International Trade, Transportation Networks and Port Choice

by

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Abstract: Rapid increases in international trade have led to congestion in many of the worlds' ports and have raised concern over the ability of transportation networks to handle the increased volumes. Increased volumes and the resulting congestion may impact trade flow patterns by affecting choices of importers and exporters. Trade flow patterns are most certainly determined by a wide variety of factors that include the internal (intra-country) and external (inter-country) transport costs, as well as the costs of interchange (port costs). Yet, there is little evidence that documents each of these factors in the determination of trade flow patterns. As any of these factors become relatively more or less congested, there may be significant impacts not only on the network paths chosen, but also on the volume of activity. This paper develops a model of port choice and trading volumes and then estimates the impact of ocean transport rates, efficiency of U.S. ocean ports, and internal transport systems on port choice and trade volume over a sample trade flows between over 150 foreign countries and the top U.S. ports for the period from 1991 through 2003. Our estimates provide strong evidence for the importance of economic factors in port choices. Distance and transport prices are very significant factors with quite elastic responses by shipments well above one in absolute magnitude. Unlike previous studies, this paper's analysis finds a significant role for an individual's port efficiency in determining its share of activity, with estimates ranging from 0.8 to 2.0 depending on the empirical specification used.

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I. INTRODUCTION

Tremendous increases in international trade have led to increasing pressure on the world's transportation markets and, in particular, the ability of ocean ports to handle the freight. Increases in congestion, particularly on the west coast of the U.S. are well documented and point to increases in the costs of shippers operating internationally. Policy-makers look to allocating investment budgets across different ports to not only handle the additional volume, but also to accommodate investments by the shipping industry in larger container ships that require deep sea channels, wide berths at docks, and appropriate unloading equipment. The effect of investments, of course, depends critically on the responses of shippers and traders with respect to not only the ports to use in routing shipments, but also the volume of trade. These choices are a function of the locations of the traders and the total transportation costs on the links and nodes that connect the traders. These include the ocean rate, the port costs, and the internal transportation rate. In this study, we develop a model of bilateral trades that captures each of these elements and then test the impacts of each of these factors on the ocean port choices made by shippers for imports into the United States (US).

The US provides an exceptionally interesting country to study such port decisions for a number of reasons. First, operations of ocean ports are decentralized and governed by local port authorities that may or may not own and/or operate significant portions of the port. There is little coordination of port operation at the federal level and, thus, ports compete for both business and funds to maintain and improve infrastructure. This contrasts with a country where ports are government-owned and a central authority makes resource allocation decisions.[1] Second, the US is geographically a very large country, spanning thousands of miles. Thus, internal transport may be just as important (or more important) of a factor in seaport choice than ocean transport. For example, goods from China may be delivered in a Midwestern state from relatively close West-coast ocean ports and relatively long land costs. Alternatively, these same goods may be shipped from China to Gulf or eastern ports through the Panama Canal with relatively shorter land costs. While the connection of routing with external (ocean) and internal transport costs is obvious, there are also congestion costs associated with different ports. Indeed, if west coast ports are congested, with associated higher costs, or if attributes of the port do not lend themselves to low cost transference of the good shipped, shippers may choose to opt to another port.

Despite these obvious policy implications at stake, systematic information about the factors that influence ocean port choice is sparse in general.[2] Many studies in the literature, particularly earlier ones, rely on surveys of shippers to attain information on factors that affect port choice and their relative importance for those decisions.[3] As noted by Malchow and Kanafani (2001), these studies identify various factors related to geography, port attributes, transport costs, and fees as important, but there is significant variation across studies in which factors are found to be most important for survey respondents. In addition, as Brooks (1984) points out, a factor may be deemed important by shippers, but may vary little across ports and so have no practical impact on port choice. An extension of this literature is use of an analytic hierarchy process (AHP) to analyze survey data, as in Lirn et al. (2003) and Song and Yeo (2004). This methodology allows the research to prioritize responses in a certain manner so that weights can be attached to various factors. Such studies still suffer from the Brooks critique concerning stated versus practical importance and rely on strong assumptions to generate weights on the various factors.

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[1] Annual capital expenditures at U.S. ocean ports have averaged over $1 billion.

[2] It is not difficult to find articles in media outlets that mention likely factors in port choice often surrounding a decision being made by a shipper regarding location of operations at a specific port. However, our point is that there is little systematic study of data covering many ports over time to look for general patterns and relationships.

