Ports and Highways Infrastructure Investment and Inter-state Spatial Spillovers

Jeffrey Cohen

Kristen Monaco

Abstract

U.S. ports serve a vital role in the nations' supply chain and international trade. While the areas surrounding these ports bear the external costs of port expansion (congestion, air pollution, noise pollution) the benefits from port activity are felt by other regions that do not bear these costs. The purpose of this study is to assess the role that transportation infrastructure plays in production and employment in the manufacturing industry. Using state-level data from the 48 contiguous states, we model manufacturing production and cost, incorporating state and local investment in port and highway infrastructure as variables in the model. We find that states benefit from increasing their own ports infrastructure, but do not benefit from increased infrastructure in neighboring states. We also find that highways and ports infrastructure are neither complements nor substitutes.

Introduction

Of the top 50 container ports in the World, six are located in the United States and three of these (Los Angeles #6, Long Beach #13, and Oakland #39) are located in California (Journal of Commerce, 7/19/2004). The other three are New York (#15), Tacoma (#42) and Virginia (#47). The number of twenty-foot equivalent units (TEUs) handled by all US Ports doubled between 1990 and 2000 (15.2 million to 30.4 million) and is expected to double again by 2010, with volume more than doubling at the West Coast ports (Testimony of Jane C. Godwin, 11/20/2003).

A port, like any other major infrastructure investment, provides both direct and indirect benefits to a region, primarily through the addition of jobs. Jobs that are directly involved in port operations (longshore and stevedores) as well as those that provide secondary services to move freight in and out of the port (truck drivers, for example) are easy to trace. It is more difficult to assess the indirect job creation since a number of jobs indirectly related to port operations (ocean liner back office staff, customs brokers, etc.) need not locate in the immediate vicinity of the port, due to improvements in communications technology. These “port-dependent” jobs need not benefit the region in which the port is located (Campbell, 1993). In fact, Haveman and Hummels (2004) note that there are 22 states in the U.S. that have a larger share of their workforce involved in transportation and logistics than California.

Another industry dependent on port activity is manufacturing. The ports provide a low cost means of acquiring inputs to production from abroad. Investments in ports as well as accompanying highway infrastructure have potentially ambiguous effects on state manufacturing employment. Manufacturing firms may be more likely to locate in a state with these amenities, however, it is also possible that efficient transportation systems allow firms to locate in lower cost adjacent states and benefit from the port and highway infrastructure. In the event the latter is the dominant effect, there exists potential for states with considerable investment in port and highway infrastructure to "tax" states which reap those benefits. The purpose of this study is to examine whether there are "spillover" effects of port and highway infrastructure on the manufacturing industry in adjacent states.

Port Infrastructure

The bulk of U.S. ports are government-owned, typically by either a city (eg. Long Beach, Los Angeles) or the state (eg. New York and New Jersey). The decision to invest in infrastructure is imperative, given the structure of ports and the degree of competition between ports. For example, in 2002, Maersk, the largest container shipping line in the world, moved its Southern California port operations from the Port of Long Beach to new state-of-the-art facilities at the adjacent Port of Los Angeles . Newman and Walder (2003) note that the United States lacks a Federal ports policy, perhaps due to provisions in the Constitution which prevent the federal government granting preference to a single port. The bulk of the Federal government's role in this country's ports is through the U.S. Army Corps of Engineers which is primarily responsible for dredging the access to ports.

The confluence of increased trade (especially with Asia), the rise of containerization, and regulatory changes in ocean shipping have resulted in ports that compete with one another, often working to attract customers through improved infrastructure. Before the 1950s, almost all freight that was shipped over water was "break bulk," with pallets loaded and unloaded with a considerable amount of labor. Containerization led to standardization of ship structure with most freight moved in either twenty foot or forty foot equivalent units (TEUs and FEUs, respectively). These containers could then be placed on truck chassis or rail cars and shipped cross-country. The process is capital intensive, with a variety of cranes used to load and unload the containers from ships, as well as move containers within the port facility. In addition to this capital equipment, the ever-increasing size of container ships requires deeper channels. As noted, the federal government often bears the cost of dredging so ships can gain access to ports, however, the ports typically are responsible for most of the cost of dredging berths and channels within the port complex.

Ocean shipping moved towards deregulation with the Shipping Act of 1984 and the Ocean Shipping Reform Act of 1998. Both acts served to make the industry more competitive with shipping conferences losing power as the steamship lines were allowed to negotiate confidential service agreements with shippers, which often include subcontracts with truck or rail firms to move goods to their final destination. These regulatory changes, along with the flexibility provided by containerization, resulted in competition between ports on different coasts. For example, freight from China destined for the East Coast can be sent by ship from Asia through the Panama Canal to the port closest to their final destination, or this freight can be sent to a West Coast port, unloaded and shipped by rail (typically low value freight) or truck (high value, time sensitive freight) to the East Coast (Luo and Grigalunas 2002).

The ability of ports to accommodate the increase in trade is imperative for the nation's economy as well as the ports' competitive advantage, however, the costs of this increase in trade are felt mainly by the ports and the surrounding area. While the benefits of the port may be spread across the nation (and certainly internationally as well), the costs are typically borne by the region immediately surrounding the port. The direct costs of port operations are typically funded by the Port Authority itself through leases, user fees, and bonds, with a small proportion funded by local, state, and federal governments. Of more concern, however, are the indirect costs – particularly congestion and pollution. A recent study found that health effects from particulate matter in Los Angeles and its surrounding areas are two to three times what was previously thought (Jerrett et al, 2005). In 2001 vehicles calling at the Ports of Los Angeles and Long Beach (ships, trucks, trains) emitted 2.3 tons of particulate matter per day in the region (Barringer, 2005).

