The Navigation Economic Technologies Program

November 2006

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Port Efficiency and Trade Flows

US Army Corps of Engineers®

IWR Report 06-NETS-R-11

Navigation Economic Technologies

The purpose of the Navigation Economic Technologies (NETS) research program is to develop a standardized and defensible suite of economic tools for navigation improvement evaluation. NETS addresses specific navigation economic evaluation and modeling issues that have been raised inside and outside the Corps and is responsive to our commitment to develop and use peer-reviewed tools, techniques and procedures as expressed in the Civil Works strategic plan. The new tools and techniques developed by the NETS research program are to be based on 1) reviews of economic theory, 2) current practices across the Corps (and elsewhere), 3) data needs and availability, and 4) peer recommendations.

The NETS research program has two focus points: expansion of the body of knowledge about the economics underlying uses of the waterways; and creation of a toolbox of practical planning models, methods and techniques that can be applied to a variety of situations.

Expanding the Body of Knowledge

NETS will strive to expand the available body of knowledge about core concepts underlying navigation economic models through the development of scientific papers and reports. For example, NETS will explore how the economic benefits of building new navigation projects are affected by market conditions and/or changes in shipper behaviors, particularly decisions to switch to non-water modes of transportation. The results of such studies will help Corps planners determine whether their economic models are based on realistic premises.

Creating a Planning Toolbox

The NETS research program will develop a series of practical tools and techniques that can be used by Corps navigation planners. The centerpiece of these efforts will be a suite of simulation models. The suite will include models for forecasting international and domestic traffic flows and how they may change with project improvements. It will also include a regional traffic routing model that identifies the annual quantities from each origin and the routes used to satisfy the forecasted demand at each destination. Finally, the suite will include a microscopic event model that generates and routes individual shipments through a system from commodity origin to destination to evaluate non-structural and reliability based measures.

This suite of economic models will enable Corps planners across the country to develop consistent, accurate, useful and comparable analyses regarding the likely impact of changes to navigation infrastructure or systems.

NETS research has been accomplished by a team of academicians, contractors and Corps employees in consultation with other Federal agencies, including the US DOT and USDA; and the Corps Planning Centers of Expertise for Inland and Deep Draft Navigation.

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Port Efficiency and Trade Flows

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IWR Report 06-NETS-R-11

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Abstract

Growing international trade and increasing congestion focus attention on trade facilitation. Ocean ports are a central and necessary component in facilitating trade. Yet, there is only limited comprehensive information available on the efficiency of ports, much less evidence of the effect of port efficiency on trade. We develop and apply a straightforward approach to estimate port efficiency. The approach uses detailed data on U.S. imports and associated import costs, yielding estimates across ports, products, and time. These measures are incorporated into a gravity trade model where we estimate that improved port efficiency significantly increases trade volumes.

Acknowledgements: This research has been conducted under and supported by the Navigation Economics Technologies (NETS) program at the Institute for Water Resources at the U.S. Army Corps of Engineers. The research was facilitated by the efforts of Douglas MacDonald, discussions with Susan Hassett and David Hummels, and excellent comments by an anonymous referee, Keith Hofseth, Bruce Lambert and other participants of the January 2006 NETS symposium in Salt Lake City, Utah Any remaining errors are ours.

1. 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 may reduce trade volumes, particularly for small, less-developed countries (Clark et al., 2004, and Wilson et al., 2003).[1] Thus, port efficiency is an important issue in addressing trade facilitation practices, which has been a recent focus of the World Trade Organization and regional trade institutions, such as the Asia-Pacific Economic Cooperation organization. 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).

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, consistent data and methods to construct measures allow comparisons across ports are not currently available even in developed countries. 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).[2]

[1] See Hummels (2001) for analysis of other transportation frictions affecting international trade flows.
[2] 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).

This concession by MARAD is of great importance as the main motivation for the report was a Congressional request for a comparison of port efficiency, not only for commercial reasons, but also for national security concerns in light of Operation Iraqi Freedom.

As concluded by MARAD and others (described in the next section), analyses of port efficiencies do not provide comprehensive measures across ports, products, or time, much less tie such measures to trade flows. This paper provides a new method for uncovering measures of port efficiency. The methodology uses readily available U.S. Census data on imports into U.S. port districts (hereinafter referred to as "ports"). It is econometric-based and, hence, provides standard errors for the estimated port efficiency measures. Not only are the data readily available and of high-quality, they allow the estimation of port efficiencies across literally hundreds of ports and over relatively lengthy time periods.

While there are many applications of this method and the resulting port efficiency measures, we focus on using our measures to examine the relationship between port efficiency and international trade flows in a standard gravity-trade specification. Clark et al. (2004) and Wilson et al. (2004) estimate this relationship using survey measures of port efficiency drawn from the Global Competitiveness Report.[3] A potential drawback of these studies is that the survey measures are for only a point in time and may proxy other unobserved country characteristics. In contrast, our port efficiency measures are time-varying, allowing controls for unobserved country-level heterogeneity in trade flows. We find that port efficiency is quite important in explaining trade flows between countries with a statistically-significant elasticity of 0.4 after controlling for unobserved country-level heterogeneity. While significant, this is much

[3] Similarly, Sanchez et al. (2003) use cross-sectional 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.

lower than the elasticity we estimate when excluding country-level fixed effects; this suggests that previous studies may be overstating the impact of port efficiency on trade.

