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The Economic Impacts of the September 11 Terrorist Attacks: A Computable General Equilibrium Analysis

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Abstract

This paper develops a bottom-up approach that focuses on behavioral responses in estimating the total economic impacts of the September 11, 2001, World Trade Center (WTC) attacks. The estimation includes several new features. First, is the collection of data on the relocation of firms displaced by the attack, the major source of resilience in muting the direct impacts of the event. Second, is a new estimate of the major source of impacts off-site – the ensuing decline of air travel and related tourism in the U.S. due to the social amplification of the fear of terrorism. Third, the estimation is performed for the first time using Computable General Equilibrium (CGE) analysis, including a new approach to reflecting the direct effects of external shocks. This modeling framework has many advantages in this application, such as the ability to include behavioral responses of individual businesses and households, to incorporate features of inherent and adaptive resilience at the level of the individual decision maker and the market, and to gauge quantity and price interaction effects across sectors of the regional and national economies. We find that the total business interruption losses from the WTC attacks on the U.S. economy were only slightly over $100 billion, or less than 1.0% of Gross Domestic Product. The impacts were only a loss of $14 billion of Gross Regional Product for the New York Metropolitan Area.

KEYWORDS: economic consequence analysis, terrorist attacks, September 11, computable general equilibrium analysis

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Erratum

On June 15, 2010 the following acknowledgment was added for the article:

"The authors are, respectively, Coordinator for Economics, Center for Risk and Economic Analysis of Terrorism Events (CREATE), and Research Professor, School of Policy, Planning and Development (SPPD), University of Southern California; Economist, Environmental Sciences Division, Oak Ridge National Laboratory; Assistant Professor Department of Planning, University of Illinois, Champaign; and Economist, Centers for Disease Control. This research was sponsored by CREATE through funding from the U.S. Department of Homeland Security. We wish to thank Tom Szelazek and Phil Hall-Partyka for helpful research assistance. We also appreciate the comments of other members of the CREATE Economic Impact Modeling Forum. The material in this paper represents the views of the authors, who are solely responsible for its contents."

1. Introduction

This paper summarizes the results of a bottom-up approach to estimating the total economic impacts of the September 11, 2001, World Trade Center attacks on the economies of the New York City Metropolitan Area and the entire United States. It begins by identifying various types of individual shocks to the system, estimating their direct effects, and then entering them into an economy-wide model to determine total impacts. The direct effects include ordinary business interruption and relocation costs. Another set of direct effects stems from "extended linkages," such as changes in economic behavior offsite that result in losses elsewhere in the economy (e.g., reduced airline travel nation-wide).

We also incorporate aspects of economic resilience into the model. This refers to actions at the micro, meso, and macroeconomic levels that mute the direct and indirect shocks at a given point in time by using remaining resources as efficiently as possible and that compress the time-span of losses, and hence their magnitude, by speeding recovery (see, e.g. Rose, 2007). Examples include business relocation, input substitution, import substitution, and the automatic rationing mechanism of price changes.

Our modeling framework is computable general equilibrium (CGE) analysis, a state of the art tool of economic impact and policy analysis that is being increasingly used in the study of terrorism (see, e.g., Rose et al., 2007; Dixon et al., 2007). It can be used to estimate indirect effects in terms of multi-market interactions of prices and quantities of goods and services. This applies not only to ordinary direct effects but to resilience and behavioral linkages as well.

Section II presents our analysis of direct business interruption impacts at the WTC site. Section III contains our analysis of losses from airline travel and associated tourism stemming from fears that emanated from the 9/11 attack. Section IV summarizes the various direct effects used in the analysis. Section V provides a further discussion of resilience. Section VI presents a summary of the CGE model specification used in this paper. Section VII presents and interprets the results.

2. Business Interruption and Relocation

We begin by analyzing the business interruption losses to firms at the WTC site. The analysis of this category of impacts is complicated because it has both time and policy dimensions. More than 95 percent of the WTC area firms and government agencies continued in operation by relocating to other sites, nearly all within the New York Metropolitan Area. However, this relocation was not instantaneous; therefore, a significant amount of business interruption (BI) did occur. Also, there was a cost associated with this transition in all cases, as well as a cost change in subsequent economic activity in some. In this section, we summarize our estimation of the direct BI and relocation costs of the 9/11 attacks using extensive data on business relocation, destination, and timing with respect to:

- Business failures
- Temporary and permanent relocation destinations for surviving firms
- Duration for surviving firms to reopen their business in a new location
- Business operating level during the interrupted period (between the attacks and relocation) compared to the production activity level before the attack
- Duration for firms to recover to normal production level after they reopened in a new location or returned to their old one
- Relocation costs

The main data for business relocation came from an extensive survey of the affected businesses conducted by Urbanomics (2002a). This survey compiled an almost complete list of the affected businesses, employment and their relocation patterns; however, the relocation destinations for 6.3% of affected jobs were not identified. We then tracked down the relocation destinations of these firms using business databases such as Hoover's and LexisNexis, newspaper accounts, and personal interviews.

Table 1 summarizes the compiled relocation destinations of affected businesses. There were 1,134 firms employing 114,126 workers in the destroyed and damaged buildings at the time of the 9/11 terrorist attacks. Nearly 95% of the affected businesses in terms of employment relocated within the New York Metropolitan area, with about 86% of them relocated in downtown and midtown Manhattan. Just a few firms experienced business failures and only 4% of the total jobs were caused directly by the terrorist attacks. Businesses that relocated to other regions in the U.S. and to foreign countries accounted for only 1.1% and 0.1% of the total employment, respectively.

To yield a first approximation of business interruption costs, we converted the number of jobs in the affected businesses to gross output (sales revenue) terms by applying labor productivity coefficients (output/employee) by NAICS sectors. We calculated the coefficients using 2001 IMPLAN data (MIG, 2008) for New York County (the Borough of Manhattan). The column of "Output Loss without Relocation" in Table 2 presents the potential BI losses without considering relocation. Total potential output loss was estimated at about $71.6 billion, nearly 90% of which was concentrated in Finance, Investment Banking, and Insurance sectors. On the other hand, the direct business loss to the New York Metropolitan area, assuming instantaneous relocation, was estimated at only $1.7 billion, or

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TABLE 1. RELOCATION DESTINATIONS OF AFFECTED WTC AREA BUSINESSES

Relocation Destination		Employment		Percent	
New York Metropolitan Area		108,170		94.8%	
	NYC		100,226		87.8%
	Long Island		284		0.2%
	Mid Hudson		2,758		2.4%
	New Jersey		4,680		4.1%
	Connecticut		222		0.2%
Loss to New York Metropolitan Area		5,955		5.2%	
	Rest of US		1,298		1.1%
	Foreign Countries		146		0.1%
	Out of Business		4,511		4.0%
Total		114,126		100.0%	

Source: Adapted from Urbanomics (2002b; Table 12); see text.

2.3% of the potential loss. The losses in Finance, Investment Banking, Communication, and Hospitality sectors account for about 68% of this total.

The figures in Table 2 provide the details of these upper- and lower-bound estimates for BI. In the absence of any business relocation, BI would have been $71.6 billion for the year following 9/11. If all of the firms went out of business, the BI losses would be even greater, since they would extend into the future years. We do not evaluate business failure in perpetuity, but in terms of three years, at which time we assume the unemployed resources would be re-absorbed into the economy. Note, however, that only 1.5 percent of the firms, representing only $1.1 billion of output, went out of business, so only a minor adjustment would be needed in our upper-bound to reflect a longer time horizon.

On the other hand, if relocations were instantaneous, BI losses would only be $1.7 billion for the New York Metro Area. Approximately one-third ($0.6 billion) of this total is due to relocation outside the metro area, and two-thirds of it

