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New Measures of Port Efficiency Using International Trade Data

by

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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 allows one to compare port 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 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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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., 2004, and Wilson et al., 2004). 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, 2004). 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 stated in a recent report to Congress by the U.S. Department of Transportation, Maritime Administration (MARAD),

“MARAD concluded that it was unable to provide the requested comparison of the most congested ports in terms of operational efficiency due to a lack of consistent national port efficiency data ... comparing port efficiency would require the creation of new methodologies and the collection of data that were not available for this report” (U.S. Department of Transportation, Maritime Administration, 2005, p. 8).¹

¹ This study is available from the “Publication” link at MARAD’s website: www.marad.dot.gov. Unavailability of port comparison measures is also echoed in the academic literature by Bichou and Gray (2004).

The levity of this concession by MARAD is difficult to understand as a main request of Congress for the report was for a comparison of port efficiency, not only for commercial reasons, but also for national security concerns in light of Operation Iraqi Freedom. This paper is a first attempt to provide a new methodology which is relatively simple and costless for the estimation of port efficiency over time.

The literature is not devoid of attempts to measure port efficiency. One 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. 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., 2004, and Wilson et al., 2004) Similarly, Sanchez et al. (2003) use survey data on port efficiency to examine transports costs to Latin American ports and find 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.²

Drawbacks of survey data are, 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, existing surveys of port efficiencies 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 from these studies.

² 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

An alternative methodology to measure port efficiencies, used by a number of studies is data envelopment analysis (DEA). This procedure uses data on inputs, outputs and production function theory to derive an estimate of the most efficient production frontier across a group of ports. This then allows a calculation of port efficiency based on deviations from this frontier. Examples include Roll and Hayuth (1993), Martinez-Budria et al. (1999), Tongzon (2001), and Estache et al. (2004).³ Drawbacks of this approach include, first, functional form assumptions that may not be correct. In particular, these methods typically assume constant returns to scale, though econometric evidence from production function estimates discussed below typically find economies of scale. A second drawback is that these methodologies do not generate any measure of error by which to gauge statistical confidence and are quite susceptible to bias from outliers. A third drawback is relatively strong data requirements of both inputs and output that are consistently measured across sample ports and time periods in the sample. This is a likely reason that most DEA studies are quite limited in the scope of ports analyzed.

Another alternative is econometric estimation of production/cost functions for ports which is found in a more limited number of studies. Estache et al. (2002) is an example of such a study and provides a review of previous analyses using these methodologies. While econometric estimation provides standard errors for its port efficiency measures in order to judge confidence in such measures, these studies suffer from similar difficulties with data requirements, particularly measurement of labor, capital and other inputs. As a result, such studies in the previous literature focus on only a handful of ports at a time and none that we are aware of have focused on U.S. ports.

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.

³ There is also a related literature on a similar methodology called Free Disposal Hull (FDH) and Wang et al. (2003) compares these methodologies in measuring container port production efficiencies.

In response to difficulties encountered by the previous literature, this paper provides an entirely new method of uncovering port efficiency measures using U.S. Census data on imports into U.S. port districts (hereinafter referred to as “ports”). This methodology is econometric-based, providing standard errors of our estimated port efficiency measures, and uses readily available and high-quality data to estimate port efficiencies across literally hundreds of ports over a lengthy number of years.

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. (2004), 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) 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. As mentioned above, unlike previous studies, the approach also allows for a time series analysis of the data that allows dynamic measures and comparisons of efficiencies over time; i.e., from 1991 through 2003.

The rest of the paper proceeds as follows. The next section provides details of our 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

Our statistical methodology follows Clark et al. (2004), 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:

$$IC_{ijkt} = \alpha + \beta_1 Dist_{ij} + \beta_2 Wgt_{ijkt} + \beta_3 Valwgt_{ijkt} + \beta_4 Cont_{ijkt} + \beta_5 Vol_{ijt} + \beta_6 Cont_{ijkt} \times Wgt_{ijkt} + \beta_7 Cont_{ijkt} \times Valwgt_{ijkt} + \beta_8 Im_Imbal_{ij} + \beta_9 Ex_Imbal_{ij} + \eta_i + \theta_j + \gamma_k + \tau_t + \varepsilon_{ijkt}. \quad (1)$$

IC_{ijkt} represents import charges and is specified in logarithm form, where (i) indexes U.S. ports, (j) indexes foreign ports, (k) indexes 6-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 positive 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_{ijt} is the total volume of trade in kilos across all products between port (i) and (j) for a given year (t) in logarithm form. Economies of scale arguments would suggest a negative sign for β_5 , while congestion effects would suggest a positive sign. The next two terms are interactions of our containerization variable with weight and value per weight terms to allow for the possible variation in efficiencies from containerization depending on how heavy or valuable the product is. The next two terms are included to account for trade imbalances between foreign and U.S. port pairs, as import charges may be higher if a ship is more likely to travel empty in one of the directions. Im_Imbal_{ij} is the logarithm of the difference between imports and exports when this difference is positive and “0” otherwise. Similarly, Ex_Imbal_{ij} is the logarithm of the difference between exports and imports when this difference is positive and “0” otherwise. We expect β_8 and β_9 to be positive and identical unless traveling into a U.S. port empty is systematically more or less costly than traveling out of a U.S. port empty.

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 .