The rest of the paper proceeds as follows. After briefly reviewing related previous literature in the next section, we provide details of our statistical methodology to uncover U.S. and foreign port efficiency in section 3. Section 4 describes our data, while section 5 provides the papers statistical results new efficiency rankings of U.S. and foreign ports, as well as gravity-model estimates of the effect of port efficiency on international trade flows.

2. PREVIOUS LITERATURE

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 published by the World Economic Forum. 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. 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 limited timeframe. Thus, there is almost no information on how port efficiencies evolve over time from these studies. [4]

[4] 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

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. Port efficiency measures are then based on deviations from this frontier. Examples include Roll and Hayuth (1993), Martinez-Budria et al. (1999), Tongzon (2001), and Estache et al. (2004).[5] 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.

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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.

[5] 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.

3. METHODOLOGY

Our conceptual starting point for estimating port efficiencies 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).

Given this breakdown of components comprising import charges, 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. This leaves components 1 and 3 in the error term along with assumed 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) uncovers 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.

More formally, our statistical methodology primarily 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.[6] The model estimated is given by equation (1) and is based on a simple cost model of transporting goods:

$$IC_{ijkt} = \alpha + \beta_1 Dist_{ij} + \beta_2 Wgt_{ijkt} + \beta_3 Valwgt_{ijkt} + \beta_4 Cont_{ijkt} + \beta_5 Cont_{ijkt} \times Wgt_{ijkt} + B_6 Cont_{ijkt} \times Valwgt_{ijkt} + \beta_7 Im_Imbal_{ij} + \beta_8 Ex_Imbal_{ij} + \eta_i + \theta_j + \gamma_k + \tau_t + \varepsilon_{ijkt}. \quad (1)$$

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

[6] Clark et al. (2004) also include a measure of import volume between the foreign port and all U.S. coastal ports. Such a measure could capture congestion effects or economies of scale effects on import charges. We see these effects as related directly to port efficiency and, thus, do not include such a regressor so that our port fixed effects estimates capture these congestion and scale effects. Further, estimation in such a case may be complicated by the possible joint determination of volume and efficiency. Later, we assess the effects of efficiency on trade. Finally, we also estimated the model with and without trade volumes and find that the coefficients in TABLE 1 are qualitatively the same with very similar numerical values.

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, β_3 is expected to 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 a more efficient means of transportation, and therefore, β_4 should have a negative 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 following 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_7 and β_8 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.[7]

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 the Global Competitiveness Report (various issues) -- henceforth, referred to as GCR measures -- as a regressor in their specification. These GCR measures then are external measures, while in the present study the import charge data reveal port efficiencies. 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 from 1995 through 2000 and varies only by country, not over time. 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, not just countries. 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.[8] In a later section, we compare our measurements of foreign port efficiencies with the GCR measures, as well as evaluate the effect

[7] Clark et al. (2004) also include a measure of port volume as an explanatory variable to control for possible congestion effects on import charges. We exclude this regressor since we want to capture such effects in our port fixed effect estimates. Our estimates are virtually identical whether we include such an explanatory variable or not.
[8] 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 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.

of our port efficiency measure on international trade flows and find that they are highly correlated.

It is important to stress the differences of our fixed-effects approach to other efficiency measures. Import charges capture 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, is 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. Port tariffs themselves are likely not a good measure of port efficiency since they do not explicitly include costs associated with navigation of the harbor, tide restrictions, more recently, security measures, as well as other factors that can delay shipments into ports, though these costs may be endogenous to the process by which port tariffs are determined.[9]

This raises the question of port competition, the setting of port tariffs, and how these issues may affect interpretation of port fixed effects as port efficiency measures. In order to be competitive, an inefficient port may set lower tariffs than a more efficient port, simultaneously allowing the more efficient port to capture rents. This would tend to equalize import charges across ports, though inefficient ports would be practically constrained from offering negative tariffs. From an economic/cost efficiency standpoint, one would not be concerned with these endogenous relationships between the different components of the import charges. Thus, for example, this is less of a concern with our analysis at the end of the paper where we examine the relationship between our port efficiency measures and international trade flows. On the other

[9] 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

hand, such issues prevent our measure from being an ideal measure of the inherent technical efficiency of a port.

A final related issue is the role of market power in determining import charges, either from ports or carriers. Differences in market power are another factor that may allow some ports to charge higher tariffs than their marginal costs of handling the shipments.[10] This could also distort our port efficiency measures. However, Clark et al. (2004) included measures of market power in their specifications, 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.[11]

4. 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. port data. This data set is used to construct IC_{ijkt}, $Valwgt_{ijkt}$, $Cont_{ijkt}$, ,Im_Imbal_{ij}, Ex_Imbal_{ij}, and related interaction terms 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 domestic and foreign ports. This data set is used to construct the distance ($Dist_{ij}$) variable. Merging these

(hence, inefficient) port due to navigation difficulties, congestion, etc. This highlights another important advantage of our methodology.

[10] Note that the issue of market power is different from the issue raised above, which could occur in a perfectly competitive market with differences in technical efficiency of the ports (at least in the short-run). In other words, the issue above is about the more efficient ports simply gaining infra-marginal rents due to their efficiency advantages.

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 and top 50 U.S. ports by import value which cover over 98% and 87%, respectively, of all U.S. import activity over the sample period (excluding oil). Second, we focus on non-oil imports only, since oil is relatively unique in having dedicated/specialized ships and port facilities. Despite these limits, we still had to estimate our model for each year, rather than the full sample due to computational constraints. Each year the sample was comprised of hundreds of thousands of observations and required over 10 hours of computation time on a Linux machine with 8 Gigabytes of RAM using the statistical package STATA.

