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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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 Sep.11, 2001. In a 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- 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; state policy*

I. 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?

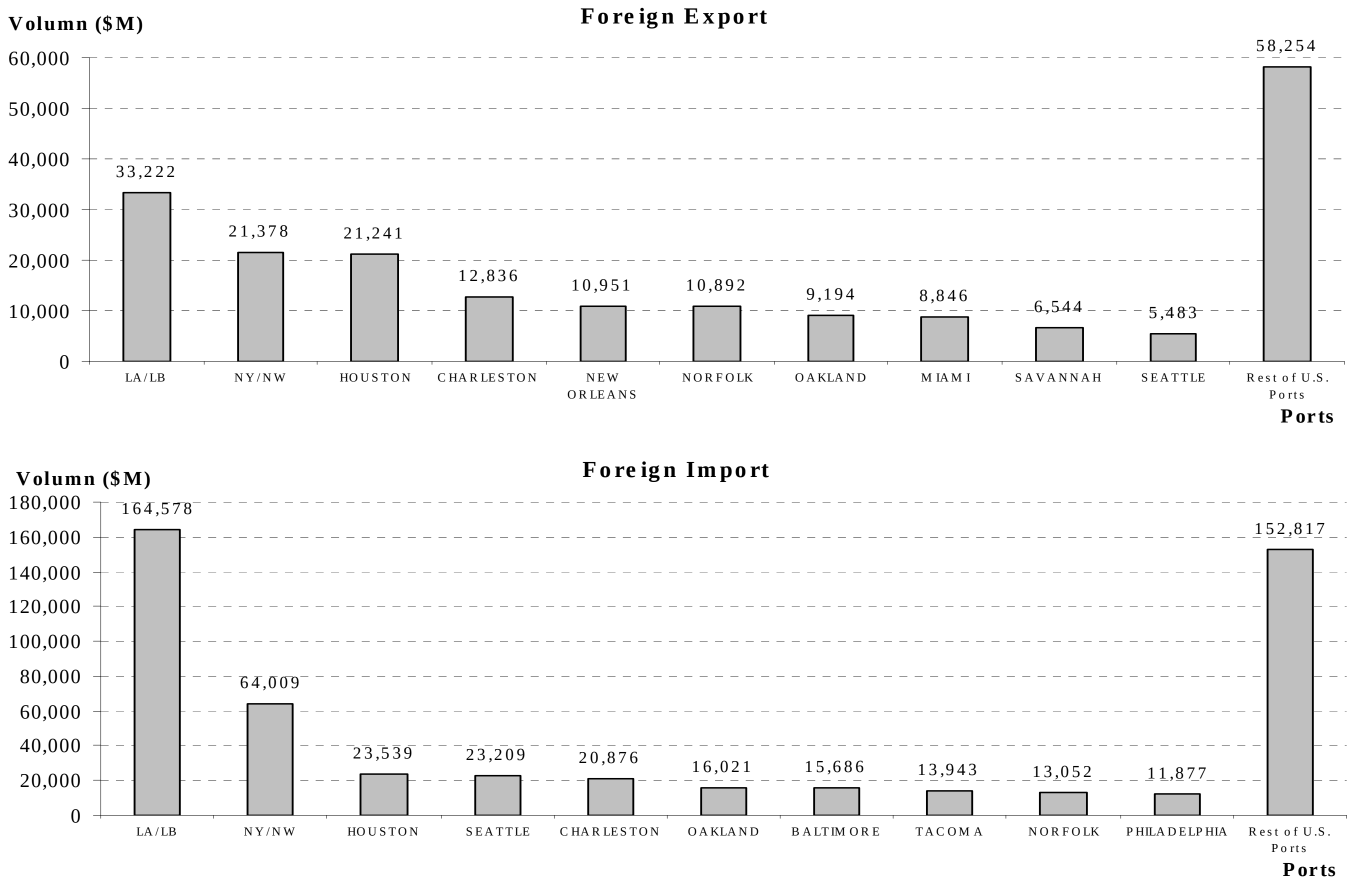
Not only are there many plausible natural events that have unique spatial incidence effects but there are growing concerns over possible terrorist attacks. Any of these have unique spatial impacts. Among the many targeted areas, the Los Angeles metropolitan area is widely exposed to attacks because of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

Attacks on the Los Angeles (LA) and Long Beach (LB) ports by dirty bombs could have major consequences from direct losses of lives and commodities, 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 choosing other ports, or using up of inventories, or relocating their businesses to obtain the necessary products by behaviors

However, the labor actions' times and places were 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 probably be hard put to absorb significant diversions to or from LA/LB.

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



Source: By author and recalculated from WISERTrade data.

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 through 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.

The 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 spatial information. Yet, 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 obtained from the Bureau of Transportation Statistics (BTS) (Park et al, 2007; Richardson et al, 2006). Hence, this discussion of the construction of a supply-driven NIEMO, will describe the initial demand-driven NIEMO (National Interstate Economic Model) and then estimate how much the economic impacts of national and other states are via interstate 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 results and policy implications from NIEMO will be addressed in the fourth section, with particular attention paid to the inter-state distribution of economic losses. The paper concludes with a brief summary in the final section of important contributions and caveats.

