New Measures of Port Efficiency Using International Trade Data

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Abstract. As the clearinghouses for a major portion of the world's rapidly increasing international trade flows, ocean ports and the efficiency with which they process cargo have become an ever more important topic. Yet, there exist very little data that allow comparisons of efficiency measures of any kind across ports and, especially, over time. This paper provides a new statistical method of uncovering port efficiency measures using U.S. Census data on imports into U.S. ports. Unlike previous survey-based measures, this study's methodology can provide such estimates for a much broader sample of countries and years with little cost. Thus, such data can be used by future researchers to examine a myriad of new issues, including the evolution of port efficiencies over time and its effects on international trade flows and country-level growth.

INTRODUCTION

As the clearinghouses for a major portion of the world's rapidly increasing international trade flows, ocean ports and the efficiency with which they process cargo have become an ever more important topic. Poorly-performing ports can substantially reduce trade volumes and may have a greater dampening impact on trade for small, less-developed countries than many other trade frictions. [Clark et al. *(1)* and Wilson et al. *(2)*] Disruptions to U.S. ports, such as the recent congestion issues at the ports of Los Angeles and Long Beach, quickly become national news because they can substantially impact supply chains throughout the country.[MacHalaba *(3)*] Local governments and port authorities are perhaps the most concerned with port efficiency, as ports compete with each other for cargo volume.

Despite the obvious significance of port efficiency, consistent and comparable measurement of such efficiencies is a daunting task. A myriad of factors contribute to port efficiency. Some of the more obvious factors include dock facilities, connections to rail and trucking lines, harbor characteristics (including channel depth and ocean/tidal movements), time to clear customs, and labor relations. However, both consistent data and methods that allow construction of a measure or index that allows comparisons across ports are not currently available. As Bichou and Gray *(4)* state,

> "Although there is widespread recognition of the potential of ports as logistic centres, widely accepted performance measurements for such centres have yet to be developed … Ports are very dissimilar and even within a single port the current or potential activities can be broad in scope and nature, so that the choice of an appropriate tool of analysis is difficult" (p. 47).

Not surprisingly, there are very little data that allow comparisons of port efficiency, especially, over time.

Of the studies that attempt to construct measures, a common methodology is through the use of surveys. A recent indicator of port efficiency has been constructed from annual firm-level surveys for the years 1995 through 2000 and reported in the Global Competitiveness Report *(5)*. These surveys ask firms to rank countries' port efficiency from 1 to 7, where 1 indicates that the firm strongly disagrees with the statement "Port facilities and inland waterways are extensive and efficient", whereas 7 indicates the firm strongly agrees with the statement. Other studies have used these measures and found that the measures have a strong and significant effect on trade. [Clark et al. *(1)* and Wilson et al. *(2)*] Similarly, Sanchez et al. *(6)* uses survey data on port efficiency to examine transports costs to Latin American ports and finds that such measures are substantial components of these transport costs and have an impact on trade flows that is similar in magnitude to that of distance.

Besides studies based on country-level survey measures of foreign port efficiencies, the U.S. Army Corps (ACE) also conducts approximately ten-year surveys of all facility locations in U.S. ports, including information on depth, berthing distance to wharf, and railway connections. To our knowledge, no one has used these data to develop measures of port efficiency. A major difficulty would be aggregation of data across facilities/docks at a port since no volume measures are given for each facility/dock. The surveys also occur infrequently which also gives little time series information on how the port facilities evolve over time.

In summary, these prior studies and data collection efforts make important contributions to an understanding of the role of port efficiency, but suffer from some key drawbacks. First, they rely on impressions of survey participants where observations of port efficiencies *per se* may be confounded with other factors connected with the country of the port's location. Second, these surveys have only been administered at a point in time or for a small window of time. Thus, there is almost no information on how port efficiencies evolve over time.

This paper provides a new method of uncovering port efficiency measures using U.S. Census data on imports into U.S. port districts (hereinafter referred to as "ports"). Our starting point is the information contained in the measure of "import charges" incurred by the goods in transit, as reported in the U.S. Census data. More specifically, the U.S. Census defines import charges as:

> "…the aggregate cost of all freight, insurance, and other charges (excluding U.S. import duties) incurred in bringing the merchandise from alongside the carrier at the port of exportation – in the country of exportation – and placing it alongside the carrier at the first port of entry in the United States."

These import charges consist of three primary components: 1) costs associated with loading the freight and disembarking from the foreign port, 2) costs connected with transportation between ports, and 3) costs associated with U.S. port arrival and unloading of the freight. Component 1 is directly related to the foreign port's efficiency, at least for the portion of the port services connected with loading freight and efficient disembarking of ships. There are undoubtedly other foreign port services and attributes that are not included in this import charges measure. However, to the extent that the efficiency of these non-included services is strongly correlated with the efficiency of the included services, component 1 of import charges should be a good measure of overall foreign port efficiency. In analogous fashion, U.S. port efficiencies are directly connected to component 3 of import charges. Component 2 costs, connected with transportation between ports, are identified with a few observable factors. Namely, ocean freight costs have been found to be highly correlated with distance, while insurance costs correlate with value per weight of the product (e.g., see Clark et al. *(1)*, pp. 8-9).