5. 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.

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

[11] Sanchez et al. (2003) provided a similar analysis to Clark et al. (2004) focusing only on Latin American ports and also found no significant correlation between these proxies for market power and import charges.

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 0.1297 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 0.90 over the sample years. The coefficient estimates on VALWGT suggest that a 10% increase in the value per kilo increases import charges by about 5.5%. As expected, the effect of containerization, everything else equal, is a reduction in import charges, though the elasticity is fairly small, averaging about -0.055 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×WGT suggests that the cost-reducing effects of containerization are mitigated for heavier products. On the other hand, the negative coefficient on CONT×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. The coefficients on these variables are almost always positive and statistically significant as expected, suggesting higher costs for imbalanced trade into the port, though the effects are quite small in magnitude with elasticities less than 0.01.

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. To facilitate comparisons and discussion, Column 1 of TABLE 2 provides the average fixed-effect estimate for the top 50 (by value) 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, the Port of Oakland is excluded 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.[12] Over two-thirds of our U.S. port fixed-effects are statistically different from that of Oakland at the 95% level.

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 Richmond-Petersburg topping the list with a coefficient of -0.086, indicating import charges average roughly 8% less than the Port of Oakland. The island ports of Honolulu, Hawaii and Mayaguez, PR are essentially outliers at the bottom of the list in terms of efficiency with coefficients of 0.589 and 0.438, respectively. Overall, there is a significant range of estimated port efficiencies. Only 13 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 0.13.

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 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 0.04 relative to the Port of Oakland; in other

[12] 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.

words, everything else equal, an import shipment to the average port cost roughly 4% 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 East coast ports, generally lost ground.

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 Rotterdam, the Netherlands (the excluded port). 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 0.14, but the average change in port efficiency relative to Rotterdam is about -0.05, or a 5% efficiency gain.

The Link Between Our Port Efficiency Measures and International Trade

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 1999 to find a significant effect between port efficiency and trade. An average country-level port efficiency measure for the 1997-1999 period using this study's estimated foreign port fixed effects estimates is constructed, which yields 30 matches with the GCR data. The pairwise correlation is 0.33 between the two measures and is statistically significant at the 10% significance level.[13]

However, to go a significant step further, we examine the explanatory power of the measures of port efficiency for world trade in a standard gravity framework. We focus on trade across countries using our measures of foreign port efficiency and the data set on world trade flows constructed by Andrew Rose and available from his website.[14] The data construction and sources are described more fully in Rose (2004). The trade data end with the year 1999, while the port efficiency measures begin in 1991. Thus, our sample spans the years from 1991 through

[13] We note that the relatively small number of observations is due to the fact that we there are only 41 different countries represented in our 100 foreign port estimates, and a number of these are not in the GCR database.
[14] The URL for the website is: http://faculty.haas.berkeley.edu/arose/RecRes.htm#Software.

1999. The number of countries in the sample is limited by where we have estimated foreign port efficiencies (i.e., those in TABLE 2), which leads to measures for 40 countries.[15]

Column 1 of TABLE 4 provides estimates of Rose's (2004) benchmark gravity model specification relating the log of total trade (in real dollars) between two countries to a variety of explanatory factors for our sample of years (1991-1999) and country-pairs where our foreign port efficiency measures are available.[16] The results are qualitatively similar to Rose's results despite a smaller sample.

We next include a measure of port efficiency constructed from our estimated foreign port fixed effects. Since the dependent variable is the combined trade between a country pair, we first add up the weighted-average port fixed effects from both countries. Since our fixed effects estimates are inversely related to port efficiency, we then construct our port efficiency measure as 2 minus the sum of the two countries weighted-average foreign-port fixed effects. We take the log of this port efficiency measure so that we can interpret its coefficient as an elasticity. Column 2 of TABLE 4 provides estimates when we add our measure of port efficiency to the benchmark specification. The estimated elasticity of trade with respect to port efficiency is quite large -- 1.27 -- and statistically significant at the 1% level.

An issue with these estimates of port efficiency, however, is that such a measure may simply proxy for a number of characteristics of the foreign countries that facilitate or hinder trade. If ports have poor infrastructure, contributing to port inefficiency, the country likely has other related infrastructure and development issues that hinder trade. Not controlling for these other country-level characteristics that are likely positively correlated with port efficiency, may bias the estimated effect of port efficiency on trade upwards. However, this is where our time-

[15] Taiwan is not included because Rose's dataset does not include this country.

varying measures of port efficiency can overcome this issue, whereas other measures, such as those employed in the cross-sectional analysis of Clark et al. (2004), cannot.

Column 3 of TABLE 4 provides estimates when we include country-pair fixed effects that control for all time-invariant factors (both observed and unobserved) connected with the country-pair. This is a demanding specification to test for port efficiency effects as we now identify such effects only from time variation of our port efficiency measure within each country-pair. Our estimates continue to find a statistically significant correlation between port efficiency and trade, though the elasticity is significantly smaller at 0.32. This implies that a 10% increase in port efficiency leads to 3.2% increase in real trade between a country pair, which represents a reasonably large, and perhaps more realistic, effect of port efficiency on trade. Clark et al.'s (2004) cross-sectional study finds that an increase in port efficiency from the 25th percentile to the 75th percentile leads a 25% increase in trade. Our estimates, which control for unobserved country-pair characteristics that may be significantly correlated with port efficiencies, find that a change in port efficiency from the 25th percentile to the 75th percentile leads to a more modest 5% increase in trade.