The typical state relies on multiple (13-15) ports to accommodate the majority of its imports and exports and the majority of these ports are external to the state benefiting from them. (Testimony of Jane C. Godwin, 11/20/2003). As the location of the three largest US container ports, California provides easy access to foreign markets (particularly emerging Eastern Asian countries) for the bulk of the nation. Nearly $300 billion in imports and exports for other states passed through California ports in 2000, while only $120.9 billion in California imports and exports went through other U.S. ports (Haveman and Hummels, 2004). It is not surprising, then, that states with considerable port activity are interested in the spillover effects on neighboring states and the benefits to the manufacturing sectors in the cities surrounding the ports and their hinterlands.

Theoretical Model, Methodology, and Data Sources

In order to analyze the impacts of ports on manufacturing costs, as well as the impacts of ports on the employment of manufacturing workers, we estimate input demands together with a cost function model with ports as a "free" variable, using state level data on the manufacturing sector for the 48 continental United States from 1984 to 1996. The data are described in more detail in Appendix A.

The state-level total cost function (see Cohen and Morrison Paul, 2004) can be written in the form TC = VC(Y,**p**,K,**I**,t) + p_kK, where VC is own-state variable (or restricted) costs, Y is manufacturing output, K represents the quasi-fixed private capital input (with market price p_k), **p** is a vector of variable input prices (for non-production labor, L1, production labor, L2, and materials, M), and t is the standard time counter which represents exogenous technical change. The vector **I** represents a vector of shift variables consisting of a variety of infrastructure variables. Since the choice of these infrastructure variables are assumed to be outside of the cost minimization problem of the typical firm, the infrastructure variables are assumed to be "free" inputs to the firm. These infrastructure variables include the stock of ports in a particular state (S), the weighted average of ports in neighboring states (N), and the stock of highways in a particular state (H).[1]

Specifically, the cost function can be written as follows (as presented by Cohen and Paul 2004):

[1] Cohen and Paul (2003, 2004) separately examine the direct and neighboring state spillover cost impacts of additional airport infrastructure and additional highway infrastructure on manufacturing firms costs and variable input demands.

1) $VC_{i,t}(Y_{i,t}, K_{i,t}, \mathbf{p_{i,t}}, S_{i,t}, N_{i,t}, H_{i,t}, t) = \Sigma_m\Sigma_i\ \delta_{m,i}\ p_{m,i,t}\ F_i + \Sigma_l\Sigma_m\ \alpha_{lm}\, p_{l,i,t}^{\ .5}\ p_{m,i,t}^{\ .5}$

$+ \Sigma_m\ \delta_{mY}\ p_{m,i,t}Y_{i,t} + \Sigma_m\ \delta_{mK}\ p_{m,i,t}K_{i,t} + \Sigma_m\ \delta_{mS}\ p_{m,i,t}S_{i,t} + \Sigma_m\ \delta_{mN}\ p_{m,i,t}N_{i,t}$

$+ \Sigma_m\ \delta_{mH}\ p_{m,i,t}H_{i,t} + \Sigma_m\delta_{mt}\, p_{m,i,t}\, t + \Sigma_m\, p_{m,i,t}(\delta_{YY}\ Y_{i,t}^{\ 2} + \delta_{KK}\ K_{i,t}^{\ 2} + \delta_{YK}\ K_{i,t}Y_{i,t}$

$+ \delta_{SY}\ S_{i,t}\ Y_{i,t} + \delta_{SK}\ S_{i,t}\ K_{i,t} + \delta_{St}\ S_{i,t}\ t + \delta_{SS}\ S_{i,t}^{\ 2} + \delta_{NY}\ N_{i,t}\ Y_{i,t}$

$+ \delta_{NK}\ N_{i,t}\ K_{i,t} + \delta_{Nt}\ N_{i,t}\ t + \delta_{NN}\ N_{i,t}^{\ 2} + \delta_{HH}\ H_{i,t}^{\ 2} + \delta_{tY}\ Y_{i,t}\ t + \delta_{NH}\ H_{i,t}\, N_{i,t} + \delta_{Ht}\ H_{i,t}\ t$

$+ \delta_{SH}\ H_{i,t}S_{i,t} + \delta_{HY}\ H_{i,t}\ Y_{i,t} + \delta_{HK}\ H_{i,t}\, K_{i,t} + \delta_{tK}\ K_{i,t}\ t + \delta_{tt}\ t^2) + u_{i,t},$

with $u_{i,t} = \rho\Sigma_j w_{i,j}\ u_{i,t} + \varepsilon_{i,t}$

and $\varepsilon_{i,t} \sim N(0, \sigma^2)$

where l,m =(L1,L2,M), l≠m; i,j =(1,2,...,48); t=(1984, 1983,..., 1996); and F_i represents a fixed effect (dummy) term for state i. For example, $S_{i,t}$ represents the ports capital stock for state i at time t; $N_{i,t}$ is the average of the ports capital stocks in states that are geographic neighbors to state i at time t; and $H_{i,t}$ is the public highway infrastructure capital stocks for state i at time t. See the data appendix for elaboration of the data construction for these capital stocks.