This study implements a simple statistical analysis to disentangle and separately identify the effect of these three components. Namely, a regression of import charges on distance measures, weight and value of the product, and other observables described in the next section, remove component 2 effects and leave components 1 and 3 in the error term along with random white noise. Identifying components 1 and 3 can be accomplished through the introduction of "fixed effects" for the U.S. and foreign ports. In particular, there are repeated shipments to many U.S. ports in a given year for a given product originating from the same foreign port, we can include a dummy variable (fixed effect) for each foreign port and uncover its underlying contribution to import charges. Likewise, with multiple observations for each U.S. port for a given year and a given product, a dummy variable (fixed effect) will uncover each U.S. port's underlying contribution to import charges. These port fixed effects provide measures of port efficiencies. That is, as a port's contribution to import charges (i.e., the costs of getting the products to the docks and unloaded) increases, costs increase, and, thus, will be inversely related to the port's efficiency.

Estimation of these measures of U.S. and foreign port efficiencies allow the construction of efficiency measures and a ranking of ports by efficiency. These estimates are then compared with the rankings with the few "survey-based" studies that offer rankings of foreign ports. These comparisons yield statistical correlations that suggest the model is, indeed, picking up efficiencies for foreign ports, and we assert for domestic ports. Unlike previous studies, the approach also allows for a time series analysis of the data that allows dynamic measures and comparions of efficiencies over time i.e., from 1991 through 2003.

The rest of the paper proceeds as follows. The next section provides details of the statistical methodology to uncover U.S. and foreign port efficiency and describes our data. The following section provides our results including new efficiency rankings of U.S. and foreign ports, comparison to previous rankings, and an analysis of changes in rankings over time.

METHODOLOGY AND DATA

The statistical methodology follows Clark et al. *(1)*, with important modifications to uncover U.S. and foreign port fixed effects – the measures of U.S. and foreign port efficiencies. The base model estimated is given by equation (1) although different measures (i.e., functional forms, characterizations of variables, etc. yield comparable effects). The base model is:

$$IC_{ijkt} = \alpha + \beta_1 Dist_{ij} + \beta_2 Wgt_{ijkt} + \beta_3 Valwgt_{ijkt} + \beta_4 Cont_{ijkt} + \beta_5 Vol_{ij} + \eta_i + \theta_j + \gamma_k + \tau_t + \varepsilon_{ijkt}. \quad (1)$$

IC_{ijkt} represents import charges and is specified in logarithm form, where (i) indexes U.S. ports, (j) indexes foreign ports, (k) indexes 2-digit Harmonized System (HS) products, and (t) indexes year. $Dist_{ij}$ is the logarithm of nautical miles between port (i) and (j) and is expected to have a negative coefficient (β_1) as freight charges increase with distance transported. Wgt_{ijkt} is the logarithm of weight for product (k) transported between ports (i) and (j) in year (t) and is expected to be directly correlated with freight costs and, thus, have a positive sign for β_2. $Valwgt_{ijkt}$ is the U.S. dollar value of the shipments divided by its weight in kilos in logarithm form. Holding weight constant, a higher value of the product per unit is expected to increase insurance costs, and thus, is expected β_3 should have a positive sign as well. $Cont_{ijkt}$ is the percent of shipments between port (i) and (j) for product (k) in year (t) that use container ships. Container shipments are expected to be less costly, and therefore, β_4 should have a negative sign. Vol_{ij} is the total volume of trade in kilos across all products over our sample years between port (i) and (j) in logarithm form. Economies of scale arguments would suggest a negative sign for β_5, while congestion effects would suggest a positive sign.

The final sets of estimated parameters are the model's fixed effects – sets of dummy variables. η_i is the set of fixed-effects parameters that estimate the separate impact of each U.S. port on import charges holding all other factors constant. These represent the estimated measures of U.S. port efficiencies, with lower coefficients suggesting a more efficient port. In analogous fashion, θ_j are the foreign port fixed-effects parameters and identify foreign port efficiencies. γ_k are product fixed-effects that control for other (unobserved) characteristics of products beyond value per weight that affect import charges differently across products. τ_t is a set of year effects that capture macroeconomic and technological shocks to import charges. Finally, ε_{ijkt} is assumed to be a random, white-noise error term. One effect is excluded from each set of fixed effects to avoid perfect multicollinearity with our constant term, α.

The data used in this analysis are from two sources both provided by the National Data Center (NDC) of the Army Corps of Engineers (ACE). ACE maintains public-use trade data comparable to the U.S. Census IA 245 files. These data are generated from Census files and matched to Customs vessel entrances/clearances for more complete and accurate vessel and U.S. port data. This data set is used to construct IC_{ijkt}, $Valwgt_{ijkt}$, $Cont_{ijkt}$, and Vol_{ij} measures over all the years available with the necessary data - 1991 through 2003.

ACE has also developed a preliminary databank containing port-to-port nautical miles. There are 375 different US ports in these data which connect to 1789 different ports. This data set is used to construct the distance ($Dist_{ij}$) variable. Merging these distance data into the trade data was problematic since the files did not have common U.S. port codes. The authors developed a correspondence between the two datasets for these U.S. port codes in order to merge the data.