As a final point of comparison, when we use the log of the GCR measures as our port efficiency variable in the column 2 specification in TABLE 4, we obtain an elasticity of 3.08 which is statistically significant at the 1% significance level. These GCR port-efficiency measures only vary by country, not over time. Thus, we cannot control for unobserved country-level characteristics with the GCR measures, as we can with our port-efficiency measures in the column 3 estimates of TABLE 4. This suggests that use of the GCR measures may lead to a

[16] Three variables in Rose's (2004) benchmark specification are excluded here because they do not vary across observations in our more limited sample: currency union, number landlocked, and common country.

significant overstatement of the estimated effect of port efficiencies on trade volumes due to the inability to include country-level fixed effects.

Product-level Heterogeneity in Estimated Port Efficiencies

A final issue concerns the generality (or stability) or our port efficiency measures across products. Our methodology above provides an estimate of a port's *average* contribution (in percentage terms) to import charges across all products the port may export to the U.S. (in the case of foreign ports) or may import from abroad (in the case of U.S. ports). A natural question is whether ports' efficiencies vary significantly across products. Our preliminary investigations suggest that rankings of port efficiency using our methodology can vary across products. As an example, our earlier version of this paper (Blonigen and Wilson, 2006) provides separate rankings of U.S. ports for autos and steel products, which are different from each other, as well as the general rankings of U.S. ports' efficiencies.

These differences in product-level efficiencies within ports are potentially problematic for our estimates of average port efficiency and their estimated correlations with international trade flows. The concern is that changes in product composition at the port level over time could be driving the positive correlation with trade flows, not changes in the ports' inherent efficiencies. A way of handling this statistically is to include port-by-product specific effects into our estimation procedure. While theortically plausible, as a practical matter, this approach substantially increases the number of fixed effects to be estimated in an already model that already pushes computation limits.

However, if product composition at the ports is stable over our panel of years (1991-1999) in the gravity model estimates, then we can be reasonably confident that product composition

changes are not affecting the relationship between port efficiencies and international trade flows. To evaluate this possibility, we calculate the correlation between foreign ports' 2-digit product-level U.S. export values in 1999 and 1991 as well as the same correlation at the 4-digit level. The result yields strong and statistically significant correlations of .86 for 2-digit levels and 0.82 for 4-digit levls. These results do not suggest that the composition of products has changed dramatically over time. Thus, we believe this issue is unlikely to be significantly biasing our estimates of the relationship between port efficiency and trade flows.[17] Nevertheless, exploring the factors behind the heterogeneity in port efficiency across products is clearly an area for future research.

6. CONCLUSIONS AND FUTURE RESEARCH

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 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-

[17] We also note that we get very similar port rankings when we estimate port efficiencies using data on containerized-only imports and qualitatively similar estimated effects of these port efficiency measures on trade.

level growth. Importantly, we show that our port efficiency measures allow one to more credibly estimate the effect of port efficiencies on international trade flows. Our measures vary over time, allowing us to control for unobserved country-level heterogeneity in our gravity trade specifications, without which we show one can severely overestimate the impact of port efficiencies on international trade flows.

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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	**0.1488.***	**0.1656***	**0.1845***	**0.1926***	**0.1591***	**0.1581***	**0.1863940***	**0.2003***	**0.1693***	**0.2059***	**0.2123***	**0.1810***	**0.1297***
	(0.0043)	(0.0044)	(0.0043)	(0.0044)	(0.0045)	(0.0044)	(0.0041)	(0.0041)	(0.0045)	(0.0044)	(0.0046)	(0.0042)	(0.0040)
WGT	**0.9039***	**0.9098***	**0.9115***	**0.9106***	**0.9072***	**0.9130***	**0.9139***	**0.9053***	**0.9107***	**0.9047***	**0.8993***	**0.9011***	**0.8907***
	(0.0024)	(0.0028)	(0.0026)	(0.0021)	(0.0022)	(0.0016)	(0.0018)	(0.0020)	(0.0023)	(0.0023)	(0.0024)	(0.0023)	(0.0024)
VALWGT	**0.5515***	**0.5824***	**0.5701***	**0.5253***	**0.5257***	**0.5231***	**0.5372***	**0.5383***	**0.5443***	**0.5347***	**0.5337***	**0.5377***	**0.5265***
	(0.0044)	(0.0052)	(0.0050)	(0.0039)	(0.0043)	(0.0029)	(0.0033)	(0.0039)	(0.0043)	(0.0044)	(0.0047)	(0.0045)	(0.0045)
CONT	**-0.0472***	**-0.0491***	**-0.0397***	**-0.0482***	**-0.0570***	**-0.0380***	**-0.0401***	**-0.0545***	**-0.0391***	**-0.0532***	**-0.0649***	**-0.0676***	**-0.0809***
	(0.0058)	(0.0068)	(0.0064)	(0.0050)	(0.0054)	(0.0039)	(0.0044)	(0.0050)	(0.0056)	(0.0057)	(0.0061)	(0.0058)	(0.0059)
CONT*WGT	**0.0071***	**0.0064***	**0.0064***	**0.0069***	**0.0079***	**0.0057***	**0.0057***	**0.0074***	**0.0071***	**0.0086***	**0.0091***	**0.0091***	**0.0115***
	(0.0005)	(0.0006)	(0.0006)	(0.0005)	(0.0005)	(0.0004)	(0.0004)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
CONT*VALWGT	**-0.0041***	**-0.0044***	**-0.0067***	**-0.0032***	**-0.0026***	**-0.0022***	**-0.0034***	**-0.0065***	**-0.0102***	**-0.0101***	**-0.0196***	**-0.0097***	**-0.0070***
	(0.0010)	(0.0011)	(0.0011)	(0.0009)	(0.0009)	(0.0006)	(0.0007)	(0.0008)	(0.0009)	(0.0010)	(0.0010)	(0.0010)	(0.0010)
IM_IMBAL	**-0.0007**	**0.0020***	**0.0052***	**0.0079***	**0.0026***	**0.0024***	**0.0022***	**0.0039***	**0.0031***	**0.0040***	**0.0018**	**-0.0000**	**0.0025***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0008)	(0.0007)	(0.0008)	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0008)
EX_IMBAL	**-0.0016**	**0.0008**	**0.0045***	**0.0070***	**0.0019***	**0.0025***	**0.0019***	**0.0037***	**0.0026***	**0.0039***	**0.0016**	**-0.0011**	**0.0014****
	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0008)	(0.0007)	(0.0008)	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0008)
Number of Observations	346094	353623	382870	394102	402413	480968	486553	556407	470490	514033	482210	532606	613220
R-Squared	92	92	92	92	92	91	91	91	91	91	90	91	90
F-Statistic	777	787	861	938	940	994	988	1094	923	1006	900	1014	1129