It is desirable to model the current problem with a cost function framework because the cost function represents optimizing behavior by manufacturing firms. Thus, we can also employ Shephard's Lemma to derive the optimal input demands for the variable inputs. In other words, $D_m(Y,\mathbf{p},K,I,t) = \partial VC(Y,\mathbf{p},K,I,t)/\partial p_m$, m=L1,L2,M. Specifically,

2) $D_m\ (Y_{i,t}, K_{i,t}, \mathbf{p_{i,t}}, S_{i,t}, N_{i,t}, H_{i,t}, t) = \Sigma_i\ \delta_{mi}\ F_i + \Sigma_l\ \alpha_{lm}\, p_{m,i,t}^{\ -.5}\ p_{l,i,t}^{\ .5} + \delta_{mY}Y_{i,t}$

$+ \delta_{mK}\ K_{i,t} + \delta_{mS}\ S_{i,t} + \delta_{mN}\ N_{i,t} + \delta_{mH}\ H_{i,t} + \delta_{mt}\, t + \delta_{YY}\ Y_{i,t}^{\ 2} + \delta_{KK}\ K_{i,t}^{\ 2} + \delta_{YK}\ K_{i,t}\ Y_{i,t}$

$+ \delta_{SY}\ S_{i,t}\ Y_{i,t} + \delta_{SK}\ S_{i,t}\ K_{i,t} + \delta_{SN}\ N_{i,t}\, S_{i,t} + \delta_{St}\ S_{i,t}\ t + \delta_{SS}\ S_{i,t}^{\ 2} + \delta_{NY}\ N_{i,t}\ Y_{i,t} + \delta_{NK}\ N_{i,t}\, K_{i,t}$

$+ \delta_{Nt} N_{i,t} t + \delta_{NN} N_{i,t}^2 + \delta_{tY} Y_{i,t} t + \delta_{NH} N_{i,t} H_{i,t} + \delta_{Ht} H_{i,t} t + \delta_{SH} H_{i,t} S_{i,t} + \delta_{HY} H_{i,t} Y_{i,t}$

$+ \delta_{HK} H_{i,t} K_{i,t} + \delta_{tK} K_{i,t} t + \delta_{tt} t^2 + u_{m,i,t}$

where $u_{m,i,t} = \rho_m \Sigma_j w_{i,j} u_{m,i,t} + \varepsilon_{m,i,t}$

and $\varepsilon_{m,i,t} \sim N(0, (\sigma_m)^2)$.

We also follow the approach of Cohen and Morrison Paul (2003) by including an "imperfect competition" equation to estimate the extent of divergence of price from marginal costs in the manufacturing sector:

3) $p_{Y,i,t} = -\lambda_Y \bullet Y_{i,t} + MC_{i,t} = -\lambda_Y \bullet Y_{i,t} + \Sigma_m \delta_{mY} p_{m,i,t} + \Sigma_m p_m (2\delta_{YY} Y_{i,t} + \delta_{YK} K_{i,t} + \delta_{SY} S_{i,t} +$

$\delta_{NY} N_{i,t} + \delta_{tY} t + \delta_{HY} H_{i,t}) + u_{Y,i,t}$, where $u_{Y,i,t} \sim N(0,(\sigma_Y)^2)$.

We test the significance of the parameter λ_Y to justify the inclusion of equation 3) in our analysis.

The Generalized Leontief functional form allows us to test for the possible substitutability or complementarity between pairs of inputs (either the variable inputs, the "external" factors, or some combination).

We econometrically estimate equation 1 (the restricted cost equation) along with equation 2 for all three inputs (non-production labor L1, production labor L2, and materials M), and equation 3 using Seemingly Unrelated Regressions techniques with PC TSP software. Once we obtain parameter estimates for all the alphas and deltas, we can then take the derivative of $D_m(Y,\mathbf{p},K,I,t)$ -- for each type of worker and for materials -- with respect to S (which is $\partial D_m(Y,\mathbf{p},K,I,t)/ \partial S$), to see how an increase in the stock of ports infrastructure affects input demand. We can also examine how increases in ports infrastructure in neighboring states impacts input demands in a particular state by looking at the sign and significance of the derivative $\partial D_m(Y,\mathbf{p},K,I,t)/ \partial N$.

We also adapt the model to account for the possibility of the presence of spatial autocorrelation in the cost function and each of the input demand equations. First order spatial autocorrelation (SAR1) is analogous in geographic space to first order time series autocorrelation (AR1). Namely, with AR1 a shock to the error terms at any given point in time is transmitted to later observations in time. Similarly, the "weighted average" of a shock to the error terms for some units in geographic space (such as states, counties, or households) can "spill over" to a "neighboring" unit. This concept is known as first order spatial autocorrelation (SAR1). Ignoring the presence of SAR1 can lead to inefficient parameter estimates, and in turn, invalid hypothesis testing.

Mathematically, the error terms in a SAR1 error process is as follows:

$$u_{i,t} = \rho\Sigma_j w_{i,j}\, u_{i,t} + \varepsilon_{i,t}$$

Here, $w_{i,j}$ represents the "weight" that neighboring state j's error term has on state i's error term. In the present context, we define:

$$w_{i,j} = 1/n_i, \text{ if state j is a border state to state i,}$$
$$= 0, \text{ otherwise,}$$

where n_i represents the number of states that share common borders with state i. For example, if there are 4 "neighboring" states (j's) that border state i, each of the 4 border states' error terms would have equal weight (1/4) on state i's error term.

This spatial autocorrelation adaptation can be particularly useful when shocks to the manufacturing sector that hit some states spill over to a neighboring state. The recent series of hurricanes that hit the U.S. Gulf Coast can be viewed as an example of this. When we adjust for spatial autocorrelation, we account for the potential impacts on manufacturing costs of shocks that spill over to neighboring states.

To obtain the spatial autocorrelation parameter estimates for ρ, $\rho_{L1,}$ $\rho_{L2\,,}$ ρ_M as well as adapt the model, we employ the maximum likelihood estimation procedure followed by Cohen and Paul (2004) on the system of variable costs and input demand equations. Their procedure is equivalent to estimating the spatial autocorrelation coefficients by maximum likelihood separately on each equation. This spatial autocorrelation adaptation can be particularly useful when shocks to the manufacturing sector that hit some states spill over to a neighboring state. The recent series of hurricanes that hit the U.S. Gulf Coast is an example of this. When we adjust for spatial autocorrelation, we account for the potential impacts on manufacturing costs of shocks that spill over to neighboring states.

