Risking House and Home: Disasters, Cities, Public Policy

John M. Quigley and Larry A. Rosenthal
Editors

2008
Berkeley Public Policy Press
Institute of Governmental Studies Publications
Berkeley, California

Cover: Loma Prieta Earthquake, October 17, 1989. San Francisco, California. Collapsed and burned buildings at Beach and Divisadero streets in the city's Marina District.

Photograph: C. E. Meyer, US Geological Survey

Library of Congress Cataloging-in-Publication Data

Risking house and home : disasters, cities, public policy / John M. Quigley and Larry A. Rosenthal, editors.

p. cm.

Includes bibliographical references.

ISBN 978-0-87772-427-8

1. Disaster relief—United States. 2. Insurance, Disaster—United States. 3. Urban policy—United States. I. Quigley, John M., 1942- II. Rosenthal, Larry A., 1959-

HV555.U657 2008

363.34'80973—dc22

2007043427

The Economic Impacts of Alternative Terrorist Attacks on the Twin Ports of Los Angeles-Long Beach

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Harry W. Richardson
Peter Gordon
James Moore
Jiyoung Park
University of Southern California

Qisheng Pan
Texas Southern University

This chapter integrates recent research on the economic impacts of terrorist attacks on the twin ports of Los Angeles and Long Beach, California. The research considers two types of attack—radiological bombs in the ports, and conventional ones against freeway bridges—either together or in isolation. The analysis uses the Southern California Planning Model (SCPM), a Los Angeles-area input-output model with the capability to allocate indirect and induced effects to over three thousand zones within an endogenous transportation network. The research measures the business-interruption losses associated with alternative scenarios varying as to port closure periods, bridge reconstruction and the duration of radiation plume evacuations. Losses are estimated at $34 billion in output and more than 200,000 worker-years in lost productivity. On long-haul impacts of the radiation plume itself, losses grow by $4.1 billion in output and nearly 45,000 worker-years. Expanding the models to cover interstate and international effects via transportation networks, the consequences include another $90 billion in cumulative losses.

Introduction

This chapter evaluates the economic impacts of terrorist attacks on the twin ports of Los Angeles and Long Beach, California. The first scenario we explore is a simultaneous but small radiological bomb attack on both ports combined with a conventional bomb attack on the three main-access freeway overpasses. We report the results for a 120-day shutdown (although in practice there might be very modest operation via the Alameda Corridor rail link and via trucks on the few, highly congested surface streets). These results are based on the Southern California Planning Model (SCPM), a spatially disaggregated regional input-output (I-O) model. SCPM features more than three thousand zones, and we have enhanced the approach by adding a highway network. The out-of-region impacts are calculated using the National Interstate Economic Model (NIEMO), multiregional input-output model covering all fifty states, Washington, DC, and the rest of the world.

After such an attack there would also be a radioactive plume over a wide area. This would result in business disruption and a decline in property values. The extent of these effects may be rather speculative, but we examine one plume scenario.

A quite different alternative attack would cut off Terminal Island, which has the more modern port terminals and accounts for about fifty-five percent of the twin ports' trade. Such an attack would require conventional bomb detonations on three road bridges and one rail bridge. Construction of temporary bridges might take three to four months; the replacement of permanent bridges might take more than two years. We elect to report on a one-year closure. Because of the model's linear character, these results can be scaled upwards or downwards according to different assumptions.

An important methodological issue is whether it is possible to endogenize disasters, especially man-made disasters such as terrorism.[1] Our approach treats the direct effects of a terrorist attack as an exogenous shock converted, given the focus on economic impacts, into changes in final demand. One important reason for this strategy is that terrorist attacks are even more difficult to predict than natural disasters such as earthquakes, because the unknowns of when and where (at least at the microscale) are compounded by the multiplicity of types of attacks and number of potential targets. Uncertainty can be reduced, if not wholly eliminated, by limiting our inquiries to *ex post* analyses, but that would be very restrictive in terms of research. The alternative, as represented here, is to explore "what if" scenarios of potential attacks. If the range of alternative scenarios is broadened considerably (not the intention in this paper), a degree of quasi-endogenization might be achieved. Identifying the magnitude of the economic impacts of alternative types of attack, while also assessing their probabilities, is a key element in a risk-based allocation of resources to counterterrorist activities.

The Los Angeles and Long Beach Ports

The Los Angeles and Long Beach ports' role in the local and national economy is widely recognized. In a metropolitan region of more than 16.4 million

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[1] This issue was raised by Stephen Maurer, our discussant at the Berkeley Symposium on Real Estate, Catastrophic Risk, and Public Policy, UC Berkeley, March 22-23, 2006.

people—featuring a labor force of almost 7.5 million and a median household income of $46,000—the twin ports account for 111 million tons of seaborne trade. Together they constitute the fifth largest port complex in the world after Hong Kong, Singapore, Shanghai, and Shenzen. Directly and indirectly, the ports employ 600,000 workers, accounting for more than seven percent of the region's labor force. In terms of containerized traffic, the two ports rank first and second nationally. To put this in perspective, these facilities' combined import and export trade flows of $300 billion in 2004 was equivalent to about thirty percent of the Greater Los Angeles gross regional product (GRP) (but, of course, not all are counted as part of that GRP). Reflecting trends in the national economy, imports at the twin ports are about five times larger than exports. About one-half of the imports and two-thirds of the exports are to and from points outside the region. In other words, the ports fulfill a national function, even more than a regional one. Thus, the ports of Los Angeles and Long Beach are of central importance to both the national and regional economies, and the loss of transshipment capabilities at these sites would have profound impacts both locally and nationally.

The ports are so critical because major disruptions do not merely reduce international trade flows. Although international air freight is growing rapidly in dollar terms, high-weight items still have to be shipped by sea. The impacts of disruption are much wider than a short-term deprivation of imported purchases by consumers or deferred export sales by producers. The supply chains for imported raw materials and intermediate inputs would be disconnected and, as a result, the productive capacity of firms both inside and outside the region is reduced. This problem is accentuated by low inventories associated with a widespread shift to the usually more efficient "just-in-time" inventory system.