TABLE 2. BUSINESS INTERRUPTION OF WTC AREA FIRMS WITH AND WITHOUT RELOCATION

Industry	NAICS	Employment			Labor	Output Loss (million 2001$)			
			NY	Loss to	Productivity	Without Relocation [c]		With Relocation [d]	
		Total	Metro [a]	NY Metro [b]	($/worker)	(level)	(%)	(level)	(%)
Publishing		615	611	4	453,644	279.1	0.4	2.0	0.1
Construction	23	120	120	0	161,097	19.3	0.0	0.0	0.0
Manufacturing	311-339	89	89	0	384,355	34.4	0.0	0.0	0.0
Commodities	421	80	72	7	279,198	22.2	0.0	2.1	0.1
Wholesale	421	208	80	127	279,198	57.9	0.1	35.5	2.1
Retail	453	2,073	1,917	155	90,594	187.8	0.3	14.1	0.8
Transportation	481-488	609	560	49	199,418	121.5	0.2	9.7	0.6
Communications	5131, 5132	2,924	2,579	346	530,954	1552.6	2.2	183.5	11.0
Telecommunications	5133	449	325	124	529,447	237.8	0.3	65.9	3.9
Computer Services	5142, 5415	3,222	2,957	265	168,184	541.8	0.8	44.6	2.7
Technology	5142, 5415	234	221	13	168,184	39.4	0.1	2.1	0.1
Finance	521, 522	56,860	56,522	339	1,001,973	56,972.3	79.5	339.2	20.3
Investments	523, 525	7,919	6,911	1,008	355310	2,813.8	3.9	358.1	21.4
Insurance	524	9,273	9,063	210	412,734	3,827.3	5.3	86.6	5.2
Real Estate	531	181	118	63	528,361	95.6	0.1	33.0	2.0
Business Services	541	4,383	3,890	493	211,892	928.7	1.3	104.3	6.2
Law	5411	5,184	5,099	85	237,879	1,233.2	1.7	20.3	1.2
Accounting	5412	141	138	3	168,049	23.7	0.0	0.5	0.0
Architecture	5413	153	153	0	177,891	27.1	0.0	0.0	0.0
Engineering	5413	545	530	15	177,891	97.1	0.1	2.7	0.2
Design	5414	190	164	26	246,213	46.8	0.1	6.4	0.4
Consulting	5416	1,359	1,326	33	241,925	328.8	0.5	8.0	0.5
Travel Agency	5615	38	38	0	129,393	4.9	0.0	0.0	0.0
Education	611	297	297	0	73,742	21.8	0.0	0.0	0.0
Health Care	621	334	256	78	124,864	41.7	0.1	9.7	0.6
Hospitality	721	2,082	347	1,735	151,457	315.4	0.4	262.8	15.7
Concessions	722	560	482	79	77,294	43.3	0.1	6.1	0.4
Restaurant	722	813	586	227	77,294	62.8	0.1	17.6	1.0

Personal Services	812	1,081	919	162	166,559	180.0	0.3	27.0	1.6
Non-profit	813	1,453	1,142	311	107,628	156.4	0.2	33.4	2.0
Government	921-928	10,657	10,657	0	122,657	1307.2	1.8	0.0	0.0
Total		114,126	108,170	5,955		71,621.7	100.0	1,675.2	100.0
		100%	94.8%	5.2%		100%		2.3%	

a. Jobs that were relocated within the New York Metropolitan Area.

b. Loss to the NY Metro Area includes businesses that left the Area and those that went out of business.

c. Output loss without relocation represents maximum potential loss assuming no relocation (total employment multiplied by labor productivity).

d. Output loss with relocation represents the loss due to relocation outside the NY Metro Area and business failure.

is due to business failures. For the U.S. as a whole, only the latter number is relevant, and the lower-bound estimate would be $1.1 billion.

The difference between the upper- and lower- bound estimates reflects *potential resilience*. According to a metric developed by Rose (2004; 2007), resilience is the ratio of the avoided loss to the potential maximum loss. In this case, it is $70.5 billion/$71.6 billion = 98.5%. The measurement of actual resilience is discussed below.

Further insight into at what point in this range the direct loss falls, comes from two sources. First, the official insurance estimate of losses from 9/11 is approximately $9 billion. However, this includes both BI and relocation costs. On the other hand, it is not comprehensive for either category because not all businesses were fully insured or insured at all.

A more accurate approach to estimating direct BI losses is to adjust the "With Relocation" figures in Table 2 for the time phasing of relocation. This consists of two components: 1) the time it took to relocate and 2) the level of economic activity at the time of relocation and subsequently. It is unlikely that all firms were operating at their pre-9/11 production levels upon relocation, so an estimate of "ramping up" would be desirable. In addition, we also examined the prospects that some firms were able to operate in the interim between locations.

3. DIRECT AIRLINE TRAVEL AND ASSOCIATED TOURISM LOSSES

We estimated passenger losses using a regression framework very similar to Ito and Lee (2005). First, we fit a regression equation to monthly passenger data from the U.S. Department of Transportation (DOT, 2007) for January 1990 until March 2007. The regression model is log-linear with the natural log of the monthly number of passengers as the dependent variable.[1] Explanatory variables are: the national unemployment rate, the log of the employment rate, the jet fuel spot

[1] A Durbin Watson test performed in the STATA statistical software yielded evidence of autocorrelation. To keep our standard errors consistent, we apply Newey-West robust standard errors in all regressions. We also performed a co-integration test (Johansen 1995) using a method in the STATA statistical package which yielded one significant co-integration equation. We follow Ito & Lee's (2005) reasoning in that the estimate on employment is likely biased; however, our goal is to estimate the effect of 9/11 while holding the level of economic activity constant. If we did estimate a vector error correction model including employment and passengers, we would more accurately observe the dynamics between the two series; however, our observation of the actual 9/11 effect would be difficult for two reasons: 1) specifying a lag structure and then pinning down the effects of 9/11 is cumbersome because of the serious drop in September 9/11 and, 2) 9/11 is long-term shock, making it difficult to know the precise lag structure needed.

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price, low cost carrier share of market, percent of flights nationally on-time, a time trend, and indicator variables.[2]

After fitting the model, we construct a counter-factual by using the model parameters to estimate a within-sample prediction of air travel without 9/11. We accomplished this by predicting the expected level of air travel with the 9/11 explanatory variables set to zero. The conditional prediction results are presented in Figure 1.

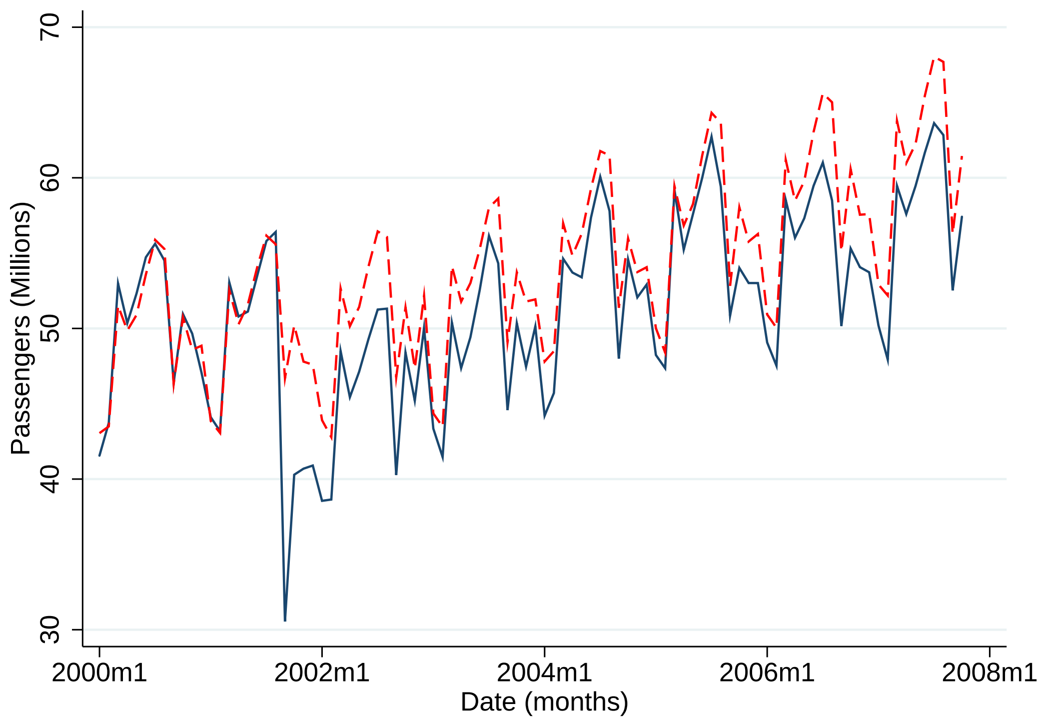

FIGURE 1. PREDICTED AND ACTUAL US NATIONAL PASSENGER LEVELS (2000 - 2007)

We then construct a 95% confidence region around our prediction to provide an upper and lower bound on predicted passenger travel without the effects of 9/11. We can also use this confidence region to make a judgment about when air travel returned to its normal rate, which is the point where the confidence region encompasses the actual passenger rate. We estimate that actual passenger travel returned to its pre-trend level sometime in the middle of 2003; when actual passenger levels fall within the confidence region.

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[2]We include the following indicator variables: September 2001, time greater than September 2001, leap year, Gulf War, Iraq War, SARS outbreak, seasonal dummies, and indicators for when the Thanksgiving Holiday is in December.

Using the predicted trend, upper bound, and lower bound, we computed the difference between predicted passengers and actual passengers. The data we observe represents aggregate one-way trips, so that we must divide our passenger estimates by two. In order to compute output losses, we first use a survey from Travel Industry of America (Maplesden et al., 2002) that describes the spending patterns of domestic air travelers. We then match these spending patters to IMPLAN economic sectors.

Table 3 displays the sectoring scheme for domestic travelers by economic sector. Spending is in dollars per domestic traveler. To convert the above spending patterns into aggregate losses we multiply the spending per passenger by total passengers. Table 1 presents these estimates at the sector level for the entire period of interest (September 2001 to end of the third quarter of 2003). All estimates are in year 2006 dollars.