It is important to stress what our fixed-effects measurements of port efficiency capture and how they may differ from other “efficiency” measures. Given how import charges are calculated, we are only capturing factors that affect the shipment costs that are connected with navigating the harbor and unloading the goods dockside. Efficiency of other port activities, particularly intermodal connections, are less likely to be captured. However, since import charges include port tariffs, we are also capturing any factors that affect these tariffs, such as port administration and financing efficiency. This begs the question why port tariffs are not an equally appropriate measure of efficiency. The answer is that such tariffs do not necessarily include costs associated with navigation of the harbor, tide restrictions, and other factors that can delay shipments into ports. We also note that such harbor and navigation costs do not factor into efficiency measures derived through DEA calculations of estimation of production or cost functions that only consider the use of dockside inputs (capital and labor typically) for the observed output. A port may be fully efficient once the ship is dockside, but a high-cost (hence, inefficient) port due to navigation difficulties, congestion, etc. This highlights another important advantage of our methodology.

The main difference with the specification employed in this paper and that employed in Clark et al. (2004) is the estimation of foreign port efficiencies with fixed effects. Clark et al. (2004) does not estimate these, but instead includes survey measures of foreign port efficiencies reported in GCR (various issues) -- henceforth, referred to as 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. (2004) uses 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. (2004) includes U.S. port fixed effects in its specification. However, Clark et al. (2004) does not report these, nor do they make the link to using these as measures of U.S. ports' efficiencies.⁴ Towards the end of the paper we compare our measurements of foreign port efficiencies with the GCR measures.

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. (2004), 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. (2004) included 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. Finally, to the extent that "larger" ports have greater market power, our volume measure will control for market power effects.

DATA

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.

⁴ On a more technical note, Clark et al. (2004) specifies 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

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 contains millions of observations, where the unit of observation is a U.S. port, foreign port, a six-digit HS product code and year. Such a large data set presents some computation difficulties. To mitigate this, we first limit our sample to the top 100 foreign ports by import volume which covers over 81% of all U.S. import activity. Second, we estimated our model for each year, rather than the full sample. Yearly samples had hundreds of thousands of observations and each required over 10 hours of computation time on a Linux machine with 8 Gigabytes of RAM using the statistical package, STATA.

RESULTS AND PORT EFFICIENCY ESTIMATES

OLS is applied to equation (1) for each year of our sample, 1991 through 2003, and TABLE 1 provides our econometric results. 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.

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 fit of the model to the data is quite high and stable across years, with R^2 statistics ranging from 0.90 to 0.92, indicating that our control variables explain 90% (or more) of the variation in import charges. 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 and its coefficient ranges from 0.1277 to 0.2123 over the sample years. Thus, these estimates suggest that a 10% increase in distance will increase import charges from 1.3 to 2.1%. 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 that averages around 0.91 over the sample years. The coefficient estimates on VALWGT suggest that a 10% increase in the value per kilo increases import charges by 5.5%. The volume measure displays an estimated positive correlation with import charges for all but one year and is typically statistically significant though very small in magnitude. This suggests that congestion effects of volume slightly outweigh the economies of scale effects. As expected, the effect of containerization, everything else equal, is a reduction in import charges, though the elasticity is fairly small, averaging about -0.05 over our sample years. The terms interacted with the containerization variable are also statistically significant, though small in magnitude as well. The positive coefficient on $CONT \times WGT$ suggests that the cost-reducing effects of containerization are mitigated for heavier products. On the other hand, the negative coefficient on $CONT \times VALWGT$ reveals that the cost-reducing impact of

containerization is larger for products with higher value per unit. The final controls for which we list results in TABLE 1 are our trade imbalance measures which are typically not statistically significant. Clark et al. (2004), using alternative measure of trade imbalances, likewise find no robust evidence that trade imbalances affect import charges in a significant manner.

Estimated Port Efficiency Measures

U.S. Port Efficiencies Measures

The model estimated for our results in Table 1 also includes sets of fixed effects for U.S. ports, foreign ports, and 6-digit HTS products. Each of these sets of fixed effects is jointly statistically different from zero at the 1% significance level in all regressions. Column 1 of TABLE 2 provides the average fixed-effect estimate for the top 50 (by volume) U.S. ports across all years in our 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 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 multicollinearity with our constant term, we dropped the Port of Oakland from the set of U.S. port fixed effects. Thus, the fixed-effects estimates in TABLE 2 are relative to the Port of Oakland's effect on import charges which is zero by construction. Given our dependent variable is in logarithm form, the coefficients in column 1 in TABLE 2 are approximately equal to the percentage difference (in decimal form) in the port's effect on import

charges relative to the Port of Oakland effect, after controlling for all other factors. 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 Oakland for a shipment of the same product from a foreign port that is the same distance away. To get the percentage difference in efficiency from Oakland, one simply takes the difference in the exponent of the fixed effect coefficient minus one and multiplies by 100.⁵ Statistical confidence of the fixed-effects estimates for our top 50 ports all average greater than 95% over our sample years.

An examination of the U.S. port fixed effects estimates reveals that many of the Gulf Coast and West Coast ports rank in the upper half of the list, with Gulfport, Mississippi topping the list with a coefficient of -0.087, indicating import charges average roughly 8% less than the Port of Oakland. The island ports of Honolulu, Hawaii and San Juan are essentially outliers at the bottom of the list in terms of efficiency with coefficients of 0.349 and 0.609, respectively. Overall, there is a significant range of estimated port efficiencies. Only 15 of the 50 ports are within 0.05 of the Port of Oakland; that is, within roughly 5% of the Port of Oakland's impact on import charges. The average port has a fixed effect around 0.08 with a standard deviation for the sample around 0.11.

