Container Demand In North American Markets: A Spatial Autocorrelation Analysis

Towards a Global Forecast of Container Flows
Container Model and Analysis:
Longer Term Analysis of Infrastructure Demands and Risks

By

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Task 3: Analyze historical movements in US container markets including an econometric analysis of container demands

***Draft Report** 1*
for Review
December 31, 2007
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Container Demand in North American Markets: A Cross-Sectional Spatial Autocorrelation Analysis

1. Introduction

The Institute for Water Resource's (IWR) Navigation Economic Technologies (NETS) Research program has developed a global spatial equilibrium model for the forecasting of grains.[1] This analytical approach to forecasting projects supplies and demand by region and transfers excess supplies to the excess demand regions by the least cost route. It also can be used to evaluate comparative static analysis to assess how changes in infrastructure impact the equilibrium shipments during the projection period. A crucial component of spatial optimization models is some way to estimate demands.

The overall objective of this research is to evaluate the applicability of this approach to the forecasting of container cargoes.[2]

2. Purpose and Related Studies

This report addresses task 3 as part of a larger overview of the container shipping industry. In particular, it seeks to:

> *Analyze historical movements in US container markets including an econometric analysis of container demands.*

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[1] This is available at Wilson, DeVuyst, Taylor, Dahl, and Koo (2006) and summarized in Wilson, DeVuyst, Taylor, Dahl and Koo, 2007. Additional papers from that study include are in Wilson, Koo, Taylor and Dahl (2008a and 2008b) and several articles under review including DeVuyst, Wilson and Dahl (2008) and Wilson, Dahl, Taylor and Koo (2008) which are available from the authors.

[2] Other tasks include the following, and are available in accompanying reports: Task 2 Describes historical movements in world container trade; Task 3 Analyzes historical movements in US container markets including an econometric analysis of container demands; Task 4 Rail rate analysis of container shipments; Task 5 Ocean rate analysis of container shipments; Task 6 is included in this report; and Task 7 An evaluation of alternatives for spatial modeling of container shipments.

Reports on each of these topics are available from the authors and IWR and are titled:

Report 1:	Review of Previous Studies on Container Shipping: Infrastructure, Projections and Constraints
Report 2:	Analysis of Container Flows: World Trade, US Waterborne Commerce and Rail Shipments In North American Markets
Report 3:	Container Demand In North American Markets: A Cross-Sectional Spatial Autocorrelation Analysis
Report 4:	Container Shipping: Rail and Ocean Shipping Rates
Report 5:	Optimization Models of Container Shipments in North America: Spatial Competition and Projections (Methodology)

A companion report[3] provides a detailed description of the data used in this study. It also describes container flows within the US, to/from the US and in world trade. This study uses that data to analyze factors impacting demand for containers within the United States.

The model analyzes the cross-sectional demands for containers by BEAs (Bureau of Economic Analysis regions, which are groups of counties). Ultimately, we seek to measure market size (e.g., how many containers does Chicago consume) and factors impacting demand. It seeks to identify factors that determine the demand for containers, and how these vary both through space, as well as through time.[3]

There are two important econometric issues that have to be captured in the specification. First, there are 179 BEA's in the Untied States, but, only 89 receive containers, at least by rail in 2005. Hence there were 90 BEAs that had a nil value for the dependent variable. Since a number of BEA's do not receive containers by rail, the econometric model requires a Tobit specification. Second, an important characteristic of container demand is that though shipments may occur by rail, which we measure, consumption may occur in contiguous BEAs that may or may not receive containers by rail. Different BEA areas are also likely to be close substitutes for container demand shipments. That is, container demand in a given BEA region may not only depend on that region attributes, but also on characteristics of other BEAs that represent alternative markets for container shipments. Hence, this is a classic application of spatial autocorrelation models which introduce the link amongst contiguous regions characteristics on explaining other regions' demands.

A related study is that done recently by Blonigen and Wilson (forthcoming) who use a gravity model to explain container flows. This differs from explaining termination of containers which is an essential input to development of a spatial optimization model. The difference is that while we interpret these as market size, the Blonigen and Wilson analysis is really an equilibrium of the accumulation of multiple rail flows, hence, the reason for using a gravity model.

3. **Data Sources**

The geographic scope of the analysis is the BEA (Bureau of Economic Analysis). These are groups of naturally contiguously located counties that are relevant for economic analysis. The definition of these was changed in 2004 and we used the revised definition from as explained in the appendix.

Alternatives exist. We could have used less aggregated data and focused on counties or zip codes. Or, we could have used States. We chose the BEA because in reality counties and zip codes were probably too disaggregated to get meaningful definitions of demand for a natural

[3] See Wilson and Benson (2008b) in report 2 above.

[3] See Sarmiento (2008) for other applications that model spatial effects in a panel data framework.

economic regions. Certainly, in considering the geographic scope of container shipments, it is entirely likely that the scope spans across multiple counties. In contrast, States would likely be too aggregated partly due to size, but, also, state boundaries are not necessarily compatible with natural economic regions. For these reasons, we used the BEA.

The data used in this study come from multiple sources and details are described in Table A1 in the Appendix.

