

**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**
Von Kleinsmid Center 382
School of Policy, Planning, and Development
University of Southern California
Los Angeles, CA 90089-0001
Email: jiyoungp@usc.edu
Phone: (213) 821-1351

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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?

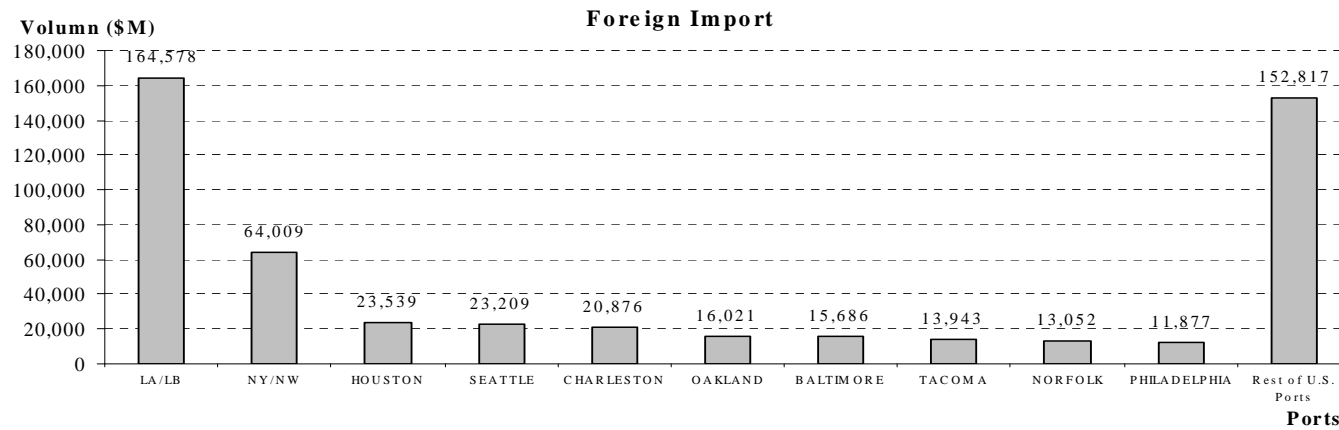
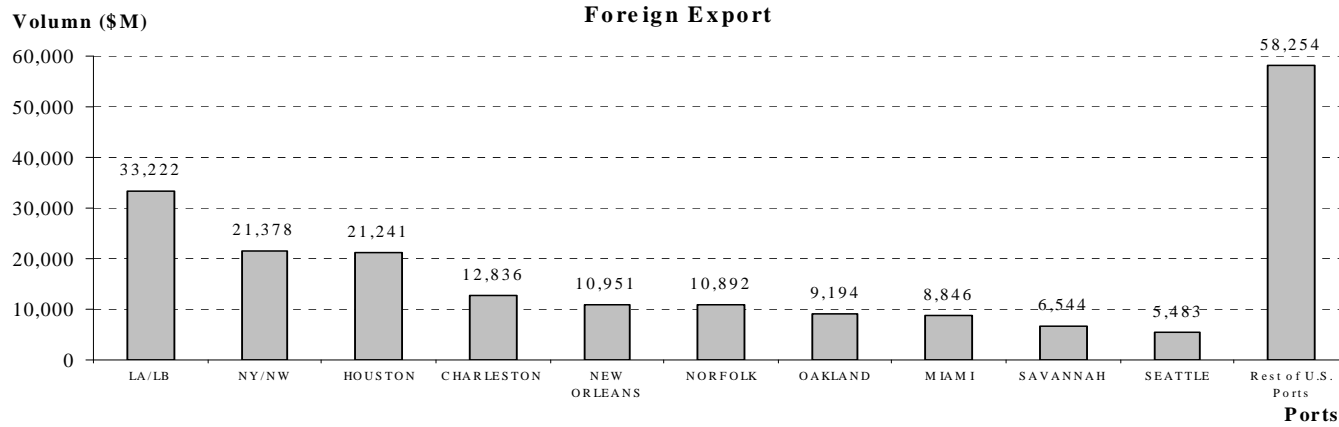
Not only are there many plausible natural events that have unique spatial incidence effects but there are growing concerns over possible terrorist attacks. Any of these have unique spatial impacts. Among the many targeted areas, the Los Angeles metropolitan area is widely exposed to attacks because of 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 $52 \times 52 \times 47 \times 47$) 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 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".