We assume that both export and import flows currently using local seaport facilities would terminate for as long as the ports are out of service. We have not yet modeled port diversion, but may do so in future research, probably beginning with a survey of fleet operators. Some observers have suggested focusing on the experience provided by the West Coast dockworker strike of 2002, but it is of limited relevance because the closure was widely anticipated and the loss estimates suggested at the time (more than a billion dollars per day) were wildly inaccurate. Such estimates were quoted widely in many newspapers and other media outlets, but the original source remains elusive. One billion dollars per day is about three-and-a-half times our upper-bound estimate for the Los Angeles and Long Beach ports alone, even after accounting for multiplier effects.

During that 2002 strike, some carriers substituted access to Gulf Coast locations for service at local ports. There was also an increase in container flows through the Panama Canal. However, approximately fifty percent of all Pacific cargo ships are of post-"Panamax" design, and other Pacific ports do not have the draft or cranes (e.g., Oakland and Portland) sufficient to absorb the current traffic moving through Los Angeles and Long Beach. The extent and duration of diversions resulting from the unscheduled closure of local ports thus remain difficult to predict. Although more than eight thousand TEU (twenty-foot equivalent unit) container ships have been put into service, their only West Coast destination, in addition to Los Angeles-Long Beach, is Seattle-Tacoma, Washington.

Port diversion is only one of many strategies that might be adopted to alleviate the effects of bomb attacks on the twin ports. The possibility of mitigation implies that our estimates of economic impact are probably upper bounds.

The Models

The Southern California Planning Model (SCPM)

Interindustry models, based upon the transactions flows between intermediate suppliers and end producers, are widely used to measure regional economic impacts. They trace all economic impacts, including those of intra- and interregional shipments, usually at a high level of sectoral disaggregation. They are demand-driven and account for losses primarily via backward and forward linkages between economic sectors.

The input-output model component in this study is built upon the Minnesota Planning Group's well-known IMPLAN model, which has a high degree of sectoral disaggregation (509 sectors), originally aggregated to seventeen sectors for small-scale area impacts.[2] The second basic model component is spatial, allocating sectoral impacts across more than three thousand geographic zones (often aggregated to 308 primarily political jurisdictions throughout a five-county region in Southern California).

The key function of the model is to allocate the indirect and induced impacts generated by the input-output model spatially. The direct impacts consist of the final demand changes at the source of the attack (in this case, the ports). The indirect effects trace the interindustry linkages with other sectors, either forwards or backwards (locally, regionally, nationally, and internationally). The induced effects measure the secondary consumption impacts associated with the reduced spending of workers in both the direct and indirect sectors.

To estimate the latter, we use a journey-to-work matrix, showing all commuting flows between residential and workplace zones, to trace wages earned back to the home. We then use a journey-to-services matrix to trace retail and personal service purchases from the home to retail and service establishments. The journey-to-services matrix includes any trip associated with a home-based transaction other than the sale of labor to an employer. This includes retail and other service transaction trips but excludes nontransaction-based trips such as those made to visit friends and relatives. Data for the journey-to-services matrix include all trips classified by the Southern California Association of Governments (SCAG) as home-

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[2] Our research at the University of Southern California (USC) has reorganized the aggregates for certain purposes into forty-seven groups, now sometimes referred to as USC Sectors.

to-shop trips, and a subset of the trips SCAG classifies as home-to-other and other-to-other trips.

The current version of SCPM endogenizes traffic flows. It uses traffic analysis zones (TAZs), which are very small geographical units appropriate for measuring traffic flows from one node to another. This extension is important, because many types of terrorist attacks to induce changes in supply, including infrastructure capacity losses, which will contribute to reductions in network-level service and increases in travel delays. These delays and potential infrastructure damage are not negligible, but they are swamped by the general business interruption impacts.

When traffic flows are endogenous, any change in economic activity that affects the travel behavior of individuals or the movement of freight will influence how the transportation network is used, and these impacts will work themselves out as a change from one network equilibrium to another. The model has the capability to estimate losses from concurrent attacks against shipping, infrastructure, and productive capacity. Treating the transportation network explicitly endogenizes the otherwise exogenous travel behavior of households and intraregional freight flows, achieving consistency across network costs and origin-destination requirements.

The model makes explicit both distance decay (i.e., the decline in the number of trips with increasing distance) and congestion functions (i.e., the buildup of traffic congestion and delay costs when particular routes attract more traffic as other parts of the network are disrupted). This allows us to determine the geographical location of indirect and induced economic losses by endogenizing route and destination choice. This also enables us to allocate indirect and induced economic losses over TAZs in response to port-related direct losses in trade, employment, and transportation accessibility more accurately (see Cho, Gordon et al., 2001 [detailed summary of an earlier model version]). A flow chart of the model is shown in Appendix Figure 1.

NIEMO (National Interstate Economic Model)

In pursuing our research goals, the choice of approaches involved difficult tradeoffs. The use of linear economic models is justified by various factors, including the richness of the detailed results made possible at relatively low cost. NIEMO, for example, includes approximately six million multipliers. The principal insight that drives our research is that, with some effort, it is possible to integrate data from the IMPLAN state-level input-output models with commodity flow data from the US Department of Transportation's Commodity Flow Survey (CFS) and other sources for all individual states. This approach makes it possible to build an operational multiregional input-output model.

The drive behind the development of NIEMO was twofold: to assess the interstate impacts of events analyzed with our regional model (SCPM), and to extend the range of problems studied to the national level. Recent examples include an examination of terror attacks on theme parks in fourteen states and the simultaneous spread of foot-and-mouth disease at locations in one or more of the principal livestock states.

In the sections that follow, we describe the steps involved in making all data sources compatible, integrating them to build NIEMO, and applying the model.

Background to Multiregional I-O Construction

Many economists and planners are interested in evaluating the socioeconomic impacts of various disruptions. Occasionally, they use geographically detailed input-output models. Isard (1951) demonstrated that traditional (national) input-output models are inadequate because they cannot capture the effects of linkages and interactions among regions. To examine the full short-term impacts of unexpected events such as terrorist attacks or natural disasters on the US economy, the economic links among states should be considered. Multiregional input-output models (MRIOs) include interregional trade tables and avoid some of the problems associated with excessive aggregation. Building an operational MRIO for all US states, however, requires highly detailed data on interstate shipments.