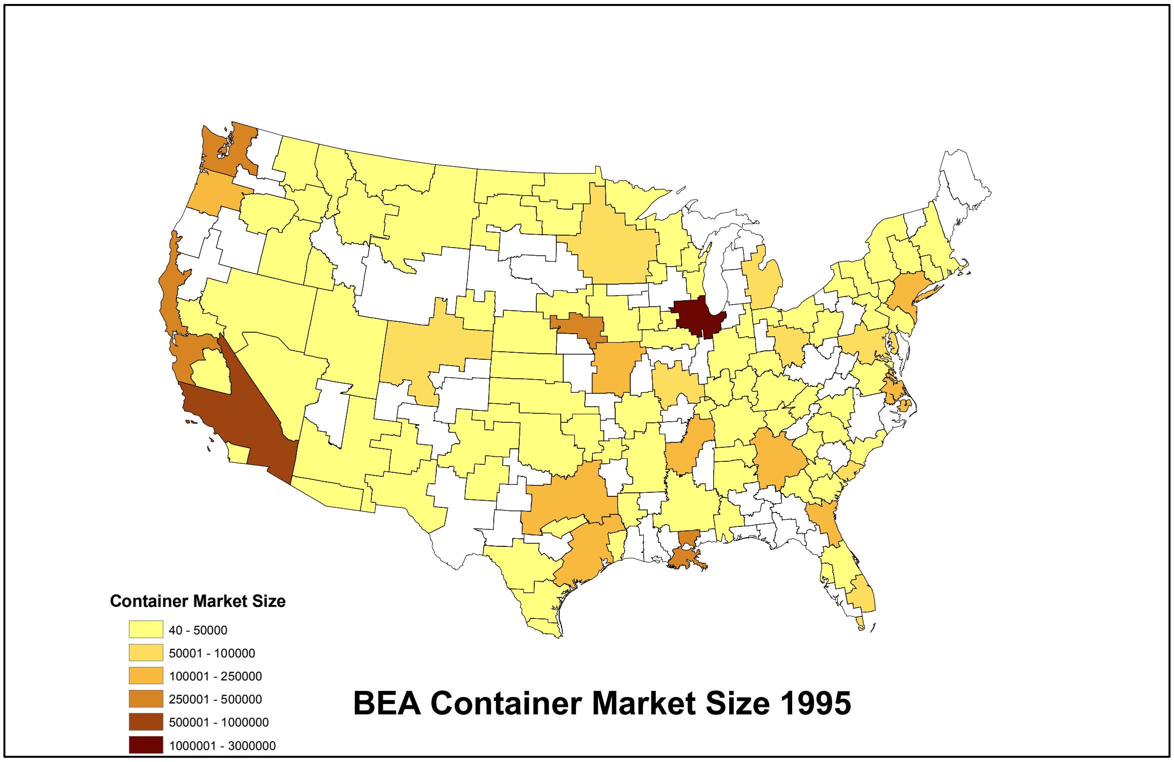
The dependent variable is the number of containers terminated in each BEA. Models were estimated separately for containers and trailers. These variables were taken as the measure of demand for containers. The data are from the Surface Transportation Board (STB) Confidential Waybill data set. This data was for the years 1995-2005 and was assembled by Tennessee Valley Authority (TVA).

Figure1 and 2 shows the container shipments by BEA in 1995 and 2005 and Table 1 shows the actual container shipments in 2005. Shipments are concentrated in a few geographic regions. These are primarily in Chicago, Los Angeles, Seattle, Dallas and Memphis, followed by 85 others each of which are substantially smaller markets. It is also apparent that there are many BEAs that do not receive container shipments. Of 179 BEAs in 2005, there were 90 that were not recipients of container shipments.

The model was also estimated for trailers. However, it is important that, in contrast to containers, the demand for trailers has been highly stagnant over time, is a small portion of the total market, and as declined in relative importance over time.

The data used in the econometric analysis is a panel data set comprised of these BEAs, for the period of time 1995-2005. These are the most recent years available and for a consistent set of BEA definitions.

Some of the explanatory variables were taken from either the Department of Commerce. These are for the same period and reported by BEA. These include measures of population, income, relative incomes, .etc. In addition, we used data on transport infrastructure in the BEA and these were taken from web pages of individual railroad, IANA, the Railway Guide, LoadMatch.com and NTAD (2004).