An alternative analytical approach is to use statistical analysis to uncover the importance of various decision factors that is revealed in the actual port decisions we observe. This seems to have never been undertaken with respect to ocean port decisions until a recent set of papers by Malchow and Kanifani (2001; 2004) and Tiwari et al. (2003).[4] These studies gather data on import shipment choices for a certain point in time, select commodities and then estimate a multinomial logit model to identify the effect of certain factors on the port choice. Malchow and Kanifani examine port choices for U.S. exports made in December 1999 for four sets of commodities (bulk minerals, fruits and vegetables, fabrics, and electrical and electronic equipment) to eight major US ports on the east and west coasts. They examine how the port choice is impacted by four factors – 1) oceanic distance between U.S. and foreign port, 2) inland distance from shipper to U.S. port, 3) sailing frequency from between the U.S. and foreign port, and 4) average vessel size between the U.S. and foreign port. Their results find a statistically significant negative correlation between all four factors and the probability a port will be chosen. While a negative correlation was expected for the two distance terms, the negative correlation for the latter two variables is unexpected. Tiwari et al. (2003) use a similar methodology to examine the joint port-shipper choice for roughly 1000 Chinese containerized shipments in 1998 across 14 alternatives. Similar to Malchow and Kanifani (2001; 2004), the study finds that inland distance and frequency of shipments are negatively correlated with the probability of a port-shipper combination being chosen. Unlike Malchow and Kanifani, the study also investigates the effect of port attributes and finds that the probability of port-shipper being chosen increases in the total number of berths at the port and negatively related to total shipment volume at the port. Other

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[3] Examples include Slack (1985), D'Este and Meyric (1992), and Murphy and Daley (1994). Brooks (1984) provides an early theoretical piece on factors affecting port choice.
[4] Winston (1981) uses a multinomial probit model to examine US domestic shippers' choices between ocean container service and surface transportation on the West coast.

port attributes such as channel depth, number of cranes and port charges were statistically insignificant factors.

This study extends the nascent statistical work in this area in a number of important ways. First, we sample all international trade shipments into U.S. seaports over the period 1991 through 2003.[5] In direct contrast to the previous studies discussed above that examine a very narrow and small set of transactions for one particular point in time, our study brings a much greater wealth of data to estimate the effects of various factors on port choice. This approach allows us to examine heterogeneity across products, modes of shipment (e.g., containerization), and time. The tradeoff with this approach is the use of data aggregated across individual shipper choices. A second extension is use of new port efficiency measures that vary across ports as well as time estimated in a companion paper (Blonigen and Wilson (2006)). Such measures provide the variation across ports and time necessary to better identify the effects of port attributes on port choice. A final difference with our paper from the previous literature is our examination of import data, rather than export data.

Our estimates provide strong evidence for the importance of economic factors in port choices for U.S. imports. Distance and transport prices are significant factors and point to elastic responses by shipments, often well above one in absolute magnitude. In addition, unlike previous studies, we also find that an individual's port efficiency plays a significant role in determining its share of activity. The effect of port efficiency on port choice is particularly strong and robust for containerized shipments.

[5] We take the decision to ship to a U.S. port as exogenously given and independent from decisions to send to other countries. Shipments to Canadian ports (and possibly land transport to U.S. locations) is an obvious way in which this assumption may be violated, but data availability prevent us from exploring this issue.

The next section discusses the theory behind our empirical approach which motivates presentation of our empirical methodology. Section III and IV describe our data and provide empirical results, respectively, and section V concludes.

II. METHODOLOGY

In this section, we present two different approaches to modeling the effects of transportation costs on bilateral trade. Transportation costs are delineated by intra- and inter-country transportation costs with an explicit representation of port efficiencies and other determinants. First, we develop a conditional logit wherein a shipper considers the routing of shipments; i.e, the port choice. Second, we also consider a more traditional international trade literature approach by specifying a gravity model of trade flows.