Although Chenery (1953) and Moses (1955) formulated a relatively simplified MRIO framework in response to earlier observations by Isard, data problems persisted and have stymied most applications. The nonexistence or rarity of useful interregional trade data is the most problematic issue. Intra- and interregional data must be comparable and compatible, yet the currently available shipments data between states are only sporadically available and difficult to use.

It is not surprising, then, that few MRIO models have been constructed or widely used. The best known are the 1963 US datasets for fifty-one regions and seventy-nine sectors published in Polenske (1980) and the 1977 US datasets for fifty-one regions and 120 sectors released by Jack Faucett Associates (1983), then updated by various Boston College researchers and reported in 1988 (Miller and Shao, 1990).

More recently, there have been two attempts to estimate interregional trade flows using data from the 1997 CFS. US Commodity Transportation Survey data on interregional trade flows have been available since 1977 but reporting was discontinued for some years. For the years since 1993, this data deficit can be met to some extent with the more recent CFS data from the Bureau of Transportation Statistics (BTS), but these data are incomplete with respect to interstate flows. Based on the currently available CFS data, Jackson (2002) and Jackson, Schwarm et al. (2004) used IMPLAN data to adjust the incomplete CFS reports by adopting gravity models constrained via distance and making other adjustments.

Along similar lines and using the same basic data sources, we elaborate upon Park, Gordon et al. (2004), who suggested a different estimation approach relying on an adjusted flow model (AFM) and a doubly-constrained Fratar model (DFM). To proceed in this way, it is first necessary to create conversion tables to reconcile the CFS and IMPLAN sectors.

The primary requirements for building an interstate model for the US of the Chenery-Moses type are two sets of data, regional coefficients tables and trade coefficients tables (Miller and Blair, 1985). Models of this type can be used to estimate interstate industrial effects as well as interindustry impacts on each state, based mainly on the two data sources. Regional input-output tables provide intraregional industry coefficients for each state and interregional trade tables provide comparable trade coefficients. This implies the creation of three types of matrices: an intraregional interindustry matrix, an interregional trade matrix, and a combined interregional, interindustry matrix (in other words, the NIEMO matrix). Before creating the matrices, however, the data reconciliation problem has to be addressed.

The main steps involved in building and testing NIEMO are shown in Figure 9.1. We developed a set of forty-seven industries into which many of the other classification systems can be converted. Figure 9.2 shows the state of our industrial code conversion matrix among the many data sources used in this study. The detailed conversion processes occasionally involved case-by-case reconciliations. Inevitably, some conversions involved mapping one sector into more than one. The light-gray cells of Figure 9.2 represent one-to-one allocations. The dark-gray cells denote bridge allocations with plausible weights specified on a case-by-case basis.

Data for NIEMO Construction

A major problem in developing an interstate, interindustrial model stems from the fact that it is difficult to obtain data describing trade flows among states. Since 1993, however, CFS data have been used, in spite of the fact that there are still problems such as high sampling variability and disclosure rules limiting the use of individual company data. The existence of many unreported values requires relying on other data sources to approximate completeness. It is not surprising, therefore, that since the work by Polenske and Jack Faucett Associates, there has been no comprehensive inventory of MRIO flows.

The 1997 CFS reports trade flows between US states for forty-three "Standard Classification of Transported Goods" (SCTG) sectors while the IMPLAN "Total Commodity Output" (TCO) data file includes 509 sector estimates, available for all states. The CFS source includes foreign imports data as well as domestic trade. This means that all commodities coming into a US port are listed as *outbound from that port* and inbound to the next destination; likewise, all commodities going to a port from anywhere in the US are outbound from the origin and inbound to the port. For these reasons, foreign imports in 2001 IMPLAN are added to the TCO tally.

In the current application, the 1997 CFS data were used as a baseline and updated using 2001 IMPLAN data. The release of 2002 CFS data, to be matched to 2002 IMPLAN data, will simplify this approach in the near future.

Differences among alternative industry classification systems from different data sources makes data reconciliation especially difficult in the absence of standardized and tested conversion bridges. The estimation of 2001 trade flows from the 1997 CFS, therefore, required intermediate conversion steps between the SCTG code system used in the 1997 CFS and IMPLAN system of sectors,

