On the Historical Relationship between Port (In)Efficiency and Transport Costs in the Developing World

Infrastructure and Energy Sector & Vicepresidency for Countries

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On the historical relationship between Port (In)Efficiency and Transport Costs in the Developing World[1]

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Abstract

Do differences in port performance explain differences in maritime transport costs? How much would improvements in port performance reduce maritime transport costs in developing countries? To answer this question, we use a widely used transport cost model, but we provide a new measure of port efficiency, estimated through a non-parametric approach. Relying on data from the early 2000s, this paper shows that for a sample of 115 container ports in 39 developing countries, becoming as efficient as the country with the most efficient port sector would reduce average maritime transport costs by 5 percent. For the most inefficient country, the reduction in transport costs could reach 15 percent. These findings point out the potential gains that can be achieved from the combination of better-quality investment and more efficient service provision in the port sector. The estimates in this paper cannot be updated because the databases were discontinued and it therefore highlights the need to generate data to evaluate the effectiveness of public policies that are key to competitiveness.

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Keywords: Trade, transport costs, ports, port efficiency, developing world.

1. Introduction

As liberalization continues to reduce artificial barriers to trade, analysis of the relevance of transport costs as a component of trade costs has become a cornerstone of the trade and development literature. Transport costs, defined as all shipping expenses of internationally traded goods from origin to destination (Kurmanalieva 2006), represent a major component of trade costs. Given that more than 80 percent of global trade volume is transported by sea (IMO n.d.), there has been considerable interest in identifying the main determinants of maritime transport costs: geography, gross domestic product (GDP), trade openness, infrastructure, technology, fuel price, policy, and culture (see Limao and Venables 2001; Fink, Mattoo, and

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Neagu 2002; Micco and Pérez 2002; Sanchez and others 2003; Clark, Dollar, and Micco 2004; Wilmsmeier, Hoffmann, and Sanchez 2006; and Blonigen and Wilson 2008, among others).

The relevance of transport costs is particularly evident when transport costs provide a higher effective protection rate than import tariffs for a large share of traded goods (Hummels 1999; Clark, Dollar, and Micco 2004; Micco and Serebrisky 2006). Clark, Dollar, and Micco (2004) find that bilateral trade falls by 22 percent when transport costs rise from the 25th to the 75th percentile of countries in their dataset. Korinek and Sourdin (2009) report that a doubling of transport costs is associated with a decline in import volumes of 66–80 percent. Limao and Venables (2001) show that increasing transport costs by 10 percent reduces trade volumes by more than 20 percent.

Because global trade moves largely through ports, growth in trade can be inferred from growth in container traffic. Worldwide container traffic rose from 225 million 20-foot equivalent units (TEUs) in 2000 to 796 million TEUs in 2019.[2] Given the relationship between ports and trade, it is logical to expect port efficiency to be a key determinant of a country's competitiveness.

Developing countries seem to be at a clear disadvantage in port efficiency, with average higher costs than developed countries. Average export costs per container were $1,070 in OECD countries, $1,283 in Latin America and the Caribbean, $1,787 in South Asia, and $2,108 in Sub-Saharan Africa, according to the World Bank's *Doing Business* report.[3] Suárez-Alemán and others (2016) show that between 2000 and 2010, the average port efficiency levels in the developing world were just 54 percent those of top global performers, such as Hong Kong, SAR China; or Singapore.[4]

An important policy question is whether better port performance in developing countries would increase trade and foster growth. To answer it, this paper attempts to quantify the role of port performance in maritime transport costs and trade.

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[2] http://data.worldbank.org/indicator/IS.SHP.GOOD.TU

[3] According to the World Bank**,** cost measures the fees levied on a 20-foot container in U.S. dollars, including all fees associated with completing the procedures to export or import the goods. These fees include costs for documents, administrative fees for customs clearance and technical control, customs broker fees, terminal handling charges, and inland transport fees. They do not include tariffs or trade taxes. Only official costs are recorded. The World Bank's database assumes that the traded product travels in a dry-cargo, 20-foot, full container load; is not hazardous and does not include military items; does not require refrigeration or any other special environment; and does not require any special phytosanitary or environmental safety standards beyond accepted international standards (http://data.worldbank.org/indicator/IC.EXP.COST.CD). Unfortunately, this indicator is only available until 2015. Currently, the Report includes information on border and documentary compliance instead.