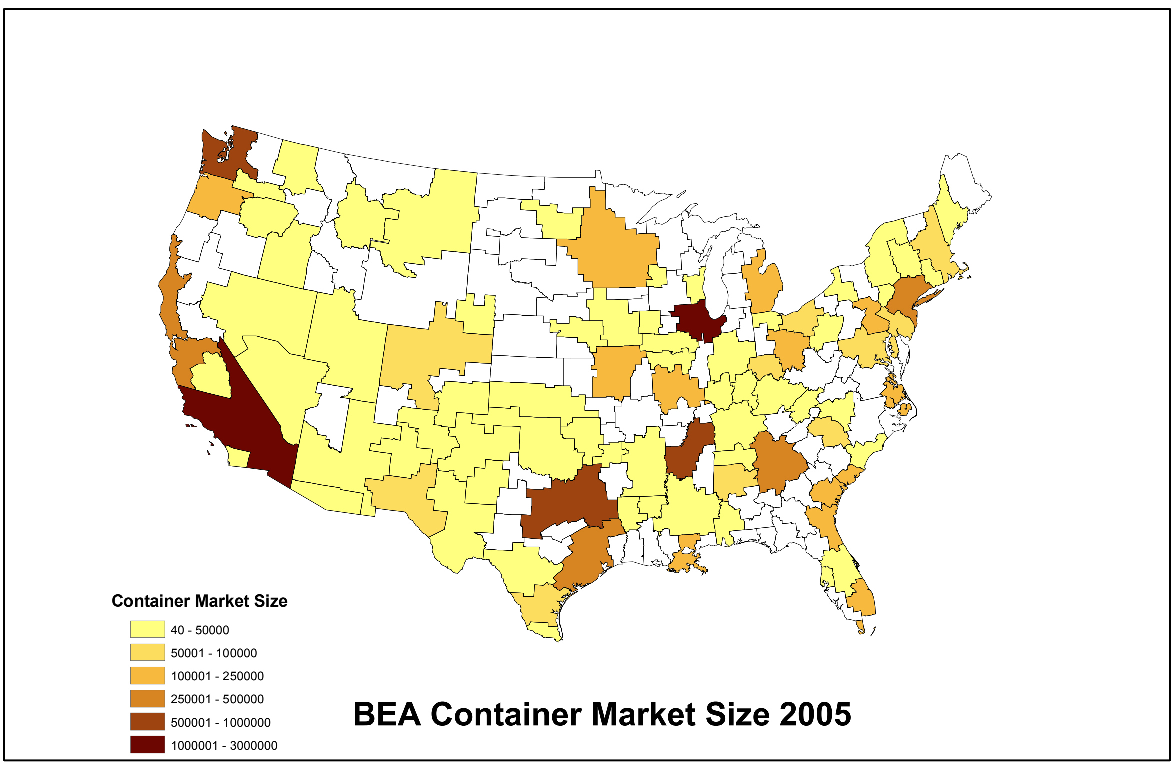


Figure 1 BEAs with Railroad Terminating Container Traffic, 1995 and 2005

Table 1 BEAs with Railroad Terminating Container Traffic, 2005

Rank	BEA	Number of Terminating Containers
1	Chicago-Naperville-Michigan City, IL-IN-WI	2,796,340
2	Los Angeles-Long Beach-Riverside, CA	1,916,800
3	Seattle-Tacoma-Olympia, WA	648,400
4	Dallas-Fort Worth, TX	557,960
5	Memphis, TN-MS-AR	550,840
6	San Jose-San Francisco-Oakland, CA	478,833
7	New York-Newark-Bridgeport, NY-NJ-CT-PA	412,000
8	Atlanta-Sandy Springs-Gainesville, GA-AL	308,800
9	Houston-Baytown-Huntsville, TX	280,880
10	New Orleans-Metairie-Bogalusa, LA	239,960
11	Portland-Vancouver-Beaverton, OR-WA	208,080
12	Kansas City-Overland Park-Kansas City, MO-KS	203,760
13	Virginia Beach-Norfolk-Newport News, VA-NC	199,960
14	Jacksonville, FL	184,600
15	St. Louis-St. Charles-Farmington, MO-IL	159,360
16	Detroit-Warren-Flint, MI	155,320
17	Savannah-Hinesville-Fort Stewart, GA	144,800
18	Columbus-Marion-Chillicothe, OH	141,440
19	Charleston-North Charleston, SC	126,320
20	Minneapolis-St. Paul-St. Cloud, MN-WI	124,360
21	Harrisburg-Carlisle-Lebanon, PA	113,080
22	Miami-Fort Lauderdale-Miami Beach, FL	100,920
23	Charlotte-Gastonia-Salisbury, NC-SC	97,840
24	Corpus Christi-Kingsville, TX	90,129
25	Philadelphia-Camden-Vineland, PA-NJ-DE-MD	88,280
26	Cleveland-Akron-Elyria, OH	87,160
27	Washington-Baltimore-Northern Virginia, DC-MD-VA-WV	81,880
28	Denver-Aurora-Boulder, CO	75,600
29	Boston-Worcester-Manchester, MA-NH	73,280
30	Cincinnati-Middletown-Wilmington, OH-KY-IN	60,360
31	Birmingham-Hoover-Cullman, AL	59,440
32	El Paso, TX	56,840
33	Louisville-Elizabethtown-Scottsburg, KY-IN	48,960
34	Salt Lake City-Ogden-Clearfield, UT	47,844
35	Pendleton-Hermiston, OR	43,680
36	Nashville-Davidson--Murfreesboro--Columbia, TN	40,200
37	Omaha-Council Bluffs-Fremont, NE-IA	36,060
38	San Antonio, TX	33,560
39	Tampa-St. Petersburg-Clearwater, FL	31,760
40	Phoenix-Mesa-Scottsdale, AZ	30,680
41	Pittsburgh-New Castle, PA	29,160
42	Orlando-The Villages, FL	23,000
43	Buffalo-Niagara-Cattaraugus, NY	20,760

Rank	BEA	Number of Terminating Containers
44	La Crosse, WI-MN	18,280
45	Huntsville-Decatur, AL	16,480
46	Albany-Schenectady-Amsterdam, NY	15,120
47	Syracuse-Auburn, NY	13,480
48	Lubbock-Levelland, TX	12,800
49	Johnson City-Kingsport-Bristol (Tri-Cities), TN-VA	12,240
50	Fresno-Madera, CA	11,640
51	Hartford-West Hartford-Willimantic, CT	10,720
52	Lexington-Fayette--Frankfort--Richmond, KY	10,560
53	Reno-Sparks, NV	8,648
54	Tucson, AZ	8,560
55	Milwaukee-Racine-Waukesha, WI	8,000
56	Indianapolis-Anderson-Columbus, IN	7,520
57	Peoria-Canton, IL	7,040
58	Springfield, IL	6,440
59	Jackson-Yazoo City, MS	5,560
60	Evansville, IN-KY	4,612
61	Spokane, WA	3,880
62	Portland-Lewiston-South Portland, ME	3,600
63	Toledo-Fremont, OH	3,360
64	Scranton—Wilkes-Barre, PA	3,080
65	Monroe-Bastrop, LA	2,720
66	Las Vegas-Paradise-Pahrump, NV	2,600
67	Mobile-Daphne-Fairhope, AL	2,600
68	Amarillo, TX	2,280
69	Fargo-Wahpeton, ND-MN	2,080
70	Little Rock-North Little Rock-Pine Bluff, AR	1,880
71	Cedar Rapids, IA	1,720
72	Greensboro--Winston-Salem--High Point, NC	1,520
73	Billings, MT	1,200
74	Albuquerque, NM	1,000
75	Myrtle Beach-Conway-Georgetown, SC	972
76	Kennewick-Richland-Pasco, WA	960
77	Santa Fe-Espanola, NM	920
78	Shreveport-Bossier City-Minden, LA	760
79	Des Moines-Newton-Pella, IA	540
80	Oklahoma City-Shawnee, OK	482
81	Tulsa-Bartlesville, OK	304
82	McAllen-Edinburg-Pharr, TX	280
83	Boise City-Nampa, ID	240
84	San Diego-Carlsbad-San Marcos, CA	240
85	Scotts Bluff, NE	240
86	Pueblo, CO	200
87	Midland-Odessa, TX	80