Of particular interest are the shadow value of ports, SHV_S, and the shadow value of ports in neighboring states, SHV_N. SHV_S tells us how an increase in ports infrastructure in a particular state affects manufacturing costs in that state. Mathematically, this is written as $SHV_S = -\partial VC(Y,\mathbf{p},K,I,t)/\partial S$. Intuitively, we would expect SHV_S to be positive – that is, additional ports infrastructure in a particular state should lead to lower manufacturing costs (i.e., generate value for manufacturing firms) in that state. This is due to the ease with which firms can ship their goods (and production inputs) through the ports – bigger and better ports should facilitate trade and lower the transportation time (and thus the transport costs) for firms.

The impact of additional N (ports infrastructure in neighboring states) on manufacturing costs in a particular state is not as intuitive. On the one hand, it could be the case that the benefits from additional ports in neighboring states might “spill over” to firms in the particular state, thus lowering costs. On the other hand, SHV_N may be negative, implying that increasing the ports capital stock in neighboring states leads to higher manufacturing costs in a particular state (that is, it creates negative value for manufacturing firms). It is possible to explain this type of result as evidence of "agglomeration economies", as found by Cohen and Paul (2005). It may be the case that it is most cost effective for firms and resources (private capital and labor) to locate near ports. By locating in another (neighboring) state, workers do not have access to as many opportunities and face higher job search/switch costs. If neighboring states improve their ports, this may draw away resources (that is, workers and firms), since the neighboring states become more attractive locations. As a result of the less attractive environment for workers, the higher quality workers have an incentive to migrate to the neighboring states with the better ports, and costs rise in the particular state. Boarnet (1998) found some evidence that California counties with additional highway infrastructure ended up being less productive, likely due to migration from the counties with less developed infrastructure to counties with greater infrastructure stocks.

A major objective of this paper is to empirically determine the sign of SHV_S and SHV_N. If SHV_S is positive, this may imply a role for authorities in states with major ports, such as California, to expand ports in the state, with the goal of lowering costs for manufacturing firms. If SHV_N is positive, states with ports can quantify the benefits from their port investment on manufacturing in neighboring states – a matter of importance for policy-makers. However, if SHV_N is negative, this would imply that states with major ports, such as California, might be able to attract firms to the state from a neighboring state by expanding ports, since California becomes a more desirable location for workers and firms.

Another objective of our study is to examine the interaction between highways and ports. We also look at the shadow value of highways (SHV_H), and take the derivative of SHV_H with respect to S, $\partial SHV_H/\partial S$. The resulting sign (and statistical significance) will shed light on whether or not additional ports infrastructure raises or lowers the shadow value of highways. In the context of ports, this will be a particularly insightful feature of our cost function framework, due to the intermodal nature of container shipments. Similarly, we will also examine the sign and significance of $\partial SHV_S/\partial H$, which will generate information on how additional highways capital stock affects the shadow value of ports in a particular state.

Finally, the cost function framework enables us to describe the impacts of changes in input prices (that is, wages or materials prices) on the shadow value of ports. We can also see how the shadow value of ports infrastructure has changed over time, holding all other variables constant, by looking at the sign and significance of the derivative $-\partial SHV_S/\partial t$. In other words, we can test whether or not the value of ports (in terms of their impact on reducing manufacturing costs) has significantly increased or decreased over time.

Estimation Results and Interpretation

First, the results of both the SUR and SAR estimation are presented in Table 1. It is noteworthy that many of the parameter estimates are significant, and the R-squared for the variable cost and input demand equations are all above .90. Furthermore, the coefficient on the imperfect competition equation (λ_Y) is statistically significant, implying evidence of imperfect competition. This result is consistent with the finding of Cohen and Morrison Paul (2003), and justifies including it in the model.

The log likelihood equals -18117.8 in the spatial autocorrelation (SAR) adjusted model, while the log likelihood equals -18183.7 in the SUR model (involving the 4 restrictions that the spatial autocorrelation coefficient in each of the 4 estimation equations are jointly zero). We performed a likelihood ratio test to gain insight on the joint significance of the spatial autocorrelation parameters. The critical value (with upper tail area of .05) is 9.49. Thus, we reject the null hypothesis that the restricted (i.e., SUR) model is preferable, in favor of the spatial autocorrelation adjusted model.

The shadow values of ports and highways infrastructure are positive and significant in both the SUR and SAR models (Table 1). We also construct cost elasticities, which are the focus of our inference (Table 2). For ports infrastructure, $\varepsilon_{VC,S} = [\partial VC/\partial S]\cdot[S/VC]$, and from the SAR estimates we find that $\varepsilon_{VC,S} = -0.043$ (p-value = .003). This implies that increasing ports infrastructure in a particular state by 1 percent will decrease manufacturing costs in that state by 0.043 percent. The analogous highway infrastructure stock elasticity estimate $\varepsilon_{VC,H} = -0.189$ (p-value < .001), similar to the SUR estimate of -0.181 (p-value<0.001). This is slightly larger than the highway infrastructure elasticity finding of Cohen and Morrison Paul (2004) of -0.15.

The sign and significance of the elasticity of variable costs with respect to the average ports infrastructure in neighboring states (N) is particularly intriguing. We find that $\varepsilon_{VC,N} = 0.129$ (p-value = .003) in the SAR model, approximately half the 0.239 (p-value < 0.001) in the SUR model. This implies that increasing neighboring states' ports infrastructure stocks by 1 percent leads to an increase in a particular state's manufacturing costs by 0.129 percent. This can be attributed to the presence of external diseconomies of scale, as was found by Cohen and Morrison Paul (2005) in the context of food manufacturing industry costs. If neighboring states become too large (in terms of the sizes of their ports), these neighbors may draw away productive resources from a particular state, leading to higher manufacturing costs in that state. Boarnet (1998) found a similar phenomenon in an analysis of California county highway capital stocks.