[4] It should be noted that ports in China, being Shanghai the best example, have efficiency levels that place them as top performers in the World.

One strand of the applied literature studies the determinants of transport costs, including port infrastructure (Fink, Mattoo, and Neagu 2002; Micco and Pérez 2002; Sanchez and others 2003; Clark, Dollar, and Micco 2004; Blonigen and Wilson 2008). It uses ad hoc measures of port efficiency that, by construction, do not control for the actual use of port inputs. Another strand of both the applied and theoretical literature develops measures of port efficiency based on the production function of ports (Cullinane and others 2006; González and Trujillo 2008; and many others). This line of research has not focused on the impact of port efficiency on transport costs and trade. This paper is the first paper to combine both approaches to quantify the cost of port inefficiency by showing what would have happened to transport costs in the developing world had ports performed better.

2. Determinants of Maritime Transport Costs

Determinants of maritime transport costs include geographical factors, product characteristics, infrastructure, competition, and regulation (Rodrigue, Comtois, and Slack 2017). Distance, value-weight, levels of containerization, and trade volume are the main drivers. Table 1 presents the point estimates for these variables found in the literature.

Table 1 Main determinants of maritime transport costs identified in the literature.

Author/year	*Period*	*Region*	*Distance*	*Value-weight*	*Containerization*	*Volume*
Blonigen and Wilson (2008)	1991–2003	Worldwide	0.21***	0.55***	–0.04***	0.00***
Clark, Dollar, and Micco (2004)	1998	Latin America	0.18***	0.55***	–0.03**	–0.04***
Fink, Mattoo, and Neagu (2002)	1998	Worldwide	0.33***		–0.07**	–0.02**
Herrera Dappe and Suárez-Alemán (2016)	2000–07	Indian Ocean	0.10**	0.60***	0.21	–0.07***
Limao and Venables (2001)	1998	Worldwide	0.38**			
Micco and Pérez (2002)	1995–99	Latin America	0.17***	0.55***	–0.02	–0.04***
Sanchez and others (2003)	2002	Latin America	0.09	0.54***	–0.02	
Wilmsmeier, Hoffmann, and Sanchez (2006)	2002	Latin America	0.35***	0.34***		–0.02**

Note: Significance level: ** = 5 percent, *** = 1 percent.

Most papers confirm that transport costs are proportional to distance. They show that a doubling in distance increases transport costs by 20–40 percent.

Value-weight coefficients are similar across papers, despite their use of different datasets: The higher the value-weight, the higher the maritime transport costs (Blonigen and Wilson 2008; Micco and Pérez 2002; Clark, Dollar, and Micco 2004; Wilmsmeier, Hoffmann, and Sanchez 2006). Because of the insurance component of transport costs, products with higher unit value have higher costs per unit of weight. On average insurance fees are about 2 percent of traded value and represent about 15 percent of total maritime charges (Micco and Pérez 2002).

The level of containerization has a (not always statistically significant) negative effect on transport costs. As Micco and Pérez (2002) explain, the hypothesis is that containerization reduces services costs, such as cargo handling, and therefore total maritime charges. Although most papers find that the level of containerization reduces transport costs, there is no consensus on the significance of this variable. This result, which is not intuitive given the rapid and widespread growth in the use of containers, is due to port specialization. Provided containers account for most traffic volume in the port system, the impact on costs of a "specialization effect" disappears.

The higher the volume of trade, the lower the costs per unit. Micco and Pérez (2002) estimate that doubling the volume of trade between a given port and the United States reduces transport costs by 3–4 percent. Sanchez and others (2003) show that a 1 percent increase in the volume of trade leads to a 0.085 percent reduction in freight cost.

Additional variables that affect maritime transport costs include trade imbalance and transport infrastructure characteristics. Directional trade imbalances occur when ships carry empty containers on one leg of the journey: Exporters that receive the empty containers and send the containers back packed often bear a higher cost. Clark, Dollar, and Micco (2004) find that moving from a favorable imbalance of 50 percent to an unfavorable one of the same size increases transport costs by about 6 percent.