We note that precision of our estimates for port efficiencies of ports smaller than the top 50 are generally quite weak and it is difficult to have much confidence in our estimates for these ports. However, the top 50 ports account for over 97% of all import volume into the U.S., so our methodology does obtain significant results for virtually all U.S. import activity.

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

⁵ This percentage will be quite close to the fixed effect coefficient (in decimal) form when the coefficients are close to zero, as is true of many of our estimated coefficients.

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 Oakland'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 the final three years of the sample, 2001 through 2003. A negative coefficient indicates that the port became more efficient relative to the Port of Oakland over this period, whereas a positive coefficient indicates that it became less efficient.

There is a wide variation in ports' efficiency changes over this time period, with the average experience being a loss in efficiency of 0.06 relative to the Port of Oakland; in other words, everything else equal, an import shipment to the average port cost roughly 6% more in import charges relative to Oakland in the early 2000s than in it did in the early 1990s. One other pattern to note is that Gulf of Mexico ports consistently gained in efficiency relative to Oakland over this period, whereas other East coast ports, generally lost ground.

To get a more detailed view of time series changes, FIGURES 1, 2 and 3 plot out port efficiency coefficients (relative to Oakland) on an annual basis for certain select ports. FIGURE 1 plots West Coast ports, FIGURE 2 plots Gulf of Mexico ports, and FIGURE 3 plots East Coast ports. FIGURE 1 shows that other West Coast ports generally lost ground to the Port of Oakland in terms of efficiency over our sample period. One can also observe that the Port of Long Beach lost some efficiency relative to the other ports during this period as well. Gulf Coast ports displayed in FIGURE 2 show a fair amount of variation in efficiency over the sample period, though their efficiencies by the end of the period are very similar to the first year of the sample. Houston and New Orleans have similar efficiency measures over time, while the Port of Mobile is slightly less efficient, particularly over the late 1990s and early 2000s. The East Coast ports

displayed in FIGURE 3 show the largest changes in relative efficiency rankings over time. In particular, the Port of Norfolk goes from the most efficient of the group to the least efficient over time, while Port Everglades goes from the least efficient of the group in 1991 to one of the more efficient by 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 – Rotterdam, the Netherlands. 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 the early 1990s to the early 2000s relative to the Port of Rotterdam's effect on import charges.

A number of obvious patterns emerge in the rankings of the foreign ports. The upper half of the list (the most-efficient ports) is primarily European and Japanese ports. The middle of the list is generally populated by newly-industrialized countries in Southeast Asia, such as Taiwan and Korea, while the least-efficient ports are primarily Central American and Chinese ports. As with the U.S. port efficiency measures, most are estimated to be statistically different from zero – the efficiency of the Rotterdam 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, we calculate this as the average port efficiency from

2001 through 2003 minus the average port efficiency from 1991 through 1993. There is substantial variation in port efficiency changes over the sample with a standard deviation of 0.16, but the average change in port efficiency relative to Rotterdam is -0.05, or a 5% efficiency gain.

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. Clark et al. (2004) 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's estimated port efficiencies is constructed, which yields 29 matches with the GCR data. The pairwise correlation is 0.33 between the two measures and is statistically significant at the 7% confidence level.

Interestingly, the two contiguous countries to the U.S. yield unexpected port efficiency measures using our methodology, with Canada's ports ranking as some of the worst and Mexico's ports ranking as some of the best in the world. Our current control regressors may not be adequately capturing these countries special geography with the U.S. If we discard these two observations, the correlation between this study's estimated measures of port efficiencies and the GCR measures is 0.65 and statistically significant at the 1% confidence level. This suggests that our study's measures are capturing similar port efficiency effects to the GCR measures (with the exception of contiguous countries). 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.

Correlation Between Observable Port Attributes and Estimated U.S. Port Efficiencies

An important issue is the extent to which one can link our estimated port efficiency measures to observable port attributes. If one felt that observable port attributes can fully characterize port efficiencies and data on such attributes were readily available, there would be little need for our methodology to estimate port efficiencies. In fact, there is very little data on port characteristics available in a consistent manner across ports or time. In addition, it may be the case that port attributes that we can actually observe have relatively little explanatory power for port efficiencies.

We have been able to collect some data on current U.S. port attributes, and in this subsection, we present results from regressing our estimated port efficiencies on these data. The data primarily come from the website www.portualia.ws, which among other things provides current data on channel depth and harbor restrictions for all the world's ports. We supplement this with MARAD data reported in U.S. EPA (1999) which provides information on the types of ships used to transport goods to various ports; i.e., barges, tankers, container ships, etc. After accounting for missing data from these various sources, we are able to match up 60 estimated U.S. port efficiencies in 2003 to the port attribute data.

TABLE 4 provides our results from this estimation. We use the Saxonhouse (1976) procedure to weight our observations by the inverse of the standard error of our estimated port efficiency measure to account for the fact that our dependent variable was generated in a prior estimation. This procedure places lower weight in the regression on observations for which we have less confidence in our estimated port efficiency measure. The regression fit produces an R^2 of 0.65. Harbor and port characteristics do not generally come in statistically significant. Island ports show a significant positive coefficient, indicating that they increase the estimated fixed

effect for the port and, therefore, are associated with lower efficiency. In contrast, West Coast ports have a statistically significant negative coefficient suggesting they are more efficient, everything else equal, relative to the excluded category, Southeast Ports. The type of ships carrying goods to the port is important, as well, with all included types associated with much less efficiency (costs) than general cargo shipments. Vehicle carriers are clearly the least efficient, most costly type of shipments.