To begin, we consider a shipper in a foreign country who is exporting a product to an importer located in the United States. Suppose there are $j \in J$ seaports to choose from. For each seaport, there is a unique combination of ocean transport costs, seaport costs, and inland transport costs for a given location of the importer. The transport costs depend on not only the distance between shipment points, but also the total cost of the transport service: i.e., ocean rate, port costs, and internal rates. We assume that the exporter/shipper chooses the lowest cost route to the U.S. importer's location. This naturally leads to the specification of a conditional logit framework in the following manner. Suppose that costs for a shipment by a shipper-importer combination i through seaport j (C_{ij}) can be expressed in the following manner:

$$C_{ij} = \beta_1 OC_{ij} + \beta_2 IC_{ij} + \beta_3 PC_j + \mu_{ij}, \qquad \textbf{(1)}$$

where OC_{ij} is the ocean transport costs between the shipper i and seaport j, IC_{ij} is the inland transport costs between seaport j and the importer i, PC_j represents the ports costs connected with seaport j, and μ_{ij} is an error term. Assuming that revenues from production and sale of the product do not depend on the transport choice, the shipper-import combination will maximize their joint profits by choosing the option that will probabilistically provide the lowest costs. With the common assumption that the error term is identically and independently distributed as a Weibull distribution, $F(\mu_{ij}) = \exp(-e^{-\mu_{ij}})$, one can estimate the parameters of interest in equation (1), β_1, β_2, and β_3, using a standard conditional logit specification. Malchow and Kanifani (2001;2004) and Tiwari et al., 2003 use this empirical framework to examine the relative impact of ocean distance, inland distance, and seaport characteristics using data on individual export shipments for a given point in time. They proxy for transports costs using data on distances between shippers and foreign importers from the sea ports they use. This ignores the effects of transport prices on transport costs and ultimate port decisions.

Our data are quite different. Specifically, our data consist of annual import volumes into various U.S. seaports from 1991 through 2003. The use of these data presents two main issues relative to these previous studies. First, these annual import volumes reflect aggregate individual port choices. One approach to modeling these choices is to assume that individual shipper-importer combinations can be theoretically represented by a single exporter who is shipping to a variety of U.S. importer locations. Then individual shipment choices can be aggregated into *shares* of the annual U.S. import volume that goes into each seaport. The conditional logit framework can accommodate use of such share (or proportions) data, rather than the typical data on discrete individual choices.

The second issue is that there is no information on the locations of the U.S. importers, and, hence, inland distance in our aggregate data. To address this, we begin by assuming that U.S. importers are distributed across locations in the U.S. directly proportional to the market activity in their location. Taking states as the unit of spatial entities, inland transport costs (*IC*) for seaport *j* can be represented as

$$IC_{jt} = ip_t \sum_{k=1}^{K} id_{jk} GSP_{kt}, \qquad \textbf{(2)}$$

where ip_t is the price of inland transport that varies with year *t*, id_{jk} is the distance between seaport *j* and other states, indexed by $k \in K$, and GSP_{jkt} is the gross state product of state *k* in year *t*. We assume inland distance between a port and importers in the same state is zero. Since there is time series variation in our data, we also can explicitly factor in the price of ocean transport into our ocean cost measure and define it as

$$OC_{ijt} = op_t od_{ij}, \qquad \textbf{(3)}$$

where op_t is the price of ocean transport in year *t* and od_{ij} is the distance between shipper *i* and U.S. seaport *j*. We note that *IC* does not vary by which foreign exporter (*i*) is shipping the product, whereas *OC* does vary over *i*. Given these modifications we can use a conditional logit framework to evaluate the various transport factors – ocean, inland, and port costs – on port choice.

The conditional logit framework obviously imposes significant structure to model port choices. This may be especially problematic when there are many alternatives considered as will the case in our estimation (i.e., many U.S. seaports). An alternative is to appeal to a "gravity model" specification that is typically used to model international trade flows. Such a framework assumes that the volume of trade between regions is positively correlated with the market size of both regions and the distance between them.[6] In these models, distance is a proxy for "trade costs" that include transport costs and other trading "frictions". Such frictions may include

[6] Anderson (1979) was the first to provide a theoretical foundation for the gravity model of trade.