II. 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 a kind of MRIO regionally specified for 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 coefficient tables and trade coefficient 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 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 many 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 (as many as 52x52x47x47) can be constructed at low cost given the fact that IMPLAN's outputs are plausible (Park and Gordon, 2005), further elaborations of the initial NIEMO model, estimating the service interactions will be suggested, applying the Geographical Weighted Regression (GWR) method (Park, 2006).

Based on the initial demand-side NIEMO, Richardson et al. (2006) examined the national and interstate economic impacts of terrorist attacks on major U.S. theme parks, and Park et al. (2006) reported the interstate economic impacts from foreign export closures resulting from BSE (Bovine Spongiform Encephalopathy) in the state of Washington.

Although many studies have focused on constructing demand-driven MRIOs because of their widely accepted usefulness in regional science, there have been only a few attempts to estimate 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 Ghoshian price model. This is why recent supply-driven IRIO or MRIO studies have only 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).

Furthermore, there is no example that examines the forward linkages for the U.S. except Shao and Miller's (1990) work based on 1977 data. The problem comes from the non-existence of an operational supply-driven MRIO model. Therefore, the construction of a supply-driven NIEMO using data on interindustry linkages and trade flow relations developed in similar ways as for the demand-side NIEMO will denote big step towards estimating forward linkages and the structure of interregional U.S. economy.

Plausibility of Supply-driven Input-Output

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). More recently, Dietzenbacher (1997) showed that the implausibility issues are mitigated if the Ghosh model is interpreted as a price model, possibly equivalent to Leontief's price model.

Applying the Leontief comparative static analysis, we move from one equilibrium to another. It is clear, however, that in reality, the economy traverses a period of disequilibrium in between. In fact, it is possible to describe the temporary disequilibrium in terms of the various models that have been discussed along with exogenously provided information on selected price elasticities of demand. Also, under normal economic equilibrium conditions, quantities are more or less fixed, but prices change, and hence Dietzenbacher's (1997) suggestion is useful.

However, unusual economic cessations such as caused by disasters will temporarily produce quantity losses and lead to further economic losses via interindustrial and interregional relations. As Dietzenbacher has noted, the basic interpretation of the supply-driven model is via price interrelations, under the assumption of fixed quantities. However, 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.

Empirical applications of Ghosh's suggestion have not been conducted., Most analysts rely on the demand-driven IO models. Ever since Oosterhaven's successive criticisms (1988, 1989, 1996) on the implausibility of the supply-side model theoretically, or 'output changes without input changes', it is hard to find dominant or widespread supply-side approaches to impact analysis. Dietzenbacher (1997) showed the supply-driven model can be interpreted as a 'price' model which is more convenient to grasp than the price effects from the 'Leontief' price model, because the ‘price’ changes are shown directly while the ‘Leontief’ results shows them as percentage changes.

Two studies of impact analysis are discussed by Giarratani (1976) and Davis and Salkin (1984); they note which criteria are necessary when applying the supply-driven model and provide the conditions. In the event that our current economic system cannot be a centralized planned economy, it is important to specify the conditions to be able to apply a supply-driven model. From the previous works, two major economic characteristics for the application of the supply-driven model can be summarized: monopolistic characteristics and scarcity of substitution opportunities Yet, the supply models still require further theoretical support in order to apply them to impact analysis empirically.

The key assumption shown in Dietzenbacher’s (1997) is the suggestion that there are only price changes among the value added changes. Corresponding changes of total outputs, consequently, result from price changes, not quantity changes. This interpretation defended successfully against attacks on the implausibility of supply-driven IO models. However, accepting the interpretation limits our understanding of the results of impact analyses, because quantity losses, e.g. labor losses or capacity losses of a facility from unexpected disasters are general and cannot be applied to the Ghoshian price model.

The market mechanism, although often modeled as “perfect” includes significant market power of various producers at any given price and quantity. due to limited accesses to market information.. That is, 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 negotiations via numerous iterations by the actors in a normal economic environment (Pindyck and Rubinfeld, 1998: 21). This leads to, as Ghosh (1958) mentioned, the result that producers will not decrease their previous outputs or factors during short-term periods even if there are the large shocks to the economy. The behavior for finding substitute products imposes many unexpected costs, e.g. costs for searching for substitutes, additional transportation costs, and so on, and hence unless those are expected in the long-run experience, their reactions will not happen. Even in the market system, therefore, two conditions that approximate monopolistic characteristic and acute scarcity of resources can be verified during the short-run.

Therefore, the general application of Oosterhaven’s critique of Ghosh’s model has incited the implausibility debates over the supply-driven model. Furthermore, even in the case that normal equilibrium is not maintained, Ghosh’s case can be switched to a price-type of Ghosh’s supply-driven IO model, and play a role in estimating economic impacts (Park, 2007). To implement this switch, it is necessary to introduce exogenous price elasticities of demand and combine them with the general supply-driven model, adjusting quantity responses to price impacts. Using an iterative adjustment based on Taylor's expansion of the supply-driven model yields better estimates than simple linear multiplicands. Yet, this study will use only the quantity losses based on the Ghosh's original position.