An interesting ramification of the finding of external diseconomies from neighboring states' ports here is that from society's viewpoint, the overall stock of ports infrastructure may be too large. When choosing the optimal size of ports infrastructure, individual states do not account for these diseconomies faced by a neighboring state, and thus states may choose too much ports infrastructure. Assistance from a higher level of government may lead state policy makers to coordinate their decisions and choose a more "socially" desirable level of ports infrastructure. It is important to qualify this finding, however, that within individual states there may be too little ports infrastructure investment. This may be due to the fact that ports infrastructure investment undertaken at the county or regional level within a particular state may impose benefits upon manufacturing firms in nearby counties or regions within that state, due to the proximity to improved ports infrastructure. If this is the case, then state or regional port authorities could be helpful through playing a more prominent role in the ports infrastructure investment decision making process. In order to assess these overall impacts, a county level follow-up study would be extremely helpful, either for ports within a particular state, or for ports over counties or regions across all states.

The spatial autocorrelation parameter estimates are positive and significant for the cost function equation as well as for each of the input demand equations. The sign and significance of these estimates implies that a shock (to costs or input demands) that hits some states, such as a hurricane in the Gulf coast, spills over to become shocks (to manufacturing costs and/or input demands) in a neighboring state. Thus, in addition to the agglomeration economies measure described above, spatial autocorrelation can be an additional source of spillovers.

We now describe findings on the relationships between the infrastructure variables. First, $\varepsilon_{SHVH,S} < 0$ and $\varepsilon_{SHVS,H} < 0$, but both are insignificant. These findings imply that additional ports infrastructure has no significant impact on the shadow value of highways, and additional highways have no impact on the shadow value of ports infrastructure, respectively. This result is robust in both the SUR and spatial autocorrelation adjusted models.

Second, $\varepsilon_{SHVN,S} < 0$ and is significant in the spatial autocorrelation model. This implies that a smaller ports infrastructure stock in a particular state results in additional ports in neighboring states causing variable costs to increase in the particular state.[2] In other words, states that are "contracting" (states with decreasing ports infrastructure stocks) are hit harder by the external diseconomies of scale due to additional neighboring states' ports infrastructure, while the shadow value of additional ports in neighboring states decreases in states that increase their ports infrastructure. On the other hand, $\varepsilon_{SHVS,N}$ was insignificant in both estimations, implying that additional ports infrastructure in neighboring states has no impact on the shadow value of ports infrastructure in a particular state.

There are other insights that the cost function can yield, including information on the elasticities of substitution between inputs and the infrastructure variables. One finding is that with both estimation procedures, the shadow value of ports increases when the number of production workers, non-production workers, or materials inputs increase. This is an

[2] $\varepsilon_{SHVN,S}$ was positive but insignificant in the SUR estimation.

important finding, since it implies that additional workers or materials inputs (that is, economic activity) make ports more valuable to manufacturing firms. Second, the shadow value of neighboring states' ports with respect to each of the three variable inputs is positive and significant. The interpretation here is that with fewer manufacturing inputs in a particular state, additional ports in neighboring states lead to higher costs to manufacturing firms in the particular state. This may be related to the negative external economies of scale from neighboring states' ports infrastructure. States with decreasing amounts of manufacturing inputs are more severely impacted by the negative external economies of scale than growing states (i.e., states with increasing manufacturing employment). The elasticity of the shadow value of ports with respect to private capital is insignificant, which says that private capital and ports are neither substitutes nor complements.

Finally, the elasticity of the shadow value of ports with respect to time is positive and significant. This finding implies that the pure passage of time makes additional ports in a particular state more valuable to manufacturing firms in that state. Similarly, the elasticity of the shadow value of other states' ports with respect to time is positive and significant, implying that the passage of time (holding all other cost determinants constant) makes additional neighboring states' ports capital stocks more valuable to a particular state in terms of how this extra capital would reduce manufacturing costs in the particular state.

Conclusions

Using both seemingly unrelated regression and spatial autocorrelation models, we estimate input demands together with a cost function model with state-level data. This allows us to measure the effects on manufacturing from increasing ports and highways infrastructure. We find that increasing ports and highway infrastructure will decrease manufacturing costs at the state-level. However, if a neighboring state increases its port infrastructure, manufacturing costs will increase, evidence of external diseconomies of scale. Finally, we find no significant relationship between the shadow value of ports and highways infrastructure or the shadow value of highways and port infrastructure.

This research has the potential to be extended in a number of directions. First, the methodology could potentially be expanded to other industries dependent on port operations, such as retail and wholesale trade. Second, rather than examining the data at the state level, a county level model could be constructed for California (or a combination of a number of states). This could generate useful insights on the potential roles for inter-governmental policy makers in determining how many and which ports to expand, by quantifying the spillover benefits or costs from ports in adjacent counties or regions, especially the LA county ports. Whether larger nearby ports generate positive spillovers (i.e., benefits due to access to improved shipment facilities) or negative spillovers (due to factor migration) could provide helpful guidance for policy makers at the regional, state, and local levels.