*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. *, **, *** indicate significance at the 1%, 5%, and 10% levels, respectively.*

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
Richmond-Petersburg,VA	-0.086	0.14	0.155
Port Huron, MI	-0.081	0.40	0.160
Port Hueneme, CA	-0.081	0.91	0.204
Gulfport, MS	-0.074	0.26	-0.066
Cleveland, OH	-0.068	0.09	-0.105
San Francisco, CA	-0.067	0.26	0.124
Baton Rouge, LA	-0.058	0.32	-0.035
New Haven, CT	-0.019	0.12	0.220
Carquinez Strait, CA	-0.005	0.16	-0.100
Oakland, CA	0.000	4.48	0.000
Portland, OR	0.010	1.64	0.012
Galveston, TX	0.020	0.23	-0.016
Chester, PA	0.021	0.29	0.074
West Palm Beach, FL	0.022	0.18	0.051
Newport News, VA	0.036	0.30	0.137
Long Beach, CA	0.043	17.31	0.077
Boston, MA	0.043	0.77	0.078
Mobile, AL	0.047	0.27	0.090
Norfolk, VA	0.049	3.27	0.123
Los Angeles, CA	0.050	18.64	0.036
Houston, TX	0.053	2.79	0.013
Brunswick, GA	0.053	0.62	-0.271
Savannah, GA	0.060	2.33	0.067
Providence, RI	0.062	0.14	-0.264
Wilmington, NC	0.065	0.34	0.167
Jacksonville, FL	0.065	1.86	-0.059
Charleston, SC	0.067	4.26	0.061
Philadelphia, PA	0.071	0.98	-0.015
Beaumont, TX	0.071	0.07	0.489
Baltimore, MD	0.072	3.67	-0.021
New Orleans, LA	0.073	1.75	0.051
Vancouver, WA	0.088	0.17	0.120
New York, NY	0.089	12.75	0.023
Port Everglades, FL	0.104	1.06	-0.069
Detroit, MI	0.110	0.37	-0.056

Miami, FL	0.110	1.86	-0.007
Chicago, IL	0.127	0.15	0.070
Seattle, WA	0.141	6.25	0.017
Tacoma, WA	0.147	4.26	0.018
Richmond, CA	0.152	0.19	0.623
Tampa, FL	0.159	0.21	0.082
Camden, NJ	0.161	0.12	0.136
Wilmington, DE	0.182	0.48	0.021
San Diego, CA	0.185	0.61	-0.021
Gloucester City, NJ	0.230	0.11	-0.093
San Juan, PR	0.341	0.70	0.028
Ponce, PR	0.361	0.12	-0.137
Mayaguez, PR	0.438	0.11	-0.218
Honolulu, HI	0.589	0.14	0.136
Port of South LA	NA	0.14	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 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
Zeebrugge, Belgium	-0.059	0.22	-0.488
Shimizu,Japan	-0.051	0.75	-0.101
Chiba, Japan	-0.027	0.69	0.141
Osaka, Japan	-0.016	1.15	0.102
Bremerhaven, Germany	-0.015	4.74	-0.021
Antwerp,Belgium	-0.011	2.62	0.063
Hakata, Japan	-0.002	0.31	0.167
Rotterdam, Netherlands	0.000	2.57	0.000
Chi Lung, Taiwan	0.015	2.27	0.000
Le Havre, France	0.017	1.35	-0.002
Emden, Germany	0.018	0.79	-0.176
Hamburg, Germany	0.018	0.62	-0.027
Bremen, Germany	0.029	0.76	0.014
Fos, France	0.029	0.21	-0.083
Kawasaki, Japan	0.037	0.25	0.359
Nagoya, Japan	0.055	3.86	-0.059
Toyohashi, Japan	0.055	2.97	-0.260
Tai Chung, Taiwan	0.056	0.30	0.060
Thamesport, United Kingdom	0.062	0.19	NA
Liverpool, United Kingdom	0.063	0.46	-0.064
Kao Hsiung, Taiwan	0.064	2.99	-0.017
Southhampton, United Kingdom	0.064	0.81	0.003
Kobe, Japan	0.075	2.60	-0.025
Haifa, Israel	0.075	0.36	-0.176
Tokyo, Japan	0.081	4.95	-0.066
Felixstowe, United Kingdom	0.084	1.18	-0.069
Inchon, South Korea	0.088	0.26	0.138
Puerto Plata, Dominican Rep	0.090	0.20	-0.169
All Other Ports, South Korea	0.097	0.29	0.093
Goteborg, Sweden	0.098	0.83	-0.057
Yokohama, Japan	0.101	3.28	0.041
Santo Domingo, Dominican Rep	0.101	0.14	0.073
Rio Grande, Brazil	0.103	0.26	-0.097
Pusan, South Korea	0.109	3.20	0.029
Hong Kong, Hong Kong	0.114	10.96	0.002