Scenario

The U.S. Department of Homeland Security announced on Apr. 25 of 2006 that they would take "significant steps to enhance security by checking the backgrounds of port workers" (www.dhs.gov). This is to minimize the access by suspects to those ports playing a key role for the U.S. economy and because of the vulnerability of ports possibly accessed by terrorists. 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 many 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".

Therefore, based on the above discussions, tests of a different scenario from port closures due to strikes can be informative. This study follows the hypothesis of Gordon et al. (2005) and Park et al. (2007) in previous studies of LA/LB ports: the explosion of two small radiological dispersal devices (RDDs), of which characteristics are reported in Gordon et al. (2005: 264). Because the reopening of the ports are decided according to policy choices, 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).

III. 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 table that Park et al. (2007) have recently developed. The system allows conversion to a set of 47 common sectors that are called the USC Sectors as shown in Appendix 1. Among the many data sources utilized, the 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 United States) data for 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, Jackson et al. (2006) used IMPLAN data to adjust incomplete CFS information primarily by adopting a Box-Cox transformation as well as double-log distance-decay functions. Another approach is to use a doubly-constrained gravity model based on county-level data from IMPLAN and ton-mile data from CFS (Lindall et al, 2005). As a trial to estimate trade inflows of subregional below the state-level using CFS, Lie and Vilain (2004) suggested the use of location quotients, but this requires very restrictive assumptions. Also, because CFS does not provide service sector information, estimating service sector trade requires even stronger assumptions.

To construct trade tables between all 50 states plus D.C. and the rest of the world, this study follows the first version of a trade flow estimation methodology suggested by Park et al. (2004), which used the same basic data sources as Jackson et al. (2006), but adopted a different estimation approach relying on an Adjusted Flow Model (AFM) and a Doubly-constrained Fratar Model (DFM). The AFM was used to fill the empty cells in the CFS-based trade flow matrices for the USC Sectors that can then be manipulated iteratively via a Fratar model. However, the conventional Fratar model cannot estimate the diagonal (intrastate flow) values, so DFM incorporates both the non-diagonal flow estimates and the standard Fratar model. To obtain the trade flow matrix, I implemented the initial two-stage models, the AFM and DFM, presented by Park et al. (2004, 2007).

Related to these initial trials, 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 service 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 application, assuming no substantial interstate trade in services.

Methodology

The supply-side NIEMO is developed based on the estimated 2001 commodity trade flows between all 50 states plus Washington, D.C. and the rest of the world, which was developed from the original 1997 CFS for 29 USC commodity sectors, using Visual Basic to develop the AFM estimating these missing values, and to execute the Fratar updates. The procedures for building the supply-side NIEMO used in this study are the same as those of the demand-side NIEMO reported carefully in Park et al. (2007), except for the construction process of interindusty and trade flow coefficients matrices. This is because the supply-side NIEMO depends upon 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.

The NIEMO version of an MRIO coefficient matrix is created by taking the product of the two matrices: the tables of intrastate industrial commodity trade coefficients and the tables of inter-industry transaction coefficients for each state, D.C., and rest of world (and hence, totally 52 regions and 47 sectors). Note the model includes no transaction coefficients for 18 service 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.

Applying Bon's (1988) suggestion of 'Row Coefficient Model' for interregional trade coefficients, let $\mathbf{X} = \mathbf{X}^{\mathbf{s}} = (\mathbf{X}^{\mathbf{d}})^{\mathbf{T}}$ be total output vector for $m(=1,...,47)$ non-service and service commodities, labeled as the USC Sectors and $n(=1,...,52)$ 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.

$$\mathbf{X}^{\mathbf{s}} = \mathbf{X}^{\mathbf{s}}\mathbf{B}\mathbf{C}^{\mathbf{s}} + \mathbf{V}\mathbf{C}^{\mathbf{s}} \tag{1}$$

and,

$$\mathbf{X}^{\mathbf{s}} = \mathbf{V}\mathbf{C}^{\mathbf{s}}(\mathbf{I} - \mathbf{B}\mathbf{C}^{\mathbf{s}})^{-1} \tag{2}$$

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

$$\mathbf{X}^{\mathbf{s}} = \mathbf{V}^{*}(\mathbf{I} - \mathbf{B}\mathbf{C}^{\mathbf{s}})^{-1} \tag{3}$$

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

$\mathbf{C^s} = (\mathbf{\hat{C}_i^m})^{-1}\mathbf{C}$ and $\mathbf{\hat{C}_i^m}$ 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 block should be zero and c_{ij}^m is an element of matrix $\mathbf{C}$ for region i to j trade flow of USC sector m.

Here, I applied the use matrix ($\mathbf{U^B}$) instead of the $\mathbf{B}$ matrix for the supply-side NIEMO only to reflect actual commodity flows used to each industry. In Figure A1 of the appendices, the figures of $\mathbf{U^B}$, $\mathbf{C^s}$, and $(\mathbf{I} - \mathbf{U^B C^s})^{-1}$ matrices are shown.

IV. Results

While many businesses are located in California and depend on the LA/LB ports, they also have interindustry relationships as well as interstate connections in spite the fact that some of the importing commodities are finished goods. Also, most of the finished goods are related to logistics and hence connected spatially over state-boundaries. Therefore, using the supply-driven NIEMO clearly considers the spatial and interindustrial information on economic impacts that one 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 this 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 basis.