Figure 9.1. NIEMO Modeling Steps

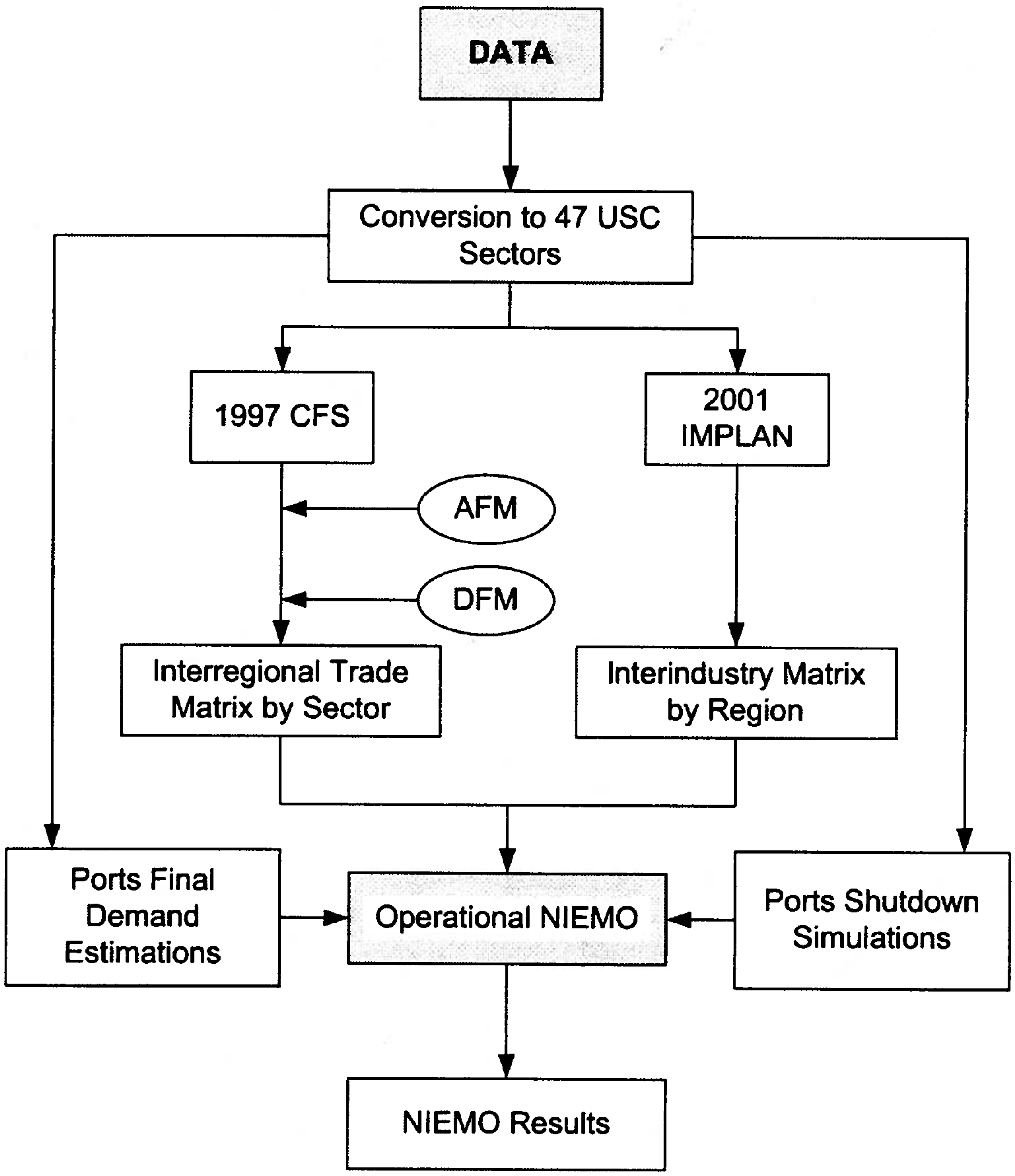


Figure 9.2. Industrial Code Conversions

CODE	USC	SCTG	BEA	NAICS	IMPLAN	SIC	HS	SITC	WCUS
USC		C, E	C, E	C, E	C, E	C, W	C, E	C, W	C, W
SCTG	C, E		C, E	C, E	C, E	P	C, E	C, W	C, W
BEA	C, E	C, E		A	A	P	A	P	P
NAICS	C, E	C, E	A		A	C, W	C, E	P	P
IMPLAN	C, E	C, E	A	A		P	C, E	P	P
SIC	C, W	P	P	C, W	P		P	P	P
HS	C, E	C, E	A	C, E	C, E	P		C, W	C, W
SITC	C, W	C, W	P	P	P	P	C, W		C, E
WCUS	C, W	C, W	P	P	P	P	C, W	C, E	

Key

Light-shaded: *1-to-1 allocations*
Dark-shaded: *Weights specified case by case*
C: Created
A: Available from other sources

P: Possible to create
E: Bridge allocations evenly made, where necessary, without any weights
W: Bridge allocations made with plausible weights

Code Descriptions

USC: USC sectors newly created
SCTG: Standard Classification of Transported Goods (http://www.bts.gov/cfs/sctg/welcome.htm)
BEA: Bureau of Economic Analysis (http://www.bea.gov)
NAICS: North American Industry Classification System (http://www.census.gov/epcd/www/naics.html)
IMPLAN: 2001 IMPLAN 509-sector codes
SIC: Standard Industrial Classification (http://www.osha.gov/oshstats/sicser.html)
HS: Harmonized System (http://www.statcan.ca/trade/htdocs/hsinfo.html)
SITC: Standard International Trade Classification available from WISERTrade (http://www.wisertrade.org/home/index.jsp)
WCUS: Waterborne Commerce of the United States (http://www.iwr.usace.army.mil/ndc/data/datacomm.htm)

not always one-to-one matched pairs. Figure 9.3 shows the data reconciliation steps used in creating a SCTG-IMPLAN conversion bridge, enabling the aggregation of 509 IMPLAN sectors to forty-three SCTG sectors. A flow chart of NIEMO is shown in Appendix Figure 2.