The combined database contained well over one million observations per year, where the unit of observation is a U.S. port, foreign port, a six-digit HS product code and year. The data were refined in a number of ways to overcome computation difficulties with such a large database. First, the data were aggregated to the two-digit product code, reducing the number of observations over the entire sample to approximately 1.5 million observations. Second, the number of ports in the database was limited, since only a subset of ports account for the vast majority of activity. For the U.S. ports, the sample was limited to the top 50 ports by import volume (measured in dollar value), which account for over 97% of all trade activity. Finally, the sample was to the top 100 foreign ports by import volume which covers over 81% of all trade activity. The final data sample used for estimation of our model has over 500,000 observations.

The main difference with the specification employed in this paper and that employed in Clark et al. *(1)* is the estimation of foreign port efficiencies with fixed effects. Clark et al. *(1)* does not estimate these, but instead includes survey measures of foreign port efficiencies reported in *(5)* (GCR measures) as a regressor in their specification. In other words, the difference is that, in the present study, the import charge data reveal foreign port efficiencies, whereas Clark et al. *(1)* use an external data source. There are two main strengths of the fixed effect model relative to the GCR measure of foreign port efficiencies. First, foreign port efficiencies are measured by year for as many years as the trade data exist, whereas the GCR measure is only reported beginning in 1995. Second, the GCR measure is only available for a limited set of countries (approximately 50), whereas we can estimate such measures for all foreign ports. As in this study, Clark et al. *(1)* include U.S. port fixed effects in its specification. However, Clark et al. *(1)* do not report these, nor do they make the link of using these as measures of U.S. ports' efficiencies.

On a more technical note, Clark et al. *(1)* specify their dependent variable as the logarithm of import charges *divided by the weight of the product.* The study also combines the value and weight regressors into one variable by taking the logarithm of the ratio of value to weight. An obvious statistical concern with this is that the value to weight regressor is endogenous with the dependent variable as they both contain the weight variable. For this reason, the present study does not use ratios of the variables.

The main difference between our data sample and that of Clark et al. *(1)* is that while they examine a 1998 cross-section of the trade data for 6-digit HS products, while the present study examines data form 1991 through 2003 for 2-digit HS products. As shown below, this approach provides port efficiencies over time and allows an examination of how port efficiencies evolve over time.

A final issue is the role of market power in determining import charges, either from ports or carriers. Estimation of the specification in (1) is based on a model of marginal costs of transporting merchandise and handling shipments. For example, as noted by Clark et al. *(1)*, it's possible that two different ports may have identical efficiencies, but one port charges more in fees due to greater market power. Clark et al. *(1)* include measures of market power, including information on price-fixing agreements and cooperative agreements between ports and carriers, and found that they did not provide any significant explanatory information for import charges. We will maintain the assumption of competitive ports and leave the investigation of market power influences for future research.

RESULTS AND PORT EFFICIENCY ESTIMATES

OLS is applied to equation (1), and Column 1 of TABLE 1 provides the results for the full sample from 1991 through 2003. Before focusing on the estimates for the port fixed effects (our measures of port efficiencies), a short discussion of the overall fit and efficacy of the model is provided.

The fit of the model to the data is quite high with an R^2 statistic of 0.92, indicating that our model explains 92% of the variation in import charges. The separate control variables

TABLE 1: OLS Estimates of Determinants of Import Charges for U.S. Imports, 1991-2003.

	Full Sample	Select Years in Sample		
Regressors		1991	1997	2003
Dist	0.137*	0.156*	0.145*	0.054*
	(0.004)	(0.011)	(0.013)	(0.017)
Wgt	0.932*	0.927*	0.927*	0.940*
	(0.0004)	(0.001)	(0.001)	(0.001)
Valwgt	0.470*	0.478*	0.468*	0.460*
	(0.001)	(0.004)	(0.004)	(0.005)
Cont	0.035*	0.021*	0.020*	0.056*
	(0.001)	(0.003)	(0.003)	(0.005)
Vol	0.020*	0.013*	0.018*	0.013*
	(0.001)	(0.004)	(0.004)	(0.005)
U.S. Port Fixed Effects	Yes	Yes	Yes	Yes
Foreign Port Fixed Effects	Yes	Yes	Yes	Yes
Product Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
R^2	0.92	0.94	0.93	0.90
F-statistic	23444.6	2586.9	2386.4	1577.7
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	544,710	38,010	42,436	544,710

*Notes: * indicates significance at the 1% level. A constant intercept term was included, but is not reported.*

reported in TABLE 1 are all statistically significant at the 1% level. In addition, F-statistics confirm the statistical significance for each of our sets of fixed effects at the 1% significance level.

In general, the control regressors separately listed in TABLE 1 have expected signs and conform to results from previous studies. Given these control regressors are in logarithm form, the coefficients on these regressors can be read as elasticities. Distance is positively correlated with import charges with a coefficient of 0.137. Thus, these estimates suggest that a 10% increase in distance increases import charges by 1.37%. This is consistent with previous studies in that there is not a one-to-one increase in import charges with distance. Weight and value per unit (Valwgt) are also positively correlated with import charges. Import charges increase almost one-to-one with weight as indicated by a coefficient of 0.932. The coefficient estimate on Valwgt means that a 10% increase in the value per kilo increases import charges by 4.7%. Unexpectedly, the effect of containers is positive in this model although the magnitude is small. The estimated coefficient indicates that a 10% increase in the percent of the cargo by container increases import charges by 0.35%. There are a couple possible explanations. First, the efficiency gains from container shipments may come primarily from the easier handling after the cargo has been unloaded. Again, import charges do not cover costs before or after the cargo is unloaded in the ports. A second possibility is that even though container shipping is theoretically less costly, the costs associated with the bigger ships that have been spawned from this innovation may outweigh this given the current state of ocean port infrastructure to adequately handle these vessels. The final control variable (besides our fixed effects) is the volume measure which displays an estimated positive correlation with import charges, suggesting that congestion effects outweigh economies of scale. The magnitude of this effect is also fairly small, with a 10% increase correlated with a 0.2% increase in import charges.