Based on the last column of average one-month final losses shown in Table A2, 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). As shown in the *Scenario*, the LA/LB ports would be closed for one month without any substitutions and mitigations. The fact that 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 economic roles of LA/LB ports.

Table 2 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, using 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 shows that individuals are somewhat subject to market power in the case of radical disruptions, as Ghosh expected in 1958. 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 California in the case of exports.[1]

This also can be found in the following Figure 1 and Figure 2. The actual indirect impacts for both imports and exports disturbances are distributed nation-wide. The LA/LB ports closures by imports disturbances (Figure 1A) impact the relatively proximate states such as Arizona, Texas, and Washington with over $200 million of indirect impacts. While only Texas experiences indirect impacts according to the exports disturbances over $100 million (Figure 1B), 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 2 shows the proportional disturbances between the two, and 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 hurt 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.

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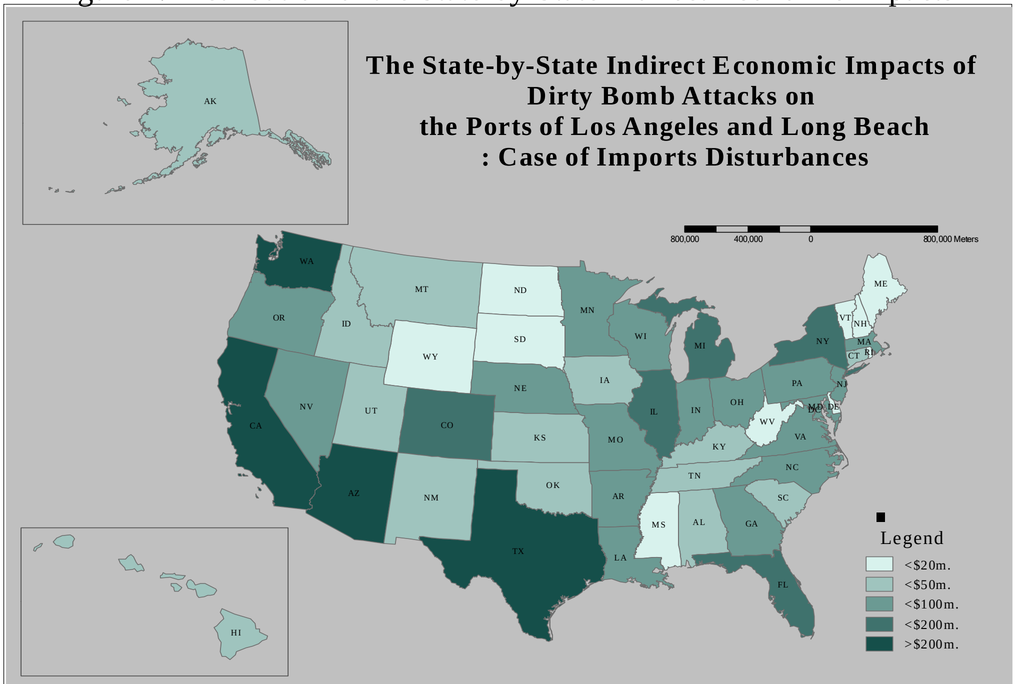
[1] The percentage calculated as follows: $100(\sum_{i \neq CA} \Delta^i)/(\sum_i \Delta^i)$, where Δ^i means indirect impacts of region i. For example, 46.34%={100* (4,921.94-2,641.24)}/ 4,921.94.

Table 2. The State-by-State Impacts of Port of Los Angeles/Long Beach One-month Closures

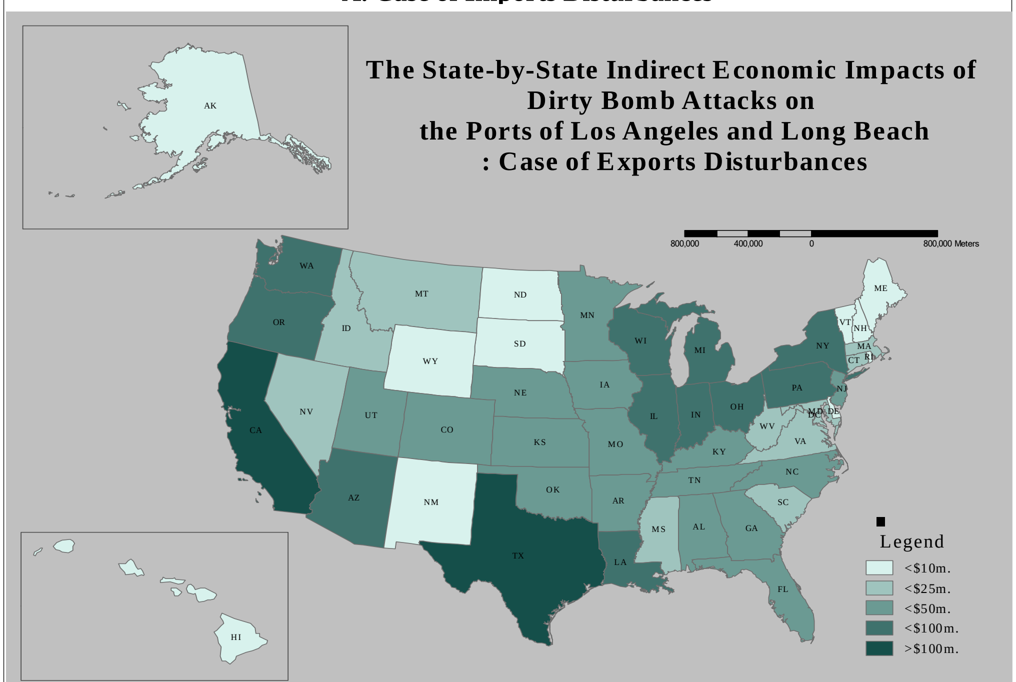
State	Export Losses ($M.) Direct Impacts	Export Losses ($M.) Indirect Impacts	Import Losses($M.) Direct Impacts	Import Losses($M.) Indirect Impacts	2000 Total Population (Unit: 1,000)	Total Export Losses by Per Person	Total Import Losses by Per Person
AL	0.00	26.96	0.00	48.73	4,447	6.06	10.96
AK	0.00	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

