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## The Economic Impacts of Dirty Bomb Attacks on the Los Angeles and Long Beach Ports: Applying the Supply-Driven NIEMO (National Interstate Economic Model)

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# The Economic Impacts of Dirty Bomb Attacks on the Los Angeles and Long Beach Ports: Applying the Supply-Driven NIEMO (National Interstate Economic Model)\*

JiYoung Park

## Abstract

As homeland security policy makers seek to funnel scarce resources to the most vulnerable areas, geographic impact studies have become ever more crucial since the events of September 11, 2001. In the sense that the Los Angeles and Long Beach ports are among the largest in the world, service interruptions there would have nation-wide economic impacts. Because foreign and domestic imports are in greater volumes than exports, the interruption of imports should be examined with a supply-side MRIO-type model. Hence, a new supply-side National Interstate Economic Model (NIEMO) yields extra information with important political implications – in addition to the previously estimated demand-side results – because both simulations show that terrorist attacks in one state have significant economic impacts in other states. Especially in the U.S. Senate where political power is evenly distributed among the states, the supply-side and demand-side results could help garner nationwide support for prevention measures in specific places, often distant from the states where the measures are taken.

**KEYWORDS:** economic impacts, supply-driven MRIO, terrorist attacks, port disruption

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## ISSUES AND IMPLICATIONS

The 2001 terrorist attacks on the U.S. have prompted many studies evaluating the socioeconomic impacts on the U.S. economy of various hypothetical attacks (Richardson et al., 2005). Homeland security expenditures are limited and should be funneled to the most vulnerable places. Can we develop spatially detailed information to guide policy makers in this task?

Not only are there many plausible natural events that have unique spatial incidence effects but there are growing concerns over possible terrorist attacks. Any of these have unique spatial impacts. Among the many targeted areas, the Los Angeles metropolitan area is widely exposed to attacks because of many attractive and economically important sites, e.g. major theme parks such as Disneyland, Los Angeles International Airport (LAX), and so on.

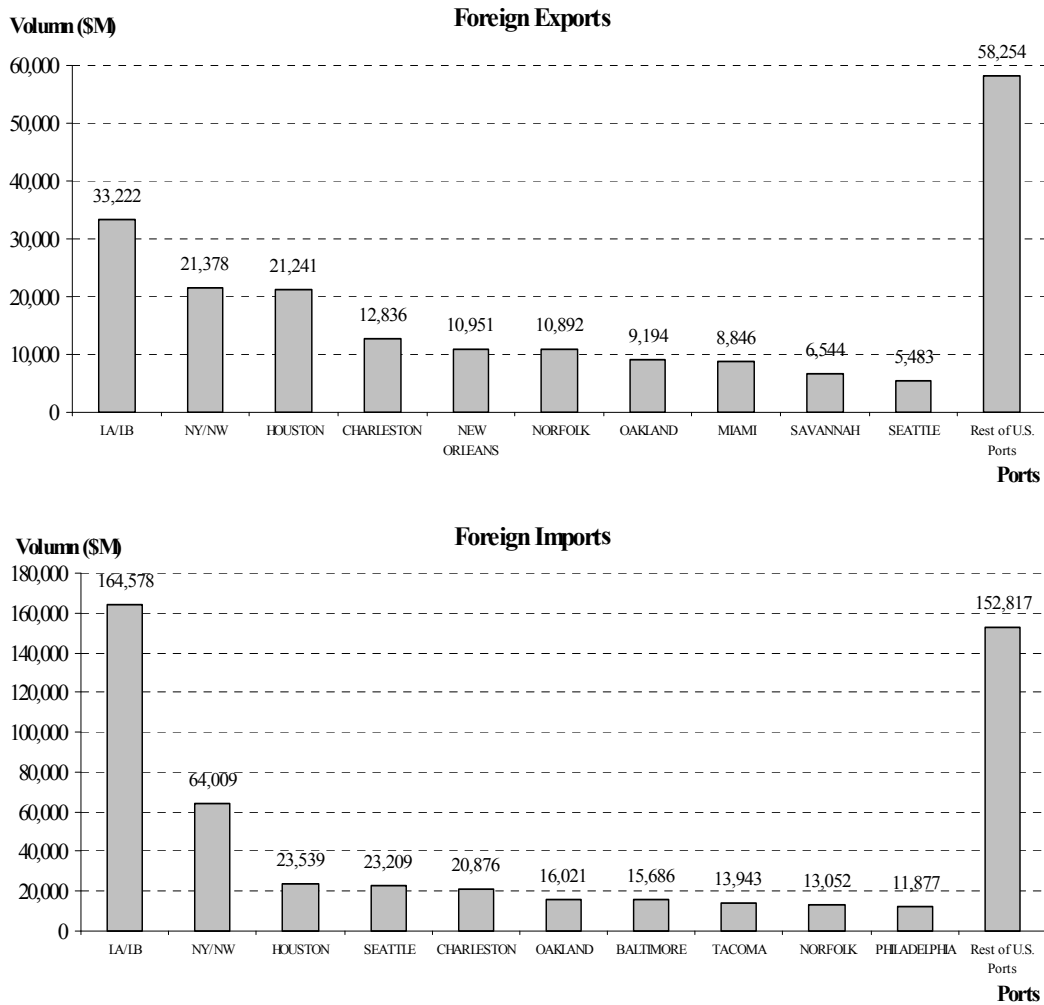
Attacks on the Los Angeles and Long Beach (LA/LB) ports by dirty bombs could have major consequences from direct losses of lives and property, and direct and indirect losses through the duration of port closures. This is because the LA/LB ports play a very important role in the local and national economy, as shown in Figure 1, where it is seen that the LA/LB twin ports account for 17 percent of all U.S. exports and 32 percent proportion to all U.S. imports. Further, because the LA/LB ports are among the largest in the world, major disturbances there will have nationwide economic repercussions.