Rank	BEA	Number of Terminating Containers
88	Fort Smith, AR-OK	40
89	Helena, MT	40
90	Wichita-Winfield, KS	40

Figures 1 and 2 illustrated the importance of geographical location in explaining container demand, while Table 1 illustrated levels of concentration on rail shipment of containers. In the econometric analysis, we next decompose factors that explain geographical destinations of rail container shipment as well as levels of concentration in market shares of container demand.

To fully capture the factors that explain BEA container demand, we use a spatial econometric model. In the model, we use ARCGIS to calculate the geographical coordinates of the center of each BEA as well as the distance amongst all BEAs. Geographical distance is necessary in the model to create a spatial correlation index as described in below. Geographical coordinates in the model are quite important since it captures the effect of location on container demand maintaining all else equal.

4. Econometric Specification and Estimation Procedures

4.1 Model specifications The basic model is specified as:

$$M_{jt} = f(\text{Popn}_{jt}, Y_{jt}, X_{jt}, Z_{jt}, T_j) + u_{jt}$$

where M_{jt} is the market size of rail container shipments in time BEA j and time t; Popn is population; Y_{jt} is income; X_{jt} is a group of other demographic variables; and Z_{jt} a group of other industrial variables, each defined below; T_j is a set of binary dummy variables to indicate if the BEA is a port area; and u_{jt} is the residual term that captures all variables not included in the model.

The demographic variables included were population and personal income. Other demographic variables included varying measures of employment and numbers of business establishments. However, for varying reasons these were either correlated with other variables, or otherwise insignificant.

A set of variables representing the industrial and logistical characteristics of a BEA were included. These were the geographic size of the BEA, the number of railroads terminating in the BEA (derived from the STB data set) and the number of interstate highway models in the BEA (NTAD 2004). Others were included initially including the number of terminals in the BEA (derived from IANA, and Railway Guide) but this was dropped due to insignificance.

There is an important issue in using these data as a measure of demand. This relates to the interpretation of port-area-BEAs vs. non-port-area-BEAs. We are trying to depict the demand for containers, viewing them as being consumption in the region and/or contiguous regions. However, there are a number of destination BEA's that are both consuming BEA's (as we define them), and BEA's that demand container shipments for shipping to off-shore destinations. Thus, for BEA destinations like Los Angeles, LongBeach, Seattle, Houston, etc. we show demand explained by the RHS variables. But, we don't capture any particular impact due to that some (likely a significant portion) of these are re-shipped to off-shore markets.

To deal with this, we included a set of dummies T_j to indicate whether the market is a port-area-BEA or not. If the bea is a port...so BEA's are 0/1 with 1 if it is a port area

4.2 Econometric Specifications and Estimation

The model has two econometric characteristics that are important. One is that the dependent variable is bounded by 0 that reflects that some BEAs do not receive container shipments by rail. Second, this is a market in which there are important spatial interrelations. The first issue is dealt with a Tobit model specification that truncates the econometric residual. The second issue is dealt by incorporating spatial correlation in the container demand model. Spatial correlation allows shipments of one region to directly impact container demand in other regions.

4.2.1 The Model Specification

In container demand model, there are several BEAs that do not receive container shipments. In this instance the container demand is equal to zero. For these observations, the distribution of the econometric residual is truncated. This implies that ordinary least squares estimation is not a consistent estimator and a more general estimation method is needed. The Tobit model specification involves truncating the distribution of the econometric residual. A preferred model of estimation is Heckman (1976) maximum likelihood estimator.

Under the assumption that the econometric residual has a truncated normal distributed, it follows that the container demand model – with several zero demand regions – can be specified as:

(1) $M_{jt} = \Phi[\varsigma + \beta'\mathbf{X_{jt}}] + \sigma\phi + \varepsilon_{jt}$

where

$\mathbf{X_{jt}} = (Popn_{jt}, Y_{jt}, X_{jt}, Z_{jt} , T_j);$

$\Phi = \text{Prob } (M_{jt} - \varsigma - \beta'\mathbf{X_{jt}} > 0)$

$\phi = \Phi'(M_{jt} - \varsigma - \beta'\mathbf{X_{jt}}, \sigma);$

and

$\varepsilon_{jt} \sim N(0, \sigma_2).$

In the Tobit formulation, Φ and ϕ are respectively the distribution and density function of the Gaussian distribution.