TABLE 3. ESTIMATED TOTAL OUTPUT LOSSES BY SECTOR FOR 8 QUARTERS FOLLOWING 9/11 (million 2006$)

Sector	Mean	Upper	Lower
Air transportation	35,343	52,491	18,967
Other transportation	2,192	3,255	1,176
Accommodation	21,919	32,554	11,763
Gasoline stations	1,096	1,628	588
Auto equipment rental & leasing	6,851	10,176	3,677
Food	13,517	20,075	7,254
Gifts/shopping	5,114	7,596	2,745
Amusement	5,206	7,732	2,794
Total losses	91,238	135,506	48,964

Our estimate of the overall direct impact of 9/11 is lower than a recent study by Gordon et al. (2007). We attribute this difference to our inclusion of additional predictive variables, namely a measure of the business cycle effect through the unemployment and employment rate. The assumption here is that the 9/11 event did not significantly alter the business cycle.

4. SUMMARY OF DIRECT EFFECTS

The major direct impacts of the 9/11 attacks on the WTC are business interruption losses to firms at the site, as well as relocation costs (see Table 4.) If all of the firms in the WTC area had gone out of business, BI would amount to $71.6 billion per year (in 2006 dollars) for the relevant time span. In this case,

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TABLE 4. DIRECT IMPACTS AND BEHAVIORAL LINKAGES NATIONWIDE OF THE 9/11 ATTACKS ON THE WTC (in billion 2006 dollars)

Type	Upper Bound	Best Estimate	Lower Bound
Ordinary Direct Effects			
Business Interruption	71.6	19.8	1.7
Relocation Costs[a]	0	5.3	7.2
Direct Extended Linkages			
Airline Travel	52.5	35.3	19.0
Other Related Travel	83.0	55.9	30.0

[a] Upper and lower bounds defined in relation to relocation.

relocation costs would of course be zero. On the other hand, about 95% of the WTC area firms relocated, nearly all within the U.S. We estimated the associated relocation costs to be $5.9 billion. If relocation would have been instantaneous, BI losses would only have been $1.7 billion. Below, we focus on a "best estimate" of direct BI losses that factors in the duration of relocation. This estimate is $16.1 billion in 2001 dollars, or $19.8 billion in 2006 dollars.

One other direct effect of the WTC attacks was the destruction of the Path Train station to New Jersey. We enter this into the CGE model at an approximate reduction of gross output of $500 million. The model then analyzes the potential that much of the lost ridership simply shifted to another transportation mode. Note that we have not integrated any estimates of the cost of any travel delays into the analysis at this time.

The major quantifiable extended linkage stems from the "fear factor" in terms of a direct reduction of air travel and decrease in spending on related tourist goods and services throughout the U.S. (Beeler Asay, 2008; cf., Gordon et al., 2007). The mean estimate is $91.2 billion (2006 dollars) over a two-year period. However, in the analysis below we compress the impacts into one year.

Our best estimate of direct BI for major sectors and sector aggregates is presented in Table 5, and amounts to $111 billion (2006 dollars). It is the sum of the three categories noted above: direct BI at the WTC site, Path Train BI impacts, and air travel related tourism declines.

TABLE 5. OUTPUT REDUCTIONS BY MAJOR SECTORS: BEST-ESTIMATE CASE

	USA (million 2006$)	NY Metro (million 2006$)
Air Transportation	35,343	1
Other Transportation	2,336	141
Finance, Banking & Credit	15,909	15,857
Security Brokers	710	688
Insurance	1,059	1,047
Other Business Services	8,866	898
Hotel & Restaurants	35,476	38
Entertainment	5,206	0
Other Sectors	6,068	1,683
Total	110,972	20,353

There are numerous other impacts of the 9/11 attacks relating to psychological, societal, environmental, and other hard to quantify impacts. Therefore, the characterization of upper-bound impacts noted throughout this chapter only applies to quantifiable impacts.

5. RESILIENCE

Resilience refers to the ability of an entity or system to maintain function (e.g., continue producing) when shocked (see also Rose, 2004b; 2007). It is thus aligned with the fundamental economic problem--efficient allocation of resources, which is exacerbated in the context of disasters. This aspect is interpreted as static because it can be attained without repair and reconstruction activities, which affect not only the current level of economic activity but also its future time path. Another key feature of static economic resilience is that it is primarily a demand-side phenomenon involving users of inputs (customers) rather than producers (suppliers). It pertains to ways to use resources available as effectively as possible. This is in contrast to supply-side considerations, which definitely require the repair or reconstruction of critical inputs.

A more general definition that incorporates dynamic considerations is the speed at which an entity or system recovers from a severe shock to achieve a desired state. This also subsumes the concept of mathematical or system stability because it implies the system is able to bounce back. This version of resilience is relatively more complex because it involves a long-term investment problem associated with repair and reconstruction.

Ability implies a level of attainment will be achieved. Hence, the definition is contextual--the level of function has to be compared to the level that would have existed had the ability been absent. This means a reference point or

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type of worst case outcome must be established first. Further discussion of this oft-neglected point is provided below.

Two other dimensions of resilience can be distinguished. Inherent resilience refers to the ordinary ability to deal with crises (e.g., the ability of individual firms to substitute other inputs for those curtailed by an external shock, or the ability of markets to reallocate resources in response to price signals). This is itself a type of resource already in place that can be enhanced prior to a disaster, so that capabilities that are not damaged or eroded can be implemented in the disaster aftermath.

Adaptive resilience in contrast refers to the ability in crisis situations to maintain function on the basis of ingenuity or extra effort (e.g., increasing input substitution possibilities in individual business operations or strengthening the market by providing information to match suppliers with customers). This corresponds to pushing the efficiency frontier outward.

Resilience can take place at three levels:

Microeconomic: Individual producer and consumer decisions to conserve scarce resources, use inventories, or substitute one input or good for another, use of alternative technologies (e.g., distributed power generation), excess capacity, relocation, or making up lost economic activity at a later date.

Mesoeconomic: Individual market adjustments relating to price changes in the face of demand and supply changes, improved information flows to compensate for market deficiencies in a crisis (e.g., information clearing houses that match customers who lost their suppliers with suppliers who have lost their customers).

Macroeconomic: The ability of an economy to input more goods when there is a shortfall at home, multi-market interactions through quantity changes (ordinary multiplier impacts) and/or through price changes. Finally, we should note the overall ability in the market to provide valuable information to producers and consumers, spur efficiency and innovation, and otherwise maintain organization.

Several studies have found resilience to be sizeable in short-term or limited cases, such as water and electricity outages following the Northridge Earthquake (Tierney, 1997), or simulations of earthquakes (Rose and Liao, 2005) and terrorist attacks (Rose et al., 2007). Conservation input-substitution, and inventories were found to be of limited effect. Alternative technologies (e.g., back-up electricity generators) or alternative sources (e. g., well water or riverine water), price adjustments, and production rescheduling were found to be major sources of resilience.

On the other hand, large-scale disasters, in terms of breadth of area covered, duration, and basic coping ability, are likely to witness a severe erosion of resilience. The most poignant recent example of this is Hurricane Katrina.

Several types of resilience are difficult to model and measure as noted in the last column of Table 6. We are currently working on incorporating more of them in the analysis. Below, we discuss the details of our modeling efforts and results on this score.

TABLE 6. RESILIENCE IN THE FACE OF THE 9/11 ATTACKS

Type	Direct Effect	Indirect Effect	How Modeled (Direct/Indirect)
Microeconomic			
Business Relocation	external shock	internal	data compilation/CGE
Conservation	-[a]	n.a.	not modeled[a]
Input-Substitution [b.c]	internal	internal	CGE/CGE
Inventories	-[a]	-[a]	not modeled[a]
Excess Capacity	office space only	office space only	modeled separately[d]
Macroeconomic			
Import Substitution[b]	internal	internal	CGE/CGE
Price Adjustments[c]	see text	see text	CGE/CGE

[a] Assumed to be minor.
[b] Inherent (rather than adaptive) only. Adaptive assumed to be minor.
[c] Applies to extended linkages as well.
[d] Major example was excess office space, so associated with relocation.

6. CGE ANALYSIS

A. Basic Modeling Considerations

CGE refers to a multi-market model of an economy based on the behavioral responses of individual producers and consumers within the constraints of labor, capital and natural resources. CGE models maintain most of the advantageous features of input-output (I-O) models (e.g., full accounting of all inputs, multi-sector detail, ability to measure interdependence) while overcoming many of their limitations (e.g., absence of behavioral content, linearity, lack of substitution, absence of prices and markets). CGE models have many valuable attributes that make them well-suited to the analysis of terrorist attacks (Rose, 2005) and are increasingly being used to analyze these and related issues (Rose et al., 2007; Dixon et al., 2008). In short, they have the ability to incorporate estimates of

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direct effects and to translate them into economy-wide (general equilibrium) effects through the interaction of producers and consumers and markets and subject to the constraints imposed by the attack. The behavioral, market, and flexible basis of CGE models gives them an edge in modeling most types of resilience (see, e.g., Rose and Liao, 2005). Input substitution is readily addressed in production functions and household expenditure systems, as is import substitution. Price adjustments are an inherent feature of these models. Excess capacity and relocation can easily be modeled through relaxing constraints on the system, and several other resilience adjustments can be incorporated through changes in parameters (e.g., adaptive input/import substitution, adaptive conservation) or side calculations (e.g., production rescheduling).