U.S. Port Efficiencies for Select Products: Steel and Autos

Another significant advantage of the methodology in this paper is our ability to easily estimate port efficiencies for only a subset of products. This is done by simply re-estimating the model represented in equation (1) for only observations on the products of interest. For example, TABLES 5 and 6 provide information on U.S. port efficiencies estimated when focusing on only steel products or autos, respectively, using data for the year 1999. For both products, the port efficiencies are again measured relative to the Port of Oakland, which is a significant port for both types of imported products. Panel A of each table displays ports with at least a 1% market share in the product and which are significantly different than Oakland in terms of efficiency, while Panel B of each table displays other ports with at least 1% market share that are not statistically different than Oakland in terms of efficiency. Our estimates reported in TABLE 5 suggest that both the Ports of Tampa and Baton Rouge are significantly more efficient for handling steel products, while Los Angeles, Chester, Camden, and San Juan are ports with significant market shares, but less efficient than Oakland in handling these products. In autos (TABLE 6), the Port of Brunswick, Georgia is estimated to be significantly more efficient than

all other ports, while Long Beach, Norfolk, Charleston, Tacoma, New York & New Jersey, and Boston are estimated to be significantly inefficient relative to Oakland.

CONCLUSION

This study provides new measures of ocean port efficiencies through simple statistical tools using U.S. data on import flows from 1991 through 2003. Unlike previous measures using surveys, DEA, or production/cost function estimation, this study's methodology can provide such estimates for a much broader sample of countries and years with little cost. It also has the flexibility to quickly provide port efficiency comparisons on a commodity-by-commodity basis (e.g., which U.S. ports are more efficient at handling steel products). The costliness and strong data requirements of other methodologies is likely why MARAD was unable to identify or provide any port efficiency comparison in a recent Congressional request. Beyond the important role of informing policy makers, the readily-available measures of port efficiency 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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TABLE 1: OLS Estimates of Determinants of Import Charges for U.S. Imports, 1991-2003.

Dependent Variable: Import Charges													
Regressors	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
DIST	0.1643*	0.1785*	0.1883*	0.1978*	0.1573*	0.1508*	0.1892*	0.1967*	0.1710*	0.2123*	0.2106*	0.1893*	0.1277*
	(0.0050)	(0.0052)	(0.0052)	(0.0052)	(0.0052)	(0.0050)	(0.0050)	(0.0049)	(0.0054)	(0.0053)	(0.0057)	(0.0052)	(0.0050)
WGT	0.9046*	0.9103*	0.9141*	0.9124*	0.9121*	0.9156*	0.9161*	0.9088*	0.9143*	0.9046*	0.9013*	0.9053*	0.8953*
	(0.0024)	(0.0028)	(0.0026)	(0.0021)	(0.0022)	(0.0016)	(0.0018)	(0.0020)	(0.0023)	(0.0023)	(0.0025)	(0.0023)	(0.0024)
VALWGT	0.5550*	0.5818*	0.5718*	0.5267*	0.5326*	0.5276*	0.5466*	0.5498*	0.5540*	0.5335*	0.5377*	0.5465*	0.5381*
	(0.0045)	(0.0052)	(0.0051)	(0.0039)	(0.0044)	(0.0030)	(0.0034)	(0.0039)	(0.0044)	(0.0045)	(0.0048)	(0.0046)	(0.0047)
CONT	-0.0454*	-0.0489*	-0.0365*	-0.0466*	-0.0465*	-0.0334*	-0.0352*	-0.0466*	-0.0318*	-0.0551*	-0.0607*	-0.0568*	-0.0693*
	(0.0059)	(0.0069)	(0.0065)	(0.0051)	(0.0056)	(0.0040)	(0.0046)	(0.0051)	(0.0058)	(0.0058)	(0.0063)	(0.0059)	(0.0061)
VOL	0.0073*	0.0055*	0.0059*	0.0063*	0.0057*	0.0020	0.0068*	0.0041*	0.0039*	0.0096*	0.0009	0.0055*	-0.0008*
	(0.0015)	(0.0017)	(0.0015)	(0.0015)	(0.0015)	(0.0014)	(0.0015)	(0.0015)	(0.0017)	(0.0016)	(0.0017)	(0.0016)	(0.0016)
CONT*WGT	0.0068*	0.0064*	0.0060*	0.0068*	0.0070*	0.0053*	0.0054*	0.0069*	0.0066*	0.0088*	0.0089*	0.0083*	0.0107*
	(0.0005)	(0.0006)	(0.0006)	(0.0005)	(0.0005)	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0005)	(0.0006)	(0.0005)	(0.0005)
CONT*VALWGT	-0.0040*	-0.0044*	-0.0074*	-0.0036*	-0.0041*	-0.0029*	-0.0047*	-0.0083*	-0.0118*	-0.0103*	-0.0118*	-0.0119*	-0.0095*
	(0.0010)	(0.0011)	(0.0011)	(0.0009)	(0.0010)	(0.0007)	(0.0008)	(0.0009)	(0.0010)	(0.0010)	(0.0011)	(0.0010)	(0.0010)
IM_IMBAL	-0.0003	0.0016	-0.0010	0.0014	-0.0048*	-0.0008	-0.0039*	-0.0003	-0.0014	-0.0028*	0.0008	-0.0021*	0.0020*
	(0.0009)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0008)	(0.0010)	(0.0010)	(0.0012)	(0.0010)	(0.0011)	(0.0010)	(0.0009)
EX_IMBAL	-0.0006	0.0008	-0.0012	0.0013	-0.0052*	-0.0006	-0.0042*	-0.0010	-0.0017	-0.0031*	0.0004	-0.0031*	0.0008
	(0.0009)	(0.0010)	(0.0010)	(0.0010)	(0.0009)	(0.0008)	(0.0009)	(0.0010)	(0.0011)	(0.0010)	(0.0010)	(0.0009)	(0.0009)
Number of													
Observations	337677	343131	371185	379158	382293	456418	465566	521467	437691	473245	442076	483595	549804
R-Squared	92	92	92	92	92	91	91	91	91	91	90	91	90
F-Statistic	748	756	823	893	891	942	943	1024	857	923	817	917	1009

Notes: All variables are logged. A constant intercept term was included, as well as U.S. port fixed effects, foreign port fixed effects, and 6-digit HTS product fixed effects. * indicates significance at the 1% level.