Yokkaichi, Japan	0.126	0.46	0.258
Yokosuka, Japan	0.127	1.07	-0.010
Rio Haina, Dominican Rep	0.127	0.31	-0.085
Mizushima, Japan	0.130	0.19	0.234
Victoria, Brazil	0.140	0.11	0.084
Buenos Aires, Argentina	0.141	0.22	-0.253
La Spezia, Italy	0.142	0.66	-0.100
All Other Ports, Japan	0.143	0.77	0.227
All Other Ports, Thailand	0.143	0.27	0.056
Penang, Malaysia	0.144	0.57	-0.030
Singapore, Singapore	0.144	1.90	-0.008
Genoa, Italy	0.145	0.59	-0.048
Johore, Malaysia	0.148	0.24	0.003
Buenaventura, Colombia	0.148	0.14	-0.309
Bilbao, Spain	0.151	0.13	-0.064
Durban, South Africa	0.157	0.28	0.014
Melbourne, Australia	0.164	0.26	-0.260
Las Salinas, Chile	0.171	0.18	-0.132
Karachi, Pakistan	0.172	0.33	-0.098
Limon, Costa Rica	0.174	0.37	-0.131
Point Lisas, Trinidad	0.178	0.14	-0.167
Leghorn, Italy	0.178	0.63	-0.086
Izmir, Turkey	0.179	0.17	0.032
Rio de Janeiro, Brazil	0.181	0.20	-0.153
Sydney, Australia	0.181	0.16	-0.174
Barcelona, Spain	0.183	0.14	-0.099
Kelang, Malaysia	0.191	0.47	-0.065
Puerto Cortes, Honduras	0.191	0.52	-0.017
Istanbul, Turkey	0.193	0.17	-0.001
Laem Chabang, Thailand	0.194	0.49	NA
Bangkok, Thailand	0.194	1.13	-0.013
Valencia, Spain	0.195	0.23	-0.146
Naples, Italy	0.196	0.17	-0.122
San Antonio, Chile	0.200	0.13	-0.200
Sao Paulo, Brazil	0.200	0.72	-0.216
All Malaysia Ports, Malaysia	0.200	0.34	-0.132
Callao, Peru	0.213	0.13	-0.076
Colombo, Sri Lanka	0.220	0.33	-0.091
Onsan, South Korea	0.221	0.37	0.265
Veracruz, Mexico	0.225	0.34	-0.162
All Other Ports, China	0.232	1.11	-0.013
Yantian, China	0.233	2.17	0.051

Jakarta, Indonesia	0.241	0.75	-0.071
All Indonesia Ports, Indonesia	0.250	0.20	-0.009
Bombay, India	0.252	0.34	-0.198
All Other West Coast Ports, India	0.253	0.15	-0.170
Ching Tao, China	0.254	0.39	-0.084
Auckland, New Zealand	0.256	0.19	-0.233
Madras, India	0.269	0.17	-0.186
Shanghai, China	0.270	2.39	-0.146
Ning Bo, China	0.273	0.14	-0.031
Dagu/Tanggu, China	0.273	0.34	-0.115
Dalian, China	0.274	0.21	-0.137
St. Petersburg, Russia	0.275	0.35	-0.405
Amoy, China	0.281	0.16	NA
Chittagong, Bangladesh	0.283	0.32	-0.065
Santo Tomas de Castilla, Guatemala	0.292	0.48	-0.107
Hiroshima, Japan	0.299	0.45	0.312
Duran, Ecuador	0.306	0.23	-0.178
Manila, Philippines	0.317	0.82	-0.026
Foochow, China	0.319	0.11	NA
Soerabaja, Indonesia	0.328	0.14	-0.039
Sarnia, ONT, Canada	0.414	0.40	NA
Windsor, ONT, Canada	0.428	0.21	0.194
Saigon, Vietnam	0.447	0.13	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: Significance of Port Efficiency Measures in Gravity Trade Regressions

	Rose's Benchmark	Inclusion of Port Efficiency Measure	Inclusion of Country-Pair Fixed Effects
Log Port Efficiency Measure		1.27***	0.32***
		(0.16)	(0.09)
Both countries in GATT/WTO	0.25	0.14	0.77***
	(0.36)	(0.35)	(0.20)
One country in GATT/WTO	0.48	0.42	0.88***
	(0.36)	(0.35)	(0.19)
GSP	0.04	0.05	-0.23***
	(0.03)	(0.03)	(0.09)
Log Distance	-0.99***	-0.99***	
	(0.03)	(0.03)	
Log Product of Real GDPs	0.83***	0.82***	1.12***
	(0.01)	(0.01)	(0.21)
Log Product of Real GDPs p/c	0.55***	0.53***	-1.20***
	(0.02)	(0.02)	(0.21)
Regional FTA	0.31***	0.33***	0.06
	(0.09)	(0.09)	(0.04)
Common Language	0.61***	0.63***	
	(0.04)	(0.04)	
Land Border	0.26**	0.27**	
	(0.11)	(0.11)	
Number Islands	0.24***	0.27***	
	(0.03)	(0.03)	
Log Product Land Area	-0.08***	-0.07***	
	(0.01)	(0.01)	
Common Colonizer	0.57***	0.59***	
	(0.10)	(0.10)	
Currently Colonized	0.66***	0.64***	0.03
	(0.08)	(0.08)	(0.03)
Ever Colony	0.46***	0.43***	
	(0.07)	(0.07)	
Year Fixed Effects	Yes	Yes	Yes
Country-Pair Fixed Effects	No	No	Yes
Observations	5539	5539	5539
R-squared	0.81	0.81	0.97