efficiencies of seaports, though this has been rarely considered.[7] For our data, market size of the import region is the key issue; i.e., what is the market size of the region connected with seaport *j*. However, we can construct a useful measure that is related to our measure of inland distance in equation (2). Assuming that there are no inland transport costs for importers in the same state as the port, a simple measure of market size for each seaport is its state's GSP. Since not all states have seaports, yet importers exist in these inland states, this clearly needs to be modified. Effective market size of a seaport can then be assumed to include other state's GSP weighted by an inverse function of the inland transport costs to that state. Such terms are typically called "market potential" variables in the literature and have their origins with Harris (1954).[8] We assume a simple market potential (*MP*) variable of the following form for a seaport *j* in year *t*:

$$MP_{jt} = \sum_{k=1}^{K} \frac{1}{ip_t id_{jk}} GSP_{kt} = \frac{1}{ip_t} \sum_{k=1}^{K} \frac{1}{id_{jk}} GSP_{kt}, \qquad \textbf{(4)}$$

where the variables on the RHS of have the same definitions as indicated in our discussion above. Using this market potential variable as a measure of the market size of seaport *j* in year *t* and logging it to be consistent with previous studies, our base empirical gravity model is:

$$\ln V_{ijt} = \alpha + \pi_1 \ln GDP_{it} + \pi_2 \ln MP_{jt} + \pi_3 \ln OC_{ijt} + \pi_4 \ln PC_{jt} + \varepsilon_{ijt}, \qquad \textbf{(5)}$$

where GDP_{ijt} is real GDP of the foreign country and proxies for the number of exporter/shippers in the foreign country, ε_{ijt} is an assumed white noise error term, and all other terms are as defined above. Using equations (3) and (4), we can rewrite (5) as:

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[7] The exception is Clark et al. (2004) which estimated trade volumes between countries and found that port efficiencies were significant in explaining trade volumes. As we discuss in Blonigen and Wilson (2006), they rely on measures of port efficiency based on country-level survey data from the Global Competitiveness Report and estimate using a cross-section of data. The measures of port efficiency we use in this study are port-specific, not country-specific and vary over time. Also, our data focus on trade activity across U.S. ports, whereas theirs is a country-level analysis.

[8] See Head and Mayer (2004) as a recent work that discusses various formulations of market potential measures in estimating trading opportunities amongst neighboring regions.

$$\ln V_{ijt} = \alpha + \gamma_1 \ln GDP_{it} + \gamma_2 \ln ip_t + \gamma_3 \ln(\sum_{k=1}^{K} \frac{1}{id_{jk}} GSP_{kt}) + \gamma_4 \ln op_t + \gamma_5 \ln od_{ij} + \gamma_6 \ln PC_{jt} + \varepsilon_{ijt}, \quad \textbf{(6)}$$

Equation (6) is our base model for our gravity specification and can be estimated using Ordinary Least Squares (OLS).

We expect the coefficient on γ_1 to be positive as the supply of trading opportunities increases with the market size of the foreign country. Likewise, we expect the coefficient on γ_3 to be positive as imports into a port should be larger when the spatially-weighted market size around the U.S. port is larger. We also expect γ_2 to be negative since imports should increase as the price of inland transport increases. The coefficients γ_4 and γ_5 are expected to be negative as higher ocean transport prices and ocean distances should decrease trade volumes. Finally, γ_6 should be positive as greater port efficiency attracts greater import volumes.

III. DATA

The data used in this analysis are from a variety of sources. Our measure of port-level U.S. import volumes (dependent variable, V_{ijt}) comes from the National Data Center (NDC) of the Army Corps of Engineers (ACE), which 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. We define our measure of import volume by value measured in dollars, though we note that we obtain very similar results in our statistical analysis when measuring import volumes by weight. While these data contain detailed information on import flows by 6-digit HS commodities, we primarily focus on the aggregate import volumes across all products for our analysis although such an approach can be adapted for specific commodities and is adapted as an illustration later.

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 ocean distance (od_{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.

Data for our measure of market size for the foreign country source of the imports is real GDP data from the World Bank's *World Development Indicators* CD-ROM. Our measure of market size around the U.S. port is constructed using real gross state product reported by the Bureau of Economic Analysis, U.S. Census Department and distances between ports and U.S. state capitol cities using the website: http://www.symsys.com/~ingram/mileage/index.php. When calculating our market potential variable for the gravity specifications as in equation (4), we truncate our weighted sum of state GDPs around the port to only those states whose capitol cities are within 500 miles of the U.S. port. More specifically, the weight on surrounding states' GSP for our market potential variable were calculated as maximum of {(500-d)/500, 0}, where d is the distance from the port to the U.S. state's capitol city. We restrict the distance between the port and the capitol city for the state in which it is located to be 0, so that the home state of the port gets the maximum weight of 1. Analogously, for our calculation of inland transport costs as in equation (2) we truncate at 500 miles as well, where the maximum weight of 1 occurs for a state with a capitol city 500 miles from the U.S. port. Specifically, the distance weights here are calculated as the maximum of {d/500, 1} where we restrict the distance between the port and its state's capitol city to be zero.