While the model specification in (1) captures industrial and economic variables, it may not fully capture all regional factors that impact container demand. Indeed, the container demand is a market in which there are important spatial interrelations. There are several reasons to expect that spatial autocorrelation is an important attribute of this problem. First, the BEAs are contiguously located and as such compete amongst each other for container shipments. Second, businesses in one BEA may receive truck shipments of containers that terminate by rail in another geographically related BEA. This is a critical feature in that we cannot observe these trucks shipments, yet, we know they are important. Spatial econometrics is a perfect way to capture and analyze these effects. Specifically, spatial autocorrelation allows us to examine impacts of distance and other variables to competing regions origins/destinations.

Sarmiento and Wilson (2005, 2007) use a spatial lagged dependent variables to capture spatial correlation in a logit specification. Container demand in Equation (1) with an index of competition from other locations, captured with a spatial lagged dependent variable is:

(2) $$M_{jt} = \Phi[\varsigma + \beta' \mathbf{X_{jt}} + SL_{-j}] + \sigma\phi + \varepsilon_{jt}$$

where

(3) $$SL_{-j} = \sum_{k \neq j} M_{kt} exp(-Dist_{jk}/\gamma),$$

where M_{kt} is the container demand for BEA region K and $Dist_{jk}$ is the distance between BEA *j* and *k*. In the spatial model, interrelation across regions decreases at a decreasing rate with distance (Sarmiento and Wilson, 2005). The likelihood function of equation (2) is well-behaved and can be estimated using ML estimator. In addition to a spatial lag, location may have a systematic effect on container demand. In this instance, geographical coordinates are also introduced in (2) to capture spatial trends (Sarmiento, 2004) .

5. Results

The model seeks to measure demand for containers using demographic, industrial and logistical characteristics, as well as spatial variables. The model was estimated with and without port-BEA dummy variables. ML estimates of equation (2) are shown below. Other specifications including other demographic variables were estimated as well. However, for varying reasons these were not significant of provided inferior results and therefore their results are not shown.

Results for each are shown first, then the econometric results are discussed and interpreted. The results of the base model without the port-BEA dummies are shown in Table 2a for container and trailer shipments and Table 2b shows the model with dummies for port-area-BEAs.

Table 2a: Tobit Model Results from Base Specification without port-BEA Variables

	Containers		Trailers	
	Coefficient	***t-value***	***Coefficient***	***t-value***
Constant	-98470	-1.3	222	2.23
Latitude	-2092	-2.1	3.02	2.58
Longitude	4347	10.6	0.33	0.61
Population	0.03	13.1	0.00	1.84
Personal income	5.12	4.1	0.00	-2.84
Area	-1.02	-4.3	0.00	-0.68
Numofterminatingrrs	53930	16.1	-2.85	-0.76
Interstate miles	113	3.0	-0.12	-3.15
Spatial Lag	-0.12	-2.5	0.10	1.99
Goodness of Fit				

Table 2b: Tobit Model Results from Base Specification with Port Variable

	Containers		Trailers	
	Coefficient	***t-value***	***Coefficient***	***t-value***
Constant	-110556	-1.42	231	2.49
Latitude	-1032	-0.99	2.72	2.23
Longitude	4293	10.48	0.32	0.69
Population	0.03	10.60	0.00	2.03
Personal income	4.93	3.95	0.00	-2.93
Area	-1.13	-4.75	0.00	-0.51
Numofterminatingrrs	53952	16.12	-2.91	-0.78
Interstate miles	154	3.92	-0.14	-3.26
Port Dummy	70817	3.63	-18.01	-0.85
Spatial Lag	-0.10	-2.08	0.10	1.94
Goodness of Fit	0.52		0.05	

The most important variable in explaining container demand is number of terminating railroads followed by population and geographical attributes. Each is discussed below. These results mean that BEA container demand is positively related to market size and income, and inversely related to BEA area. Simply, large markets as represented by large populations, and markets with greater personal income, have greater demands for containers. The geographic size of the BEA has negative impact of container demand. Thus, these results would suggest that BEA's with larger geographic area would have a lesser demand for containers.

Both the number of terminating railroads and the number of interstate miles in the BEA are positive and significant. Simply, the more railroads serving a BEA the greater the demand for containers, and the more interstate miles in a BEA the greater the demand for containers. Both of these are logistical measures and indicate their impacts on container demand. BEAs with a larger highway network would have a greater demand for containers. No doubt this is capturing the impact of shipping to contiguous regions from the terminal-hub. These indicate that BEAs with large highway miles would have greater container demand due to intermodal connections

The most interesting economic variable is income. Table 3 shows the elasticity for container demand for both the economic and industry variables.

Table 3: Elasticity Estimated for Container Model

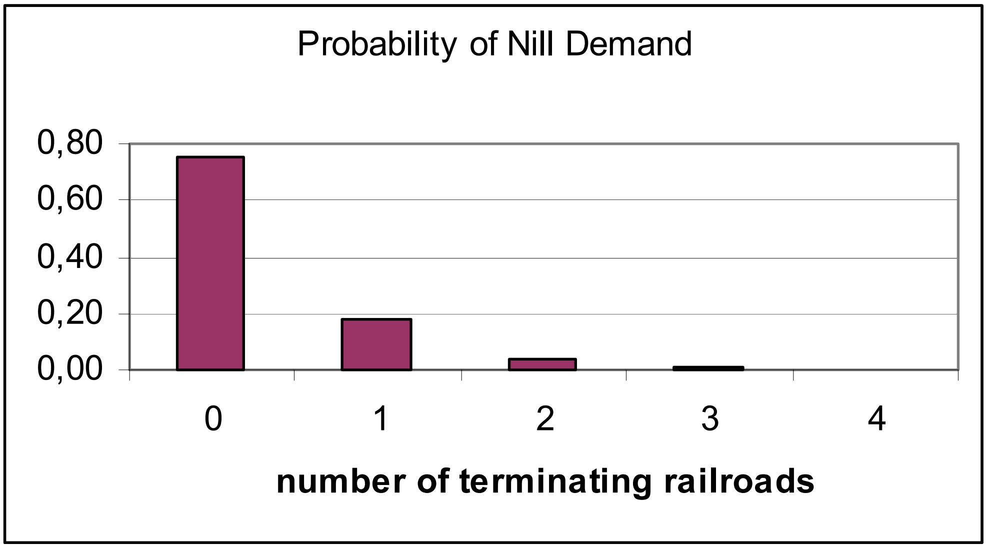
Variable	Elasticity *
Latitude	-0.48
Longitude	4.85
Beapopulation	0.79
Beapercapitapersonalincome	1.54
Tbeaarea	-0.29
Numofterminatingrrs	1.36
Beainterstatemiles	0.61