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Table 1: Estimation Results

Seemingly Unrelated Regression Results				Spatial Autocorrelation Results			
Parameter	Estimate	t-stat	p-value	Parameter	Estimate	t-stat	p-value
$\alpha_{L1,L2}$	-1410.54	-2.154	[.031]	$\alpha_{L1,L2}$	-591.532	-0.896	[.370]
$\alpha_{L1,M}$	3168.35	2.473	[.013]	$\alpha_{L1,M}$	1524.53	1.172	[.241]
$\alpha_{L2,M}$	7306.09	6.466	[.000]	$\alpha_{L2,M}$	6543.61	5.386	[.000]
$\delta_{L1,H}$	0.024483	0.421	[.674]	$\delta_{L1,H}$	-0.076462	-1.455	[.146]
$\delta_{L2,H}$	0.116735	2.048	[.041]	$\delta_{L2,H}$	2.20E-04	0.004	[.997]
$\delta_{M,H}$	-0.737882	-9.700	[.000]	$\delta_{M,H}$	-0.854196	-12.184	[.000]
$\delta_{L1,Y}$	0.177286	39.110	[.000]	$\delta_{L1,Y}$	0.175838	36.647	[.000]
$\delta_{L2,Y}$	0.208397	52.864	[.000]	$\delta_{L2,Y}$	0.206473	49.854	[.000]
$\delta_{M,Y}$	0.73626	103.07	[.000]	$\delta_{M,Y}$	0.734498	98.730	[.000]
$\delta_{L1,T}$	-7.11639	-0.478	[.633]	$\delta_{L1,T}$	-18.8264	-1.149	[.250]
$\delta_{L2,T}$	10.0996	0.752	[.452]	$\delta_{L2,T}$	3.68653	0.240	[.810]
$\delta_{M,T}$	26.5888	0.879	[.379]	$\delta_{M,T}$	32.963	0.863	[.388]
$\delta_{L1,S}$	-4.91E-03	-5.983	[.000]	$\delta_{L1,S}$	-2.61E-03	-5.565	[.000]
$\delta_{L2,S}$	-5.01E-03	-6.134	[.000]	$\delta_{L2,S}$	-2.89E-03	-6.149	[.000]
$\delta_{M,S}$	-6.36E-03	-7.042	[.000]	$\delta_{M,S}$	-4.36E-03	-6.886	[.000]
$\delta_{L1,N}$	3.21E-03	2.893	[.004]	$\delta_{L1,N}$	4.26E-03	3.354	[.001]
$\delta_{L2,N}$	4.22E-03	3.825	[.000]	$\delta_{L2,N}$	5.67E-03	4.474	[.000]
$\delta_{M,N}$	3.22E-03	2.492	[.013]	$\delta_{M,N}$	6.00E-03	3.966	[.000]
$\delta_{L1,K}$	-0.06038	-1.969	[.049]	$\delta_{L1,K}$	-0.012571	-0.398	[.691]
$\delta_{L2,K}$	-0.225011	-7.724	[.000]	$\delta_{L2,K}$	-0.192588	-6.426	[.000]
$\delta_{M,K}$	-0.846113	-16.632	[.000]	$\delta_{M,K}$	-0.838482	-15.702	[.000]
$\delta_{H,H}$	1.77E-06	2.160	[.031]	$\delta_{H,H}$	2.86E-06	4.052	[.000]
$\delta_{Y,Y}$	-3.81E-07	-10.965	[.000]	$\delta_{Y,Y}$	-3.82E-07	-11.060	[.000]
$\delta_{S,S}$	-6.82E-12	-0.189	[.850]	$\delta_{S,S}$	-4.41E-11	-1.285	[.199]
$\delta_{K,K}$	2.96E-06	5.94237	[.000]	$\delta_{K,K}$	3.16E-06	6.641	[.000]
$\delta_{N,N}$	-1.02E-10	-0.642	[.521]	$\delta_{N,N}$	-4.93E-10	-3.529	[.000]
$\delta_{H,Y}$	-1.31E-08	-0.083	[.934]	$\delta_{H,Y}$	7.09E-08	0.455	[.649]
$\delta_{H,N}$	7.10E-08	1.080	[.280]	$\delta_{H,N}$	2.90E-08	0.496	[.620]
$\delta_{H,K}$	-3.16E-06	-3.324	[.001]	$\delta_{H,K}$	-4.52E-06	-5.086	[.000]
$\delta_{Y,N}$	8.35E-09	3.751	[.000]	$\delta_{Y,N}$	7.54E-09	3.355	[.001]
$\delta_{Y,K}$	3.21E-07	1.624	[.104]	$\delta_{Y,K}$	4.79E-07	2.451	[.014]
$\delta_{N,K}$	2.54E-08	0.841	[.401]	$\delta_{N,K}$	2.69E-08	0.973	[.330]
$\delta_{H,S}$	1.40E-08	0.840	[.401]	$\delta_{H,S}$	6.27E-08	4.954	[.000]
$\delta_{Y,S}$	1.62E-09	1.444	[.149]	$\delta_{Y,S}$	4.89E-10	0.443	[.658]
$\delta_{N,S}$	4.63E-11	0.257	[.797]	$\delta_{N,S}$	6.09E-10	3.799	[.000]
$\delta_{K,S}$	1.45E-09	0.207	[.836]	$\delta_{K,S}$	-1.28E-09	-0.210	[.834]
$\delta_{H,T}$	-3.13E-03	-1.720	[.085]	$\delta_{H,T}$	-3.77E-04	-0.213	[.831]
$\delta_{Y,T}$	-2.10E-03	-8.825	[.000]	$\delta_{Y,T}$	-1.96E-03	-8.132	[.000]
$\delta_{N,T}$	2.49E-04	3.240	[.001]	$\delta_{N,T}$	2.94E-04	3.227	[.001]

$\delta_{S,T}$	-3.03E-04	-5.034	[.000]	$\delta_{S,T}$	-6.53E-05	-2.934	[.003]
$\delta_{K,T}$	8.59E-04	0.841	[.401]	$\delta_{K,T}$	-1.63E-03	-1.610	[.107]
λ_Y	-1.81E-06	-34.204	[.000]	ρ	0.425677	12.839	[.000]
				ρ_{L1}	0.380955	9.921	[.000]
				ρ_{L2}	0.485287	12.590	[.000]
				ρ_M	0.416867	12.411	[.000]
				λ_Y	-1.67E-06	-31.125	[.000]