Columns 2 through 4 of TABLE 1 provide separate estimates of our model for select years of our sample to examine the stability of parameter coefficients over time. Weight, Valwgt, and Vol are extremely stable over time and change very little across samples. The effect of distance on import charges declines some over time though continues to be positively correlated with import charges. The effect of container vessels on import charges rises slightly over time. This would be consistent with the notion that ports have become less able to efficiently handle the ever-larger container ships over the latter years of our sample. However, it is clear that the model fits the data well throughout the sample with quite stable coefficient estimates.

Estimated Port Efficiency Measures

U.S. Port Efficiencies Measures

As indicated in TABLE 1, the model also provides for sets of fixed effects for U.S. ports, foreign ports, products, and years in the regressions, and each of these sets of fixed effects are jointly statistically different from zero at the 1% significance level in all regressions. Column 1 of TABLE 2 provides our estimates of U.S. port fixed effects from the OLS results using our entire sample and ranks them from most efficient to least efficient port. These port fixed effects coefficients provide estimates of a port's impact on import charges that are independent from other variables included in our regression. The inclusion of product fixed effects in our regression, for example, means that the port fixed effects should be free of bias from differences

TABLE 2: U.S. Port Efficiencies

Port Name	Port Fixed Effects: Efficiencies Relative to Boston	Port's Market Share of U.S. Import Volume Over Sample Years (percent)	Change Over Sample Years in Port Efficiency Relative to Boston
Port Arthur, TX	-0.495	0.71	-0.710
Providence, RI	-0.453	0.21	-1.663
Beaumont, TX	-0.447	0.96	-0.682
Paulsboro, NJ	-0.387	0.42	-0.155
Morgan City, LA	-0.333	0.86	-0.472
Marcus Hook, PA	-0.239	0.20	NA
Baton Rouge, LA	-0.235	0.68	-0.199
Texas City, TX	-0.233	0.69	-0.285
Corpus Christi, TX	-0.226	1.21	-0.043
Gramercy, LA	-0.198	0.17	NA
Freeport, TX	-0.176	0.54	0.080
Pascagoula, MS	-0.167	0.43	0.085
New Haven, CT	-0.117	0.17	-0.108
Port Hueneme, CA	-0.117	0.77	-0.248
Richmond, CA	-0.113	0.27	-0.195
St. Croix, VI	-0.112	0.70	0.597
Gulfport, MS	-0.108	0.22	-0.153
Mobile, AL	-0.099	0.39	-0.077
Chester, PA	-0.097	0.46	-0.033
San Francisco, CA	-0.093	0.27	-0.135
Galveston, TX	-0.062	0.31	-0.176
Portland, OR	-0.056	1.42	-0.138
Port Huron, MI	-0.054	0.34	-0.522
Newport News, VA	-0.053	0.33	-0.036
Wilmington, DE	-0.048	0.65	-0.373
Lake Charles, LA	-0.037	0.65	-0.061
San Diego, CA	-0.027	0.51	-0.057
Brunswick, GA	-0.025	0.53	-0.009
Philadelphia, PA	-0.021	1.60	-0.093
New Orleans, LA	-0.016	1.92	-0.173
Detroit, MI	-0.016	0.32	-0.058
Boston, MA	0.000	1.00	0.000
Jacksonville, FL	0.004	1.67	-0.135
Port Everglades, FL	0.007	1.01	-0.194
Houston, TX	0.009	4.08	-0.079
Baltimore, MD	0.019	3.18	-0.187
Oakland, CA	0.021	3.82	-0.103
Savannah, GA	0.023	2.04	-0.101
Wilmington, NC	0.035	0.31	0.011
Charleston, SC	0.042	3.64	-0.084

Long Beach, CA	0.057	14.91	-0.042
Los Angeles, CA	0.057	15.96	-0.052
Norfolk, VA	0.059	2.82	-0.059
Miami, FL	0.063	1.59	-0.125
Tampa, FL	0.065	0.19	0.086
Seattle, WA	0.083	5.32	-0.139
NY & NJ	0.086	12.07	-0.043
Tacoma, WA	0.090	3.62	-0.142
San Juan, PR	0.298	0.68	-0.097
Honolulu, HI	0.606	0.29	0.052

Notes: "NA" indicates that this figure is not available for this port, since it did not have an estimated port fixed effect for one of the years.

in the mix of products a port handles. The lower (or more negative) the coefficient, the lower the U.S. port's effects on import charges all other variables held constant and, thus, the more efficient the port.

