3

ESTIMATING INDIRECT ECONOMIC LOSSES FROM ELECTRICITY LIFELINE DISRUPTION FOLLOWING A CATASTROPHIC EARTHQUAKE IN MEMPHIS, TN (USING A CGE MODEL, SURVEY & SIMULATIONS)

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Abstract

The research objective was to develop an economic model that simulates the total economic impact of lifeline losses in the event of large magnitude earthquakes in Memphis, Tennessee. We obtained economic estimates of potential losses to sectoral output arising from a 1 week outage of electricity, considering adaptive responses, based on survey / simulation results of actual business loss expectations. The new methodology isolates electricity lifeline losses, incorporates resiliency of economy and estimates indirect impacts as the difference between recalibrated total (general equilibrium) impacts and the direct impacts shown by the survey. Simulations have been run for various socio-economic scenarios that are plausible in the wake of an earthquake, like a price hike, priority supply to households, etc.

The Problem

In a purely anthropogenic sense, an earthquake may be considered as the joint interaction of an extreme natural event and a human settlement. They differ in terms of duration, intensities, and the nature of devastation they leave behind. Media reports of a natural disaster usually reflect only the directly visible damage. Losses, however, extend beyond what meets the eye, and extend beyond the actual duration of ground-shaking. *Indirect economic losses* from business disruption, due both to the loss of housing and lifeline services, may often be several *multiples* of the initial estimates of direct damage (see for e.g., Boisvert, 1992; Brookshire et al., 1997; Cochrane, 1997).

Interest in modeling these issues arise out of the increasing human susceptibility and scale of damages, and also the potential for impacting a wider area due to strategic linkages existing beyond the regional economy. There are several modeling techniques that may be employed to capture the direct, indirect and institutional effects of an earthquake, ranging from Input-Output Analysis, Simulation Modeling to Computable General Equilibrium (CGE) Modeling.

This research is motivated by the twin objectives of examining a region with a history of a major earthquake event in recent times, and that of employing a sophisticated modeling technique that can best capture the economic impacts of an external stimulus.

The Setting

The *New Madrid Seismic Zone* located near Memphis, Tennessee served as the venue in 1811-12 for the largest earthquake events, of around 8.5 scale, in the U.S. At that stage, the estimated losses were quite modest. However, such an event today could be very expensive in terms of human and economic losses, even after discounting the differences in estimation technologies, because the area is now densely populated and industrialized. Memphis is now a city of 295 Sq. miles and houses close to a million people and sits on the intersection of several lifelines like oil and gas pipelines and electric gridlines, as well as an important center for transportation and distribution (Shinozuka et al., 1998). This fact has prompted previous research in the Memphis area, and is also the basis for the current research. The major difference in this essay is the use of a CGE model for the Memphis economy as opposed to the earlier treatments using Input-Output methodologies.

The CGE model

The computable general equilibrium [CGE] approach is an excellent framework for regional impact assessment since it allows behavioral response simulation. Using this approach, it is possible to analyze disjointed changes and incorporate engineering information. CGE models may beconstructed for any desired level of sectoral disaggregation, since it allows the use of multisector, multi-tier production functions. The model is driven by markets & price signals, which makes it a meaningful policy instrument. Our adaptation of the implementation mechanism of the CGE makes it possible to model resiliency features of the economy, thus reflecting the real world economic conditions (see, for e.g., Scarf, 1973; Partridge et al., 1997).