In a study of port closures, Cohen (2002) reported the losses from the 2002 shut-down of the West Coast docks by a labor lockout were estimated to be \$1.96 billion per day. As CBO (2006) and Hall (2004) suggest, however, more sophisticated models with additional data are required so that port loss impacts can be better understood. Studies of the West Coast ports closures did not account for any substitution effects which might have occurred from diversions to other ports, or the using up of inventories, or relocation of businesses.

However, labor action times and places are usually widely anticipated whereas terrorist attacks would not be. Further, many industries and economies that depend on the LA/LB ports are densely settled in and around Southern California. It is unclear how quickly and how adequately they might discover alternate shipping options. Nearby ports such as San Diego or San Francisco/Oakland would be hard put to absorb significant diversions to or from LA/LB (Giuliano et al., 2005).

In this sense, Gordon et al. (2005) reported the economic impacts of a terrorist attack on the LA/LB ports, but such impacts were only estimated by tracing effects through inter-connected industries as well as inter-metropolitan relationships confined to five counties in Southern California, not by estimating all of the inter-state economic relations. Examining the full-costs through the U.S.

economy, using an integrated model of losses that considers the many spatial connections between states is appropriate.



Source: Author recalculation of WISERTrade data.

Figure 1. Top Ten U.S. Ports: Foreign Exports and Imports (\$millions), 2001

A recent study by Park et al. (2007) suggests the necessity of estimating the interstate effects, because mitigation and precautionary approaches to the attacks cannot easily be analyzed unless interstate effects are estimated. All of this is illustrated in the Department of Homeland Security's recently issued *Planning Scenarios* (Howe, 2004) which included preliminary estimates of the losses from various hypothetical terrorist attacks on selected major targets, but which contains no spatially detailed information. It is clear that alternative defensive and

mitigation measures can best be evaluated by policy makers with information on the nature of spatially distributed impacts throughout the national economy. Such impacts can be estimated by tracing effects through inter-connected industries as well as inter-regional commodity flows.

Two major problems, however, in developing integrated interstate-interindustry models must first be resolved: 1) To develop a way to combine not easily compatible databases and 2) to estimate usable interstate trade flows from incomplete Commodity Flow Survey (CFS) data from the Bureau of Transportation Statistics (BTS) (Park et al., 2008a). Hence, this discussion on constructing a supply-driven NIEMO describes the initial demand-driven NIEMO (National Interstate Economic Model), and then estimates the economic impacts for the nation and the states via the use of interstate and interindustry forward linkages.

The next section provides background on tests with NIEMO-type models and applications and with a discussion of major issues associated with supply-driven input-output (IO) models. The third section draws on methodology and data necessary to build a general supply-side multiregional IO model (MRIO), which is then extended to NIEMO. The NIEMO results and policy implications will be addressed in the fourth section, with particular attention paid to the interstate distribution of economic losses. The paper concludes with a brief summary in the final section of important contributions and caveats.

## **BACKGROUND**

### **Multiregional Input-Output**

After the suggestion of an ‘ideal’ Interregional Input-Output model (IRIO) by Isard (1951), a Chenery-Moses-type MRIO model was developed as an alternate and potentially operational model using more simplified data set than IRIO (Chenery, 1953; Moses, 1955). NIEMO is an MRIO, regionally specified for the 50 U.S. states, the District of Columbia, and the rest of world. To estimate short-term impacts, multi-regional models consisting of two sets of tables, regional coefficients tables and trade coefficients tables, are appropriate (Miller and Blair, 1985). These Chenery-Moses-type models can be used to estimate inter-state industry effects as well as inter-industry impacts on each state. To proceed in this way, it is necessary to calculate multi-regional interindustry coefficients among the U.S. states; the regional tables that give us intra-regional industry coefficients by state and the interregional trade tables to give us trade coefficients by industry.

Among NIEMO’s strengths, the greatest is the ability to obtain spatially detailed indirect impact information. For example, direct economic impacts are often estimated in the aftermath of an event. If plausible scenarios for the time-

profile of reduced shipping facilities are available, spatially detailed indirect and induced economic effects can be estimated with a NIEMO-type model. Standard applications of IO that determine indirect and induced impacts typically do not include interactions among industries and states. Park et al. (2007) have developed a trial version of the demand-driven MRIO-type model based on an initial examination of the data, estimating the trade flows -- but without trade in the service sectors. While preliminary results to test NIEMO's accuracy showed that almost six-million multipliers in NIEMO can be constructed at low cost, based on acceptance of the idea that IMPLAN's outputs are plausible (Park and Gordon, 2005), further elaborations of the initial NIEMO model, estimating the service interactions have been suggested, applying the Geographical Weighted Regression (GWR) method (Park, 2006).

Although many studies have focused on constructing demand-driven MRIOs because of their widely accepted usefulness in regional science (see Richardson et al., 2007; Park et al., 2006; Lee et al., 2007 for the application of demand-driven MRIO), there have been only a few attempts to construct a supply-driven MRIO. Bon (1988) generalized the supply-driven MRIO theoretically, and Shao and Miller (1990) elaborated the structure of the supply-side commodity-industry MRIO.

As seen in the next section, although there is theoretical support for the supply-driven model, it is difficult to find empirical applications that model the effects of supply shocks. This might be due to difficulties of interpretation. Direct and indirect impacts from a disruption by supply-side factors are quantity losses not price decreases, but there is no adequate way to examine the losses when interpreting the supply-side model as a price model. This is why some supply-driven IRIO or MRIO studies have focused on the forward linkages (Dietzenbacher, 2002) or structural changes of an economy, rather than impact analysis (Wang, 1997; Bon and Yashiro, 1996; Bon, 2001).