Radiological Bomb Attack at the Ports

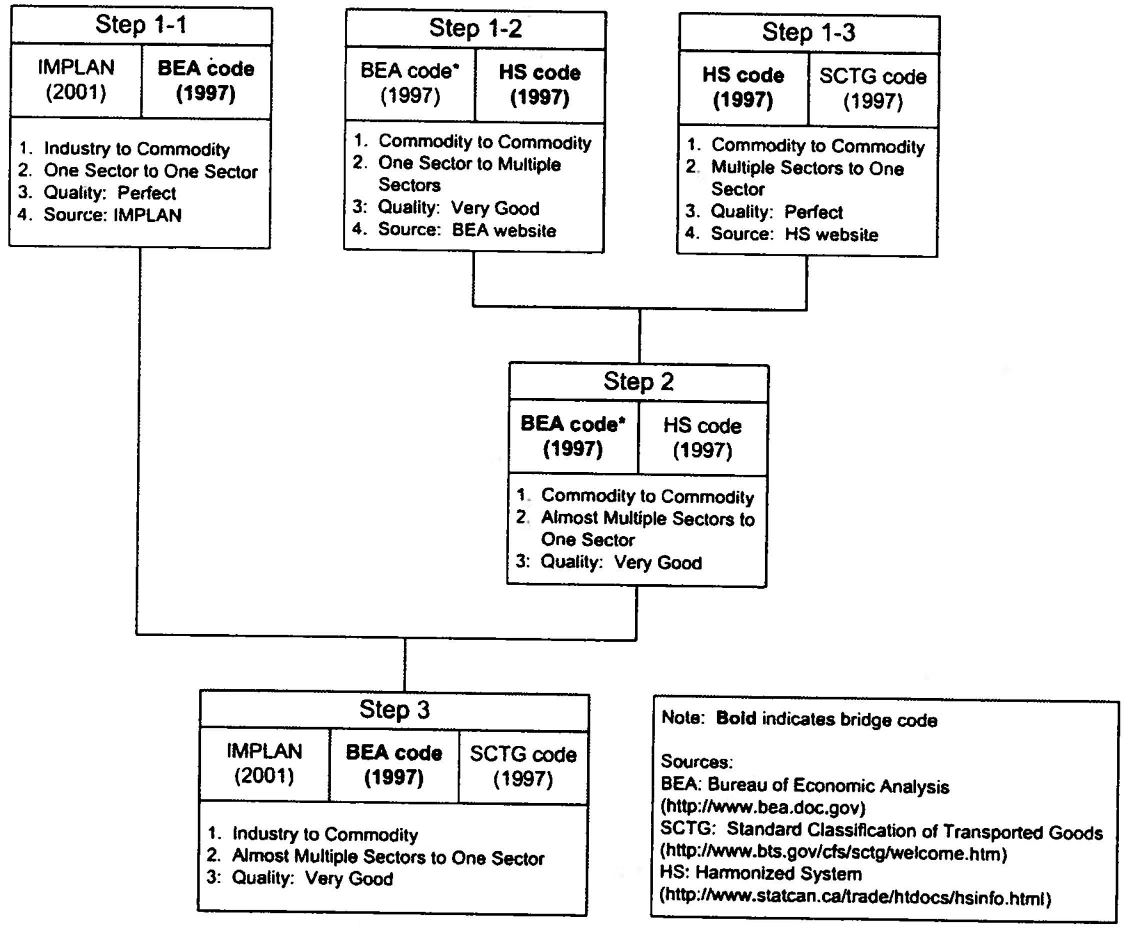
We explored simultaneous radiological bomb attacks on the twin ports of Los Angeles and Long Beach. These could either be smuggled in by container or planted within the country very close to the port perimeter (assuming that terrorists would have access to suitable radioactive material within the United States). The extent of the disruption would depend on the size of the bombs. We assumed the explosion of two small radiological dispersal devices (RDDs), each of them containing five pounds of high explosive, more or less simultaneously at the two ports. The attack would require the closure of both ports for health reasons, let alone security concerns. When the ports might reopen would be a policy rather than a technical decision, but without renewed transportation access the reopening would have minimal consequences economically.

We estimated that the closure of the Los Angeles and Long Beach ports would run anywhere from fifteen to 120 days. For the longer closure scenario, we combine radiological bomb attacks with conventional bombs blowing up three key access bridges and overpasses. Table 9.1 reports on the 120-day case, with county-level data. It could cost the US economy up to $34 billion, or more than 212,000 person-years of employment. The model is also capable of providing economic results in much greater spatial detail, to the level of census tracts or TAZs if required.

Plume Effects

We also attempt to measure the plume effects in terms of household disruption, business losses and the decline in real estate values. The numbers are very speculative, but our best estimate is a $4 billion loss in output and close to a decline of 42,600 person-years of employment. Blast damage would be quite limited, with deaths and serious injuries within a range of perhaps fifty meters and with moderate damage to physical infrastructure, except at ground zero. The outer evacuation zone would include all areas with exposure greater than one rem. We assume a hypothetical radiation plume—a long, narrow ellipse four kilometers long and more than two-hundred meters wide, with an inner and more contaminated zone of about one-hundred meters' radius (i.e., an area of 0.03 square kilometers). There are standard formulae for converting radiation releases to plume areas and shapes, subject to wind direction and other climatic conditions (Muller, 2004; Buddemeier, 2003).

Figure 9.3. Data Reconciliation Steps, SCTG and IMPLAN



In the ports' case, the wind usually comes in from the southwest, so the plume would not affect Los Angeles International Airport or other strategic locations except for the ports themselves. The critical early phase of exposure would be expected to last about four days. The time frame for intermediate and later phases is variable and subjective, and could range from weeks to years.

We assume a one-week evacuation in the outer zone. This may be conservative, because some firms and households may only trickle back with a lag, after being given permission to return. Health factors may dictate an immediate evacuation, but because such effects are long-term, the decision to allow a return will be determined more by political than scientific considerations.

The more speculative economic consequences of a radiological bomb attack relate to the radiation plume. They depend on so many variables: the size of the bomb, the amount of the radioactive release, the wind direction and prevailing climatic conditions, and the downwind population and business densities. Moreover, much depends on public-policy decisions, such as: whether to mandate an evacuation, and if so, when to allow people to come back; and whether to pro-

Table 9.1. Output and Employment Losses Associated with a 120-Day Closure of the Ports of Los Angeles and Long Beach

	Output ($millions)				Jobs (Person-Years)			
	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total
City of Los Angeles	2,113	753	520	3,385	9,492	5,788	5,831	21,111
City of Long Beach	554	93	53	700	4,008	640	601	5,249
County of Los Angeles	5,252	1,759	1,260	8,271	24,722	13,233	14,142	52,097
County of Orange	1,247	496	357	2,100	5,502	3,841	4,009	13,352
County of Ventura	345	143	93	581	1,459	971	1,052	3,482
County of Riverside	296	115	102	513	1,306	890	1,175	3,371
County of San Bernardino	424	161	129	715	1,842	1,218	1,487	4,548
Sum of Five Counties	7,564	2,674	1,941	12,179	34,831	20,154	21,865	76,850
Out of Region	14,256	4,116	3,520	21,892	64,401	31,259	39,655	135,316
TOTAL	21,820	6,791	5,461	34,071	99,232	51,413	61,520	212,165

ceed in a more measured if less cautious manner. Given these uncertainties, we reporthere only our best estimate of the *maximum* economic impacts of the plume, for comparison with the economic effects of the interruption of trade to and from the ports. By maximum, we mean under a reasonable set of assumptions.

Specifically, we assume in the first year after the attack a twenty-five percent drop in residential property values, and a twenty-five percent reduction in retail trade. Net input-output effects are very modest here, because consumption of shopping and services shifts to other locations outside the plume area. We also assume a ten-percent fall in other business activities as firms leave the region. An alternative assumption is that the businesses might relocate elsewhere in the region, in which case the impacts would be primarily redistributional from a spatial perspective and the net effects would be minimal.