*Notes: Robust standard errors in parentheses. ** denotes significance at 5% level; *** denotes significance at 1% level.*

Appendix

Blonigen and Wilson's Responses to Referee's Comments

We thank the referee for truly outstanding comments that have led us to substantially revise the paper to better link our port efficiency measures to international trade flows, as well as address other concerns. The paper is much improved. Below we list the referee's comments in **bold** and our responses to each comment in order.

1. These aren't measures of port efficiency, per se, they are really per port average shipping costs after conditioning on the included variables. Greater port efficiency could yield lower shipping costs, but they need not. For example, suppose ports A and B offer competing services, but A has very slow throughput. A can compensate by offering lower port costs and still attract business, while B extracts some of the value of its more efficient handling by charging higher costs. The issue is that there might be unmeasured port quality differences that not only introduce noise in the estimates but are plausibly negatively correlated with costs.

This is an excellent point. While we discussed these issues briefly in the previous draft, we had not fully discussed all the ramifications of this issue for our method of estimating port efficiencies. We now do two things to address this better. First, we have now added a new analysis section that shows our port efficiency measures are positively correlated with international trade flows, which you suggested in your next comment to mitigate these concerns (see discussion below for more details on this). Second, we provide a much more thorough discussion of this issue in this draft:

"It is important to stress the differences of our fixed-effects approach to other efficiency measures. Import charges capture 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, is 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. Port tariffs themselves are likely not a good measure of port efficiency since they do not explicitly include costs associated with navigation of the harbor, tide restrictions, more recently, security measures, as well as other factors that can delay shipments into ports, though these costs may be endogenous to the process by which port tariffs are determined.

This raises the question of port competition, the setting of port tariffs, and how these issues may affect interpretation of port fixed effects as port efficiency measures. In order to be competitive, an inefficient port may set lower tariffs than a more efficient port, simultaneously allowing the more efficient port to capture rents. This would tend to equalize import charges across ports, though inefficient ports would be practically constrained from offering negative tariffs. From an economic/cost efficiency standpoint, one would not be concerned with these endogenous relationships between the different components of the import charges. Thus, for example, this is less of a concern with our analysis at the end of the paper where we examine the relationship between our port efficiency measures and international trade flows. On the other hand, such issues prevent our measure from being an ideal measure of the inherent technical efficiency of a port.

A final related issue is the role of market power in determining import charges, either from ports or carriers. Differences in market power are another factor that may allow some ports to charge higher tariffs than their marginal costs of handling the shipments. This could also distort our port efficiency measures. However, Clark et al. (2004) included measures of market power in their specifications, 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." (pp. 9-10)

2. The fact that the intercepts (aggregated by country) are positively correlated with survey data on port quality helps address this issue somewhat. Another approach that might be useful would start from the following idea: if the included measures really do capture something about port efficiency, then high intercept ports ought to be moving a lot of trade volume. This is a kind of revealed preference argument for exporting firms. The value of this kind of approach is that it would broaden the paper from the narrow "how to measure port efficiency" question that is primarily a transport economics issue, to a broader "how does port efficiency affect trade" that is probably of more interest to trade economists.

We have spent considerable time addressing this issue in the revised draft. The referee suggests looking at the pairwise correlation between our measures of port efficiency and trade volumes. We decided to go a step further in order to control for other important factors, such as market size surrounding the port, and estimate the effects of our port efficiency measures in a multivariate gravity-model framework commonly used to estimate determinants of trade patterns. We use the world trade data collected by Andrew Rose which has been used by many subsequent studies, including Clark et al. (2005) cited in our references. We start with his the basic gravity-trade model specification and then explore the effect of including our port efficiency measures into this framework.

The results are quite strong, showing a statistically significant correlation between our port efficiency measure and international trade, even after controlling for unobserved heterogeneity across countries in the panel using country-level fixed effects. We also show that the effects of port efficiency on international trade are biased upward substantially when not including these country-level fixed effects. This is a serious issue for the only alternative port efficiency measures we are aware of – from the surveys by the World Economic Forum published in the Global Competitiveness Report – as they do not have time series variation and, thus, cannot be estimated when including country-fixed effects.

We now include a new section titled "*The Link Between Our Port Efficiency Measures and International Trade*," which documents this analysis in Section 4 of the paper beginning on p 16.

3. The identification technique assumes that there are not port x product interactions. That is, a low cost port is a low cost port regardless of the product in question. As long as we're focused primarily on manufactured goods and container ports, this seems entirely reasonable. If we are mixing port facilities that handle grain and oil and containerized manufactures and noncontainerized manufactures, then the assumption of no port x product interactions seems more problematic.