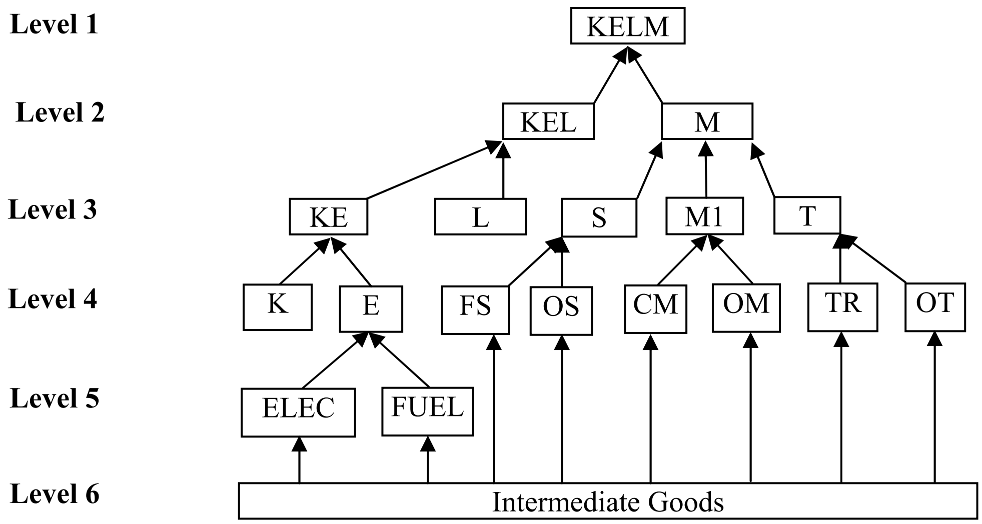
B. Model Design

We constructed static CGE models of the U.S. economy and the New York Metro Area consisting of 57 producing sectors. Institutions in the model are households, government, and external agents. There are nine household income groups and two categories each of government (State/Local and Federal) and external agents (Rest of the U.S., Rest of the world). Major features of the model are:

1. Production

Production activities are specified as constant-returns-to-scale, nested constant elasticity of substitution (CES) functions. The top level consists of substitution possibilities among sub-aggregates made up of capital (K), labor (L), energy (E) and materials (M) to form a KLEM aggregate. The next level reflects the choice of a material input aggregate and a capital-energy-labor input combination. On the third level, the capital-labor-energy combination is made up of labor and a capital-energy combination. On the fourth level, the capital-energy combination is made up of capital and energy aggregates. In order to capture the role of electricity more explicitly, we include an energy sub-nest consisting of fuels and electricity. Fuel use is a CES function of petroleum, coal and gas, while overall electricity use is derived as a Leontief (fixed coefficient) aggregation of private electric utilities and state/local electric utilities.

The nested CES function model of producer behavior provides a flexible structure of input substitution in the production of goods and services as illustrated below:



L = Labor
K = Capital
E = Energy
M = Materials
T = Transport
S = Services
FS = Financial Services
OS = Other Services
CM = Chemicals
OM = Other Materials
TR = Transport Services (Truck, Rail, Water and Air)
OT = Other Transport Services

2. Supply and Trade of Goods and Services

We specify transactions between the U.S. and the rest of the world in the model using the Armington relationship for imports and the constant elasticity of transformation function for exports. The former is specified as a CES function to reflect imperfect substitution between domestic goods and competitive imports in demand. The latter is analogous to a CES function that reflects the revenue-maximizing distribution of domestic output between exports and domestic markets, respectively. Export and import prices are based on exogenous external prices plus percentage taxes and tariffs. The New York Metro Area model incorporates trade between the region and rest of the U.S.

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3. Income Allocation, Final Demand, and Investment

Incomes from labor and capital employment in the economy are shared among institutions after the following deductions are made. Governments collect profit taxes on capital and employer-paid social security taxes on labor income, while industries deduct depreciation charges and retained earnings before paying capital incomes. The remaining incomes are then distributed to households and external agents according to fixed shares. Institutions also receive inter-institutional transfers, such as subsidies, social security, and income taxes.

Household consumption behavior in the model is represented by a Linear Expenditure System of aggregate commodities. The commodities are Food, Housing, Gasoline, Local Transit, Other Transportation, Health, Equipment, Water & Sanitary Services, Electricity, Other Fuels, Other Goods, and Other Services. The commodities are produced from market goods and services by household production functions.

Government consumption is specified as a Leontief expenditure function. Savings by households and governments are fixed proportions of disposable income, while external savings balance out this account. Households, government, and external entities also borrow from the capital account. Net savings by institutions, plus depreciation charges and retained earnings, are used to finance investment in capital goods. Investment in individual capital goods categories is a fixed proportion of total investment funding.

4. Equilibrium/Disequilibrium Conditions

Equilibrium conditions balance supply and demand in goods and services markets. Capital endowments in the economy are fixed to reflect the short-run nature of our simulations. In the labor market, the Keynesian closure rule is used to allow for unemployment even in equilibrium. This disequilibrium condition prevents the muting of impacts inherent in the forcing of an equilibrium by the application of the Neoclassical closure rule (zero unemployment equilibrium).

Disequilibrium is introduced into the model in several other ways (see, e.g., Rose et al., 2004; Rose and Liao, 2005). Most important are constraints on supplies of sectors directly hit by the terrorist attack. This causes a shift away from an efficient equilibrium to a second-best world.

Another source of disequilibrium stems from temporary imbalances in trade and financial flows in and out of the country. An increased demand for imports will likely be required to offset the reduced production within the U.S.

Finally, the model can incorporate fiscal imbalances. This would include debt, as well as other options (increased taxes, user fees or outside aid) to fund mitigation, and deficit spending to fund recovery and reconstruction. These various alternatives are likely to have significantly different impacts on a regional economy. An infusion of outside aid will translate into an unfettered boon, and the economy might expand or contract depending on shifts in spending from one stream to another (fewer consumer goods and more public services from tax increases, or shifts from ordinary consumer expenditures to repair and reconstruction expenditures).

C. Model Construction

The sectoring classification of the models (see the first column of Table 3) was selected to highlight businesses that were especially affected by 9/11, e.g., finance and airline transportation. A major amount of the data for the model are taken from the detailed 2006 Social Accounting Matrix (SAM) for the U.S. derived from the Impact Planning and Analysis (IMPLAN) database (MIG, 2008). This is based on the National Income and Product Accounts and an update of the benchmark U.S. Department of Commerce I-O Table.

A review of the literature was conducted to update the various elasticity parameters needed in the model. These include input substitution elasticities in production, trade elasticities, household income and price elasticities, and household substitution elasticities.

For Armington elasticities previous estimates were compared with Tsigas (1997), Donnelly et al. (2004), and Dixon et al. (2007). Although having different sectoral classifications, it was found that these elasticities were generally comparable to each other. As such only a few of Armington elasticities used in previous modeling efforts were updated. The elasticities are between 2-3 for agricultural and manufacturing sectors, and around 1 for most of the other sectors of the economy. No new elasticities of transformation for exports were needed.

For households, calibration of the linear expenditure system requires income elasticities and the Frisch parameter. The latter was set to -2.0. Income elasticities from Oladosu (2000) were compared with those in Canning and Tsigas (2000), Tsigas (1997), and USAGE elasticities. Most of the income elasticities were based on Oladosu (2000) because the commodity categories are more consistent with the model specification. In addition, most elasticities from the other sources were close to 1. Substitution elasticities among market goods in the household production functions were set to values in the 0.1 – 0.5 range, with most less than 0.3.

For production behavior it was difficult to find elasticities of substitution that match the nesting scheme illustrated above. Most studies estimate substitution elasticities between labor and capital only. These include Balisteri et al. (2003) and Kemfert (1998). As a result most of the production elasticities from the previous modeling efforts were retained. For many of the sub-aggregate inputs on Levels 4 - 6, substitution elasticities were set to low but non-zero values less than or equal to 0.5.

D. Model Application

The application of CGE analysis to terrorist attacks is not straightforward in a case like 9/11. Although this approach has many advantages relative to others, it is in essence an equilibrium model, meaning it is difficult to constrain (Rose, 2005; Rose et al., 2007). Several types of disequilibria have been incorporated into the methodology for prior application to terrorism and other disasters, but reduction in production capacity due to damage to the capital stock or output of many sectors simultaneously presents computational challenges to obtaining feasible and meaningful solutions.