TABLE 2: U.S. Port Efficiencies

Port Name	Port Fixed Effects: Efficiencies Relative to Oakland	Port's Market Share of U.S. Import Volume Over Sample Years (percent)	Change in Port Efficiency Relative to Oakland from 1991- 1993 Period to 2001- 2003 Period
Gulfport, MS	-0.087	0.22	-0.028
Port Hueneme, CA	-0.087	0.77	0.206
San Francisco, CA	-0.082	0.27	0.119
Pascagoula, MS	-0.082	0.43	-0.099
Port Huron, MI	-0.046	0.34	0.147
Freeport, TX	-0.028	0.54	0.114
Baton Rouge, LA	-0.018	0.68	-0.083
Oakland, CA	0.000	3.82	0.000
Galveston, TX	0.022	0.31	-0.012
New Haven, CT	0.023	0.17	0.233
Gramercy, LA	0.024	0.17	NA
Portland, OR	0.026	1.42	0.015
Chester, PA	0.030	0.46	0.060
Lake Charles, LA	0.035	0.65	-0.435
Newport News, VA	0.038	0.33	0.129
Beaumont, TX	0.039	0.96	0.203
Long Beach, CA	0.045	14.91	0.080
Boston, MA	0.048	0.71	0.073
Corpus Christi, TX	0.048	1.21	0.284
Norfolk, VA	0.051	2.82	0.131
Los Angeles, CA	0.051	15.96	0.043
Houston, TX	0.054	4.08	0.018
Savannah, GA	0.064	2.04	0.074
Mobile, AL	0.066	0.39	0.074
Charleston, SC	0.069	3.64	0.067
Jacksonville, FL	0.071	1.67	-0.070
Philadelphia, PA	0.072	1.60	-0.051
Brunswick, GA	0.072	0.53	-0.291
Wilmington, NC	0.073	0.31	0.160
Baltimore, MD	0.079	3.18	-0.021
New Orleans, LA	0.080	1.92	0.053
NY & NJ	0.091	12.07	0.022
Providence, RI	0.095	0.21	-0.203
St. Croix, VI	0.104	0.70	0.023
Port Everglades, FL	0.114	1.01	-0.088

Detroit, MI	0.116	0.32	-0.054
Miami, FL	0.123	1.59	-0.014
Texas City, TX	0.130	0.69	0.263
Seattle, WA	0.145	5.32	0.027
Paulsboro, NJ	0.145	0.42	0.707
Tacoma, WA	0.152	3.62	0.021
Richmond, CA	0.155	0.27	0.524
Tampa, FL	0.169	0.19	0.074
Marcus Hook, PA	0.175	0.20	0.793
Wilmington, DE	0.182	0.65	-0.001
San Diego, CA	0.190	0.51	-0.027
Port Arthur, TX	0.218	0.71	0.053
Morgan City, LA	0.230	0.86	-0.246
San Juan, PR	0.349	0.68	0.038
Honolulu, HI	0.609	0.29	0.133

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.

TABLE 3: Foreign Port Efficiencies

Port Name	Port Fixed Effects: Efficiencies Relative to Rotterdam	Port's Market Share of U.S. Import Volume, 1991- 2003 (percent)	Change in Port Efficiency Relative to Rotterdam from 1991-1993 Period to 2001-2003 Period
Dos Bocas, Mexico	-0.252	0.36	-0.254
Forcados, Nigeria	-0.175	0.26	NA
Zeebrugge, Belgium	-0.053	0.19	-0.479
Shimizu, Japan	-0.050	0.63	-0.109
Chiba, Japan	-0.031	0.58	0.171
Bremerhaven, Germany	-0.017	4.03	-0.027
Antwerp, Belgium	-0.015	2.32	0.060
Osaka, Japan	-0.010	0.98	0.099
Rotterdam, Netherlands	0.000	2.24	0.000
Chi Lung, Taiwan	0.013	1.93	-0.001
Escravos Oil Terminal, Nigeria	0.014	0.22	NA
Le Havre, France	0.017	1.18	-0.005
Hamburg, Germany	0.018	0.53	-0.034
Kawasaki, Japan	0.019	0.21	0.162
Hakata, Japan	0.023	0.26	0.160
Bremen, Germany	0.026	0.64	0.008
Fos, France	0.035	0.18	-0.094
Pajaritos, Mexico	0.046	0.59	-0.594
Nagoya, Japan	0.052	3.27	-0.065
Southampton, United Kingdom	0.053	0.69	-0.007
Puerto Plata, Dominican Republic	0.057	0.17	-0.166
Tai Chung, Taiwan	0.061	0.25	0.054
Emden, Germany	0.064	0.67	-0.203
Kao Hsiung, Taiwan	0.066	2.54	-0.018
Liverpool, United Kingdom	0.066	0.4	-0.072
All Other Colombian/Caribbean Ports	0.068	0.36	0.063
Haifa, Israel	0.069	0.31	-0.176
Kobe, Japan	0.077	2.21	-0.022
Felixstowe, United Kingdom	0.080	1.01	-0.074
Tokyo, Japan	0.083	4.21	-0.067
Toyohashi, Japan	0.084	2.52	-0.260
Rio Grande, Brazil	0.090	0.22	-0.105
Goteborg, Sweden	0.096	0.72	-0.068
Yokohama, Japan	0.100	2.78	0.039