Table 2: Elasticities

	Seemingly Unrelated Regression			Spatial Autocorrelation		
Measure	*Estimate*	*t-statistic*	*P-value*	*Estimate*	*t-statistic*	*P-value*
SHV_S	0.0195	5.717	[.000]	3.22E-03	3.153	[.002]
SHV_H	0.496545	6.868	[.000]	0.51871	8.949	[.000]
SHV_N	-0.01971	-4.360	[.000]	-0.010664	-2.965	[.003]
SHV_K	0.685704	14.709	[.000]	0.141988	2.852	[.004]
MC	0.810478	212.728	[.000]	0.515894	53.674	[.000]
$\varepsilon_{VC,S}$	-0.263463	-5.717	[.000]	-0.043491	-3.153	[.002]
$\varepsilon_{VC,H}$	-0.181258	-6.868	[.000]	-0.189349	-8.949	[.000]
$\varepsilon_{VC,N}$	0.238897	4.360	[.000]	0.129258	2.965	[.003]
$\varepsilon_{VC,K}$	-0.322358	-14.709	[.000]	-0.06675	-2.852	[.004]
$\varepsilon_{VC,Y}$	1.20611	212.728	[.000]	0.767724	53.674	[.000]
$\varepsilon_{VC,T}$	-0.01172	-4.711	[.000]	-2.50E-03	-1.175	[.240]
$\varepsilon_{VC,L1}$	0.130158	27.904	[.000]	0.132032	39.385	[.000]
$\varepsilon_{VC,L2}$	0.137509	27.617	[.000]	0.140813	37.945	[.000]
$\varepsilon_{VC,M}$	0.74765	143.807	[.000]	0.755582	156.124	[.000]
$\varepsilon_{SHVH,S}$	-0.040709	-0.854	[.393]	-0.027268	-0.939	[.348]
$\varepsilon_{SHVN,S}$	3.40E-03	0.254	[.799]	-0.047898	-1.975	[.048]
$\varepsilon_{SHVK,S}$	-3.07E-03	-0.207	[.836]	0.136405	1.847	[.065]
$\varepsilon_{MC,S}$	2.90E-03	1.443	[.149]	0.017604	4.298	[.000]
$\varepsilon_{L1,S}$	-0.619918	-5.298	[.000]	-0.083135	-2.454	[.014]
$\varepsilon_{L2,S}$	-0.636626	-5.376	[.000]	-0.096386	-2.798	[.005]
$\varepsilon_{M,S}$	-0.136578	-6.149	[.000]	-0.027356	-3.155	[.002]
$\varepsilon_{SHVS,H}$	-0.028007	-0.785	[.432]	-0.11872	-0.980	[.327]
$\varepsilon_{SHVN,H}$	0.141066	1.106	[.269]	0.030245	0.180	[.857]
$\varepsilon_{SHVK,H}$	0.180178	3.270	[.001]	-0.275968	-1.109	[.267]
$\varepsilon_{MC,H}$	-6.31E-04	-0.083	[.934]	-0.098308	-5.833	[.000]
$\varepsilon_{L1,H}$	0.074359	1.075	[.282]	-0.078851	-1.496	[.135]
$\varepsilon_{L2,H}$	0.290834	4.454	[.000]	0.13721	2.950	[.003]
$\varepsilon_{M,H}$	-0.309195	-12.457	[.000]	-0.266669	-12.424	[.000]
$\varepsilon_{SHVS,N}$	-3.08E-03	-0.255	[.799]	0.142357	1.734	[.083]
$\varepsilon_{SHVH,N}$	-0.185924	-1.049	[.294]	-0.020646	-0.180	[.857]
$\varepsilon_{SHVK,N}$	-0.048121	-0.836	[.403]	-1.41122	-2.539	[.011]
$\varepsilon_{MC,N}$	0.013395	3.753	[.000]	-0.027882	-1.726	[.084]
$\varepsilon_{L1,N}$	0.576895	4.163	[.000]	0.263098	2.376	[.018]
$\varepsilon_{L2,N}$	0.662539	4.729	[.000]	0.360433	3.234	[.001]
$\varepsilon_{M,N}$	0.106089	3.911	[.000]	0.065364	2.952	[.003]
$\varepsilon_{SHVS,K}$	-3.76E-03	-0.208	[.835]	0.209357	1.812	[.070]
$\varepsilon_{SHVS,Y}$	-0.013261	-1.401	[.161]	-0.310754	-2.794	[.005]
$\varepsilon_{SHVS,L1}$	0.295617	32.487	[.000]	0.240162	5.574	[.000]