Transport prices are not simple to observe and gather. As a proxy for inland transport prices (ip_t) we use annual data on U.S. railroad freight rates that are reported as revenue per ton mile (in U.S. cents) by the Surface Transportation Board and Association of American Railroads.[9] Ocean transport prices (op_t) are similarly difficult to obtain (e.g., see Hummels, 2001, for a discussion of this data issue). We use an annual index of dry cargo freight rates that has been constructed by the Lloyd's *Ship Manager*, and reported by the United Nation's Conference on Trade and Development publication, *Review of Maritime Transport*, various issues.

Finally, port efficiency measures across U.S. ports and time have not been available in the past. (see U.S. Department of Transportation, Maritime Administration, 2005) In a companion paper, Blonigen and Wilson (2006) we construct such measures based on statistical analysis of U.S. port-specific import charges. These measures are estimates of how much a U.S. port adds to the import charges all else equal relative to the Port of Oakland. Since more efficient ports would add less to import charges, we subtract these estimates from 2.0 as our measure of port efficiency, since the measures range roughly from -2.0 to 2.0.[10]

Our data span U.S. import transactions involving 46 U.S. ports, 117 foreign country sources and the years 1991 through 2003. We limit our sample of U.S. ports to the top 46 since they account for the vast majority of U.S. imports and our measures of port efficiency are often imprecisely estimated for smaller ports.[11] The sample of source countries is only limited by which foreign countries we can obtain GDP data. Table 1 provides sample statistics for our conditional logit and gravity-model estimates.

IV. RESULTS

A. Conditional Logit Estimates

[9] Similar "revenue per ton mile" statistics for truck transportation are collected by the U.S. Census, but only beginning in 1997, which is well after our sample begins.

[10] These port-specific measures of additional costs average 0.08 in value (standard deviation of 0.11) with the interpretation that the average port adds 8% more to import charges than the Port of Oakland, everything else equal.

[11] In 2003, the top 46 ports accounted for 95% of all U.S. imports (by value).

Column 1 of Table 2 provides conditional logit estimates of the factors that affect port choice for imports into the U.S. from 1991 through 2003 following equation (1). The coefficients on all three variables – ocean transport costs, inland transport costs, and port efficiency – are of expected sign and statistically significant at the 5% level or better. Both sets of transport costs (ocean and inland) have negative coefficients, suggesting that greater transport costs significantly decrease the likelihood a port will be chosen. Surprisingly, the elasticities we calculate from our coefficient estimates suggest that port choice is much more responsive to ocean transport costs than inland transport costs, which is contrary to previous literature (e.g., Tiwari et al., 2003, and Malchow and Kanifani, 2001 and 2004). The elasticity of the port choice probability with respect to ocean transport costs is around -25, whereas the elasticity of the port choice probability with respect to inland transport costs is around -0.5.[12]

Port efficiency is found to significantly affect port choice in these estimates as well. Our estimates suggest that a 10% increase in port efficiency leads to approximately an 8% increase in a port's share of U.S. imports (elasticity around 0.8), ceteris paribus. Previous studies have found mixed evidence for the effect of port efficiency, at best, and contrasts with the strong effect we find here using a more comprehensive measure.[13]

Most studies of port activity and port choice center their attention on containerized shipments, unlike the estimates we just reported that use data that aggregates shipments across all goods and shipment types. Aggregation across these various modes of transport may be inappropriate and factors affecting port choice may systematically differ. To explore this, we next

[12] Conditional logit estimates allows the calculation of individual elasticities for each alternative. We found that the variation in elasticities across alternatives was fairly small and, thus, we just report the approximate elasticity around which these individual elasticities vary.