### **Plausibility of Supply-driven Input-Output**

Most analysts rely on the demand-driven IO models for empirical applications. After Ghosh (1958) first suggested the supply-driven IO model, there was a debate over its plausibility (Oosterhaven, 1988; 1989; 1996; Rose and Allison, 1989; Gruver, 1989). Ever since Oosterhaven's successive criticisms that focused on the theoretical implausibility of the supply-side model, because of the possibility of increased consumptions with constant outputs, it is hard to find dominant or widespread supply-side approaches to impact analysis.<sup>1</sup>

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<sup>1</sup> Oosterhaven's (1988) question is that any production function would not be required if "local consumption or investment reacts perfectly to any changes in supply" and if final demands are given. For example, the final demands and input factors might be combined without any

Dietzenbacher (1997) showed that the supply-driven model can be interpreted as a price model which is a more convenient way to grasp the price effects than from the Leontief price model, because price changes in the supply-driven model are shown directly while the Leontief results shows them as percentage changes. Only prices are changed from the value added changes. Corresponding changes of total outputs, consequently, result from the price changes, not quantity changes. While this interpretation met the attacks on the implausibility of supply-driven IO models, accepting the interpretation limits our understanding of the results of impact analyses. This is because quantity losses, e.g. labor losses or capacity losses of a facility from unexpected disasters cannot be interpreted as price decreases; rather prices would increase.

Although the supply-driven IO approach has some limitations in interpretation, the supply model could be useful to roughly estimate the impacts of disasters, if the forward coefficients are tolerably fixed (Rose and Allison, 1989).<sup>2</sup> Unusual economic cessations such as caused by disasters will temporarily produce quantity losses and lead to further economic losses via interindustrial and interregional relations. In static market equilibrium, producers will not change the current technical relationships that are based on historical sales in the short-run immediately after an unexpected event. Ghosh's supply-driven model is in terms of monetarily expressed quantities and, hence, applicable to this situation. Based on the previous supply-driven IO applications of Giarratani (1976) and Davis and Salkin (1984), Park (2007) summarized major economic characteristics for the application of the supply-driven model: monopoly and scarcity of substitution opportunities. While the supply models still require further theoretical support, its economic characteristics are intuitively useful to model supply shocks.

The market mechanism includes significant market power of various producers at any given price and quantity, due to limited accesses to market information. Also, due to the natural asymmetry of information, market power associated with monopolistic status has the tendency of maintaining a short-run market equilibrium. This is the reason why a long-run solution maintains that the economic equilibrium is a result of negotiations via numerous iterations by the actors in a normal economic environment (Pindyck and Rubinfeld, 1998: 21). This leads to the result that producers will not decrease their previous outputs or factors during short-term periods even if there are large shocks to the economy. The behavior involved in finding substitute products imposes many unexpected costs. These include the costs for searching for substitutes or incurring extra

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technological relationship if “purchases are made, e.g., of cars without gas and factories without machines”.

<sup>2</sup> Since Dietzenbacher (1997), Cai et al. (2005) and Leung and Pooley (2002) have implemented applications, using supply-driven IO model for ‘potential’ economic impacts. Park (2008) also shows an extended application of supply-driven IO model combining price elasticities of demand.

transportation costs. Economic reactions will happen, only if those are expected to be persistent in the long-run. Even in the market system, therefore, two conditions that approximate monopolistic characteristics and acute scarcity of resources can be verified during the short-run.

For a relatively long run application, Park (2008)'s application of the supply-driven model is useful. The model combines exogenous price elasticities of demand with the general supply-driven model, and adjusts quantity responses to price impacts. Yet, this study will use only the quantity losses based on Ghosh's original position.

### **Scenario**

The U.S. Department of Homeland Security announced on April 25 of 2006 that they would take "significant steps to enhance security by checking the backgrounds of port workers" ([www.dhs.gov](http://www.dhs.gov)). This is to minimize access by terrorists. Major ports play a key role in the U.S. economy and they are vulnerable. Suggestions by Gordon et al. (2005: 264) remind us that: "it may be easier to plant simultaneous radiological bombs ... on outbound rather than inbound freight, especially because the effects may not be very different if the bombs are set off at the perimeter (prior to passing through security) rather in the heart of the port terminal".

Based on these discussions, tests of a different scenario from port closures due to labor actions can be informative. This study follows the hypothesis of Gordon et al. (2005) and Park et al. (2007) in previous studies of the LA/LB ports: the possible explosion of two small radiological dispersal devices (RDDs), with characteristics as reported in Gordon et al. (2005: 264). Because the reopening of the ports are decided according to policy choices that are hard to predict, I will assume a one-month closure without any mitigations and substitutions; this allows some comparisons with the demand-side NIEMO results of Park et al. (2007).

## **DATA AND METHODOLOGY**

### **Data**

An important part of data limitations is the problem of incompatible databases. This study followed the economic sector classification and reconciliation system that Park et al. (2007) have recently developed. The system allows conversion to a set of 47 common sectors, the so-called USC Sectors and can be found in Park et al. (2007; 2008a). Among the many data sources utilized, most data are obtained from 2001 IMPLAN and the 1997 Commodity Flow Survey (CFS) for NIEMO

construction, and from WISERTrade data and the WCUS (Waterborne Commerce of the U.S.) data for estimated direct losses as inputs to NIEMO.

Another problem stems from the nature of usable interstate trade flow data. The U.S. Commodity Transportation Survey data on inter-regional trade flows had been available since 1977 but were discontinued. For the years since 1993, the data deficit could be met to some extent with the recent Commodity Flow Survey (CFS) data from the Bureau of Transportation Statistics (BTS), but these data are incomplete with respect to interstate flows, with several inherent problems (Erlbaum and Holguin-Veras, 2005). Based on the currently available CFS data, this study applied the two-step approach so as to estimate a trade flow suggested by Park et al. (2008a).

Related to the initial NIEMO applications, two important points should be addressed. One is that the currently available 1997 CFS data had to be updated to match the 2001 IMPLAN data. But there are also questions about the adequacy of newer 2002 CFS data because of small sample sizes, even though these can be matched to 2002 IMPLAN data. Another question involves the assumption of no interstate trade in services for the 18 services sectors of the USC-Sector system. Park (2006) suggests a methodology for adjusting the latter, by using the state-level domestic imports and exports vectors available from IMPLAN for each state to construct origin-destination matrix marginal totals for the 18 service sectors and estimating the service trade flows using Geographically Weighted Regressions (GWR) econometric analysis along the lines suggested by LeSage (1999). However, this study followed the initial NIEMO application, assuming no substantial interstate trade in services.