$\varepsilon_{SHVS,L2}$	0.320207	40.166	[.000]	0.293686	8.158	[.000]
$\varepsilon_{SHVS,M}$	0.384176	23.543	[.000]	0.466152	6.373	[.000]
$\varepsilon_{SHVS,T}$	0.038844	22.097	[.000]	0.043709	5.308	[.000]
$\varepsilon_{SHVH,K}$	0.320438	2.911	[.004]	-0.097286	-1.189	[.234]
$\varepsilon_{SHVH,Y}$	4.20E-03	0.083	[.934]	0.398594	4.845	[.000]
$\varepsilon_{SHVH,L1}$	-0.051541	-0.971	[.332]	0.052319	1.629	[.103]
$\varepsilon_{SHVH,L2}$	-0.212625	-2.878	[.004]	-0.096026	-2.354	[.019]
$\varepsilon_{SHVH,M}$	1.26417	10.271	[.000]	1.04371	15.665	[.000]
$\varepsilon_{SHVH,T}$	0.015779	1.565	[.118]	5.56E-03	0.786	[.432]
$\varepsilon_{SHVN,K}$	0.064932	0.824	[.410]	0.728769	2.705	[.007]
$\varepsilon_{SHVN,Y}$	0.067628	3.093	[.002]	-0.165606	-1.425	[.154]
$\varepsilon_{SHVN,L1}$	0.30339	22.689	[.000]	0.255726	8.340	[.000]
$\varepsilon_{SHVN,L2}$	0.367509	26.784	[.000]	0.369517	15.641	[.000]
$\varepsilon_{SHVN,M}$	0.3291	13.689	[.000]	0.374757	8.918	[.000]
$\varepsilon_{SHVN,T}$	0.03165	8.352	[.000]	0.019527	2.097	[.036]
$\varepsilon_{SHVK,Y}$	-0.074742	-1.611	[.107]	0.785927	2.008	[.045]
$\varepsilon_{SHVK,L1}$	-0.059884	-2.329	[.020]	-0.970264	-2.422	[.015]
$\varepsilon_{SHVK,L2}$	0.139597	7.552	[.000]	-0.08187	-0.704	[.481]
$\varepsilon_{SHVK,M}$	0.920287	22.491	[.000]	2.05213	4.087	[.000]
$\varepsilon_{SHVK,T}$	-3.13E-03	-0.839	[.401]	-0.101916	-2.338	[.019]
$\varepsilon_{MC,K}$	0.019976	1.621	[.105]	-0.068333	-2.992	[.003]
$\varepsilon_{MC,L1}$	0.118805	35.436	[.000]	0.068809	13.243	[.000]
$\varepsilon_{MC,L2}$	0.159513	56.819	[.000]	0.111392	27.146	[.000]
$\varepsilon_{MC,M}$	0.721682	127.067	[.000]	0.819798	98.408	[.000]
$\varepsilon_{MC,T}$	-6.47E-03	-8.929	[.000]	-0.014158	-8.326	[.000]
$\varepsilon_{L1,K}$	0.15365	2.538	[.011]	0.515499	9.246	[.000]
$\varepsilon_{L2,K}$	-0.339584	-6.221	[.000]	0.041239	0.854	[.393]
$\varepsilon_{M,K}$	-0.400306	-16.128	[.000]	-0.184837	-7.268	[.000]

Appendix A: Data

The following state level data for the years 1984 through 1996 were utilized in this study: **Labor quantities**: The number of workers engaged in production (L2) at operating manufacturing establishments, and the number of full-time and part-time employees (TOTAL) on the payrolls of these manufacturing establishments, are from the U.S. Census Bureau's *Annual Survey of Manufactures* (ASM), *Geographic Area Statistics*. Total number of non-production workers (L1) for each state is obtained as the difference between TOTAL and L2 for each state. These data are from Cohen and Morrison Paul (2004).

Wage bills: The ASM reports wages paid to production workers and gross earnings of all employees on the payroll of operating manufacturing establishments. Wage bill for L1 is obtained by subtracting the wages paid to L2 from the gross earnings of all employees. Non-production wage is obtained by dividing the non-production wage bill by L1. Production wage is obtained by dividing the production wage bill by L2. These data are from Cohen and Morrison Paul (2004).

Private capital stock: The perpetual inventory method is applied to data on state level new capital expenditures from the ASM, with the initial capital stock (1982) values taken from Morrison and Schwartz (1996). Depreciation rates for capital equipment are from the Bureau of Labor Statistics, Office of Productivity and Technology. The investment deflator is obtained from the Bureau of Labor Statistics and is their input price deflator for total manufacturing (SIC 20-39) capital services. The price of capital is obtained as $(i_t+d_t) \bullet q_{K,t}[1/(1\text{-taxrate}_t)]$, where d_t is the depreciation rate, i_t is the Moody's Baa corporate bond rate (obtained from the Economic Report of the President), $q_{K,t}$ is the investment deflator, and taxrate_t is the corporate tax rate (obtained from the Office of Multifactor Productivity, Bureau of Labor Statistics). These data are from Cohen and Morrison Paul (2004).

Ports capital stocks: The perpetual inventory method will be applied to data on state level (state and local total) ports capital expenditures from the Census Bureau's "Government Finances" (various years). The initial ports capital stock (1984) values for each state will be obtained by taking the average of the expenditures data for 1984 through 1987 for each state and multiplying by 22 (average service life, per World Bank report). The annual depreciation rate of .045455 is taken as the inverse of the average ports service life of 22 years. This approach was described in Paul (1999). The investment deflator was from the 2000 Economic Report of the President, Table B-7, for "Government consumption expenditures and gross investment, state and local." Note that AZ, MT, ND, NM, NV, SD, UT, VT, WV, WY all have zeros for their capital stocks.

Highway capital stocks: The perpetual inventory technique is applied to state-level public infrastructure investment data to generate highway capital stock estimates. Following Eberts, Park and Dalenberg (1986), discards are assumed to follow a truncated normal distribution, with the truncation occurring at one half the average life and one and one half times the average life. The Federal Highway Administration's composite price index is used to deflate the capital and maintenance outlay series. These data are from Cohen and Morrison Paul (2004).

Materials: The ASM reports direct charges actually paid or payable for items consumed or put into production during the year. The quantity of materials (M) is obtained by deflating these charges by the ratio of nominal Gross Domestic Product to real Gross Domestic Product as reported on the Bureau of Economic Analysis website. This deflator is also used as the price of materials. These data are from Cohen and Morrison Paul (2004).

Output: Value of state-level shipments reported in the ASM are deflated by manufacturing Gross State Product (GSP) deflators for each state (provided by DRI). These state-level deflators are also used for output prices. These data are from Cohen and Morrison Paul (2004).