As for travel behavior, we assume that driving through the plume area (with warnings about windows, the use of air conditioning and regular car washing) will be permitted. Closing entry and exit roads, especially freeways, would be the more extreme measure. However, there are network effects, as the average length of personal trips increase when plume-area residents are forced to shop and access services outside their neighborhoods. Although there are fewer total trips, longer trips and more congestion results in significantly higher network costs. Our calculations of the additional network costs yield an estimate of $1.63 billion, based on a personal-trip imputed cost of $13 per hour and a freight-trip cost of $35 per passenger-car equivalent (PCE) (one truck treated as the equivalent of 2.25 cars).

Based on Census 2000, there are 401,147 persons living in the 30 TAZs of the hypothetical impact area. The evacuated population would be 377,442. Table 9.2 summarizes the input-output consequences of reduced economic activity and lower property values in the outer plume area. The total output loss is more than $4.1 billion, of which only a small part (about $167 million) is associated with the decline in property values. Two-thirds of the losses take place within Los Angeles County and almost one-quarter leak outside the region. Total job losses are 44,555 person-years of employment.

In our research on terrorism, we usually focus solely on business interruption impacts. We can also estimate the imputed cost of potential long-term loss of life. It is straightforward to convert radiological releases into radiation doses expressed in rem.[3] We assume that the evacuation zone would include parts of the plume area with a dose exposure exceeding one rem. In practice, even beyond the obvious fact that exposure declines with distance, there will be some heterogeneity at a specified distance. There is a linear, or linear-quadratic, relationship between exposure and expected cancers. Given the population of 377,442 within the evacua-

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[3] This point was brought to our attention by our symposium discussant, Stephen Maurer.

Table 9.2. Radiation Plume Scenario and Effects

	Output ($1,000s)				Jobs			
	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total
County of Los Angeles	1,840,260	361,255	435,811	2,637,326	22,319	3,302	4,876	30,498
County of Orange	0	132,022	138,458	270,480	0	1,247	1,558	2,806
County of Ventura	0	28,196	34,667	62,863	0	256	388	644
County of Riverside	0	26,532	38,225	64,756	0	250	446	697
County of San Bernardino	0	35,639	47,766	83,405	0	331	555	886
Sum of Five Counties	1,840,260	583,644	694,926	3,118,830	22,319	5,387	7,823	35,530
Regional Leakages	595,019	214,999	188,964	998,983	5,024	1,868	2,129	9,019
Regional Total	2,435,279	798,643	883,891	4,117,813	27,345	7,257	9,955	44,555

tion zone, there could be 157 long-term excess cancer deaths, with an imputed cost of $958 million.[4] This result is consistent with other terrorist-attack scenarios; business interruption effects often have a monetary cost exceeding the imputed economic cost of other types of impact. Some biological and nuclear attacks might be exceptions to this generalization. However, it is very difficult to monetize the perhaps substantial psychological impacts associated with a radiological attack.

For comparison, we have also undertaken another study of a radiological bomb attack, in this case on a downtown Los Angeles office building. There are several such buildings in the immediate downtown vicinity, so the precise target is not of much significance. A radiological bomb attack on downtown Los Angeles might be a $6 billion event. If a similar attack were mounted in metropolitan areas such as New York, Chicago, or San Francisco, which are more oriented around a central business district than Los Angeles, the economic impacts would be much larger. An attack on downtown Los Angeles would much less damaging than a similar attack on the ports, because the economic disruptions resulting from closure of America's largest port complex (in terms of dollars of trade annually) would be far greater than a disruption of the city's modest financial and office sector.

An important difference between an attack on the ports and one against a downtown target is that critical public policy reactions might vary significantly. In the ports case, there would be greater economic pressure for the ports to reopen facilities quickly, and it would be feasible to put port personnel and/or the military to work handling trade (with protective clothing and equipment if necessary). In the downtown case, there are public spaces and more of the general population involved, perhaps requiring greater caution in allowing resumption of normal activities, especially in the inner plume zone.

Interstate Impacts

One of the aims of our research is to integrate the regional SCPM and the national NIEMO more closely. NIEMO is the first operational interstate input-output model for the US. As pointed out above, it provides results for forty-seven major industrial sectors for all fifty states, the District of Columbia, and a leakage region, the rest of the world. Our early economic-impact studies using SCPM lumped together all the out-of-region impacts under this general leakage category. NIEMO enables us to break this total down into individual state impacts. However, hitherto the numbers were not precisely comparable. Regional leakages for a 120-day ports shutdown in Table 9.1 amount to about $21.3 billion, while extracting the equivalent leakages from NIEMO in Table 9.3 (by subtracting from total effects the local

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[4] Here we utilize the value-per-life of $6.1 million applied by the US Environmental Protection Agency (Sunstein, 2005). Note that the US Federal Aviation Administration uses a much lower estimate of $1.5 million.

direct impacts) and the Southern Californian component of the California indirect impacts yields a total of about $13.1 billion.

What accounts for the discrepancies? First, SCPM includes some backward and forward linkages (i.e., both demand and supply effects) via freight shipments; when this research was undertaken, NIEMO had no supply component (although a supply-side analysis has recently been added). Second, SCPM measures induced impacts; in the interests of keeping our estimates conservative, we have limited NIEMO at this stage of the research to direct and indirect effects. Third, NIEMO does not yet have a services component, except in the intrastate sectors; it is probably not a highly significant element concerning the ports analysis, but it is a major issue for future applications. As a consequence, the results in Table 9.3 should be interpreted as an indication of the proportional distribution of interstate impacts rather than their absolute levels.

A Conventional-Bomb Attack on Terminal Island's Bridges

In an alternative scenario, we explore another dimension of potential terrorist attacks on the region's ports. The Terminal Island docks are accessed by three major highway bridges, the Vincent Thomas Bridge, the Gerald Desmond Bridge, and the Commodore Schuyler F. Heim Lift Bridge, and a rail bridge (Badger Bridge) parallel to the Heim Bridge that handles twenty-one percent of Terminal Island trade. These bridges are all high design facilities that permit ship traffic in the waters between the coast and Terminal Island. The Desmond Bridge, for example, is 250 feet above the water, although some experts consider that it is still too low to facilitate problem-free movement.