## Methodology

The NIEMO version of an MRIO coefficient matrix is created by taking the product of two matrices: the tables of intrastate industrial commodity trade coefficients and the tables of inter-industry transaction coefficients for each state, D.C., (and hence, 51 regions with 47 sectors; for computational convenience, a identity matrix is inserted to represent transactions coefficients in the rest of the world). The procedures to estimate commodity trade flows are described in Park et al. (2008a). The supply-side NIEMO depends on the column-based (total outputs and row-summed trades) denominators, while the demand case uses the row-based (total inputs and column-summed trades) denominators.

Note that the model includes no transaction coefficients for 18 services sectors and no inter-industry data for trade between foreign countries, so the off-diagonal cells representing trade between locations in the rest of the world are necessarily zero. Thus, the NIEMO inverse coefficients for diagonal cells in the foreign-to-foreign region are one. Based on Bon's (1988) suggestion, Figure 2

shows three major matrices necessary to constructing the supply-driven NIEMO: Forward interindustrial linkage matrix by each State ( $U^B$ ), interregional trade coefficients normalized with row sum ( $C^S$ ), and inverse coefficients of supply-driven NIEMO ( $(I - U^B C^S)^{-1}$ ). Detailed description of the methodology is described in Appendix 1.

		STATE1						...	STATES1						...	FOREIGN						
		I1	...	I29	E0	...	I47	...	I1	...	I29	E0	...	I47	...	I1	...	I29	E0	...	I47	
STATE1	I1							...							...							
	...							...							...							
	I29							...							...							
	E0							...							...							
	I47							...							...							
...							...							...								
STATES1	I1							...							...							
	...							...							...							
	I29							...							...							
	E0							...							...							
	I47							...							...							
...							...							...								
FOREIGN	I1							...							...							
	...							...							...							
	I29							...							...							
	E0							...							...							
	I47							...							...							

Matrix  $U^B$

		STATE1						...	STATES1						...	FOREIGN						
		I1	...	I29	E0	...	I47	...	I1	...	I29	E0	...	I47	...	I1	...	I29	E0	...	I47	
STATE1	I1							...							...							
	...							...							...							
	I29							...							...							
	E0				1.0			...							...							
	I47					1.0		...							...							
...							...							...								
STATES1	I1							...							...							
	...							...							...							
	I29							...							...							
	E0							...				1.0			...							
	I47							...					1.0		...							
...							...						1.0	...								
FOREIGN	I1							...							...							
	...							...							...							
	I29							...							...							
	E0							...							...							
	I47							...							...							

Matrix  $C^S$

		STATE1						...	STATE51						FOREIGN					
		I1	...	I29	I30	...	I47	...	I1	...	I29	I30	...	I47	I1	...	I29	I30	...	I47
STATE1	I1							...												
	...							...												
	I29							...												
	I30							...												
	...							...												
	I47							...												
...							...													
STATE51	I1							...												
	...							...												
	I29							...												
	I30							...												
	...							...												
	I47							...												
FOREIGN	I1							...							1.0					
	...							...							1.0					
	I29							...							1.0					
	I30							...							1.0					
	...							...							1.0					
	I47							...							1.0					

Matrix  $(\mathbf{I} - \mathbf{U}^B \mathbf{C}^s)^{-1}$

Note: The ‘I’ indicates USC industry sector, and white cells identify zero values.

Figure 2. Figures describing Three Major Matrices,  $\mathbf{U}^B$ ,  $\mathbf{C}^s$ , and  $(\mathbf{I} - \mathbf{U}^B \mathbf{C}^s)^{-1}$ , for the Supply-Driven NIEMO

## RESULTS

While many businesses are located in California and depend directly on the LA/LB ports, all have interindustry relationships and many have interstate connections. Some of the imported commodities are finished goods ready for sale in the California. However, even these finished goods are subject to some local processing, including the use of logistics services. Therefore, the supply-driven NIEMO correctly considers spatial as well as interindustrial information on economic impacts that a single regional or national IO model cannot address.

Although a variety of caveats must be attached to the MRIO model, especially due to its linearity characteristics, the models are relevant to short-term-impact analyses. In the longer run, markets drive a variety of substitutions and price adjustments that the version of the model adopted here cannot account for. The models *will* make it possible to estimate short-term impact analyses for variety cases of natural disasters on a state-by-state and industry-by-industry basis.

Based on the last column of average one-month final losses shown in Table A1, the upper one for exports and the lower for imports, each direct and indirect total impacts aggregated by each state are calculated. The average one-month final losses are calculated from the total values of foreign exports and imports obtained from WISERTrade (second column) plus domestic exports/imports obtained and revised from WCUS (third column).

Table 1. The State-by-State Impacts of Port of Los Angeles/Long Beach One-month Closures