[13] Previous studies have only examined whether various port attributes (not port efficiency per se) affects port choices and have found evidence for some, but not others. For example, Tiwari et al. (2003) find that the total number of berths at a port increases its likelihood of being selected by a shipper, but report that "We tried other

estimate the factors affecting containerized imports using the same conditional logit specification. We are unable to estimate this model for the full sample of port alternatives, since many ports receive very little to no imports with container ships. Thus, we focus on the top 15 U.S. ports for containerized import volume.[14,15]

Column 2 of Table 2 presents estimates of our conditional logit specification for port choice with container shipments to the top 15 U.S. ports from 1991 through 2003. Despite a much smaller sample of observations and focus on containerized shipments only, we get very similar estimates to the overall sample. Coefficients on all three factors are have the expected sign, are statistically significant, and are of similar magnitude to column 1 estimates in Table 2. The only important change is that the effect of port efficiency on port choice is twice as large for container shipments as for all shipments. Our estimates suggest that a 10% increase in a top-15 port's efficiency leads to about a 15% increase in the share of shipments it receives.

Estimation of conditional logit estimates with a large number of alternatives can be computationally difficult. We found this to be true for these data. Attempts to include port-specific constants led to non-convergence of the estimation procedure. We found similar difficulties when exploring nested logit variations of the model.[16] We did find that our estimates were qualitatively identical if we defined our dependent variable as a port's share of imports measured by weight, rather than in dollar value. The next section provides an important robustness check for these estimates by exploring a gravity-model specification.

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variables like number of cranes, routes offered at the port, water depth, and port charges, but they were dropped as insignificant." (p. 35)

[14] These ports are, in order of largest to smallest trade volume during our sample years, Los Angeles, Long Beach, New York/New Jersey, Seattle, Houston, Oakland, Charleston, Tacoma, Baltimore, Norfolk, Savannah, New Orleans, Jacksonville, Philadelphia, and Miami.

[15] Our data report the percentage of imports that are containerized for a particular 6-digit Harmonized System good and a foreign-U.S. port combination. Before aggregating, we drop any observations that are not 100% containerized.

B. Gravity Model Estimates

Column 1 of Table 3 provides ordinary least squares estimates of the factors that affect port choice for imports into the U.S. from 1991 through 2003 following the gravity-model specification in equation (6). As with the conditional logit estimates, we find strong support for our hypotheses about how factors affect U.S. port volumes. With all variables in logarithm form, our coefficient estimates can be read as elasticities. The coefficients on ocean distance, ocean transport prices, and inland transport prices are all negative as expected, since greater transport costs are expected to reduce import volumes. Unlike the conditional logit estimates, greater inland transport prices are estimated to have a more significant impact on reducing a port's import volumes than ocean transport prices with elasticities of -2.4 and -1.1, respectively. Such an ordering, however, is more consistent with the few prior studies that exist. The coefficient on foreign market size is positive and significant as expected, though the market size around the U.S. port is surprisingly negative and statistically significant, though the elasticity is fairly small (-0.4). Port efficiency comes in with an expected positive coefficient and an elasticity (2.3) that is larger than the conditional logit estimates.

We next explore two variations to our base gravity-model specification. First, we include sets of dummy variables to capture time-invariant unobserved port-specific factors and foreign-country factors that may affect import volumes.[17] Such factors could include natural geographic features, regulatory environments, historical relationships with shippers, and other political variables that we cannot observe or otherwise measure. Column 2 of Table 3 provides estimates when we include these port-specific and foreign-country fixed effects. The R^2 measure increases

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[16] Generally, the nesting involved modeling decisions as being west, east and gulf coast and then to the specific port in each region.

[17] The port efficiency measure has both port and time variability which allows the port fixed effects to be identified. To be sure, if port efficiency varies only modestly over time, the inclusion of fixed effects make it more difficult to

substantially when these fixed-effects are included – from 0.35 to 0.64. Coefficient signs on all our variables remain the same with the exception that the sign on U.S. market potential is now positive as expected, though not statistically insignificant. The elasticity of trade volumes with respect to distance has now doubled to about -6, while the difference in the magnitudes of the inland and ocean transport price elasticities has widened. Port efficiency is still positive in sign, but now quite small and not statistically significant. This may be expected if port efficiencies do not change very much over time, since the port-specific effects would now be controlling for all the cross-sectional variation in port efficiencies (see footnote 17).