To avoid perfect collinearity with the constant term, the Port of Boston was excluded from the set of U.S. port fixed effects. Parameter estimates are, therefore, relative to the Port of Boston's effect on import charges. Given the dependent variable is in logarithm form, the coefficients in column 1 are approximately equal to the percentage difference (in decimal form) in the port's effect on import charges relative to the Port of Boston effect. For example, a coefficient of -0.02 indicates that the component of import charges connected with that port is roughly 2% less than the same port costs in the Port of Boston. All of the estimated port fixed effects are statistically different from zero at the 5 percent significance level, except for the ports of Brunswick, Jacksonville, New Orleans, Lake Charles, San Diego, Detroit, Port Everglades, and Houston. In other words, the hypothesis that these listed ports have the same average efficiency as the Port of Boston over our sample period, 1991-2003, cannot be rejected.

An examination of the U.S. port fixed effects estimates reveals that many of the Gulf of Mexico ports rank in the upper half of the list, with Port Arthur, Texas topping the list with a coefficient of -0.49. The island ports of Honolulu, Hawaii and San Juan, Puerto Rico are essentially outliers at the bottom of the list in terms of efficiency with coefficients of 0.298 and 0.606, respectively. Interestingly, some of the larger ports, including Seattle, Long Beach, Los Angeles, and New York/New Jersey rank in the bottom half of the efficiency ratings. (Column 2 lists the port's share of total U.S. import volume handled over the sample so that one can see this more clearly). There is a positive correlation between market shares and our estimated port efficiency estimates of 0.27, though this is only significant at the 6% level. Overall, there is a significant range of estimated port efficiencies. Only 16 of the 50 ports are within 0.050 of the Port of Boston; that is, within 5% of the Port of Boston's impact on import charges. The standard deviation in the estimated port efficiency coefficient is 0.182.

As indicated throughout this paper, an important feature of this study's new method of estimating port efficiencies is the ability to derive such estimates for each port over time – not just a cross-sectional comparison. As an example of the benefit of this time series element, Column 3 of TABLE 2 provides the change in the U.S. port's fixed effect coefficient over the sample years relative to the Port of Boston's effect on import charges. These come from subtracting the port's average fixed effect for the initial three years of 1991 through 1993 from the port's average fixed effect from 2001 through 2003. A negative coefficient indicates that the port became more efficient relative to the Port of Boston over this period, whereas a positive coefficient indicates that it became less efficient.

Most of the U.S. ports gained in efficiency relative to Port of Boston over this period, as indicated by the negative sign of change measure in column 3. In fact, the market-share-weighted average change relative to Boston was -0.10 over the 1991-2003 period. Thus, everything else equal, an import shipment to Boston cost 10% more in import charges relative to other ports in the early 2000s than in it did in the early 1990s. Gulf of Mexico ports consistently gained in efficiency relative to Boston over this period, whereas other East coast ports, such as New York/New Jersey, Charleston, and Philadelphia gained relatively less. Los Angeles and Long Beach, the two largest ports in the U.S. also did not gain in efficiency relative to Boston over this period, whereas Seattle and Tacoma saw significant port efficiency gains.

To get a more detailed view of time series changes, FIGURES 1, 2 and 3 plot out port efficiency coefficients (relative to Boston) on an annual basis for certain select ports. FIGURE 1 shows plots for West Coast ports, FIGURE 2 shows plots for Gulf of Mexico ports, and FIGURE 3 shows plots for East Coast ports. A common trend in all three graphs is for all ports to make significant gains in efficiency relative to Boston for a number of years after 1999. This seems to be associated with substantial difficulties at the Port of Boston during this period, including labor disruptions and the loss of major shiplines. [Boston Herald *(7)*] Noteworthy patterns in West Coast port efficiency include how closely the estimated efficiencies of Long Beach and Los Angeles track each other, and that San Francisco is estimated to be more efficient than the other listed West Coast ports. For the Gulf of Mexico ports, New Orleans is estimated to have become slightly more efficient relative to Houston over time, while the East Coast ports relative rankings do not change much over our sample period.