This suggests a couple of robustness checks:

a. There appears to be a huge amount of data, so focus only on shipments that are 100% containerized. Are the coefficients (or at least the rank order of port costs) consistent with the whole sample?

b. Similarly, if these intercepts are capturing something about port costs generically then they should be stable across subsets of goods. Estimate the intercepts separately for each 4 digit HS product (or 2 digit), and calculate the correlation between port intercepts across products. If the intercepts are not stable, what does this say about the intercept approach as a way to back out port efficiency?

We agree that this is an important issue. As you could likely predict, we simply are a long way from being able to include port x product fixed effects from a computational standpoint, as that would substantially increase our current regressor set – one causes a Linux machine with 8 Gig to crank for many days.

Instead, you give us a couple "robustness checks". Our data pass the first one, in that we get very similar port efficiency rankings when we use data only on 100% containerized import observations (this condition reduces our sample by about a third). The estimated effects of port efficiency on international trade flows are also qualitatively similar, which we note for the reader in footnote 17.

We do not pass the second robustness test, as the correlations between port rankings across 2-digit sectors (either U.S. or foreign) are quite different. Few are statistically significant and some are even negative. Where this could really matter is for our estimates of port efficiency on trade volumes. Are we picking up port efficiency effects or changes in product composition? However, we document that product composition of the imports coming from foreign ports to the U.S. does not vary much over our sample. Thus, we can believe we have ruled out that product composition changes are driving this central result of the paper.

To address these issues for the reader, we now include a final section before the conclusion titled, "Product-level Heterogeneity in Estimated Port Fixed Efficiencies" with the following text:

"A final issue concerns the generality (or stability) or our port efficiency measures across products. Our methodology above provides an estimate of a port's *average* contribution (in percentage terms) to import charges across all products the port may export to the U.S. (in the case of foreign ports) or may import from abroad (in the case of U.S. ports). A natural question is whether ports' efficiencies vary significantly across products. Our preliminary investigations suggest that rankings of port efficiency using our methodology vary substantially across products. As an example, our earlier version of this paper (Blonigen and Wilson, 2006) provides separate rankings of U.S. ports for autos and steel products, which are quite different from each other, as well as the general rankings of U.S. ports' efficiencies.

These differences in product-level efficiencies within ports are potentially problematic for our estimates of average port efficiency and their estimated correlations with international trade flows. The concern is that changes in product composition at the port level over time could be driving the positive correlation with trade flows, not changes in the ports' inherent efficiencies. A way of handling this statistically is to include port-by-product specific effects into our

estimation procedure. Unfortunately, this is practically infeasible as we are already pushing computation limits with our current regressor set and specification, and this would substantially increase the number of fixed effects to be estimated.

However, if one assumes that product composition at the ports is stable over our panel of years (1991-1999) in the gravity model estimates, then we can be reasonably confident that product composition changes are not affecting the relationship we estimate between port efficiencies and international trade flows. In fact, there is significant evidence that product composition is not changing much over our sample. The correlation between foreign ports' 2-digit product-level U.S. export values in 1999 and 1991 is 0.86. This same correlation at the 4-digit level is 0.82. Thus, we believe this issue is unlikely to be significantly biasing our estimates of the relationship between port efficiency and trade flows. Nevertheless, exploring the factors behind the heterogeneity in port efficiency across products is clearly an area for future research."

4. Presumably quantities shipped are endogenous to the transportation cost. This certainly affects consistent estimate of the quantity variables on the right hand side. Does it also affect the port intercepts if some ports have high quantities and some have low quantities?

In the original draft, we included the total annual volume of trade (across all HS codes) between the U.S. port and foreign port involved in the trade for each observation. This variable may have some endogeneity with the dependent variable (import charges) when trade between the two specific ports involves relatively few HS codes; recall that observations are the trade in an HS code between a U.S. and foreign port. However, if trade between two ports involves even a reasonable subset of the thousands of 6-digit HS codes, significant endogeneity bias is quite unlikely.

However, we note that this question made us realize that congestion is a factor that we is a component of port efficiency that we would like to capture in our port fixed effects. Including the volume measure nets this congestion effect out of these port fixed effects. So we no longer include a volume measure as a separate regressor on the right-hand side, so that these congestion effects are included in the port fixed effects we estimate. In the end, all of our coefficient estimates (including the port fixed effects) are virtually identical whether we include this volume measure or not, so it's not a significant issue.

<u>Other Changes to Note</u>

We made a number of other changes to this draft, mostly to highlight that our paper does more than just provide new estimates of port efficiency, but also estimates the relationship between port efficiency and international trade flows.

1) We have changed the title of the paper to reflect its more broad treatment of port efficiency and trade: "Port Efficiency and Trade Flows".
2) We have significantly re-written the introduction and conclusion to reflect this broadened focus. We also took the opportunity to develop a much more concise and shorter introduction, putting some of the former material into a new "Previous Literature" section.

3) We eliminated the section that provided separate U.S. port rankings for autos and steel, though we still refer the reader to these results in our previous draft, which they can access as an NBER working paper.
4) We eliminated the graphs and discussion of movement in U.S. port rankings over time. Both this deletion and that in 3) were so as not to detract from the new section providing gravity-model estimates that relate port efficiencies to international trade flows.
5) We eliminated the oil sector from our data sample, since this unique industry has so many ports (especially) foreign ones that only specialize in this commodity. U.S. port rankings are not affected much at all whether we include oil or not, but the list of top 100 foreign ports ended up being populated with oil ports from Nigeria, Saudi Arabia, etc., which we felt trade economists do not care as much about as activity with container and diversified ports.

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- 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.

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