A second alternative specification we explore is one that controls for possible endogeneity in our port efficiency measure. Current import volumes may significantly affect a port's efficiency in the same period. To control for this, column 3 of Table 3 provides two-stage least squares estimates when we instrument our port-efficiency measure with the port's previous-period port efficiency. A Hausman test rejects exogeneity of the ordinary least squares estimates. The coefficient on port efficient in the two-stage least squares estimates is larger (0.4), but still statistically insignificant. We continue to employ port-specific fixed effects in these two-stage least-squares estimates, so the time-series variation in port efficiencies may simply not be sufficient to adequately identify the effects of port efficiency on a port's import volumes. Nevertheless, these two-stage squares estimates are our preferred specification.

As a final step, we explore the gravity-model specification estimates when we only use data on shipments that are 100% containerized. Convergence problems are not an issue for this model, so we do not need to restrict ourselves to only the top 15 U.S. ports, as with the conditional logit estimates. Table 4 provides our gravity-model estimates for containerized U.S. imports with

identify separately the port efficiency effect;t i.e., it will be captured in the fixed effects. Similar effects can be anticipated with respect to the market potential variable.

analogous variations in specification to those in Table 3. Results are similar in many ways. For example, if we focus on our preferred specification in column 3, we have an identical sign pattern across the two tables. The main differences, however, are quite interesting. First, the elasticities for inland and ocean transport are much larger in absolute magnitude, suggesting that containerized shipments are much more sensitive to changes in these prices than other shipments, such as tankers, for example. Second, the port-efficiency elasticity is not only positive, but statistically significant, with a magnitude of 2.2. Unlike the estimates using the full sample, instrumenting for port-efficiency is crucial for this sample, as the estimated elasticity on port efficiency is negative and significant in the simple ordinary least squares estimates.[18]

V. CONCLUSION

This paper provides the first estimates of transport and port efficiency factors on port choice and shipment volumes for a comprehensive sample of alternative domestic ports, foreign ports, shipment types, and product types. The few previous studies have focused on much more narrow samples. Our estimates provide strong evidence for the importance of economic factors in port choices. Distance and transport prices are very significant factors with quite elastic responses by shipments well above one in absolute magnitude. Unlike previous studies, this paper's analysis finds a significant role for an individual's port efficiency in determining its share of activity, with estimates ranging from 0.8 to 2.0 depending on the empirical specification used.

Two quite different modeling specifications were used to examine the effect of transport costs and port efficiency on port choice. While the general results are consistent across these models and find significant support for the role of inland transport costs, ocean transport costs and port efficiency, there are some differences. For example, the elasticity of port choice to inland

[18] Again, a Hausman test for exogeneity rejects the null hypothesis of exogeneity in the OLS estimates.

transport costs is smaller than that of ocean transport costs in the conditional logit estimates, but much larger in the gravity-model specifications. There are further extensions of these two empirical frameworks that could be employed and may resolve remaining differences. The conditional logit framework specifically models the interdependence of the port choice across alternatives, but any violations of the assumptions underlying the structure of the framework can lead to statistically biased and inconsistent estimates. The large number of choices we are evaluating also caused convergence issues in estimation. Use of more flexible functional forms (e.g., a nested logit framework) may be ultimately able to overcome some of these problems, though we did not find that to be true in our work here.

In contrast, the gravity-model approach is very easy to estimate and does not involve strict modeling assumptions, but as currently estimated does not account for potential interdependence in the port choices across alternatives. Future analyses could estimate these models allowing for interdependence using spatial econometric techniques.

Table 1: Descriptive Statistics for Alternative Models and Samples

Descriptive Statistics for Variables in Conditional Logit Specification - All Imports

Variable	Mean	Standard Deviation	Minimum	Maximum
Import Share	0.022	0.071	0.000	1.000
Ocean Transport Costs	9.403	0.639	5.967	10.497
Inland Transport Costs	13.114	3.614	0.000	15.728
Port Efficiency	0.662	0.118	0.161	1.284

Descriptive Statistics for Variables in Conditional Logit Specification - Containerized Imports to Top 15 Ports

Variable	Mean	Standard Deviation	Minimum	Maximum
Import Share	0.057	0.112	0.000	1.000
Ocean Transport Costs	9.371	0.654	5.967	10.391
Inland Transport Costs	12.919	3.643	0.000	15.431
Port Efficiency	0.655	0.027	0.586	0.729

Descriptive Statistics for Variables in Gravity-Model Specification - All Imports