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 interindustry 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 $\mathbf{X} = \mathbf{X}^s = (\mathbf{X}^d)^T$ 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.

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

and,

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

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

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

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

¹ The percentage calculated as follows: $100(\sum_{i \neq CA} \Delta^i) / (\sum_i \Delta^i)$, where Δ^i means indirect impacts

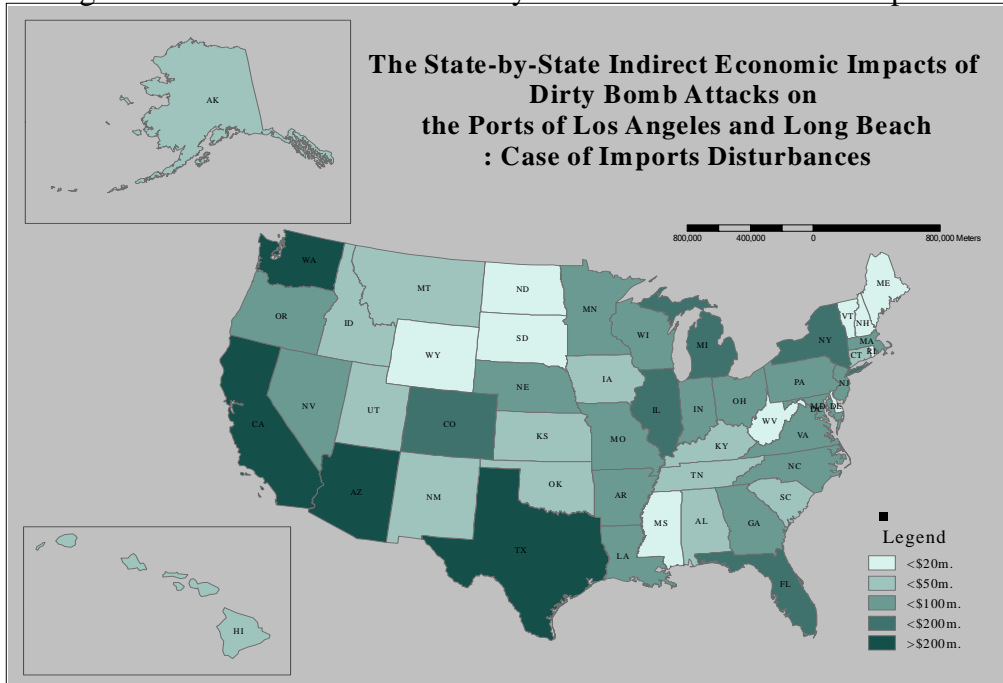
of region i . For example, $46.34\% = \{100 * (4,921.94 - 2,641.24)\} / 4,921.94$.