Inchon, South Korea	0.101	0.22	0.125
All Other South Korea Ports	0.107	0.27	0.084
Pusan, South Korea	0.108	2.74	0.026
Sarnia (Ont), Canada	0.109	0.35	NA
Amuay Bay, Venezuela	0.112	0.38	-0.096
Hong Kong, Hong Kong	0.113	9.31	0.004
Kwa Ibo Termina, Nigeria	0.117	0.32	NA
Rio Haina, Dominican Republic	0.125	0.26	-0.101
Sullom Voe, United Kingdom	0.126	0.21	NA
Yokosuka, Japan	0.127	0.91	-0.026
Mizushima, Japan	0.127	0.17	0.114
All Other Venezuelan Ports	0.133	0.61	-0.109
Yokkaichi, Japan	0.136	0.39	0.255
Buenos Aires, Argentina	0.137	0.21	-0.250
Singapore, Singapore	0.141	1.65	-0.008
Puerto La Cruz, Venezuela	0.142	0.67	0.268
La Spezia, Italy	0.144	0.56	-0.105
Penang, Malaysia	0.144	0.49	-0.039
Genoa, Italy	0.147	0.5	-0.056
All Other Thai Ports	0.149	0.23	0.034
Jahore, Malaysia	0.153	0.2	-0.024
Durban, South Africa	0.154	0.23	0.012
All Other Japan Ports	0.158	0.66	0.222
Melbourne, Australia	0.160	0.22	-0.252
Mongstad, Norway	0.166	0.22	NA
Limon, Costa Rica	0.166	0.31	-0.140
La Salina, Venezuela	0.169	0.25	-0.045
Karachi, Pakistan	0.171	0.28	-0.102
Rio de Janeiro, Brazil	0.174	0.19	-0.164
Leghorn, Italy	0.179	0.54	-0.093
Puerto Cortes, Honduras	0.185	0.44	-0.024
Valencia, Spain	0.190	0.19	-0.154
Kelang, Malaysia	0.192	0.4	-0.071
Sao Paulo, Brazil	0.193	0.64	-0.221
Laem Chabang, Thailand	0.193	0.42	NA
Bangkok, Thailand	0.195	0.96	-0.016
All Other Malaysia Ports	0.202	0.32	-0.148
Ras Tanura, Saudia Arabia	0.204	1.09	-0.165
Saint John (NB), Canada	0.213	0.27	NA
Onsan, South Korea	0.217	0.32	0.265
Al Fuhayhil, Kuwait	0.218	0.17	-0.259

Colombo, Sri Lanka	0.225	0.28	-0.102
Veracruz, Mexico	0.228	0.31	-0.195
All Other China Ports	0.234	0.98	-0.024
Jakarta, Indonesia	0.238	0.64	-0.074
Yantian, China	0.242	1.84	0.026
All Other Indonesia Ports	0.252	0.19	-0.020
Bombay, India	0.253	0.29	-0.203
Ching Tao, China	0.255	0.33	-0.103
St. Petersburg, Russia	0.259	0.3	-0.434
Al Bakir, Iraq	0.259	0.35	NA
Shanghai, China	0.267	2.04	-0.156
Dagu/Tanggu, China	0.268	0.3	-0.128
Dalian, China	0.270	0.21	-0.151
Santo Tomas de Castillo, Guatemala	0.272	0.43	-0.121
Chittagong, Bangladesh	0.287	0.27	-0.076
Hiroshima, Japan	0.301	0.39	0.301
Duran, Ecuador	0.301	0.2	-0.190
Manilla, Philippines	0.316	0.7	-0.030
Arzew, Algeria	0.347	0.23	0.483
High Seas, Gulf of Mexico	0.353	1.05	-0.109
Puerta Miranda, Venezuela	0.470	0.21	-0.022
Windsor (Ont), Canada	0.512	0.18	0.141
Bonny, Nigeria	0.580	0.22	NA
Point Tupper (CBI), Canada	NA	0.17	NA
Cayo Arcos, Mexico	NA	0.65	NA

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.

TABLE 4: Port Attributes Correlated With Our Estimated U.S. Port Efficiencies.

Regressors	Coefficient	Standard Error
Small Harbor (1=yes, 0=no)	-0.098	0.073
Medium Harbor (1=yes, 0=no)	-0.021	0.068
Large Harbor (1=yes, 0=no)	-0.103	0.069
Shallow Main Channel (Less than 9.4 Meters)	-0.033	0.041
Shallow Main Channel X Large Harbor	0.084	0.066
Harbor Restrictions	-0.007	0.010
Island Port (1=yes, 0=no)	0.239*	0.062
Gulf Coast Port (1=yes, 0=no)	-0.023	0.035
West Coast Port (1=yes, 0=no)	-0.067*	0.031
Northeast Coast Port (1=yes, 0=no)	-0.005	0.032
Percentage of Tons Carried by Container Ships	0.462*	0.197
Percentage of Tons Carried by Barges	0.356*	0.158
Percentage of Tons Carried by Tankers	0.301*	0.150
Percentage of Tons Carried by Vehicle Carriers	1.363*	0.424
Constant	-0.137	0.157
Number of observations	60	
R-Squared	0.65	
F-Statistic	4.09	

Notes: Dependent variable is a U.S. port's estimated efficiency in 2003. Observations are weighted by standard error of estimated port efficiency following Saxonhouse (1976). Harbor and channel characteristics come from website: www.portualia.ws. The Harbor Restrictions variable is the number of following restrictions that apply: Tide, Swells, Overhead, Turn Area, and Other. Data on types of shipments come from 1995 MARAD data reported in U.S. EPA (1999). The excluded category for the harbor size dummies is "Very Small"; the excluded category for port regions is "Southeast Coast"; and the excluded category for percentage of tons by ship type is "General Cargo". A * represents statistical significance at the 95% confidence level.