State	Export Losses (\$M.)		Import Losses(\$M.)		2000 Total Population (Unit: 1,000)	Total Export Losses by Per Person	Total Import Losses by Per Person
	Direct Impacts	Indirect Impacts	Direct Impacts	Indirect Impacts			
AL	0.00	26.96	0.00	48.73	4,447	6.06	10.96
AK	0.00	3.08	0.00	40.81	627	4.92	65.09
AZ	0.00	53.69	0.00	362.98	5,131	10.47	70.75
AR	0.00	25.52	0.00	64.40	2,673	9.55	24.09
CA	4,114.66	2,641.24	14,221.60	8,485.40	33,872	199.46	670.38
CO	0.00	31.40	0.00	102.04	4,301	7.30	23.72
CT	0.00	16.04	0.00	28.44	3,406	4.71	8.35
DE	0.00	5.08	0.00	9.53	784	6.48	12.16
DC	0.00	0.63	0.00	10.02	572	1.09	17.51
FL	0.00	31.23	0.00	137.83	15,982	1.95	8.62
GA	0.00	25.92	0.00	63.96	8,186	3.17	7.81
HI	0.00	5.40	0.00	45.67	1,212	4.46	37.70
ID	0.00	12.31	0.00	26.16	1,294	9.51	20.22
IL	0.00	70.84	0.00	110.85	12,419	5.70	8.93
IN	0.00	53.17	0.00	54.61	6,080	8.74	8.98
IA	0.00	36.06	0.00	27.21	2,926	12.32	9.30
KS	0.00	31.99	0.00	38.74	2,688	11.90	14.41
KY	0.00	29.16	0.00	41.29	4,042	7.22	10.22
LA	0.00	77.95	0.00	83.00	4,469	17.44	18.57
ME	0.00	5.39	0.00	11.30	1,275	4.23	8.87
MD	0.00	11.43	0.00	51.87	5,296	2.16	9.79
MA	0.00	21.80	0.00	81.08	6,349	3.43	12.77
MI	0.00	54.99	0.00	112.97	9,938	5.53	11.37
MN	0.00	33.80	0.00	59.73	4,919	6.87	12.14
MS	0.00	14.68	0.00	17.03	2,845	5.16	5.99
MO	0.00	35.92	0.00	53.37	5,595	6.42	9.54
MT	0.00	16.27	0.00	20.57	902	18.04	22.80
NE	0.00	25.32	0.00	54.90	1,711	14.80	32.08
NV	0.00	13.08	0.00	93.43	1,998	6.55	46.76
NH	0.00	7.22	0.00	17.38	1,236	5.84	14.06
NJ	0.00	42.33	0.00	70.71	8,414	5.03	8.40
NM	0.00	6.62	0.00	21.27	1,819	3.64	11.69
NY	0.00	54.85	0.00	145.81	18,976	2.89	7.68
NC	0.00	33.14	0.00	62.03	8,049	4.12	7.71
ND	0.00	4.87	0.00	4.91	642	7.59	7.65
OH	0.00	76.85	0.00	82.01	11,353	6.77	7.22
OK	0.00	26.99	0.00	38.87	3,451	7.82	11.26
OR	0.00	50.39	0.00	90.54	3,421	14.73	26.46
PA	0.00	61.80	0.00	91.84	12,281	5.03	7.48
RI	0.00	4.85	0.00	9.83	1,048	4.63	9.38
SC	0.00	16.76	0.00	21.42	4,012	4.18	5.34
SD	0.00	6.72	0.00	9.56	755	8.91	12.66
TN	0.00	33.69	0.00	35.84	5,689	5.92	6.30
TX	0.00	391.97	0.00	303.87	20,852	18.80	14.57
UT	0.00	31.76	0.00	49.76	2,233	14.22	22.28
VM	0.00	2.41	0.00	5.07	609	3.96	8.34
VA	0.00	16.98	0.00	56.12	7,079	2.40	7.93
WA	0.00	79.50	0.00	247.00	5,894	13.49	41.91
WV	0.00	10.58	0.00	14.78	1,808	5.85	8.17
WI	0.00	52.77	0.00	64.07	5,364	9.84	11.94
WY	0.00	6.52	0.00	5.17	494	13.20	10.46
US Total	4,114.66	4,429.92	14,221.60	11,785.78	281,422	574.48	1,488.79
Rest of World	0.00	492.02	0.00	897.75	-	-	-
World Total	4,114.66	4,921.94	14,221.60	12,683.54	-	-	-

\*Population data are obtained from census 2000 at [www.census.gov](http://www.census.gov).

As shown in the *Scenario*, the LA/LB ports would be closed for one month without any substitutions and mitigations. The fact that the total direct loss of imports is three times larger than exports shows that the assumptions of previous work of Park et al. (2007) not to consider the indirect losses by imports might distort the estimated economic roles of LA/LB ports.

Table 1 summarizes the state-by-state indirect impacts and the total impacts per person living in each state, from two dirty bomb attacks on the LA/LB ports. These are from applications of demand- and supply-driven NIEMO for the direct losses of exports and imports respectively. Import disturbances would occur totaling \$27 billion, while the exports would total \$9.4 billion during the one-month closures. Total indirect impacts due to import disturbances are \$12.7 billion, of which the indirect impacts on the rest of U.S. are \$3.3 billion and those on rest of world are \$0.9 billion, 26 percent and 7 percent of total indirect impacts respectively. Note that the supply-driven NIEMO includes similar results for spatially distributed impacts by each USC Sector, although these are not shown here.

While the aggregate multiplier across all states using the demand-driven NIEMO is 2.20, the multiplier for the supply-driven NIEMO is 1.89, which suggests that sellers have some market power in the case of radical disruptions, as Ghosh expected in 1958.<sup>3</sup> Also, because the percentage of interregional indirect impacts for the disruption of imports is smaller (33.01 percent) than the exports (46.34 percent), the economy of California is much more connected to the rest of the U.S. for the case of exports.<sup>4</sup>

