of their potential costs to not only the impact area but also the nation and regions surrounding it. This report could also serve both state and federal officials by elucidating the long- and short-run costs and benefits of mitigating impacts of hazards via better engineering and planning practices, of educating local households and businesses about resilience-enhancing behaviors, of various viable evacuation alternatives, and of investing in different levels and types of post-disaster recovery, restoration and relief efforts. This reporting effort is absolutely critical. Otherwise the only people who will benefit from the knowledge gained during the exercise will be the scenario producers and the people who interpret the model results.

Two issues remain to be addressed. First, although estimating international impacts is a difficult exercise we contend that such modeling is something that remains a priority for the international community. While models exist, they are often piecemeal or out of date.[48,49] One example is a set of econometric time series models, which embrace some input-output relationships, that is maintained by Inforum and led by Clopper Almon at the University of Maryland.[50] Given the globalization of the world economies, this capacity needs to be more fully embraced and supported. Second, we know full well that modeled impact estimates are unlikely to be all that accurate. Each modeling approach that we have described has drawbacks that limit its performance. Hence, as a challenge to these models and their builders, we propose that the federal government test those models deemed to be most productive by testing results retrospectively. These comparisons are essential to the improvement of such models. They will undoubtedly determine why models are not able to produce reasonable different results, producing fodder for modelers when they go back to their drawing boards. Such an exercise could also evaluate how the models could be better applied. That is it might not be a problem of a model's ability to simulate an economy's reaction as much as it is of the user's ability to apply the models. Hence, they should be systematically evaluated for user friendliness and their cost-effectiveness, including on such elements as cost of producing and maintaining the model, model's data requirements, and the cost of the human expertise required to apply the model (in terms of time and salary),   It may well be that accuracy gained by applying some models—e.g., those that are more theoretically appealing--is insufficient to offset the relative cost of implementing them to meet federal and state objectives.

With regard to ethical considerations that derive from this exercise, we note a dilemma. We have good ideas where natural disasters tend to strike with some regularity and severity. But we have little knowledge of where terrorists are likely to strike. The World Trade Towers, the Pentagon, the London tubes are all iconic symbols. But what icon is next on the list of our unknown terrorists? Will terrorists' decide to turn away from iconic symbols and toward facilities that would affect our people and economy, e.g., electrical power systems, water supplies, and hospitals? Since we cannot anticipate the activities of terrorists, cost and benefit estimates will surely lead us to favor investing in mitigating the impacts of natural hazards, refinery fires, and other industrial accidents because there is more certainty about where natural hazard events occur. The uncertainty of terrorist attacks argues for their separate consideration.

Two final caveats are in order. We are under no illusions that elected officials could have put such data to use to prevent the events of 9/11. We do, however, believe that such proactive analyses could have been put to use in recent natural hazard cases like Hurricane Katrina's effect on New Orleans. Second, it is possible that such analyses could lead to misplaced confidence upon economic analysts and policymakers, that is, we cannot know whether these individuals will be able to derive or even imagine hazard scenarios that are most likely to occur and how they may unfold. Despite these final concerns, we are certain that the exercise of gathering the data, debating the options, and reflecting on the economic results of risk-based analyses will lead to better informed policies about our society’s vulnerability to hazards and the role of proactive mitigation given the constraints of the economic resources that can be brought to bear when managing preparations for catastrophic events and their detrimental economic repercussions.

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Table I. Attributes Required for Economic Preparedness Analysis

Ability to Measure Costs and Benefits: Direct impacts -- changes in business as a direct consequence of the event, and investments to mitigate, recover, and redevelop Indirect impacts -- changes in sales of suppliers to directly affected businesses throughout the life cycle, including preparedness-related investments prior to the event, impacts of suffering the event and recovering from it Induced impacts -- shift in sales due to changes in residential income
Geographical Scale: Local/county -- the area directly hit by the event Regional/multi-county – surrounding area that suffers and/or benefits from the event and preparedness or recovery investments State -- the host state(s) of the event National -- the United States International – nations that are impacted negatively or positively by the event
Temporal Scale: Short-term aftermath (initially monthly, then quarterly for two years) Intermediate (initially quarterly, then annually for two to five years) Long-term (Annually for five or more years)
Ability to Measure Key Policy Consequences: Investments in mitigative measures (e.g., upgrading bridges, dams, electric power transformers) Investments in resiliency (e.g., education about alternative methods of

production, changing schedules, use of alternative resources, etc.) Impact on disadvantaged (e.g., isolated poor, immobile and otherwise impaired)