TABLE 5: Port Efficiencies for U.S. Ports That Handle at Least 1% of US Imported Steel, 1999

PANEL A: Ports With Significantly Different Efficiencies in Handling Steel Products Than the Port of Oakland		
Port Name	U.S. Import Market Share in Steel Products	Port (Fixed Effects) Efficiencies
Tampa, FL	1.21	-0.439
Baton Rouge, LA	4.91	-0.249
Los Angeles, CA	9.47	0.073
Chester, PA	1.09	0.112
Camden, NJ	1.75	0.151
San Juan, PR	1.91	0.251

PANEL B: Ports With No Significantly Different Efficiencies in Handling Steel Products Than the Port of Oakland	
Port Name	U.S. Import Market Share in Steel Products
New Orleans, LA	22.86
Houston, TX	8.29
Philadelphia, PA	5.94
Long Beach, CA	4.80
Detroit, MI	4.51
Chicago, IL	3.96
Baltimore, MD	3.50
Savannah, GA	3.44
NY & NJ	2.31
Mobile, AL	1.60
New Haven, CT	1.59
Cleveland, OH	1.50

TABLE 6: Port Efficiencies for U.S. Ports That Handle at Least 1% of US Imported Autos, 1999

PANEL A: Ports With Significantly Different Efficiencies in Handling Autos Than the Port of Oakland		
Port Name	U.S. Import Market Share in Autos	Port (Fixed Effect) Efficiency
Brunswick, GA	2.95	-0.271
Long Beach, CA	11.29	0.090
Norfolk, VA	3.96	0.106
Charleston, SC	3.67	0.111
Tacoma, WA	3.73	0.117
NY & NJ	13.00	0.153
Boston, MA	1.83	0.428

PANEL B: Ports With No Significantly Different Efficiencies in Handling Autos Than the Port of Oakland	
Port Name	U.S. Import Market Share in Autos
Los Angeles, CA	14.35
Jacksonville, FL	7.39
Baltimore, MD	6.49
Portland, OR	6.27
Seattle, WA	5.11
Port Hueneme, CA	3.98
San Diego, CA	3.50
Houston, TX	2.14
Wilmington, DE	1.77
Vancouver, WA	1.06