FIGURE 1: West Coast Ports' Efficiencies Relative to Boston, 1991-2003

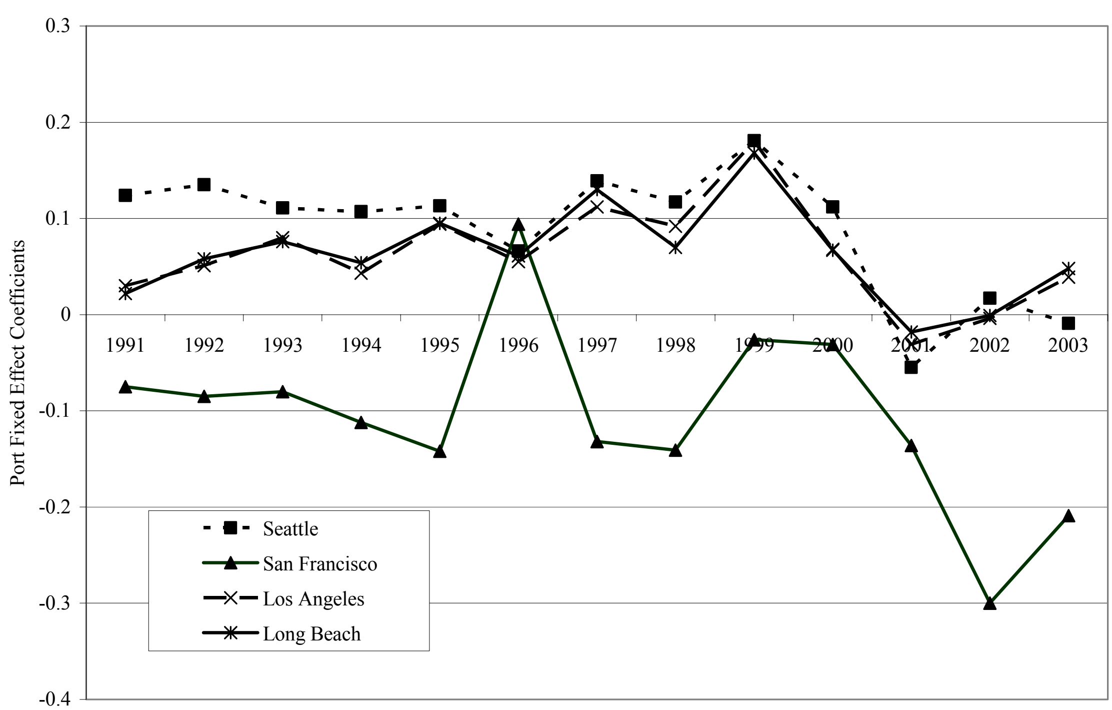


FIGURE 2: Gulf of Mexico Ports' Efficiencies Relative to Boston, 1991-2003

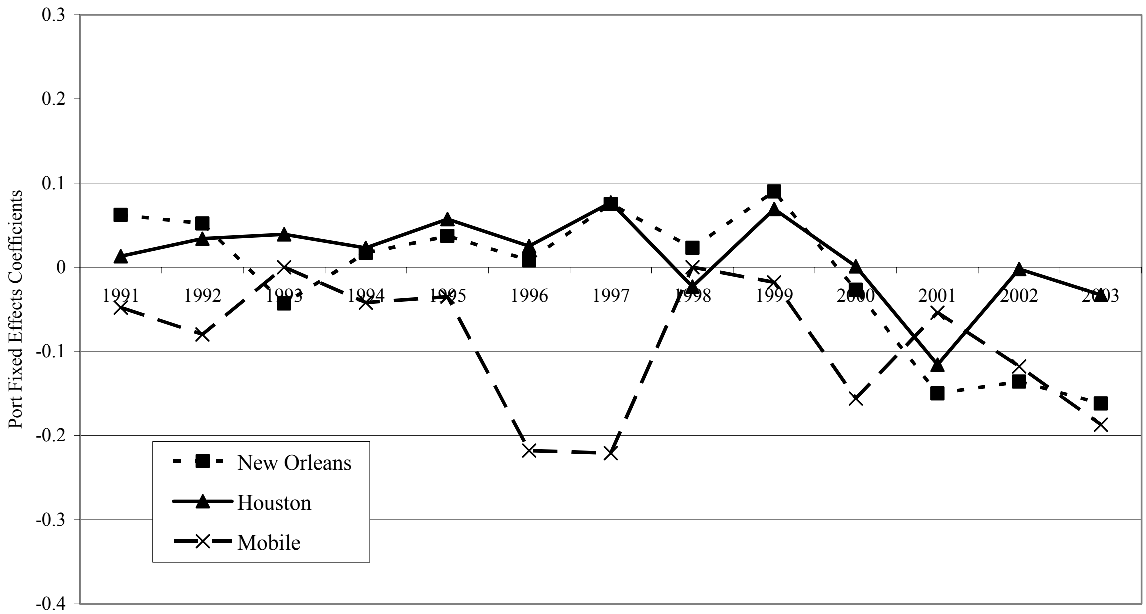
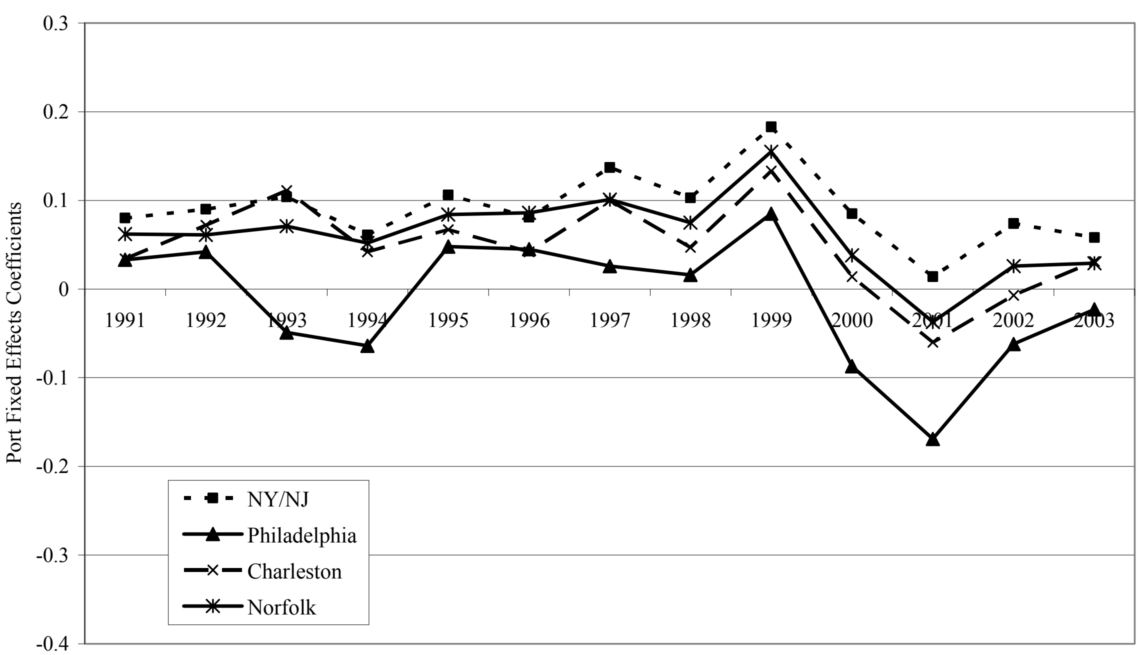