CGE models can be solved as a set of simultaneous equations, reflecting market equilibria, or as some form of mathematical programming model, reflecting the optimizing behavior of individual producers and consumers. The disequilibrium analysis requires the inclusion of constraints and thus dictates the latter. In this paper, the general equilibrium effects of output losses were simulated using the following approach in a non-linear programming format of the GAMS software:

1. Upper bounds on output of the affected sectors were imposed as the base year level minus estimated direct losses from the September 11 attack.

2. A slack price variable was introduced into the revenue equation for each sector. This variable is allowed to take on positive, negative or zero values and enables producer's revenue in these sectors to be greater than, less than or equal to the cost of production (Note that for the U.S. simulations this variable was restricted to be positive or zero) in order to obtain a feasible solution.

3. For each sector a complementary equation was introduced that requires the product of the slack price variable from (2) and the gap between actual and upper bound on output to be greater than or equal to zero as:

$$\underset{(-\,or\,0)}{\left(X_i - X_i^{up}\right)} \times \underset{(+,-\,or\,0)}{P_{slack}} \quad \geq \quad 0$$

This equation implies that revenue received by any sector could be greater than its cost (positive P_{slack}), provided that the upper-bound constraint on output is binding. However, revenues received could also be lower than the cost of production (negative P_{slack}) when actual production is lower than or equal to the upper-bound constraint. Thus, P_{slack} represents a shadow price that serves to ration the available output when the upper-bound constraint is binding, but also allows producers to reduce production and/or prices.

4. Extra revenues (or losses) are added to (or subtracted from) the affected sector's capital returns. This ensures that revenues/losses in the economy are completely distributed.

5. Since the above equation introduces disequilibrium into the model, its value is squeezed towards zero in relation to the objective function of the model.

7. Simulation Results For The Best Estimate Case

A. Impacts on the U.S. Economy

Four cases are simulated using the direct impact estimates in column 1 of Table 3. Results of the simulations are summarized for 34 sectors in Table 5 above. The 34 sectors are aggregates of the original 57 production sectors of the model.

Case 1 represents the total economic impacts of all the direct BI reductions summarized in the previous section, about \$111 billion, on the U.S. economy. Overall, this results in a total economic output (gross sales) loss of \$243 billion, or 1.16 percent decrease relative to the base year economy, on an annual basis for 2001-02. Note that impacts actually occur over a two-year period, though most take place during the first year. The total impact on value-added (a measure of net output that is roughly equivalent to GDP), is a decline of \$108 billion, or 0.96 percent of base values.[3]

Almost all sectors of the economy are affected, but the greatest effects are seen in the directly impacted sectors, namely Banking, Securities, Other Transport (Airlines), Hotels & Restaurants, Entertainment, and Local Transit. Other sectors with output reductions greater than 1 percent include those with strong linkages to the aforementioned, such as Food Manufacturing and Petroleum Refining. Most of the remaining sectors show output reductions much less than 1.0 percent. A

[3] Note that while the simulations are conducted with a model using 2006 as its baseline economy, and all level numbers in Tables 7 and 8 are as obtained from the model, percentage changes have been calculated relative to a 2001 baseline economy. The 2001 baseline economy was obtained by scaling-down the 2006 baseline levels (Output and Value-added) by the aggregate real growth rate between 2001 and 2006. All calculations are in 2006 dollars.

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look at the impacts in terms of real value-added in Table 7 provides additional insights into these results. It shows that percentage reductions in real value-added are less than output reductions for most sectors. This reveals a tendency to substitute labor both for reduced capital stocks and for other inputs under output constraints on many sectors.

Cases 2 to 4 simulate the total impacts of direct shocks to Transportation, Financial Services, and Other Sectors separately. Case 2 is the Transportation simulation, and produces a total output reduction of 0.56 percent relative to the base year. Sectoral output reductions, except for the transport sectors, are generally less than 0.5 percent. All of the sectoral output reductions are lower than their counterparts compared to Case 1.

Case 3 simulates the direct impacts on Financial Services from Table 3. As in Case 2, the directly affected sectors have the largest reductions, with total general equilibrium output reductions being 0.29 percent. The output reductions in other sectors are also far different from the previous case because of differences in the weights of intersectoral linkages that come into play.

Case 4 simulates the direct impacts of Other Sectors (e.g., Hotels and Restaurants), apart from Transportation and Financial Services. The direct BI (partial equilibrium) impacts are the largest of the three decomposition cases, with general equilibrium impacts of 0.57 percent. The Hotel & Restaurant sector and the Entertainment sector incur the largest total impacts, followed by the obviously related Food Manufacturing sector and the less obvious linkage to Construction.

Note that the sum of impacts from the three separate simulations add up to a \$299 billion (1.42 percent) total decline in output in contrast to the “all sector” simulation results of \$243 billion (1.16 percent). This means that the whole is not the simple sum of the parts and that interactive effects, which primarily increases downward price pressures mute the overall impacts. This illustrates the advantage of general equilibrium analysis in evaluating the economic effects of sudden events, validating the expectation that the total economic impacts are not simply additive, but rather involve many complex price and quantity interactions in the economy.

Note also that the outcome of the comprehensive simulation of impacted sectors (Case 1), resulting in a decrease in gross output of approximately \$243 billion, is about 2.20 times the total direct impacts. The 2.20 represents an implicit multiplier of the model. This is in contrast to a U.S. I-O table that would have an economy-wide multiplier of greater than 3.0. Our lower multiplier value primarily reflects the price adjustment features of a CGE model, which mute the impacts. In other words, price decreases accompanying an economic downturn have a partially offsetting (stimulating) effect on demand otherwise both directly

TABLE 7. SIMULATION RESULTS FOR THE BEST ESTIMATE OF IMPACTS FOR THE U.S. ECONOMY (2006$)