*Elasticites are evaluated at the mean values of the variables of the model

The demand for container is elastic to personal income and number of terminating railroads, but it is inelastic with respect to all other variables. The income elasticity indicates that container demand responds more than proportionally to changes in income across time and space. However, population is also highly significant and has a relatively large elasticity, though it is inelastic.

The Tobit specification indicates that the main source of nonlinearities in the container demand model is number of terminating railroads. Indeed, it is the main statistical factor in explaining nil-demand for container is number of terminating railroads. Other variables such as income and population also impact the probability of nil demand for container shipments but were of relatively minor importance.

The Figure below shows the relation of number of terminating railroads to the probability of nil demand. This indicates that if the BEA has only no class I railroad, the probability of nil demand is nearly .8; and if there is only 1 Class I railroad in the BEA, the probability of nil demand is .2; and it diminishes sharply thereafter with increases in the number of railroads serving the BEA.

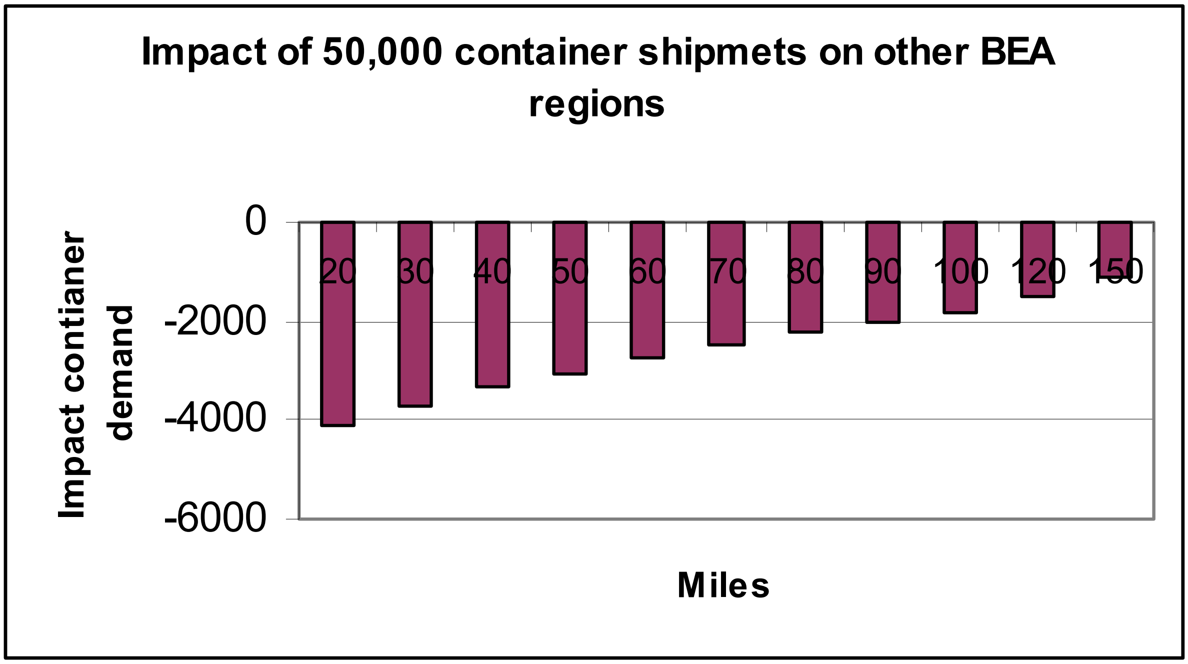


These results provide very logical explanations why BEAs such as Chicago, Atlanta, Dallas and others have large container demands. Simply, they have large populations, higher incomes and more than 1 railroad serving the market.

These results also show that if the BEA contains a port-area, there is a larger demand for containers than otherwise. The estimated coefficient means that main port-BEA-areas have 70,817 more container shipments. This simply means that port-area-BEAs will have greater demands for containers, no doubt reflecting the off-shore demand for further trans-shipments.

The spatial variables are particularly interesting. The coefficient for geographical longitude simply indicates that container demand is larger in the West coast. This result is consistent with earlier graphical analysis that shows that the larger concentration of container demand is in California. The coefficient estimate for latitude indicates that larger concentrations of container demand occur in more southern BEAs. That is, after controlling for economic and industry variables, we find that there is larger demand of containers in more southern locations.

The spatial lag variable also has a specific interpretation. Strictly this means that container demand not only depends on the BEA region attributes, but also on those characteristics of adjacent BEAs. The estimated container demand model indicates that an increase in shipments to a given BEAs has also the impact of reducing shipments to other BEAs. The size of the impact depends on the distance between the regions. Attributes of alternative markets thus impact container demand. More specifically, after controlling for economic and industry attributes, we find that competition reduces container demand. The figure below shows the impact of competition.