FIGURE 3: East Coast Ports' Efficiencies Relative to Boston, 1991-2003



Foreign Port Efficiencies Measures

Analogous to the estimated U.S. port fixed effects, the estimated foreign port fixed effects provide measures of foreign port efficiencies, where the smaller (or more negative) the coefficient, the more efficient the port relative to the port we exclude from our foreign port set – Windsor, Ontario, Canada. Column 1 of TABLE 3 provides our estimates of foreign port fixed effects from the OLS results using our entire sample and ranks them from most efficient to least efficient port. Column 2 of TABLE 3 lists the foreign port's market share of total U.S. imports, while column 3 of TABLE 3 provides the change in the foreign port's fixed effect coefficient from 1991 to 2003 relative to the Port of Windsor's (Canada) effect on import charges.

A number of obvious patterns emerge in the rankings of the foreign ports. First, despite the inclusion of product dummies, including one for oil and gas products (HS product code 27), the top-ranked ports in Column 1 of TABLE 3 are oil ports, even those from less-developed countries, such as Mexico and Nigeria. After these initial oil ports, the most-efficient ports are European and Japanese ports. These are followed generally by newly-industrialized countries in Southeast Asia, such as Taiwan and Korea. Finally, the least-efficient ports are primarily Central American and Chinese ports. With the exception of oil ports in Nigeria and one port in South Africa, no other African ports were in the top 100 in terms of U.S. import market share. As with the U.S. port efficiency measures, most are estimated to be statistically different from zero – the efficiency of the Windsor, Canada port by construction – at the 5% significance level or better.

Column 3 of TABLE 3 shows how estimated port efficiency measures changed over our sample period. As with the U.S. port data, the efficiency measure presented is the average port efficiency from 2001 through 2003 minus the average port efficiency from 1991 through 1993. With the exception of some of the oil ports, virtually all other ports are estimated to have lost in efficiency relative to Windsor, Canada over the sample years, as indicated by the positive numbers in column 3. The market-share-weighted average change in column 3 relative to Windsor is 0.269.

Comparing Our Foreign Port Efficiency Measures to the GCR Measures

As mentioned, previous literature has used the GCR measures as proxies for foreign port efficiency. While these measures are only available for certain countries, one can examine how comparable this study's measures are to the GCR measures by aggregating our port measures by country (using our import market shares as weights) and calculating a pairwise correlation. *(1)* reports and uses the GCR measures for the year 1998. An average country-level port efficiency measure for the 1997-1999 period using this study data is constructed, which yields 29 matches with the GCR data. The pairwise correlation is 0.14 between the two measures and not statistically significant. However, this study's primary data for Mexican and Venezuelan ports are oil ports which have very high efficiency ratings. When these two countries are eliminated, the correlation between this study's estimated measures of port efficiencies and the GCR measures is 0.44 and statistically significant at the 2% level. This suggests that this study's measures are capturing similar port efficiency effects to the GCR measures (with the exception of oil ports). In contrast, however, this paper's methodology can provide such port efficiency measures for many more years than the GCR data and for conceivably all foreign countries from which the U.S. imports.

TABLE 3: Foreign Port Efficiencies

Port Name	Port Fixed Effects: Efficiencies Relative to Windsor	Port's Market Share of U.S. Import Volume Over Sample Years (percent)	Change Over Sample Years in Port Efficiency Relative to Windsor
Point Tupper (CBI), Canada	-1.602	0.17	-2.328
Dos Bacas, Mexico	-0.607	0.36	0.456
Cayo Arcos, Mexico	-0.568	0.65	0.897
Kwa Ibo Termina, Nigeria	-0.504	0.32	-0.370
Forcados, Nigeria	-0.484	0.26	-0.146
Escravos Oil Terminal, Nigeria	-0.438	0.22	-0.014
Sarnia (Ont), Canada	-0.389	0.35	0.262
Sullom Voe, United Kingdom	-0.383	0.21	0.867
Pajaritos, Mexico	-0.306	0.59	-0.349
La Salina, Venezuela	-0.267	0.25	-0.134
Al Fuhayhil, Kuwait	-0.248	0.17	-0.560
Bonny, Nigeria	-0.246	0.22	-0.049
Al Bakir, Iraq	-0.241	0.35	0.177
Mongstad, Norway	-0.238	0.22	0.710
Arzew, Algeria	-0.197	0.23	0.447
All Other Venezuelan Ports	-0.155	0.61	0.081
Puerto La Cruz, Venezuela	-0.154	0.67	0.604
All Other Caribbean Ports	-0.142	0.36	0.327
Zeebrugge, Belgium	-0.129	0.19	0.109
Puerta Miranda, Venezuela	-0.112	0.21	0.344
High Seas, Gulf of Mexico	-0.057	1.05	-0.533
Yokosuka, Japan	-0.048	0.91	0.166
Amuay Bay, Venezuela	-0.044	0.38	0.320
Ras Tanura, Saudia Arabia	-0.043	1.09	0.573
Fos, France	-0.043	0.18	0.178
Emden, Germany	-0.035	0.67	0.038
Shimizu, Japan	-0.029	0.63	0.016
Osaka, Japan	-0.003	0.98	0.449
Windsor, Canada	0.000	0.18	0.000
All Other South Korea Ports	0.024	0.27	0.283
Liverpool, United Kingdom	0.027	0.4	0.145
Bremen, Germany	0.032	0.64	0.126
Rotterdam, Netherlands	0.037	2.24	0.252