Figure 1. Distribution of the State-by-State Indirect Economic Impacts



A. Case of Imports Disturbances

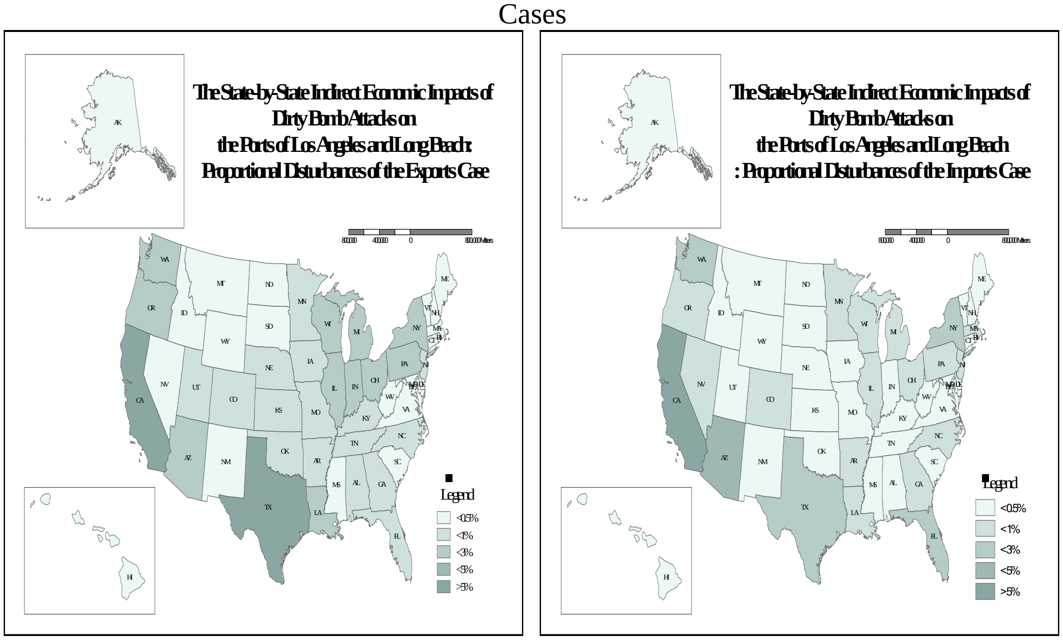


B. Case of Exports Disturbances

Finally, although the total amounts of 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 2 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.

Except California, Texas ($18.8), Louisiana ($17.44), Nebraska ($14.80), Oregon ($14.73), Washington ($13.49), and Wyoming ($13.20) will take the 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 import case shown in the last column. Different from the export cases, people living in the Arizona ($70.75), Alaska ($65.1), and Nevada ($46.76) are economically affected due to the disturbance of imports from the attack. In particular, Alaskans might prepare their financial policies in an event of LA/LB ports disruption, because of relatively small population than other sizably affected states.

Figure 2. Comparison of Proportional Disturbances for the Export and Import Disruption Cases



V. 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 in short-run analysis applies to NIEMO, even though it includes a detailed spatial dimension (Park et al, 2007). The application of 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. And although there have been debates on the plausibility of supply-side IO model, it seems that a supply-driven NIEMO should be utilized in order to analyze the import disturbances.

In this paper, I tested LA/LB ports closures from a hypothetical terrorist attack, using RDDs and based on two 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 ports labor strike that allows time to plan substitutions and other mitigation effects. 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 market power of many firms in the short run.

To address interregional spread effects, a supply-driven NIEMO was developed. The direct imports losses of LA/LB ports have powerful indirect effects on Arizona, Texas, and Washington inducing over $200 million of losses. However, the distributions of indirect losses of imports are mostly limited to California when compared with exports distributions if both total losses are same. Furthermore, the residents in Arizona, Alaska, and Nevada will have the most serious economic burdens from the import disturbances.