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

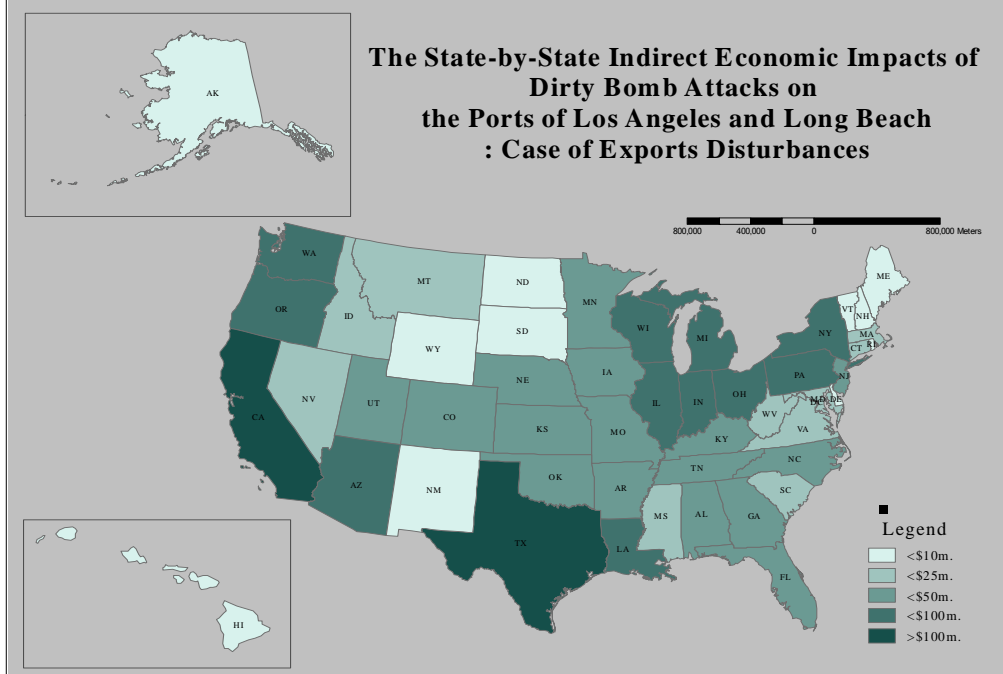
| State | Export Losses (\$M.) | | Import Losses(\$M.) | | 2000 Total Population (Unit: 1,000) | Total Export Losses by Per Person | Total Import Losses by Per Person |
|---------------|----------------------|------------------|---------------------|------------------|-------------------------------------|-----------------------------------|-----------------------------------|
| | 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

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



A. Case of Imports Disturbances

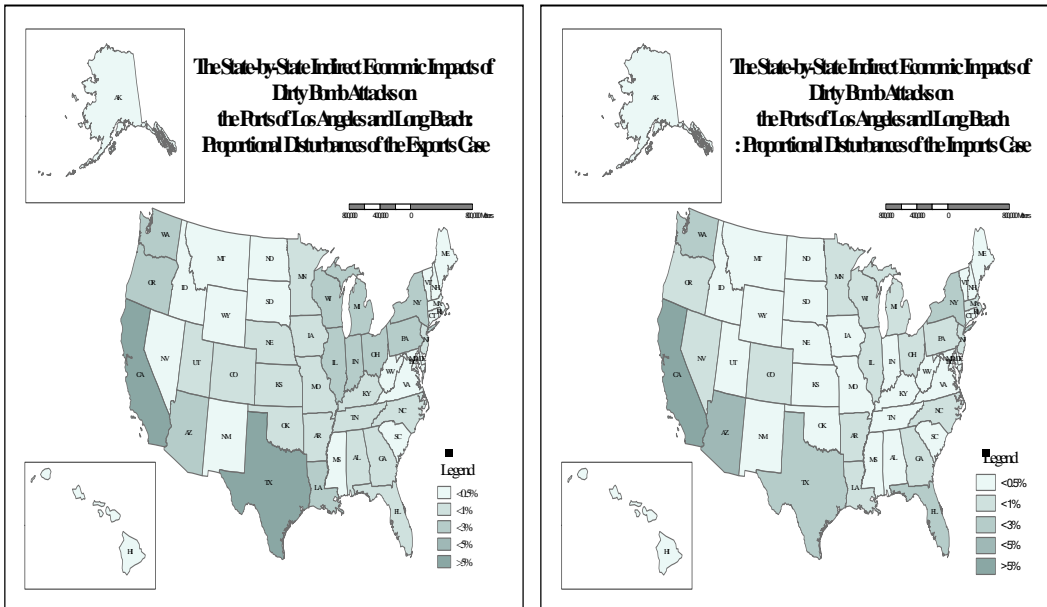


B. Case of Exports Disturbances

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 |
| 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 WISERTTrade Foreign data. Finally, convert SITC to USC sectors. | WISERT+WCUS | Distribution: SUM/12 |

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

| | | 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 | | | | | | | | | | | | | | | | | | | | |
| | ... | | | | | | | | | | | | | | | | | | | | |
| | I29 | | | | | | | | | | | | | | | | | | | | |
| | I30 | | | | | | | | | | | | | | | | | | | | |
| | I47 | | | | | | | | | | | | | | | | | | | | |

U^B

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

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 | | | | |
| | I47 | | | | | | | | | | | | | | | | | 1.0 | | | |

$(I - U^B C^S)^{-1}$

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