From the Figure, if a BEA receives 50,000 container shipments, it then reduces (all else equal) demand for a BEA located 25 miles away by 4,095. If the BEA is 100 miles away is reduces demand by 1,840.

Thus, taken together, the results show that container demand tends to be concentrated in areas with larger population, and income, as well as areas close to major port. After controlling for these factors, however, the spatial result indicates that container demand decreases with competition. That is, if there is an alternative delivery region closely located it does imply that total deliveries will be lower since there is large substitution between the regions.

Result for the base model for trailers differs. Generally, the same model for trailers does not explain as well as does the comparable model on container demand (Rsquare 0.52 vs. R-square 0.05). The most important significant variable is simply the population. BEAs with larger populations have greater trailer demand than otherwise. The results also show an inverse relation between income and trailer demand. Strictly, this means that trailers have somewhat of a inferior good characteristic in that higher income BEAs would have a lesser demand for trailer shipments. Finally, the number of interstate miles in the BEA has a negative impact on BEA trailer demand. The reason for this is not clear.

6. Summary and Implementation Issues into Optimization Models

An important aspect of analyzing demands for infrastructure for container shipments is the demand for the products. Of particularly importance is the spatial aspects of demand, and, how these have changed over time. Ultimately, any spatial optimization model requires demand estimates by region as a point of departure for the analysis. The purpose of this study was to econometrically analyze the spatial demand for container shipments in the United States.

6.1 Summary of results: There are several aspects of spatial demand for containers that are econometrically important. One is that only some BEAs have non-nil demands for containers. The other is that shipments may occur to one BEA which ultimately may be demanded by contiguously located BEAs. The implication of these is that the estimation has to capture the non-nil demands using a tobit specification, as well as the spatial interdependence amongst BEAs. Each were included in the specification estimated in this study.

The results indicated that container demand is highly dependent on the demographic characteristics, railroad competition and spatial attributes of the BEA. Specifically, container demand is positively impacted by population and income, and inversely impacted by geographical area. It is also positively related to the number of railroads operating in the BEA. Thus, simply, BEAs with large population, higher incomes and a more than 1 railroad operating in the BEA have greater demand for containers than otherwise. Lastly, port-area-BEAs have stronger demands reflecting demands for trans-shipment to off-shore markets. These results are revealing and explain why many BEAs have nil demand for containers.

The results also indicate that spatial interdependence is very important. Specifically, the spatial lag indicates that container demand not only depends on the BEA region attributes, but also on those characteristics of adjacent BEAs. The estimated container demand model indicates that an increase in shipments to a given BEA has also the impact of reducing shipments to other BEAs. The size of the impact depends on the distance between the regions. Moreover, the longitude and latitude variables indicate that all else being the same there is greater demand and the south and westerly located BEAs.

6.2 Implications for spatial optimization models: Nearly any specification of a spatial optimization model to evaluate spatial competition in container shipments requires estimates of demand. The model itself would determine optimal flows (which differs from Blonigen and Wilson who estimate flows.

The spatial optimization model would propose to use projections based on these results as the measures of demand. It could be re-estimated with other potential right hand side variables, but these would likely be mostly fine tuning of the econometric specification. Most important however would be to proceed as follows:

1) Estimates of population and income would be taken from Department of Commerce projections, by BEA;

2) These would be combined with results of the econometric model to generate projections of demand for containers, by BEA for varying periods in the future.

3) Error terms of these projections would be extracted and used as a measure of error. Somehow the spatial autocorrelation impact would need to be captured.

There are three outstanding issues that would need to be investigated further. One is that these are demands for containers received by rail. They do not include the impacts of truck delivery of containers. It is commonly recognized that up to 20-40% of outbound shipments from ports of containers are by truck (as reported in Wilson and Dahl 2008a). The exact percentage of these vary by port and are only estimates. These could be refined further through interviews with port officials. However, the decimation of these truck shipments would be more elusive.

Second, while the estimating model for containers is econometrically well-behaved and provide good statistical results that for trailers is less clear. This may simply be the results and they should be interpreted accordingly. Or, additional estimation could be pursued. However, it is important that trailers are of relatively lesser importance, and declining importance.

Third, the demand model results are not clear in terms of their interpretation at port-area-BEAs. The impacts of these are shown above. Strictly, demand for containers at port area BEAs are in part for local consumption, and in part for off-shore exports. It is not clear how to reconcile these values. Most likely would be to proceed as by deriving the amount of containers shipped in to a port-area BEA, and deducting the number of containers exported from the port-area BEA. This difference could be used to reflect the BEA demand for local consumption.

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Appendix:

Data Sources

BEA Economic Areas (BEAs) BEA's economic areas define the relevant regional markets surrounding metropolitan or micropolitan statistical areas. They consist of one or more economic nodes - metropolitan or micropolitan statistical areas that serve as regional centers of economic activity - and the surrounding counties that are economically related to the nodes. The economic areas were redefined on November 17, 2004, and are based on commuting data from the 2000 decennial population census, on redefined statistical areas from OMB (February 2004), and on newspaper circulation data from the Audit Bureau of Circulations for 2001.