Those results from the supply-driven NIEMO have important political implications because the simulations show that terrorist attacks in one state have significant economic impacts in other states. We know economic impacts have a spatial incidence and, political representatives have an obvious interest in their own constituency and jurisdiction. In addition, subnational impacts can cancel each other in the aggregate, causing national measures to obscure key dimensions of events. Therefore, in the Congress, especially in the Senate where political power is evenly distributed among the states, this conclusion could help to garner nationwide support for prevention measures for LA/LB ports, often distant from the states where the measures are taken. And the results from considering the population of each state, as shown in this study, can help to form guidelines for policies for each state on how local and national officials might implement mitigation measures and/or prevention burdens.

Appendices

Table A1. Definitions of USC Two-Digit Sectors

Classification	USC	Description	SCTG	NAICS
Commodity Sectors	USC01	Live animals and live fish & Meat, fish, seafood, and their preparations	(1+5)	
	USC02	Cereal grains & Other agricultural products except for Animal Feed	(2+3)	
	USC03	Animal feed and products of animal origin, n.e.c.	4	
	USC04	Milled grain products and preparations, and bakery products	6	
	USC05	Other prepared foodstuffs and fats and oils	7	
	USC06	Alcoholic beverages	8	
	USC07	Tobacco products	9	
	USC08	Nonmetallic minerals (Monumental or building stone, Natural sands, Gravel and crushed stone,	(10~13)	
	USC09	Metallic ores and concentrates	14	
	USC10	Coal and petroleum products (Coal and Fuel oils, n.e.c.)	(15~19)	
	USC11	Basic chemicals	20	
	USC12	Pharmaceutical products	21	
	USC13	Fertilizers	22	
	USC14	Chemical products and preparations, n.e.c.	23	
	USC15	Plastics and rubber	24	
	USC16	Logs and other wood in the rough & Wood products	(25+26)	
	USC17	Pulp, newsprint, paper, and paperboard & Paper or paperboard articles	(27+28)	
	USC18	Printed products	29	
	USC19	Textiles, leather, and articles of textiles or leather	30	
	USC20	Nonmetallic mineral products	31	
	USC21	Base metal in primary or semi-finished forms and in finished basic shapes	32	
	USC22	Articles of base metal	33	
	USC23	Machinery	34	
	USC24	Electronic and other electrical equipment and components, and office equipment	35	
	USC25	Motorized and other vehicles (including parts)	36	
	USC26	Transportation equipment, n.e.c.	37	
	USC27	Precision instruments and apparatus	38	
	USC28	Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs	39	
	USC29	Miscellaneous manufactured products, Scrap, Mixed freight, and Commodity unknown	(40~99)	
Non-Commodity (Service) Sectors	USC30	Utility		22
	USC31	Construction		23
	USC32	Wholesale Trade		42
	USC33	Transportation		48
	USC34	Postal and Warehousing		49
	USC35	Retail Trade		(44+45)
	USC36	Broadcasting and information services*		(515~519)
	USC37	Finance and Insurance		52
	USC38	Real estate and rental and leasing		53
	USC39	Professional, Scientific, and Technical services		54
	USC40	Management of companies and enterprises		55
	USC41	Administrative support and waste management		56
	USC42	Education Services		61
	USC43	Health Care and Social Assistances		62
	USC44	Arts, Entertainment, and Recreation		71
	USC45	Accommodation and Food services		72
	USC46	Public administration		92
	USC47	Other services except public administration**		81

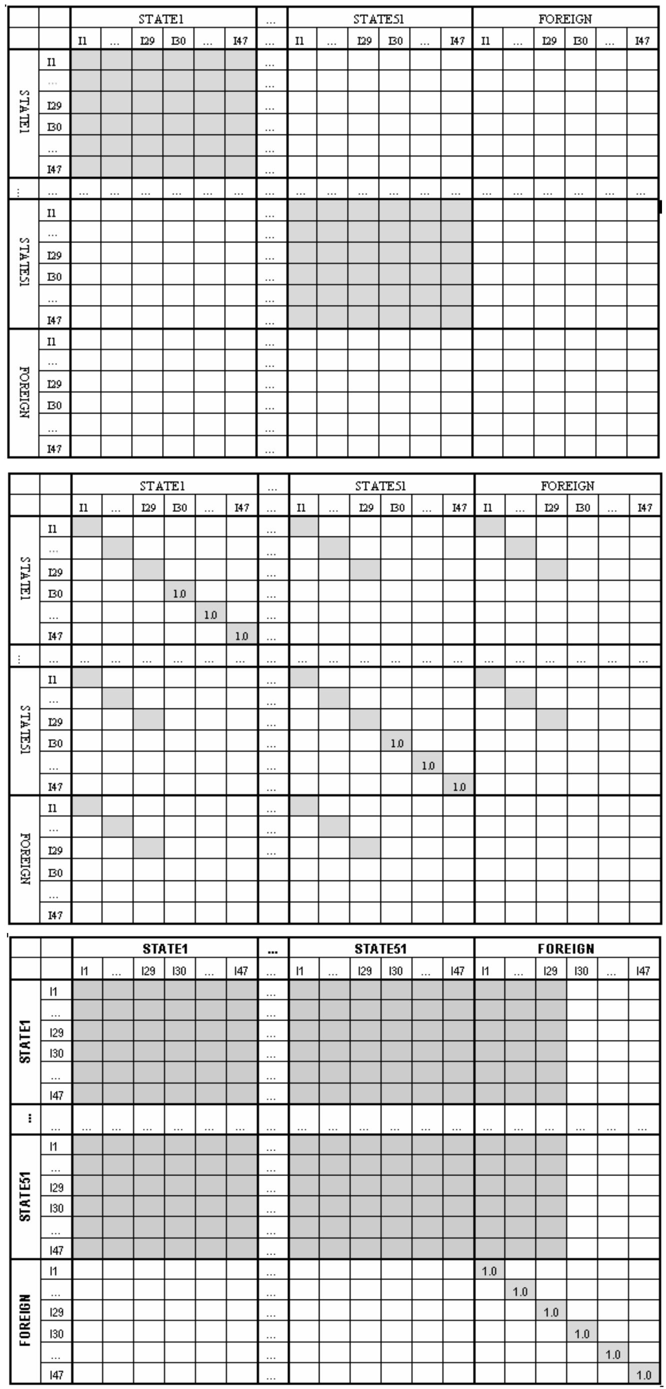
*Publishing, Motion pictures, and Recording (IMPLAN 413-415, 417-419, or NAICS 511~512) are excluded in this sector and included in Commodity Sectors