Terminal Island accounts for about fifty-five percent of the twin ports' trade, and it could easily be isolated by making all four bridges impassable. We assume four simultaneous, conventional bomb attacks on these bridges, of a size sufficient to destroy them. We then estimate the potential economic losses associated with the closure of Terminal Island.

The major problem is to determine a reasonable "back to business" recovery period, and we have chosen two plausible "bookend" durations. A lower-range estimate is three to four months, paralleling the 120-day closure of the radiological bomb scenario. This would allow the building of one or more military-type pontoon bridges. However, these would be close to sea level and built on caissons embedded into the seabed, so they would probably interfere with shipping lanes. Also, a pontoon bridge for container trains is problematic. The higher-range time estimate for our purposes would be two full years, to permit the total rebuilding of the bridges on their original scale. This is an optimistic scenario given institutional constraints, let alone reconstruction realities. Because the model is linear, any chosen time period can easily be adjusted.

The one-year economic cost for the Terminal Island bridge attack is $45 billion and job losses of nearly 280,000 person-years. Two-thirds of this impact

Table 9.3. Sum of Intra- and Interstate Effects: LA/LB Ports, Shutdowns for 120 days ($M)

State	LA/LB	Interstate Impacts of NIEMO							
Southern CA	4,874.58	AL	106.35	IN	209.76	NE	99.9	RI	19.14
Rest of CA	5,545.64	AK	12.17	IA	142.25	NV	51.6	SC	66.12
Direct_Impact_EXPORT	16,233.20	AZ	211.83	KS	126.21	NH	28.48	SD	26.52
Direct_Impact_IMPORT	56,107.13	AR	100.69	KY	115.05	NJ	167	TN	132.92
US Total	89,817.26	CO	123.88	LA	307.54	NM	26.1	TX	1,546.39
Rest of World	492.02	CT	63.28	ME	21.25	NY	216.38	UT	125.31
World Total	90,309.29	DE	20.04	MD	45.09	NC	130.76	VM	9.51
		DC	2.47	MA	86.01	ND	19.22	VA	66.99
		FL	123.19	MI	216.96	OH	303.19	WA	313.64
		GA	102.26	MN	133.34	OK	106.47	WV	41.75
		HI	21.31	MS	57.91	OR	198.81	WI	208.17
		ID	48.57	MO	141.71	PA	243.81	WY	25.71
		IL	279.47	MT	64.21				

lies outside the region and one-third within (see Table 9.4). The bookend range of impacts concerning bridge-restoration time is between $15 billion and $90 billion (see Table 9.5). Predictions regarding estimates of how long it would take to reopen Terminal Island and with what level and permanence of infrastructure access are somewhat speculative. Yet there is no doubt such an attack would be a significant and costly event that fully merits substantial resource expenditures to prevent. Similarly, if an attack were to occur, there would be substantial cost savings derived from efforts to accelerate the reopening date.

The geographical distribution of impacts is also shown in Table 9.5. About sixty-five percent of both output and job impacts are experienced outside the region. Of the intraregional impacts, sixty-eight percent occur within Los Angeles County. The impacts in the other counties are not negligible, especially in Orange County where northern sectors are located relatively close to the ports. Not surprisingly, within Los Angeles County, about one-half of the impacts occur in the two port cities themselves, overwhelmingly in Los Angeles rather than Long Beach. Los Angeles's relative size captures high shares of the indirect (i.e., intermediate linkage) and induced (i.e., secondary consumption effects). Also, the bulk of the facilities on Terminal Island are owned by the Port of Los Angeles, not by the Port of Long Beach.

Network costs alone would increase by $58 million per year after the Terminal Island event. This represents only a 0.04 percent increase in travel delays. There are substantial reductions in freight-travel costs when many of the port-related trucks are not on the road. However, these would be offset by increased personal travel delays. These delays largely result from increased congestion on both freeways and arterial roads, as cars no longer would have the convenient link from San Pedro, Wilmington, Harbor City, Palos Verdes, and other cities in the Los Angeles Harbor area to Long Beach via the Vincent Thomas Bridge. This value is lower than the increase in delay costs of $90 million associated with the 120-day scenario in the prior radiological bomb scenario, because the Terminal Island case represents only a partial elimination of port capacity and the disruptions of transportation infrastructure are more localized. It is important to note that these are delay costs only; we have not made precise estimates of bridge-repair costs.

It is difficult to determine how quickly access to Terminal Island could or would be restored. If under normal circumstances bridge repairs on this scale take up to two years, then our approach can be used to approximate the benefits of speedier repairs, including the installation of temporary facilities. High capacity temporary bridges might be constructed relatively quickly, but these low-design facilities would block ship traffic in the channels separating Terminal Island from the remainder of the port complex.

Current estimates from the California Department of Transportation are that the costs of the replacement span for the San Francisco-Oakland Bay Bridge are over $6 billion. This span carries 275,000 PCEs daily, approximating the scale of

Table 9.4. Highway Access Bridges to Terminal Island

Bridge	City	Year Built	Span
Vincent Thomas Bridge	Los Angeles	1964	6,500 ft.
Gerald Desmond Bridge	Long Beach	1968	5,134 ft.
Commodore Schuyler F. Heim Lift Bridge	Long Beach	1946	3,976 ft.
Badger Rail Bridge	Long Beach	1997	3,976 ft.

the Vincent Thomas Bridge. The other bridges now serving Terminal Island are comparatively smaller and would be cheaper to replace. Assuming a $12 billion total reconstruction cost for all bridges is reasonable. These costs might rise if construction were accelerated, but it is difficult to tell by how much. The benefits of reducing the economic losses, on the other hand, are easy to estimate given the linearity of the model, about $3.75 billion per month.

Planning now to protect these critical bridges, and to temporarily replace and then permanently rebuild them in the event of an attack, is clearly sensible. The costs of accelerated repairs to the Santa Monica Freeway bridges following the Northridge Earthquake were easily justified. Our modeling approach makes it possible to be specific *ex ante* about the efficiency gains of accelerated repairs.