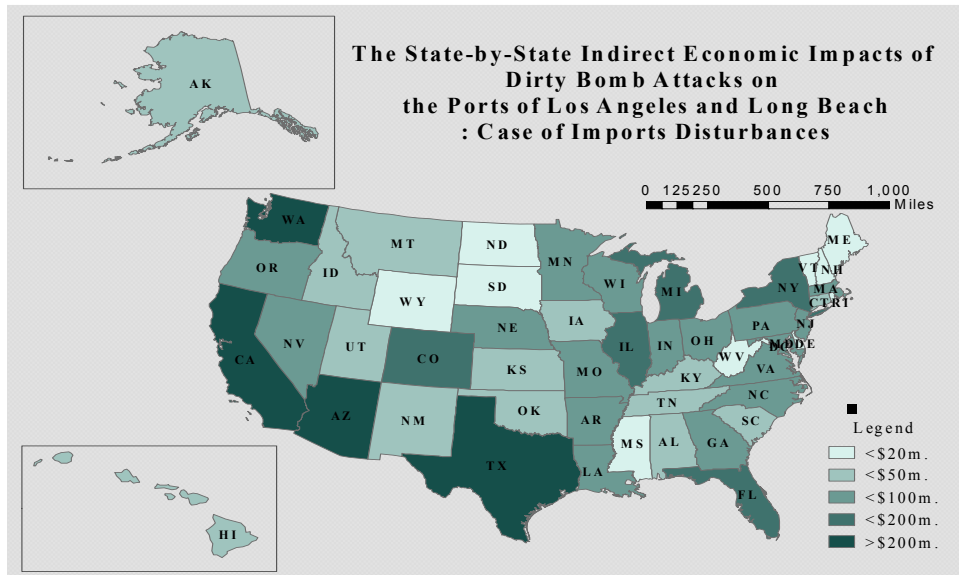
This also can be found in the following Figures 3 and 4. The actual indirect impacts for both imports and exports disturbances are distributed nationwide. The LA/LB ports closures by imports disturbances (Figure 3A) impact the relatively proximate states such as Arizona, Texas, and Washington with over \$200 million of indirect impacts. But only Texas experiences indirect impacts according to the exports disturbances over \$100 million (Figure 3B), eight states are affected nation-wide in the case of the imports disturbances.

However, to examine the distribution effects of dirty-bomb attacks irrespective of its magnitude, it is necessary to normalize the actual indirect impacts divided by total indirect impacts (World Total) for each case. Figure 4 shows the proportional disturbances of indirect impacts for exports and imports

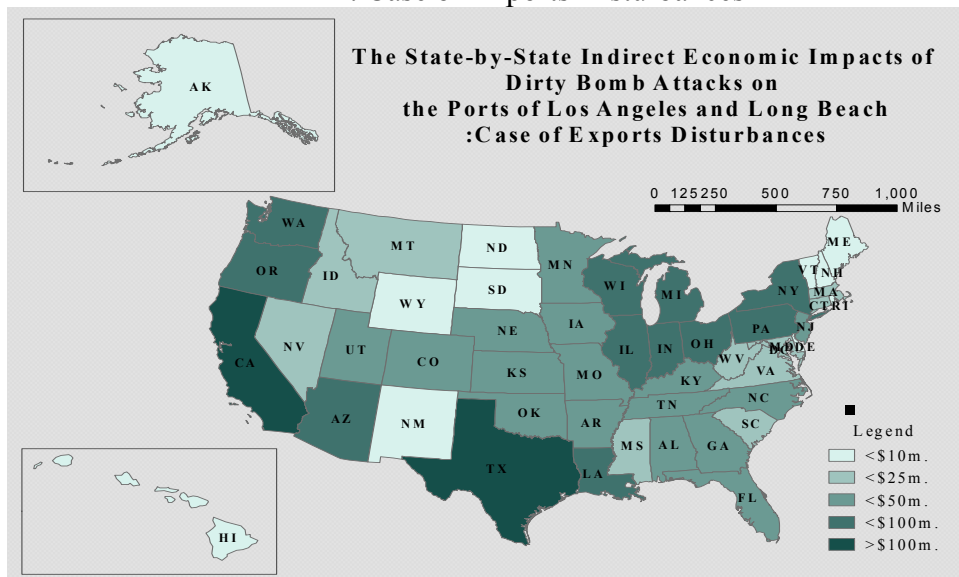
<sup>3</sup> Park et al. (2008c) also applied the supply-driven NIEMO for estimating the economic impacts of the Louisiana' ports disruption due to Hurricane Katrina for the end of 2005 post-Katrina and the first quarter of 2006. The total multipliers for foreign imports losses are in a range of 1.77~1.90, which are similar to the estimates reported here.

<sup>4</sup> The percentage calculated as follows:  $100(\sum_{i \neq CA} \Delta^i) / (\sum_i \Delta^i)$ , where  $\Delta^i$  means indirect impacts of region  $i$ . For example,  $46.34\% = \{100 * (4,921.94 - 2,641.24)\} / 4,921.94$ .

losses. Exports disturbances cause more nation-wide economic losses indirectly, whereas imports disturbances are relatively constrained to within California. If the same indirect losses occur when closing the LA/LB ports, other states will be impacted more in the case when individuals cannot export through the LA/LB ports than when they cannot import from the ports. There are more demand-side spillovers outside California.



A. Case of Imports Disturbances



B. Case of Exports Disturbances

Figure 3. Distribution of the State-by-State Indirect Economic Impacts

Finally, although the total economic impacts from attacks on the LA/LB ports vary by state, it is hard to estimate how much mitigation or prevention costs should be distributed among U.S. residents. The last two columns in Table 1 address how much residents in each state would be burdened as a result of terrorist attacks on the LA/LB twin-ports. As expected, each resident in California has the biggest burden, showing \$200 for the case of total export losses and \$670 for the total import losses.