**USC47 includes NAICS 81 plus Support activities (18=Agriculture and forestry, 27-29=Mining) and Etc. (243=Machine shops) in IMPLAN

Table A2. 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/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/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 ommodity 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 WISERTrade Foreign data. Finally, convert SITC to USC sectors.	WISERT+WCUS	Distribution: SUM/12

Figure A1. Figures describing Three Major Matrices, $\mathbf{U^B}$, $\mathbf{C^s}$, and $(\mathbf{I}-\mathbf{U^B C^s})^{-1}$, for the Supply-Driven NIEMO



$\mathbf{U^B}$

$\mathbf{C^s}$

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

References

Bon, R. and T. Yashiro, 1995, Comparative Stability Analysis of Demand-side and Supply-side Input-Output Models: The Case of Japan, 1960-90, *Applied Economics Letters*, Vol. 3: 349-354.

Bon, R., 1988, Supply-side Multiregional Input-Output Models, *Journal of Regional Science*, Vol. 28, No 1: 41-50.

Bon, R., 2001, Comparative Stability Analysis of Demand-side and Supply-side Input-Output Models: Toward Index of Economic "Maturity", in Lahr, M.L. and E. Dietzenbacher eds., *Input-Output Analysis: Frontiers and Extensions*, NY, Palgrave.

CBO (Congressional Budget Office), 2006, *The Economic Costs of Disruptions in Container Shipments*, available at http://www.cbo.gov/ftpdocs/71xx/doc7106/03-29-Container_Shipments.pdf

Chenery, H.B., 1953, Regional Analysis, in *The Structure and Growth of the Italian Economy*, edited by H.B. Chenery, P.G. Clark and V.C. Pinna, US Mutual Security Agency, Rome: 98-139

Cohen, S. S., 2002, Economic impacts of a West Coast dock shutdown, Unpublished report prepared for the Pacific Maritime Association, Berkeley Roundtable on the International Economy, University of California at Berkeley, http://brie.berkeley.edu/~briewww/publications/ships%202002%20final.pdf

Davis, H.C. and E.L. Salkin, 1984, Alternative Approaches to the Estimation of Economic Impacts Resulting from Supply Constraints, *The Annals of Regional Science*, Vol.18: 25-34.

Dietzenbacher, E., 1997, In Vindication of the Ghosh Model: A Reinterpretation as a Price Model, *Journal of Regional Science*, Vol.37: 629-651.

Dietzenbacher, E., 2002, Interregional Multipliers: Looking Backward, Looking Forward, *Regional Studies*, Vol. 36, No.2:125-136.

Erlbaum, N. and J. Holguin-Veras, 2005, Some Suggestions for Improving CFS Data Products, Paper presented at *Commodity Flow Survey (CFS) Conference*, Boston Seaport Hotel & World Trade Center, Boston, Massachusetts, Jul. 8~9.

Ghosh, A., 1958, Input-Output Approach to an Allocative System, *Economica*, Vol. XXV: 58-64.

Giarratani, F., 1976, Application of an Interindustry Supply Model to Energy Issues, *Environmental Planning A*, Vol. 8: 447-454.

Gordon, P., J.E. Moore II, H.W. Richardson, and Q. Pan, 2005, The Economic Impact of a Terrorist Attack on the Twin Ports of Los Angeles-Long

Beach, in H.W. Richardson, P. Gordon and J.E. Moore II, eds., *The Economic Impacts of Terrorist Attacks*. Cheltenham: Edward Elgar.

Gruver, G.W., 1989, On the Plausibility of the Supply-driven Input-Output Model: A Theoretical Basis for Input-coefficient Change, *Journal of Regional Science*, Vol.29, 441-450.

Hall, P., 2004, “We’d Have to Sink the Ships”: Impact Studies and the 2002 West Coast Prot Lockout, Economic Development Quarterly, Vol.18, No.4: 354-367

Isard, W., 1951, Interregional and Regional Input-Output Analysis: A Model of a Space Economy, *Review of Economics and Statistics*, 33: 318-328

Jack Faucett Associates, INC, 1983, *The Multiregional Input-Output Accounts, 1977: Introduction and Summary, Vol. I (Final Report)*, prepared for the US Department of Health and Human Services, Washington

Jackson, R.W., W.R. Schwarm, Y. Okuyama, and S. Islam, 2006, A Method for Constructing Commodity by Industry Flow Matrices, *Annals of Regional Science*, (forthcoming).