Chiba, Japan	0.039	0.58	0.598
Antwerp, Belgium	0.042	2.32	0.293
Le Havre, France	0.045	1.18	0.248
All Other Japan Ports	0.045	0.66	0.255
Toyohashi, Japan	0.047	2.52	0.038
Yokkaichi, Japan	0.049	0.39	0.590
Hakata, Japan	0.049	0.26	0.329
Nagoya, Japan	0.051	3.27	0.246
Onsan, South Korea	0.053	0.32	0.435
Hamburg, Germany	0.059	0.53	0.259
Rio Grande, Brazil	0.060	0.22	0.210
St. Petersburg, Russia	0.062	0.3	-0.415
Haifa, Israel	0.069	0.31	0.174
Chi Lung, Taiwan	0.078	1.93	0.346
Tai Chung, Taiwan	0.084	0.25	0.402
Inchon, South Korea	0.084	0.22	0.346
Bremerhaven, Germany	0.087	4.03	0.279
Southhampton, United Kingdom	0.091	0.69	0.246
Kawasaki, Japan	0.093	0.21	0.560
Tokyo, Japan	0.093	4.21	0.227
Yokohama, Japan	0.098	2.78	0.277
Felixstowe, United Kingdom	0.099	1.01	0.237
Kobe, Japan	0.105	2.21	0.305
Rio de Janeiro, Brazil	0.105	0.19	0.076
Buenos Aires, Argentina	0.105	0.21	0.017
Goteborg, Sweden	0.110	0.72	0.182
Penang, Malaysia	0.113	0.49	0.229
Kelang, Malaysia	0.116	0.4	0.280
Saint John (NB), Canada	0.117	0.27	0.232
Rio Haina, Dominican Republic	0.120	0.26	0.016
Melbourne, Australia	0.122	0.22	0.011
Pusan, South Korea	0.123	2.74	0.406
Hiroshima, Japan	0.126	0.39	0.528
Kao Hsiung, Taiwan	0.128	2.54	0.339
Jahore, Malaysia	0.138	0.2	0.292
Sao Paulo, Brazil	0.138	0.64	0.115
Puerto Plata, Dom. Republic	0.146	0.17	-0.033
Singapore, Singapore	0.149	1.65	0.248
La Spezia, Italy	0.152	0.56	0.221
Veracruz, Mexico	0.155	0.31	0.161
Durban, South Africa	0.163	0.23	0.247

Genoa, Italy	0.165	0.5	0.271
All Other Thai Ports	0.170	0.23	0.329
Valencia, Spain	0.174	0.19	0.167
All Other Malaysia Ports	0.177	0.32	0.334
Mizushima, Japan	0.189	0.17	0.426
Karachi, Pakistan	0.201	0.28	0.182
Leghorn, Italy	0.214	0.54	0.259
All Other Indonesia Ports	0.215	0.19	0.271
Hong Kong, Hong Kong	0.219	9.31	0.380
Dalian, China	0.219	0.21	0.268
Limon, Costa Rica	0.222	0.31	0.143
Duran, Ecuador	0.239	0.2	-0.003
Colombo, Sri Lanka	0.240	0.28	0.185
Bangkok, Thailand	0.247	0.96	0.314
Laem Chabang, Thailand	0.254	0.42	NA
Dagu/Tanggu, China	0.260	0.3	0.263
All Other China Ports	0.270	0.98	0.408
Bombay, India	0.275	0.29	0.141
S. Tomas de Castillo, Guatemala	0.282	0.43	0.076
Jakarta, Indonesia	0.284	0.64	0.293
Ching Tao, China	0.287	0.33	0.286
Puerto Cortes, Honduras	0.298	0.44	0.301
Shanghai, China	0.303	2.04	0.305
Chittagong, Bangladesh	0.308	0.27	0.278
Yantian, China	0.337	1.84	0.644
Manilla, Philippines	0.423	0.7	0.325

Notes: "NA" indicates that this figure is not available for this port, since it did not have an estimated port fixed effect for one of the years.

CONCLUSION

This study provides new measures of ocean port efficiencies through simple statistical tools using U.S. data on import flows form 1991 through 2003. Unlike previous survey-based measures, this study's methodology can provide such estimates for a much broader sample of countries and years with little cost. Thus, such data can be used by future researchers to examine a myriad of new issues, including the evolution of port efficiencies over time and its effects on international trade flows and country-level growth.

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