	Output ($billion)					Value Added ($billion)		Output Change (%)				Value Added Change (%)	Output Change ($million)				Value Added Change ($million)
	Baseline	All Sectors	Transport Sectors	Financial Sectors	Other Sectors	Baseline	All Sectors	All Sectors	Transport Sectors	Financial Sectors	Other Sectors	All Sectors	All Sectors	Transport Sectors	Financial Sectors	Other Sectors	All Sectors
Agriculture	324	322	324	324	322	126	125	-0.75	-0.06	-0.05	-0.72	-0.42	-2.1	-0.2	-0.2	-2.0	-0.5
Mining	432	429	430	431	430	278	277	-0.69	-0.34	-0.21	-0.39	-0.48	-2.5	-1.3	-0.8	-1.4	-1.1
Construction	1403	1384	1398	1395	1388	628	620	-1.56	-0.44	-0.65	-1.27	-1.44	-18.5	-5.2	-7.8	-15.1	-7.7
Food Manufacturing	624	616	623	624	618	123	122	-1.48	-0.29	-0.10	-1.25	-1.18	-7.8	-1.6	-0.5	-6.6	-1.2
Chemicals	962	960	961	961	961	216	215	-0.31	-0.14	-0.12	-0.15	-0.24	-2.5	-1.1	-1.0	-1.2	-0.4
Petroleum	595	589	590	595	595	72	72	-1.20	-1.06	-0.07	-0.14	-0.63	-6.0	-5.4	-0.3	-0.7	-0.4
Other Non-Durables	828	823	826	827	825	300	299	-0.69	-0.30	-0.15	-0.40	-0.56	-4.9	-2.1	-1.1	-2.8	-1.4
Primary Metals	250	249	249	249	249	68	68	-0.53	-0.38	-0.18	-0.17	-0.46	-1.1	-0.8	-0.4	-0.4	-0.3
Electronics	670	663	667	668	667	100	99	-1.24	-0.62	-0.49	-0.64	-1.16	-7.0	-3.5	-2.8	-3.6	-1.0
Other Durables	2424	2409	2416	2419	2416	667	664	-0.76	-0.41	-0.27	-0.38	-0.60	-15.7	-8.5	-5.5	-7.7	-3.4
Local Transit - Private	32	32	32	32	32	20	19	-1.52	-1.23	-0.15	-0.25	-1.53	-0.4	-0.3	0.0	-0.1	-0.3
Other Transportation	744	706	708	743	741	421	405	-6.03	-5.62	-0.18	-0.35	-4.49	-38.0	-35.5	-1.1	-2.2	-16.0
Communication	671	667	669	670	670	335	334	-0.65	-0.39	-0.17	-0.24	-0.51	-3.7	-2.2	-0.9	-1.4	-1.5
Information	513	509	511	512	511	268	266	-0.94	-0.49	-0.29	-0.45	-0.79	-4.1	-2.1	-1.3	-2.0	-1.8
Electricity - Private	271	271	271	271	271	237	237	-0.18	-0.08	-0.04	-0.10	-0.15	-0.4	-0.2	-0.1	-0.2	-0.3
Gas Utilities	97	97	97	97	97	46	46	-0.27	-0.12	-0.05	-0.14	-0.17	-0.2	-0.1	0.0	-0.1	-0.1
Water - Private	7	7	7	7	7	6	6	-0.15	-0.06	-0.03	-0.09	-0.11	0.0	0.0	0.0	0.0	0.0
Sanitary Services	7	7	7	7	7	4	4	-0.42	-0.15	-0.09	-0.27	-0.33	0.0	0.0	0.0	0.0	0.0
Wholesale Trade	1169	1160	1165	1167	1165	830	824	-0.93	-0.47	-0.25	-0.46	-0.93	-9.3	-4.7	-2.4	-4.6	-6.6
Retail Trade	1306	1300	1302	1304	1301	911	906	-0.54	-0.44	-0.20	-0.47	-0.56	-6.0	-4.9	-2.2	-5.2	-4.3
Real Estate	1070	1064	1067	1068	1066	763	759	-0.68	-0.27	-0.18	-0.40	-0.56	-6.2	-2.5	-1.7	-3.7	-3.6
Banking	807	791	805	791	806	524	515	-2.32	-0.39	-2.32	-0.17	-2.04	-15.9	-2.6	-15.9	-1.2	-9.1
Securities	375	370	373	371	374	222	220	-1.39	-0.50	-1.07	-0.16	-1.36	-4.4	-1.6	-3.4	-0.5	-2.6
Insurance	592	590	590	591	592	323	321	-0.46	-0.37	-0.21	-0.04	-0.45	-2.3	-1.9	-1.1	-0.2	-1.2
Owner Dwellings	1014	1014	1014	1014	1014	930	930	-0.01	-0.01	-0.01	0.00	0.00	-0.1	-0.1	-0.1	0.0	0.0
Hotels & Restaurants	674	639	671	673	639	362	346	-6.20	-0.46	-0.10	-6.20	-5.32	-35.5	-2.7	-0.6	-35.5	-16.4
Other Services	3625	3591	3606	3616	3611	1995	1978	-1.08	-0.61	-0.28	-0.45	-1.03	-33.4	-18.7	-8.7	-13.8	-17.5
Entertainment	200	195	199	200	195	129	126	-3.07	-0.39	-0.11	-3.07	-2.91	-5.2	-0.7	-0.2	-5.2	-3.2
Education	744	743	742	743	744	672	671	-0.16	-0.20	-0.03	0.00	-0.17	-1.0	-1.3	-0.2	0.0	-1.0
Medical Services	1295	1290	1292	1294	1294	791	788	-0.51	-0.35	-0.11	-0.14	-0.51	-5.6	-3.9	-1.2	-1.5	-3.4
Electricity - Public	71	71	71	71	71	42	42	-0.17	-0.07	-0.04	-0.09	-0.20	-0.1	0.0	0.0	-0.1	-0.1
Local Transit - Public	25	23	23	25	25	16	14	-10.73	-10.73	-0.12	-0.16	-10.95	-2.3	-2.3	0.0	0.0	-1.5
Federal Military	172	172	172	172	172	172	172	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0
Other Government	816	815	816	816	816	724	724	-0.13	-0.07	-0.03	-0.06	-0.12	-0.9	-0.5	-0.2	-0.4	-0.7
Total	**24812**	**24569**	**24694**	**24750**	**24693**	**13321**	**13212**	**-1.16**	**-0.56**	**-0.29**	**-0.57**	**-0.96**	**-243.3**	**-118.3**	**-61.7**	**-119.4**	**-108.5**

and indirectly. This is a form of market resilience. Also captured by the model are other types of resilience, such as input and import substitution for goods in short supply.

For now, we have presented the results in terms of a single year. There are a couple of inconsistencies that will be resolved in future simulations. First, although BI for firms that fail would extend into the future for several years, we believe it reasonable to truncate these losses to 3 years because the resources would be reemployed in the economy by that time. On the other hand, the airline and travel BI figures we used are for a cumulative 2-year period, but we have compressed them into a single year. Thus, the time period considerations offset each other to some extent, especially in the upper-bound case, in which we assume all WTC area firms went out of business rather than relocating.

B. Impact on the New York Metropolitan Area

Simulation results of impacts on the New York Metro Area economy are presented in Table 8. The BI simulated for the regional area represents reductions from Table 3 excluding those due to relocations to the rest of the world and the rest of the U.S., as well as those due to companies that went out of business. Similarly, the tourism and transportation impacts are only those affecting the New York Metro Area. The total best estimate of these direct impacts is about $20 billion.

Case 1 simulates all the direct regional impacts. The total loss of output amounts to about $25 billion or an 1.29 percent reduction relative to the base year. The value-added impact is a decline of $14 billion or 1.18 percent. Although most sectors of the economy show output declines, the largest impacts are again seen for the directly affected sectors. Only six sectors show output declines greater than 1 percent: Banking, Public Transit, Insurance, Electronics, Entertainment, and Construction.

Cases 2 to 4 simulate the impacts on transport sectors, financial sectors, and other sectors separately. The impacts for Case 2 are small at 0.08 percent or $2 billion reduction in total output, which matches the transport sector direct impacts of only about $150 million. Given that the financial sectors account for almost 90 percent of direct losses, Case 3 has an overall output reduction comparable to Case 1 at 1.22 percent. There were also direct output reductions in most of the remaining sectors. However the financial sectors accounted for almost $17 billion of the total $23 billion output loss. Case 4 produces a total output loss of $9 billion, or 0.49 percent relative to the base case.

The total regional output impact in Case 1 is about 1.25 times the total direct impacts. This multiplier is much lower than the 2.20 estimated for the U.S.

TABLE 8. SIMULATION RESULTS FOR THE BEST ESTIMATE OF IMPACTS FOR THE NEW YORK METRO AREA ECONOMY (2006$)