Conclusions

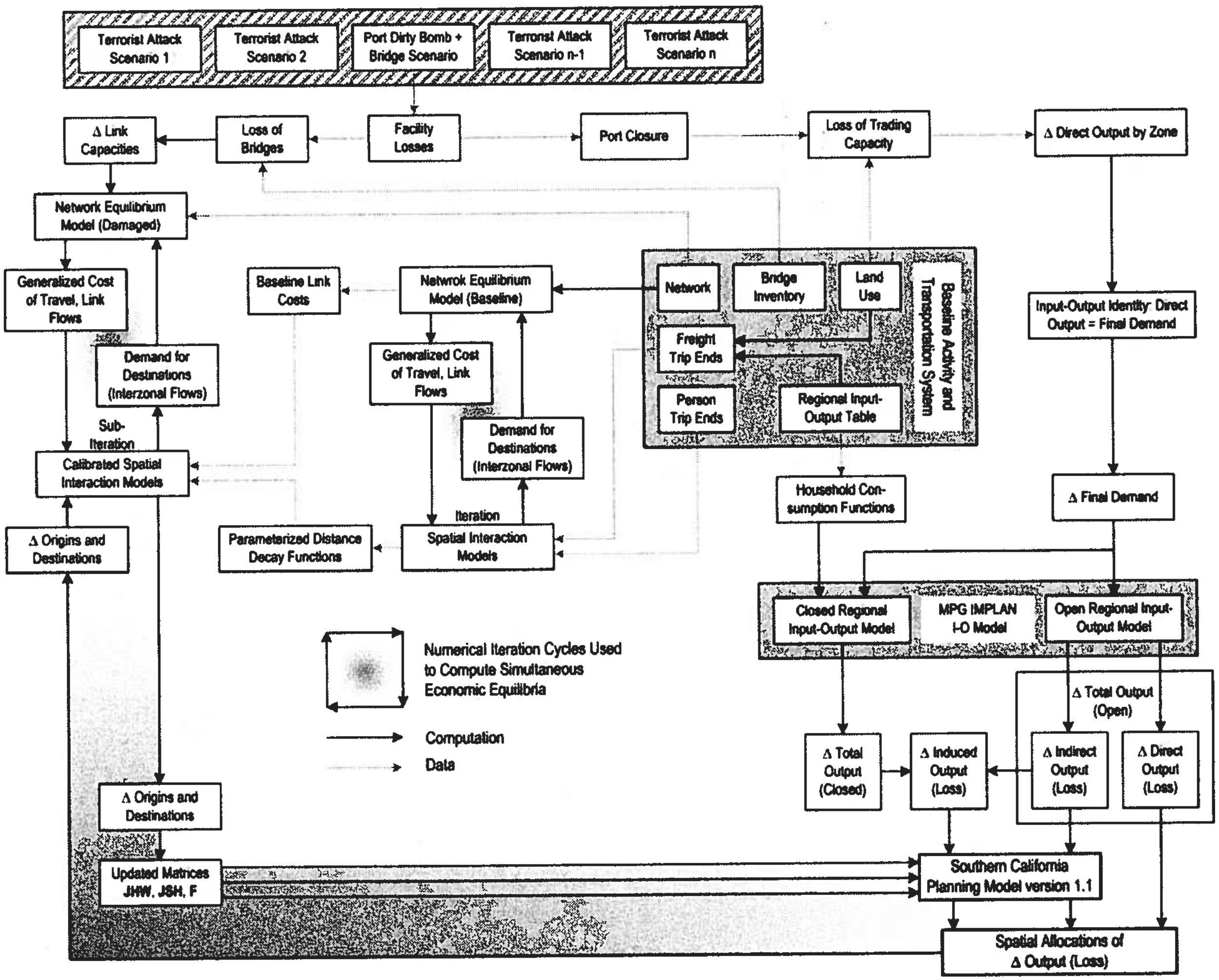
This chapter summarizes research the economic modeling team at USC's Center for Risk and Economic Analysis of Terrorism Events (CREATE) has been pursuing for the past few years. The research is both methodological and substantive. The methodological path is to integrate more closely two models (one regional, one national) in the input-output, but spatially disaggregated, mode. The substantive approach is to consider the business-interruption consequences of bomb attacks, both radiological and conventional, at the twin ports of Los Angeles-Long Beach. The economic impacts are very substantial. Although the potential loss of life from terrorist attacks attracts more attention and, no doubt, would have serious psychological effects, the business-interruption impacts are large enough to persuade terrorists that economic targets are as "productive" as human targets. The SCPM and NIEMO models are applicable to a much wider range of attack-scenarios than those examined here, such as airports and theme parks. However, the integrated model needs improvement to overcome well-

Table 9.5. Output and Employment Effects Associated with One-Year Closure of Terminal Island

	Output ($Millions)				Jobs (Person-Years)			
	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total
City of Los Angeles	2,848	1,001	687	4,537	13,087	7,708	7,707	28,503
City of Long Beach	621	123	70	815	4,143	851	792	5,787
County of Los Angeles	6,907	2,342	1,664	10,914	32,213	17,629	18,692	68,535
County of Orange	1,663	660	472	2,796	7,371	5,118	5,302	17,791
County of Ventura	462	189	123	774	1,961	1,290	1,390	4,641
County of Riverside	393	152	134	680	1,744	1,185	1,546	4,475
County of San Bernardino	563	214	170	949	2,460	1,621	1,963	6,044
Sum of Five Counties	9,990	3,559	2,565	16,115	45,749	26,842	28,894	101,485
Out of Region	18,686	5,441	4,625	28,754	84,920	41,445	52,116	178,482
TOTAL	28,677	9,001	7,190	44,869	130,669	68,288	81,010	279,967

known limitations of the input-output approach, especially in terms of price-substitution effects; we have now begun to make progress on this front. Also, as far as NIEMO is concerned, the rise of information technology makes the introduction of tradable services into the commodity-dominated multiregional input-output framework more critical.

Appendix Figure 1. SCPM2 Data Flows and Calculations



Appendix Figure 2. NIEMO Data Flows and Calculations