Table A1 Variable Definition and Data Sources

Data Category	Data Element Detail			
	Variable	Variable Concept	Description	Data Source
Market Size/Railroad Traffic	tbeanumberofcontainers	Measure traffic volume of containers (COFC) terminating in the BEA	Number of containers terminating in the BEA	STB
	tbeanumberoftrailers	Measure traffic volume of trailers (TOFC) terminating in the BEA	Number of trailers terminating in the BEA	STB
	tbeaallcontainerstrailers	The total container and trailer traffic terminating in the BEA	Number of containers and trailers terminating in the BEA	STB
Logistical Characteristics	numofterminatingrrs	Measure of number of operating railroads in the terminating BEA which terminated a container or trailer in the terminating BEA for that year		STB
	Bnsf,cprs,cn,csxt,up,ns,cr	Measures if a particular railroad operates in the terminating BEA	Boolean variable. A value of 1 in the variable means the railroad operates in the terminating BEA	STB
BEA demography	beapopulation	Measure of BEA population	Department of Commerce's estimated population in BEA	Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce. Table CA1-3 April 2007
	tbeaarea	Measure of BEA geographical size	Area, in square miles, of the BEA	National Transportation Atlas Database (NTAD), 2005

Data Category	Data Element Detail			
	Variable	Variable Concept	Description	Data Source
	tbeapopulationdensity	Measure of BEA population density	Number of people per square mile in the BEA	Calculated: NTAD; Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce. Table CA1-3 April 2007
BEA Economics	beafullandparttimeemployment	Measure of BEA employment	Full and part time employment as measured by the Bureau of Economic Analysis	Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce. Table CA30 April 2007
	beapersonalincome	Measure of personal income in BEA	Total personal income for the BEA	Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce. Table CA1-3 April 2007
	beapersonalincomegrowthrate	Measure of personal income growth in BEA	Growth rates from the previous year of personal income in the BEA	Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce. Table CA1-3 April 2007

Data Category	Data Element Detail			
	Variable	Variable Concept	Description	Data Source
	Avg_annualgrowthrate1969to2005_	Measure of average annual personal income growth from 1969 to 2005	Long term annual personal income growth rate for the BEA	Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce. Table CA1-3 April 2007
	beapercapitapersonalincome	Measure of personal income per person in BEA	Per Capita income in BEA	Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce. Table CA1-3 April 2007
BEA Economics	beapercapitapercentofUS	Comparative measure of BEA's per capita personal income	BEA's per capita personal income as a percentage of the U.S. per capita personal income	Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce. Table CA1-3 April 2007
	beacountynumberofemployees	Measure of employment using annual County Business Patterns data from the U.S. Census Bureau	Number of employees as measured by the annual County Business Patterns aggregated to the BEA level.	U.S. Census Bureau, Economic Planning and Coordination Division, Register Analysis Branch http://www.census.gov/epcd/cbp/view/cbpview.html

Data Category	Data Element Detail			
	Variable	Variable Concept	Description	Data Source
	beacountynumberofestablishments	Measure of business establishments using annual County Business Patterns data from the U.S. Census Bureau	Number of business establishments as measured by the annual County Business Patterns aggregated to the BEA level.	U.S. Census Bureau, Economic Planning and Coordination Division, Register Analysis Branch http://www.census.gov/epcd/cbp/view/cbpview.html
	beacountyannualpayroll	Measure of business payrolls using annual County Business Patterns data from the U.S. Census Bureau	Number of business payrolls as measured by the annual County Business Patterns aggregated to the BEA level.	U.S. Census Bureau, Economic Planning and Coordination Division, Register Analysis Branch http://www.census.gov/epcd/cbp/view/cbpview.html
BEA Infrastructure	beanumberofterminals	Measure Intermodal infrastructure	Estimated number of intermodal terminals in the tbea	Railroad web pages, IANA, Railway Guide LoadMatch.com
	beainterstatemiles	Measure Highway Intermodal infrastructure	Interstate mileage in the tbea	NTAD 2004

Department of Commerce Table Footnotes:

Footnotes for Table CA1-3

1. Census Bureau midyear population estimates. Estimates for 2000-2005 reflect county population estimates available as of March 2007.

2. Per capita personal income was computed using Census Bureau midyear population estimates. Estimates for 2000-2005 reflect county population estimates available as of March 2007. See footnote 1.

3. Estimates for 1979 forward reflect Alaska Census Areas as defined by the Census Bureau; those for prior years reflect Alaska Census Divisions as defined in the 1970 Decennial Census. Estimates from 1988 forward separate Aleutian Islands Census Area into Aleutians East Borough and Aleutians West Census Area. Estimates for 1991 forward separate Denali Borough from Yukon-Koyukuk Census Area and Lake and Peninsula Borough from Dillingham Census Area. Estimates from 1993 forward separate Skagway-Yakutat-Angoon Census Area into Skagway-Hoonah-Angoon Census Area and Yakutat Borough.

4. Virginia combination areas consist of one or two independent cities with populations of less than 100,000 combined with an adjacent county. The county name appears first, followed by the city name(s). Separate estimates for the jurisdictions making up the combination areas are not available.

5. La Paz County, AZ was separated from Yuma County on January 1, 1983. The Yuma, AZ MSA contains the area that became La Paz County, AZ through 1982 and excludes it beginning with 1983.

6. Cibola, NM was separated from Valencia in June 1981, but in these estimates, Valencia includes Cibola through the end of 1981.

7. Shawano, WI and Menominee, WI are combined as Shawano (incl. Menominee), WI for the years prior to 1989.

8. Broomfield County, CO, was created from parts of Adams, Boulder, Jefferson, and Weld counties effective November 15, 2001. Estimates for Broomfield county begin with 2002.

- All state and local area dollar estimates are in current dollars (not adjusted for inflation).

- (N) Data not available for this year.

Regional Economic Information System
Bureau of Economic Analysis
Table CA1-3
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