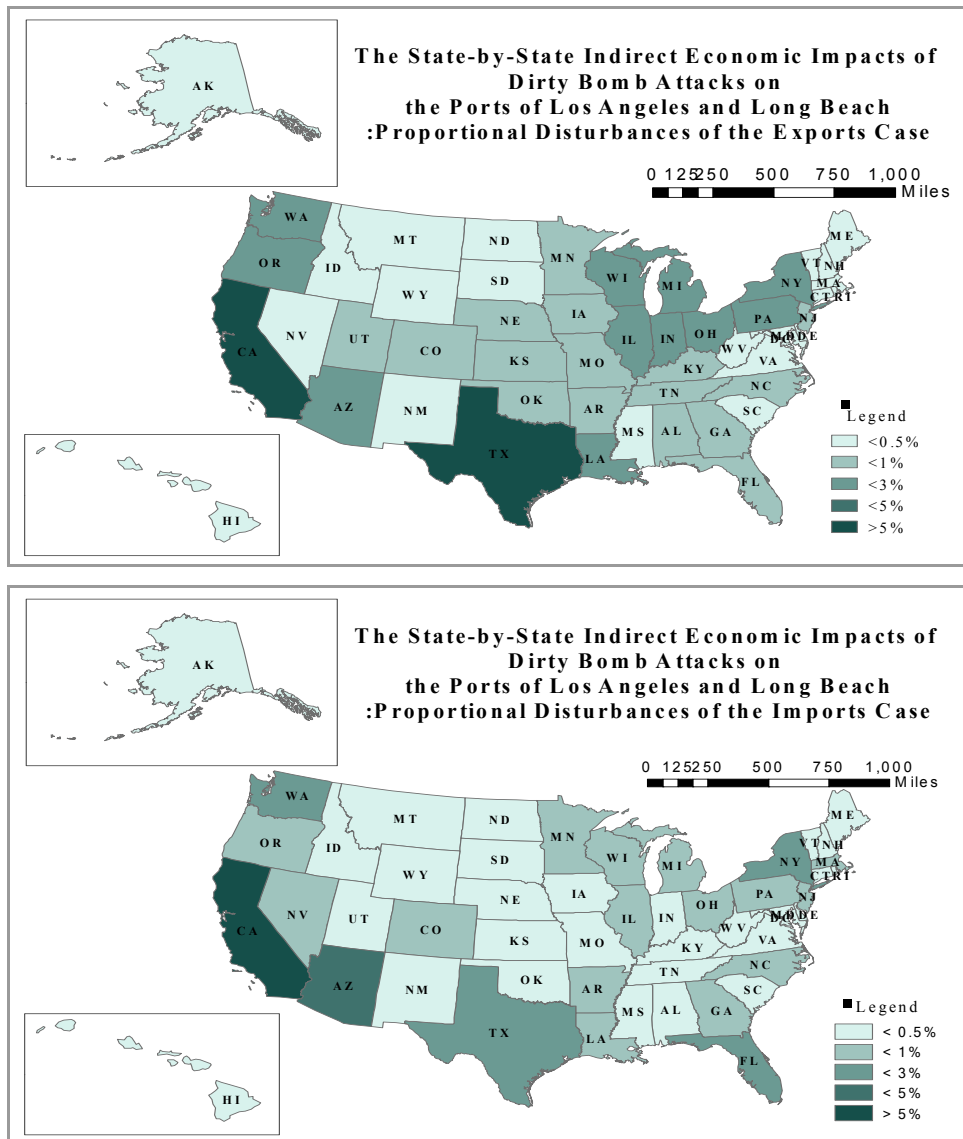


Figure 4. Comparison of Proportional Disturbances for the Exports and Imports Disruption Cases

Except California, Texas (\$18.8), Louisiana (\$17.44), Nebraska (\$14.80), Oregon (\$14.73), Washington (\$13.49), and Wyoming (\$13.20) will take sizable losses in the case of exports closure. In those cases, it is especially interesting that people residing in Louisiana, Nebraska, and Wyoming have large burdens although the total indirect amounts are not so sizable. This phenomenon is much more explicit in the total imports case shown in the last column. Different from the exports cases, people living in Arizona (\$70.75), Alaska (\$65.1), and Nevada (\$46.76) are economically impacted due to the disturbance of imports from the attack.

## CONCLUSIONS

This paper has been about modeling spatially detailed economic impacts. It was argued that most plausible terrorist attacks cannot adequately be analyzed using national economic models. To accomplish the modeling goal, standard input-output analysis was modified and elaborated in several ways.

There is no doubt that any IO model has many limitations. The limitation to short-run analysis applies to NIEMO, even though it includes a detailed spatial dimension (Park et al., 2007). The application of the demand-side NIEMO to an analysis of port activity disruptions is only useful for tracing backward linkages, that is, in the case of export disturbances. However, the LA/LB ports have more economic activity devoted to imports, which should be analyzed via a supply-driven IO model. Also, although there have been debates on the plausibility of supply-side IO model, I have shown that a supply-driven NIEMO should be utilized in order to analyze the import disturbances.

This paper tested LA/LB port closures from a hypothetical terrorist attack, using RDDs and based on three important likelihoods. First, sudden disruptions of national facilities playing a key economic role cannot be anticipated and these cases should be differentiated from more expected disruptions such as a port labor lockout that allows agents time to plan substitutions and other mitigation effects.<sup>5</sup> Second, because of such unexpected occurrences, in reality, the supply-driven IO model can be applied to analyze the case of quantity losses due to the short run market power of many firms. Third, related to data availability limits, the hypothetical case study approach is easiest to implement and learn from.

To address interregional spread effects, a supply-driven NIEMO was developed and applied. The direct imports losses at the LA/LB ports have

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<sup>5</sup> A recent study by Park et al. (2008b) addresses this issue via regional, modal, and periodical substitutions, applying a random coefficients model to time-series data for the West Coast ports lockout. In that study, they report that the positive direct economic impacts of foreign imports *before* the 2002 ports lockout from anticipating the event reached \$3.76 billion, while the direct economic impacts *during* and *after* the event were negative and in a range of \$268~318 millions.

powerful indirect effects on Arizona, Texas, and Washington creating over \$200 million of losses. However, the distributions of indirect losses of imports are mostly limited to California when compared with the spatial distribution of impacts from an exports disruption of the same magnitude. The residents in Arizona, Alaska, and Nevada would incur the most economic burdens from the import disturbances.<sup>6</sup>

## APPENDICES

### Appendix 1: Supply-driven NIEMO Construction

Applying Bon's (1988) suggestion of 'Row Coefficient Model' for interregional trade coefficients, let  $\mathbf{X} = \mathbf{X}^s = (\mathbf{X}^d)^T$  be total output vector for  $m(=1, \dots, 47)$  non-service and service commodities, labeled as the USC Sectors and  $n(=1, \dots, 52)$  regions. If  $\mathbf{Z}$  is an  $nm \times nm$  block diagonal matrix of direct technical flows between industries within a region, and  $\mathbf{C}$  is an  $nm \times nm$  diagonal block matrix of interregional trade flows, the supply-side NIEMO can be estimated.