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

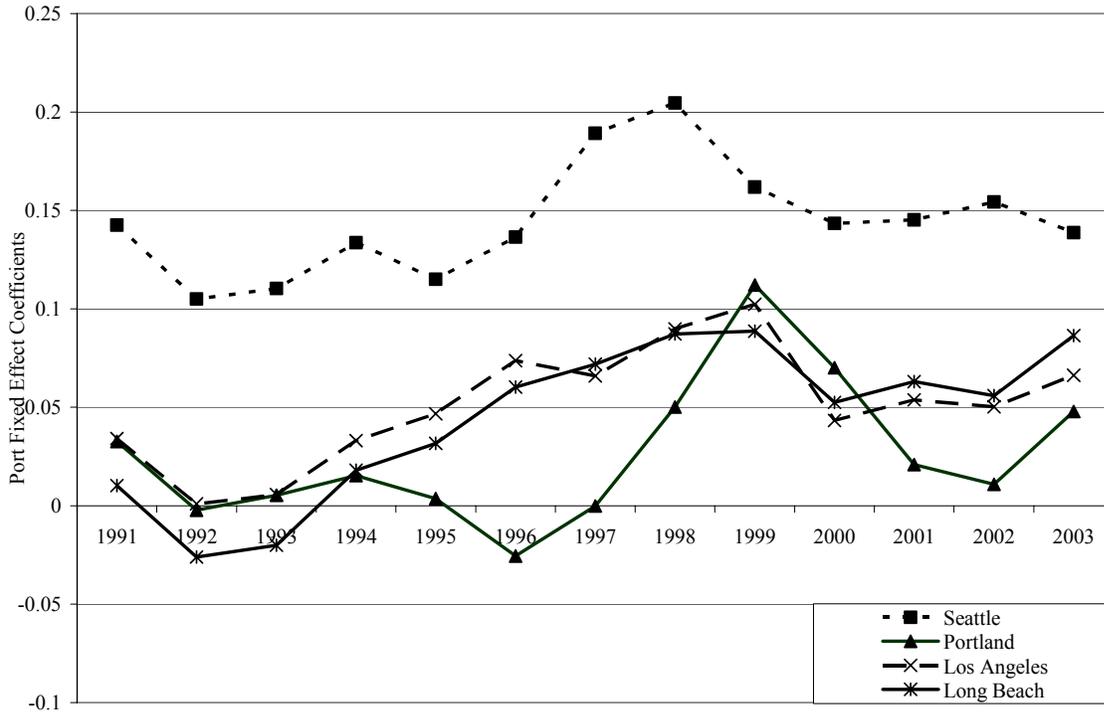


FIGURE 2: Gulf of Mexico Ports' Efficiencies Relative to Oakland, 1991-2003

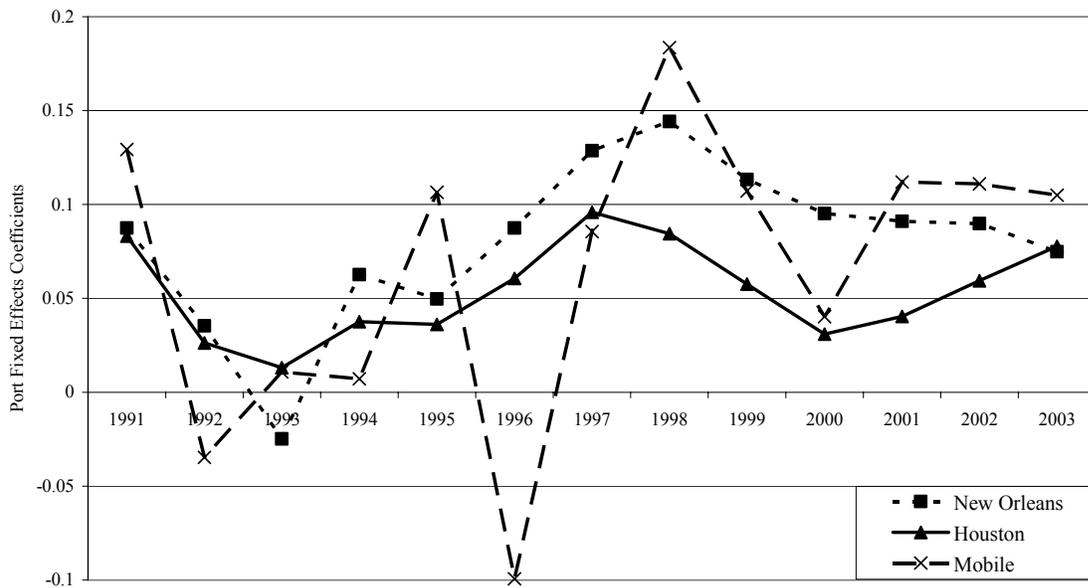
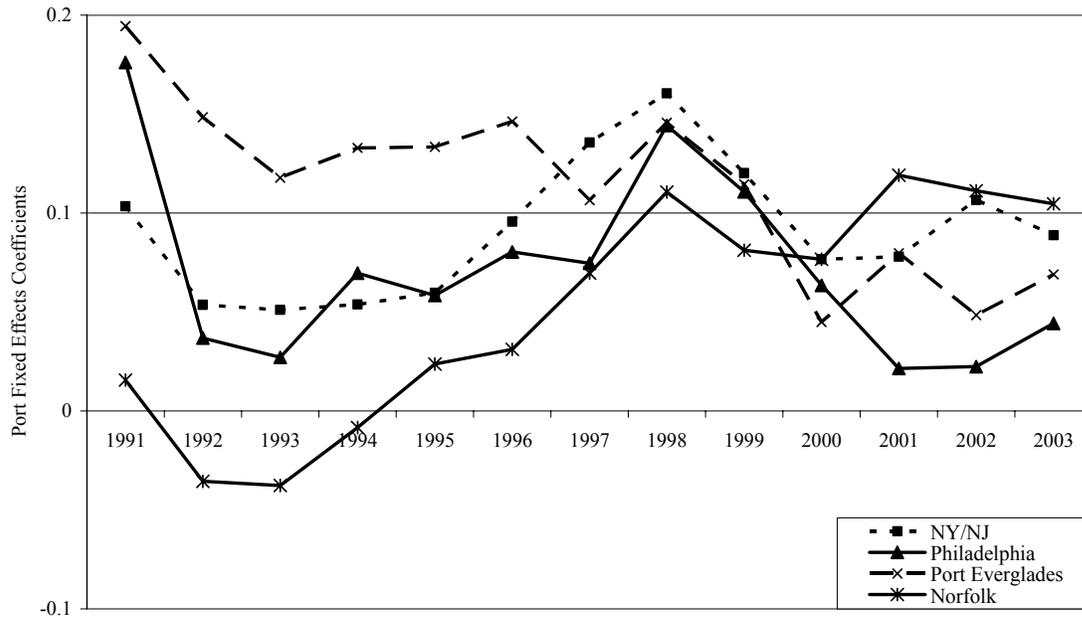


FIGURE 3: East Coast Ports' Efficiencies Relative to Oakland, 1991-2003





The NETS research program is developing a series of practical tools and techniques that can be used by Corps navigation planners across the country to develop consistent, accurate, useful and comparable information regarding the likely impact of proposed changes to navigation infrastructure or systems.

The centerpiece of these efforts will be a suite of simulation models. This suite will include:

- A model for forecasting **international and domestic traffic flows** and how they may be affected by project improvements.
- A **regional traffic routing model** that will identify the annual quantities of commodities coming from various origin points and the routes used to satisfy forecasted demand at each destination.
- A **microscopic event model** that will generate routes for individual shipments from commodity origin to destination in order to evaluate non-structural and reliability measures.

As these models and other tools are finalized they will be available on the NETS web site:

<http://www.corpsnets.us/toolbox.cfm>

The NETS bookshelf contains the NETS body of knowledge in the form of final reports, models, and policy guidance. Documents are posted as they become available and can be accessed here:

<http://www.corpsnets.us/bookshelf.cfm>