	Output ($billion)					Value Added ($billion)		Output Change (%)				Value Added Change (%)	Output Change ($billion)				Value Added Change ($billion)
	Baseline	All Sectors	Transport Sectors	Financial Sectors	Other Sectors	Baseline	All Sectors	All Sectors	Transport Sectors	Financial Sectors	Other Sectors	All Sectors	All Sectors	Transport Sectors	Financial Sectors	Other Sectors	All Sectors
Agriculture	2	2	2	2	2	1	1	0.01	-0.03	-0.10	-0.26	-0.01	0.0	0.0	0.0	0.0	0.0
Mining	6	6	6	6	6	4	4	-0.09	-0.02	0.00	-0.13	0.00	0.0	0.0	0.0	0.0	0.0
Construction	81	81	80	83	78	46	46	-0.21	-0.78	3.31	-4.45	-0.20	-0.2	-0.6	2.4	-3.2	-0.1
Food Manufacturing	17	17	17	17	17	6	6	-0.90	0.04	-0.24	-1.12	-0.54	-0.1	0.0	0.0	-0.2	0.0
Chemicals	104	103	104	107	103	24	24	-0.72	0.12	2.75	-0.83	-0.34	-0.7	0.1	2.6	-0.8	-0.1
Petroleum	11	11	11	11	11	1	1	-0.38	-0.09	-0.51	-0.39	-0.20	0.0	0.0	0.0	0.0	0.0
Other Non-Durables	43	43	43	43	43	15	15	-0.83	-0.10	-1.31	-0.83	-0.52	-0.3	0.0	-0.5	-0.3	-0.1
Primary Metals	6	5	6	6	6	1	1	-3.57	14.10	14.57	0.25	-2.77	-0.2	0.7	0.7	0.0	0.0
Electronics	31	30	31	31	30	3	3	-2.76	-0.37	0.33	-4.02	-2.05	-0.8	-0.1	0.1	-1.1	-0.1
Other Durables	78	78	78	77	77	36	36	-0.62	-0.47	-1.55	-1.62	-0.43	-0.4	-0.3	-1.1	-1.1	-0.1
Local Transit - Private	8	8	8	7	8	5	5	-0.55	-0.55	-3.89	2.24	-0.51	0.0	0.0	-0.3	0.2	0.0
Other Transportation	46	46	46	46	46	28	28	-0.72	-0.14	-1.77	-0.74	-0.89	-0.3	-0.1	-0.7	-0.3	-0.2
Communication	103	102	103	103	102	40	40	-0.47	0.00	0.17	-0.47	-0.27	-0.4	0.0	0.2	-0.4	-0.1
Information	77	77	77	77	77	48	48	-0.11	0.02	0.27	-0.11	-0.05	-0.1	0.0	0.2	-0.1	0.0
Electricity - Private	23	22	23	22	23	19	19	-0.10	-0.01	-0.13	-0.06	-0.07	0.0	0.0	0.0	0.0	0.0
Gas Utilities	6	6	6	6	6	2	2	-0.05	0.00	-0.11	-0.15	-0.05	0.0	0.0	0.0	0.0	0.0
Water - Private	1	1	1	1	1	0	0	-0.57	-0.02	-0.45	-0.43	-0.33	0.0	0.0	0.0	0.0	0.0
Sanitary Services	1	1	1	1	1	0	0	-0.34	0.01	-0.46	0.36	-0.28	0.0	0.0	0.0	0.0	0.0
Wholesale Trade	122	121	121	120	121	63	63	-0.14	-0.21	-1.83	-0.14	-0.12	-0.1	-0.2	-2.0	-0.1	-0.1
Retail Trade	108	108	108	106	108	81	80	-0.35	-0.23	-2.70	-0.35	-0.36	-0.3	-0.2	-2.6	-0.3	-0.3
Real Estate	123	123	123	127	123	95	95	0.00	0.12	3.71	0.00	0.00	0.0	0.1	4.1	0.0	0.0
Banking	101	85	101	85	101	73	64	-17.63	0.01	-17.63	0.07	-14.98	-15.9	0.0	-15.9	0.1	-9.8
Securities	138	137	138	137	138	110	109	-0.57	-0.07	-0.57	-0.22	-0.57	-0.7	-0.1	-0.7	-0.3	-0.6
Insurance	64	63	64	63	66	29	29	-1.78	-0.39	-1.78	3.02	-1.65	-1.0	-0.2	-1.0	1.7	-0.4
Owner Dwellings	96	96	96	96	96	89	89	-0.01	0.00	-0.02	-0.02	0.00	0.0	0.0	0.0	0.0	0.0
Hotels & Restaurants	45	45	45	45	45	25	25	-0.11	-0.06	-0.98	-0.11	-0.06	0.0	0.0	-0.4	0.0	0.0
Other Services	419	416	418	414	416	232	231	-0.57	-0.09	-1.24	-0.62	-0.59	-2.1	-0.3	-4.6	-2.3	-1.2
Entertainment	22	22	22	22	22	16	16	-1.56	-0.20	-2.10	-0.72	-1.54	-0.3	0.0	-0.4	-0.1	-0.2
Education	74	74	74	74	74	66	66	-0.11	-0.05	-0.83	-0.04	-0.10	-0.1	0.0	-0.5	0.0	-0.1
Medical Services	117	117	117	115	117	80	80	-0.03	-0.13	-2.12	-0.14	-0.02	0.0	-0.1	-2.2	-0.1	0.0
Electricity - Public	1	1	1	1	1	0	0	-0.07	0.00	-0.32	0.25	-0.07	0.0	0.0	0.0	0.0	0.0
Local Transit - Public	1	1	1	1	1	0	0	-20.13	-20.13	-4.41	14.81	-20.10	-0.1	-0.1	0.0	0.1	0.0
Federal Military	3	3	3	3	3	3	3	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0
Other Government	67	67	67	67	67	60	60	-0.46	-0.05	-0.71	-0.45	-0.36	-0.3	0.0	-0.4	-0.3	-0.2
Total	**2143**	**2119**	**2142**	**2120**	**2134**	**1301**	**1288**	**-1.29**	**-0.08**	**-1.22**	**-0.49**	**-1.18**	**-24.6**	**-1.6**	**-23.3**	**-9.3**	**-13.7**

case to a great extent to the lower self-sufficiency and hence lower degree of interdependence of the region relative to the nation. It also likely indicates greater flexibility at the regional level. This flexibility results from a number of factors, including the ability to quickly restart business operations for a region from adjacent, but unaffected regions, and the quick availability of help from adjacent regions and federal agencies. This greater regional resilience is also seen in the fact that the total loss under Case 1 is about 30 percent lower than the sum of losses under Cases 2, 3, and 4. The comparable percent difference for the U.S. simulation is about 19 percent.

We have previously performed sensitivity tests on our CGE model parameters that suggest the model results are generally robust to consumer and producer elasticities. A more extensive sensitivity analysis is planned for future research. For this paper, we deem the major sensitivity to be the direct business interruption losses, which we have examined in this light.

8. Conclusion

This paper has analyzed the national and regional economic impacts of the September 11, 2001, attacks on the World Trade Center. It includes not only the standard aspects of economic consequence analysis, but also includes consideration of resilience and extended linkages (in this case, behavioral linkages such as the "fear factor").

Our best estimate of the economic consequences of these attacks is $109 billion in losses to U.S. GDP. This represents 1.0 percent for the 12 months following the attacks. However, there is an indication that the impacts of decreases in business travel and tourism extended well into a second year, so that this number would be lower for that extended period. The losses are significantly affected by factors other than those typically addressed in economic consequence analysis. The extensive relocation of businesses in the World Trade Center area greatly muted the impacts, while the fear of taking an airline trip great exacerbated it.

Note that this study did not include all possible impacts. For example we did not address various other psychological, or sociological effects. Nor did we incorporate the impact of any mitigation initiatives stemming from 9/11, such as increased scrutiny of airline travelers or increased military activity in Afghanistan.

We conclude that the events of 9/11 did not have a destabilizing effect on the economy of New York State or that of the U.S. as a whole. While the impact was large in absolute numbers both for the New York Metro region and the U.S., the size and the resilience of the population and of the economy in both cases enabled us to absorb this shock without devastating economic consequences.

APPENDIX A. RELOCATION TIMING

After an assessment and analysis of the relocation data,, several inferences were made about relocation timing for the WTC firms impacted by the attacks. First, most firms, especially larger ones, quickly found office space within the NYC Metro Area, while some smaller firms moved to their headquarters temporarily either within the Metro Area, elsewhere in the U.S., or overseas. Many firms found space within 2 weeks of the attacks, and some even experienced a positive rent differential.

Second, the duration of the relocation process for the WTC firms rarely exceeded one year. An example of a relocation process occurring for longer than a year was NBC's transmitter, which stood atop of the North Tower (1 WTC). While other broadcasting companies shifted their source of transmission to the Empire State Building, NBC transmitted from Armstrong Tower in Alpine, New Jersey for 4 years before utilizing the antenna on the Empire State Building.

Third, the firms' levels of operation never significantly changed, due primarily to the highly sophisticated support systems they implemented prior to the attack or emergencies in general or as side-effects of general technological advances. It took many firms only 2-4 weeks after the attacks to return to their previous levels of operation or a new equilibrium.

The timing of relocation bears heavily on our estimates of BI. On average, the durations for moving to new sites are rather short, and most firms did not suffer a significant decrease in output at the new site for too long. A summary of data on relocation duration for 30 firms is presented in Table 3-6. From the information in the table we can conclude that all 30 firms moved to a permanent location within 8 months. The table also provides us with the temporary destinations to which these firms moved, as well as the dates of theses moves; temporary destinations were generally found within the first two weeks of the attacks. In addition to relocation duration and destination, the table compares employment figures of most firms' new locations to employment in their WTC complex offices. Several firms experienced a positive employment differential while some, underwent severe cutbacks that produced a negative differential.

The time-path of relocation, in terms of a cumulative frequency distribution function, is presented in Figure 2 in terms of a line drawing and a fitted curve. The recovery takes on the shape of a logistical (S-shaped) curve typical of such phenomena. We use the concepts in the figure to adjust the direct BI estimates for delays in beginning and completing relocation. If all surviving firms relocated immediately, the function would be vertical at the zero point on the x-axis, and if all surviving firms relocated at the end of some given end period, the function would be horizontal at the zero point of the y-axis.

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The area above the curve represents the BI loss ("triangle") of the relocation delay. This area divided by the rectangular area provides us with an adjustment factor to convert the upper- bound estimate of $58.4 billion into a best estimate. The area below the curve represents 58% of the 8-month loss rectangle, while the area under the fitted curve represents 55% for that period. On a 12-month basis, these ratios are 72% and 70%, respectively. Because most of our loss estimation models are applied on an annualized basis, and because the fitted curve is such a rough approximations, we utilize 72% as our adjustment factor to arrive at a best estimate of BI following the WTC Attacks. Application of this ratio results in a best estimate of BI for the year following 9/11 of $16.1 billion. Note that the ratio is applied to $57.5 billion, the output of firms that did not go out of business and those that relocated within the U.S. (firms that went out of business were responsible for $0.9 billion of gross output in 2001, and firms that relocated to other countries were responsible for $0.43 billion of gross output).

Note also that the ratio from Figure A1 is also consistent with our definition of resilience. The ratio we used means that 72% of the potential BI loss was avoided by firms relocating rather than going out of business because of damage to their original location.