$$\mathbf{X}^s = \mathbf{X}^s \mathbf{B} \mathbf{C}^s + \mathbf{V} \mathbf{C}^s \quad (\text{A.1})$$

and,

$$\mathbf{X}^s = \mathbf{V} \mathbf{C}^s (\mathbf{I} - \mathbf{B} \mathbf{C}^s)^{-1} \quad (\text{A.2})$$

If letting  $\mathbf{V} \mathbf{C}^s$  be  $\mathbf{V}^*$  assuming a row vector of regional specific losses of value added factors, then

$$\mathbf{X}^s = \mathbf{V}^* (\mathbf{I} - \mathbf{B} \mathbf{C}^s)^{-1} \quad (\text{A.3})$$

where,  $\mathbf{B} = (\hat{\mathbf{X}}^d)^{-1} \mathbf{Z}$  and  $\hat{\mathbf{X}}^d$  is a  $nm \times nm$  block diagonal matrix of vector  $\mathbf{X}^d$ , and hence the elements in all blocks off the regional diagonal would be zero, and

$\mathbf{C}^s = (\hat{\mathbf{C}}_i^m)^{-1} \mathbf{C}$  and  $\hat{\mathbf{C}}_i^m$  is a  $nm \times nm$  diagonal matrix of  $nm \times 1$  column vector  $c_i^m = \sum_j c_{ij}^m$ , that is, off-diagonals for a specific region

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<sup>6</sup> An anonymous referee suggested that the supply-driven NIEMO should be also tested for the ports serving different size areas, because the economic impacts might depend on the size of facilities. Further, temporally extended economic impacts over one month can be estimated. The questions will be examined in a further study.

block should be zero and  $c_{ij}^m$  is an element of matrix **C** for region  $i$  to  $j$  trade flow of USC sector  $m$ .

Here, the use matrix ( $U^B$ ) instead of the **B** matrix for the supply-side NIEMO are applied to reflect actual commodity flows used to each industry.

**Appendix 2**

Table A1. Port of Los Angeles/Long Beach Final Demand Estimates (\$Million)

USC Sectors	2001 WISERT		2001 WCUS		SUM		FD LOSS	
	EXPORT	LA+LB/F/EXP	LA+LB/D/EXP	LA+LB/D/EXP	LA+LB/EXP	LA+LB/EXP	LA+LB/EXP	LA+LB/EXP
1		1,266.907		60.587		1,327.494		110.624
2		1,841.898		72.392		1,914.290		159.524
3		1,947.819		57.233		2,005.052		167.088
4		103.623		14.076		117.699		9.808
5		932.228		69.476		1,001.705		83.475
6		115.775		99.710		215.484		17.957
7		341.525		0.872		342.397		28.533
8		142.763		4.601		147.365		12.280
9		66.424		0.000		66.424		5.535
10		668.976		4,668.766		5,337.743		444.812
11		2,562.233		44.491		2,606.724		217.227
12		489.963		21.007		510.970		42.581
13		26.460		0.000		26.460		2.205
14		2,090.564		762.382		2,852.947		237.746
15		3,445.487		18.766		3,464.254		288.688
16		191.143		715.076		906.219		75.518
17		576.009		28.128		604.137		50.345
18		225.080		552.670		777.750		64.813
19		1,223.022		439.954		1,662.976		138.581
20		507.899		2,070.120		2,578.019		214.835
21		492.649		76.759		569.408		47.451
22		657.456		480.116		1,137.572		94.798
23		5,078.266		179.124		5,257.390		438.116
24		3,160.808		793.861		3,954.669		329.556
25		1,433.580		1,047.714		2,481.294		206.774
26		791.256		540.044		1,331.300		110.942
27		821.266		1,499.755		2,321.020		193.418
28		306.662		419.763		726.425		60.535
29		1,714.392		1,416.397		3,130.789		260.899
total		33,222.132		16,153.843		49,375.975		4,114.665
IMPORT	LA+LB/F/IMP	LA+LB/D/IMP	LA+LB/D/IMP	LA+LB/IMP	LA+LB/IMP	LA+LB/IMP	LA+LB/IMP	LA+LB/IMP
1		3,461.700		3.349		3,465.049		288.754
2		797.923		44.083		842.006		70.167
3		306.265		4.829		311.094		25.924
4		215.726		2.134		217.859		18.155
5		1,025.569		106.627		1,132.195		94.350
6		586.348		1.606		587.954		48.996
7		64.640		1.301		65.941		5.495
8		37.023		3.927		40.950		3.413
9		8.631		0.000		8.631		0.719
10		3,107.925		3,103.754		6,211.679		517.640
11		2,259.888		468.453		2,728.340		227.362
12		153.331		3.390		156.722		13.060
13		3.821		0.000		3.821		0.318
14		1,432.809		1,077.606		2,510.414		209.201
15		6,638.519		8.112		6,646.632		553.886
16		1,597.950		212.786		1,810.736		150.895
17		889.126		3.774		892.900		74.408
18		1,017.440		25.850		1,043.291		86.941
19		34,785.637		62.956		34,848.593		2,904.049
20		2,568.135		28.908		2,597.043		216.420
21		1,741.001		2.663		1,743.664		145.305
22		6,420.596		42.622		6,463.218		538.601
23		12,596.629		58.189		12,654.817		1,054.568
24		41,181.253		76.173		41,257.426		3,438.119
25		17,588.402		465.260		18,053.662		1,504.472
26		539.416		55.674		595.089		49.591
27		4,018.357		143.758		4,162.115		346.843
28		7,909.832		18.231		7,928.063		660.672
29		11,623.447		55.840		11,679.287		973.274
total		164,577.337		6,081.854		170,659.191		14,221.599
Use only 29 USC commodity sectors	Convert SITC to USC sectors and then use WISERT data directly	First, Convert WCUS to SITC in Short Tons. Second, Convert Tons to Dollars from WISERT trade Foreign data. Finally, convert SITC to USC sectors.			WISERT+WCUS	Distribution: SUM/12		

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