LeSage, J.P., 1999, *The Theory and Practice of Spatial Econometrics*, University of Toledo, MN, available at the http://www.spatial-econometrics.com/html/sbook.pdf.

Lindall, S., D. Olsen and G. Alward, 2005, Deriving Multi-Regional Models Using the IMPLAN National Trade Flows Model, *Paper presented at the 2005 MCRSA/SRSA Annual Meeting*, April 7-9, Arlington, VA.

Liu, L.N. and P. Vilain, 2004, Estimating Commodity Inflows to a Substate Region Using Input-Output Data: Commodity Flow Survey Accuracy Tests, *Journal of Transportation and Statistics*, Vol. 7, No.1: 23-37.

Miller, Ronald E. and Peter D. Blair, 1985, *Input-Output Analysis: Foundations and Extensions*, New Jersey: Prentice-Hall

Moses, L.N., 1955, The Stability of Interregional Trading Patterns and Input-Output Analysis, *American Economic Review*, 45: 803-832

Oosterhaven, J., 1988, On the Plausibility of the Supply-driven Input-Output Model, *Journal of Regional Science*, Vol.28: 203-217.

Oosterhaven, J., 1989, The Supply-driven Input-Output Model: A New Interpretation but Still Implausible, *Journal of Regional Science*, Vol.29: 459-465.

Oosterhaven, J., 1996, Leontief versus Ghoshian Price and Quantity Models, *Southern Economic Journal*, Vol. 62, No.3: 750-759.

Park, J. Y., 2006, Estimation of State-by-State Trade Flows of Service Sectors Applying Geographical Weighted Regression, Paper presented at *North American Meetings of the Regional Science Association International 53rd Annual Conference*, Fairmont Royal York Hotel, Toronto, Canada, November 16-18

Park, J.Y., 2007, The Supply-Driven Input-Output Model: A New *Re*interpretation and Extension, Paper will be presented at *46thAnnual Meeting of the Western Regional Science Association*, Newport Beach, CA, USA, February 21-24.

Park, J. Y. and P. Gordon, 2005, An Evaluation of Input-Output Aggregation Error Using a New MRIO Model, Paper presented at *North American Meetings of the Regional Science Association International 52nd Annual Conference*, Riviera Hotel & Casino, Las Vegas, NV, USA, November 10-12.

Park, J. Y., P. Gordon, J. E. Moore II, and H. W. Richardson, 2004, "Construction of a U.S. Multiregional Input Output Model Using IMPLAN," Paper presented at *2004 National IMPLAN User's Conference*, Shepherdstown, West Virginia, USA, October 6-8.

Park, J.Y., C.K. Park, and S.J. Nam, 2006, "The State-by-State Effects of Mad Cow Disease using a new MRIO model", Paper will be presented at *2006 American Agricultural Economic Association (AAEA) Annual Meeting*, Long Beach, CA, July 23-26, 2006.

Park, J.Y., P. Gordon, J.E. Moore II, and H.W. Richardson, 2007, Simulating the State-by-State Effects of Terrorist Attacks on Three Major U.S. Ports: Applying NIEMO (National Interstate Economic Model), in H.W. Richardson, P. Gordon and J.E. Moore II, eds., *The Economic Costs and Consequences of Terrorism*. Cheltenham: Edward Elgar (*forthcoming*).

Pindyck, R.S. and D.L. Rubinfeld, 1998, *Microeconomics*, NJ. Prentice-Hall, Inc.

Polenske, 1980, The US Multiregional Input-Output Accounts and Model, DC Health, Lexington, MA

Richardson, H. W., P. Gordon, J. E. Moore, II, S.J. Kim, J.Y. Park, and Q. Pan, 2007, "Tourism and Terrorism: The National and Interregional Economic Impacts of Attacks on Major U.S. Theme Parks," in H.W. Richardson, P. Gordon and J.E. Moore II, eds., *The Economic Costs and Consequences of Terrorism*. Cheltenham: Edward Elgar (*forthcoming*).

Richardson, H.W., P. Gordon and J.E. Moore II, eds., 2005, *The Economic Impacts of Terrorist Attacks*. Cheltenham: Edward Elgar.

Rose, A. and T. Allison, 1989, On the Plausibility of the Supply-driven Input-Output Model: Empirical Evidence on Joint Stability, *Journal of Regional Science*, Vol.29: 451-458.

Samuelson, P.A. and W.D. Nordhaus, 1995, *Economics*, McGraw-Hill, Inc.

Shao, G. and R.E. Miller, 1990, Demand-side and Supply-side Commodity-Industry Multiregional Input-Output Models and Spatial Linkages in the US regional Economy, *Economic Systems Research*, Vol. 2, No. 4: 385-405.

Wang, E.C., 1997, Structural Change and Industrial Policy in Taiwan, 1966-91: An Extended Input-Output Analysis, *Asian Economic Journal*, Vol. 11, No. 2: 187-206.