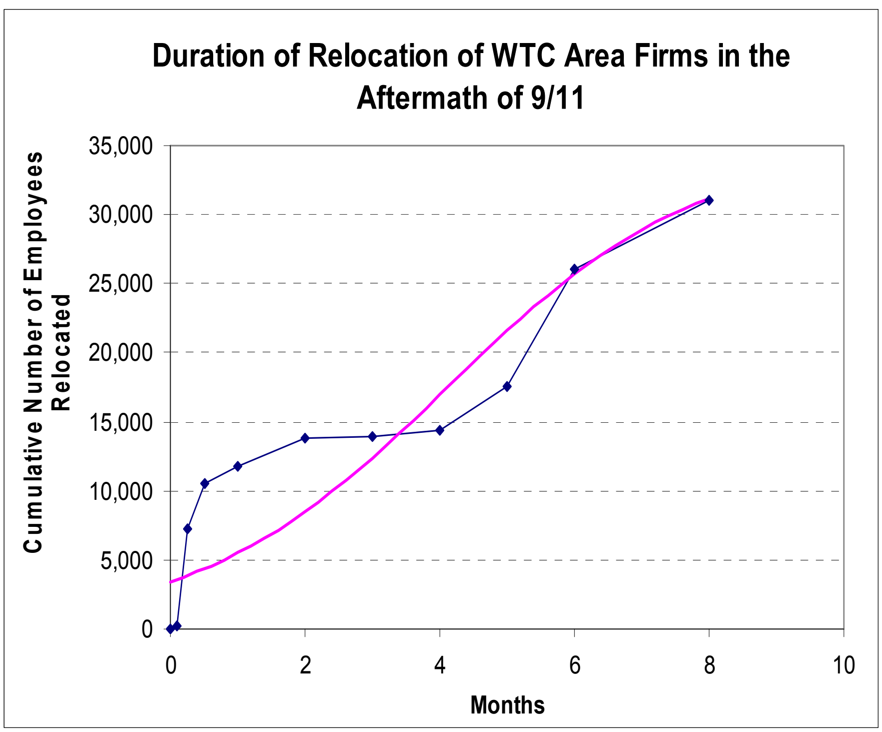

Figure A1. Duration of Relocation of WTC Area Firms in the Aftermath of 9/11

REFERENCES

BALISTRERI E.J., MCDANIEL C.A., WONG E.V., (2003), An estimation of US industry-level capital-labor substitution elasticities: support for Cobb-Douglas, *North American Journal of Economics and Finance,* vol. 14, pp. 343-356.

ASAY G.B., (2008), Estimating The Direct Economic Impact from Losses of U.S. Domestic Passenger Air Travel After 9/11, Center for Risk and Economic Analysis of Terrorism Events, USC, Los Angeles, CA.

BRUNEAU M., CHANG S., EGUCHI R., LEE G., O'ROURKE T., REINHORN A., SHINOZUKA M., TIERNEY K., WALLACE W., VON WINTERFELDT D., (2003), A Framework to Quantitatively Assess and Enhance Seismic Resilience of Communities, 2003, *Earthquake Spectra*, vol. 19, pp. 733-52.

BURNS, W., SLOVIC, P., ROSE, A., ASAY, G., (2007), "Modeling Community Response and Economic Impacts of Risk Amplification Following a Terrorist Strike," Research proposal submitted to the National Science Foundation, February 2007.

BURNS, W. SLOVIC, P., KASPERSON, R., KASPERSON, J., RENN, O., SCRINVAS, E., (1993), "Incorporating Structural Models into Research on the Social Application of Risk: Implications for Theory Construction and Decision Making," *Risk Analysis,* vol. 13 pp. 611-23.

BUSINESS CONTINUITY INSTITUTE, (2002), Good Practice in Business Continuity Management, *Continuity,* vol. 6, n.4 p. 2.

CANNING, P., TSIGAS, M., (2000), "Regionalism, Federalism and Taxation: A Food and Farm Perspective," Food and Rural Economics Division, Economic Research Service, USDA, Technical Bulletin No. 1882

CHERNICK, H., (ed.), (2005), *Resilient City: The Economic Impact of 9/11*, New York: Russell Sage Foundation

DIXON, P.B., RIMMER, M.T., TSIGAS, M.E., (2007), "Regionalising results from a detailed CGE model: Macro, industry and state effects in the U.S. of removing major tariffs and quotas," *Regional Science*, vol. 86, n.1 pp. 31-55.

DIXON, P.B., M. JOHNSON, M., RIMMER, M. T., (2008), "Reducing illegal migrants in the U.S.: a dynamic CGE analysis," paper presented at the GTAP Conference, Helsinki, June 12-14, pp. 62, available from the Centre of Policy Studies, Monash University, Clayton, Victoria, 3800, Australia.

DOI: 10.2202/1554-8597.1161

DONNELLY, W. A., JOHNSON, K., TSIGAS, M., (2004), “Revised Armington Elasticities of Substitution for the USITC Model and the Concordance for Constructing a Consistent Set for the GTAP Model,” Office of Economics Research Note, U.S. International Trade Commission.

DOW JONES & COMPANY, (2002), *Annual Report, 2002*

GIGERENZER, G., SELTEN, R. (EDS.), (2002), *Bounded Rationality: The Adaptive Toolbox,* Cambridge: MIT Press.

GORDON, P., RICHARDSON, H., MOORE, J., PARK, J., KIM, S., (2007), "Economic Impacts of a Terrorist Attack on the U.S. Commercial Aviation System," *Risk Analysis.*

HOOVER’S, INC. A D & B COMPANY online database - http://www.hoovers.com

INSURANCE INFORMATION INSTITUTE, (2007).

ITO, H., LEE, D., (2005), "Assessing the Impact of the September 11 Terrorist Attacks on U.S. Airline Demand," *Journal of Economics and Business*, vol. 57 pp. 75-95.

JOHANSEN, S., (1995), *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, Oxford University Press: Oxford.

KEMFERT, C., (1998), “Estimated substitution elasticities of a nested CES production function approach for Germany,” *Energy Economics*, vol. 20, pp. 249-264.

LEHMAN BROTHERS, *Annual Report, 2002.*

LEXISNEXIS DATABASE - http://www.lexisnexis.com/us/lnacademic.

MAPLESDEN, H., WANG, F., TIAN, T., COOK, S., (2002), *Expenditure Patterns of Travelers in the U.S.*, Travel Industry Association of America. Washington, DC.

(MIG) MINNESOTA IMPLAN GROUP (1999), *Impact Analysis for Planning (IMPLAN) System*, Stillwater, MN, U.S.A.

MOODY’S CORPORATION, *Annual Report, 2001.*

NEW YORK TIMES, various dates, 2001-08.

PROPERTY CLAIM SERVICE, (2007).

ROSE, A., (2004), “Defining and Measuring Economic Resilience to Disasters,” *Disaster Prevention and Management*, vol. 13, pp. 307-14.

ROSE, A., (2005), "Analyzing Terrorist Threats to the Economy: A Computable General Equilibrium Approach," in H. Richardson, P. Gordon, and J. Moore, II (eds.), *Economic Impacts of Terrorist Attacks*, Cheltenham, UK: Edward Elgar, pp. 196-217.

ROSE, A., (2007), "Economic Resilience to Natural and Man-made Disasters: Multidisciplinary Origins and Contextual Dimensions," *Environmental Hazards: Human and Social Dimensions*, vol. 7, pp. 383-98.

ROSE, A., (2009), "A Framework for Analyzing the Total Economic Impacts of Terrorist Attacks and Natural Disasters," *Journal of Homeland Security and Emergency Management*, vol. 6, n. 1, pp. 1-26.

ROSE, A., LIAO, S., (2005), "Modeling Resilience to Disasters: Computable General Equilibrium Analysis of a Water Service Disruption," *Journal of Regional Science*, vol. 45, n. 1, pp. 75-112.

ROSE, A., OLADOSU, G., LIAO, S., (2007), "Business Interruption Impacts of a Terrorist Attack on the Electric Power System of Los Angeles: Customer Resilience to a Total Blackout," *Risk Analysis*, vol. 27, n. 3, pp. 513-31.

SHEFFI, Y., (2007), *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage,* Cambridge, MA: MIT Press.

TIERNEY, K., (1997), "Impacts of Recent Disasters on Businesses: The 1993 Midwest Floods and the 1994 Northridge Earthquake," in B. Jones (ed.), *Economic Consequences of Earthquakes: Preparing for the Unexpected*, Buffalo, NY: National Center for Earthquake Engineering Research.

TSIGAS, M.E., (1997), "A Modeling Framework for Multiregional Analysis of the U.S. Economy," Office of Economics Research Note, U.S. International Trade Commission.

U.S. DEPARTMENT OF TRANSPORTATION, (2007), Bureau of Transportation Statistics, Air Carrier Statistics (Form 41 Traffic), Table T-100 (All Carriers).

URBANOMICS, (2002-a), *Demographic and Socioeconomic Forecasting: Post September 11th Impacts.* New York Metropolitan Transportation Council.

URBANOMICS. (2002-b), Demographic and Socioeconomic Forecasting: Post September 11th Impacts. Technical Memorandum No. 3.3: Report of Findings and Rebenchmarked Forecasts, New York Metropolitan Transportation Council.

WALL STREET JOURNAL, various dates, 2001-08.

DOI: 10.2202/1554-8597.1161