The CGE framework is a suitable device for tackling the issue of responses to both economic and non-economic but quantifiable exogenous stimuli, since it can suitably map the changes in sectoral equilibria within a region. Since it allows for *input selection*, it is a fairly reasonable simulation of the real economy, and hence it appears to be a good choice for analyzing natural hazard issues. The other favorable features of the CGE model are that it allows for flexible specification of production technology and consumer preferences, and the fact that it uses prices to drive the system’s responses to external stimuli. In essence this allows for great choice in terms of functional forms to represent technology and utility. Thus a CGE model is able to reflect the market's behavioral adaptations, which are, expected responses to natural hazards. The CGE model also allows for a user defined sectoral scheme, thus representing a choice in the levels of aggregation. We have opted for a 20-sector aggregation scheme, following an earlier analysis (Rose et al. 1997): "Agriculture, Mining, Construction, Food Products, Manufacturing, Petroleum Refining, Transportation, Communication, Electric Services, Gas Distribution, Water & Sanitary Services, Wholesale Trade, Retail Trade, Finance, Insurance & Real Estate (FIRE), Personal Services, Business & Professional Services, Entertainment, Health, Education, Government".

We employ nested CES production (KLEM) functions and Cobb-Douglas utility functions. Trade is reflected in 2 layers (Rest of the World & Rest of US) and is defined by CES (Armington) functions for Imports and CET functions for Exports. The Keynesian closure rule, which adopts a fixed wage-rate and allows for unemployment has been used to define the labor market. Benchmark data for the model includes the Social Accounting Matrix (SAM) for 1996, available from the IMPLAN System, substitution elasticities received from other studies, and primary survey / simulation results (Chang, 2000).

Innovation in Methodology

The methodology used herein has been motivated by 2 developments. First is the availability of simulated information on direct impacts from Chang based on an earlier survey data from Tierney. Second, is the development of the idea of combining CGE models and primary data to extract information on indirect effects (Chang et al., 2000). Broadly, the steps involved in incorporating resiliency & estimating indirect effects are:

- generating *direct* losses resulting from water outage based on given technology (CES production functions) for each sector, in Partial Equilibrium (PE) framework,
- making parametric adjustments (following a logic for associating various resiliency measures with different CES parameters) such that PE estimates equal Chang's,
- incorporating the re-evaluated CES parameters into MPSGE and solving for GE effects
- the difference (iii – ii) being the *indirect* impacts.

The New Approach

The overall structure of the CGE model may be viewed as having major *blocks* of equations representing the *actors* in an economy, namely, the producers, the consumers, the owners of factors and the government. There are equations that ensure consistency in the activity *levels* of these actors, for e.g., demand-supply parity, investment-savings parity etc. There are also balancing equations that *close out* the model, for e.g., the government's budget, and the labor market clearance (Rose et al., 2000)

The standard solution procedure is to calibrate the parameters in the model based on a *snapshot* of the actual economy at a point of time, which is given by a *social accounting matrix*, which is a summary record of all transactions in the economy in value terms (see for e.g., Rutherford, 1995).

Having done that, a *counterfactual simulation* is run by changing the value of an economic variable which forces all other variables to take on new values. The difference is known as the regional economc impact (Rose & Guha, 2000). Our advance to the methodology is to use survey data to recalibrate the model, thereby generating a set of parameters whose values include the resiliency features within an economy. The actual procedure involves the following steps:

1. extract the production block (sectoral production functions)
2. compute preliminary impact case with given water outages
3. compare with empirical data on direct effects
4. recalibrate model parameters making sectoral results consistent with data
5. reinsert calibrated production function into CGE model
6. run CGE model with water outages & new parameters
7. CGE results = total effects (direct + indirect)
8. estimate "indirect" effects using steps 7 & 3

Alternative Conditions

Several cases and sub-cases were formulated based on a combination of elapsed time, and restrictions that may be imposed on the economy. The restrictive cases are:

* No restrictions
* Fixed Electricity Prices
* Minimum Supply to Households
* Fixed Price plus Minimum Household Supply

Each of these were evaluated for sub-cases representing time elapsed since the earthquake.

i) Base Case: reduce capital stock of electricity sector to reflect supply loss.

ii) Very Short Run (VSR < 7days): additionally, reduce substitution elasticities to reflect "shock" (the system is "paralyzed").

iii) Short Run (SR < 6 months): increase elasticities to 50% of their normal values to show some recovery (systems have been partially restored), and to reflect resilience.

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