Variable	Mean	Standard Deviation	Minimum	Maximum
Value of Imports	9.689	7.795	0.000	24.570
Distance	8.756	0.598	5.425	9.660
U.S. Port Market Size	13.530	0.697	10.587	14.619
Foreign Market Size	23.258	2.487	17.237	29.215
Inland Transport Price	0.868	0.050	0.807	0.953
Ocean Transport Price	5.290	0.075	5.147	5.438
Port Efficiency	0.662	0.118	0.161	1.284

Descriptive Statistics for Variables in Gravity-Model Specification - Containerized Imports

Variable	Mean	Standard Deviation	Minimum	Maximum
Value of Imports	7.636	7.486	0.000	24.069
Distance	8.728	0.609	5.425	9.660
U.S. Port Market Size	13.507	0.712	10.587	14.619
Foreign Market Size	23.525	2.345	18.309	29.215
Inland Transport Price	0.869	0.050	0.807	0.953
Ocean Transport Price	5.289	0.075	5.147	5.438
Port Efficiency	0.657	0.147	-0.390	1.225

Notes: All variables are logged with the exception of the dependent variable for the conditional logit estimation which are shares in decimal form. The dependent variable in the gravity model equations are the log of one plus the value of imports.

Table 2: Conditional Logit Estimates of Factors Affecting U.S. Port Choice for Imports

	All Imports to Top 46 U.S. Ports	Container Imports to Top 15 U.S. Ports
Ocean Transport Costs	-3.153**	-3.237**
	(0.109)	(0.129)
Inland Transport Costs	-0.038**	-0.023**
	(0.005)	(0.005)
Port Efficiency	1.263**	2.438*
	(0.188)	(1.086)
Observations	95680	27285
Pseudo R-squared	0.09	0.11
Log Likelihood	-7269.74	-4362.11

NOTES: Standard errors in parentheses. * and ** denote statistical significance at 5% and 1% level, respectively.

Table 3: Estimates of Factors Affecting Import Volumes into U.S. Ports Using a Gravity-Model Specification

	Ordinary Least Squares	Fixed Effects	Two-Stage Least Squares
Distance	-2.888**	-5.963**	-6.002**
	(0.037)	(0.070)	(0.072)
U.S. Port Market Size	-0.121**	-0.094	-0.181
	(0.036)	(0.338)	(0.360)
Foreign Market Size	1.811**	0.624**	0.669**
	(0.008)	(0.182)	(0.200)
Inland Transport Price	-0.382	-2.978**	-3.034**
	(0.475)	(0.949)	(1.029)
Ocean Transport Price	-0.867**	-0.687**	-0.675**
	(0.307)	(0.230)	(0.234)
Port Efficiency	1.352**	-0.085	-0.163
	(0.228)	(0.206)	(0.894)
Constant	-1.487	53.052**	53.928**
	(1.781)	(5.780)	(6.064)
U.S. Port Fixed Effects	No	Yes	Yes
Foreign Country Fixed Effects	No	Yes	Yes
Observations	74612	74612	68954
R-squared	0.35	0.64	0.64

NOTES: Standard errors in parentheses. * and ** denote statistical significance at 5% and 1% level, respectively.

Table 4: Estimates of Factors Affecting *Containerized* Import Volumes into U.S. Ports Using a Gravity-Model Specification

	Ordinary Least Squares	**Fixed Effects**	**Two-Stage Least Squares**
Distance	-2.015**	-5.094**	-5.174**
	(0.045)	(0.078)	(0.082)
U.S. Port Market Size	0.356**	1.148**	0.310
	(0.038)	(0.356)	(0.392)
Foreign Market Size	1.395**	1.147**	1.516**
	(0.011)	(0.222)	(0.274)
Inland Transport Price	-10.982**	-8.157**	-14.581**
	(0.549)	(0.987)	(1.165)
Ocean Transport Price	1.399**	-0.388	-1.259**
	(0.361)	(0.236)	(0.341)
Port Efficiency	-1.539**	-0.596**	2.123**
	(0.210)	(0.141)	(0.509)
Constant	-9.252**	23.696**	37.521**
	(2.085)	(6.172)	(6.687)
U.S. Port Fixed Effects	No	Yes	Yes
Foreign Country Fixed Effects	No	Yes	Yes
Observations	62805	62805	55431
R-squared	0.20	0.63	0.63

NOTES: Standard errors in parentheses. * and ** denote statistical significance at 5% and 1% level, respectively.

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