Port Infrastructure Efficiency as a Determinant of Maritime Transport Costs

Port efficiency has received attention in the literature as an additional important determinant of the level of and changes in transport costs. The evidence shows a strong negative link between port efficiency and shipping costs. However, there is no agreement on the measure of port efficiency. Consequently, the coefficient on efficiency in maritime transport costs estimations varies significantly across papers.

Clark, Dollar, and Micco (2004) incorporate ad hoc measures of port efficiency derived from the World Bank's *Global Competitiveness Report*. They construct an index ranking of port efficiency, based on surveys of cargo handling firms, based on responses to the statement "Port facilities and inland waterways are extensive and efficient" (1 = strongly disagree, 7 = strongly agree). They find that for the average country, port inefficiency is equivalent to being 60 percent farther away from markets.

Wilmsmeier, Hoffmann, and Sanchez (2006) estimate the effects of port efficiency on transport costs for 16 Latin American countries in 2002 based on ad hoc measures of port efficiency derived from the World Bank's *Global Competitiveness Report*. They find that a 1 percent increase in port efficiency reduces trade costs by 0.38 percent and show that if the country with the least efficient port sector improved its port efficiency levels to those seen in countries with the most efficient port sectors, freight charges would drop by 25.9 percent.

Sanchez and others (2003) estimate the effects of port efficiency on transport costs for Latin America, deriving port-efficiency measures from a 1999 survey of 41 terminal operators. Based on extensive questionnaires, they develop port efficiency measures from principal component analysis. They find that the estimated elasticity of trade costs to port efficiency is similar to the elasticity of trade costs to distance: A 1 percent increase in distance increases transport costs by 0.09 percent.

Micco and Pérez (2002) find that increasing port efficiency from the 25th to the 75th percentile reduces shipping costs by more than 12 percent. They use data produced by the U.S. Department of Transportation for 1995–99 transport costs and an ad hoc port-efficiency measure from the World Bank's *Global Competitiveness Report*.

All these measures of port efficiency are statistically significant and show that port efficiency is an important determinant of transport costs. They rely, however, on ad hoc measures that do not control for the actual use of port assets; all of them are built using the variable "quality of port infrastructure" from the *Global Competitiveness Report* surveys. These surveys ask business executives how well developed their national port infrastructure is.[5] The lowest value (1) indicates that they believe that port facilities are extremely underdeveloped; the highest value (7) indicates that they believe their countries' ports are well developed and efficient by international standards.

Although this measure can be useful for tracking the evolution of perceptions of performance over time, it may not be the best tool for conducting a cross-country comparison, because individual perceptions are based on expectations and consequently lead to subjective measures. Comparing port efficiency based on how each port is assessed by its own nationals—and not by a single group that assess all ports worldwide—may lead to inaccurate rankings. These ad hoc measures are thus arbitrary. A developing country with poor facilities but efficient use of them could be considered inefficient, for example, whereas a country with excellent port assets but poor use of them could be considered efficient.

To avoid these problems, this paper builds a measure of economic efficiency based on the use of port inputs to deliver port output. It relies on stochastic frontier analysis, an input-output approach for measuring efficiency, to rank countries in terms of their port efficiency.

[5] According to the World Bank database, sampling follows a dual stratification based on company size and the sector of activity. Data are collected online or through in-person interviews. Responses are aggregated using sector-weighted averaging.

3. Methodology

Do differences in port performance in the developing world explain differences in maritime transport costs? By how much would improvements in port performance benefit these countries? To answer these questions, this paper (a) estimates port efficiency based on stochastic frontier analysis (based on Serebrisky and others 2016); and (b) presents a model of maritime transport costs that includes the impact of port efficiency (based on Fink, Mattoo, and Neagu 2002).

Estimating Port Efficiency Using Stochastic Frontier Analysis

To assess the efficiency level of a port or terminal, the trade and transport literature has used several methodologies. Most studies analyze efficiency by examining the relationship between inputs and outputs. These efficiency measures have proved useful and are therefore ubiquitously applied to port performance (Suárez-Alemán, Trujillo, and Cullinane 2014).

To estimate the efficiency frontier, this paper employs a parametric approach known as stochastic frontier analysis, which assumes the existence of a statistical function and allows for hypothesis testing. Numerous studies use stochastic frontier analysis to analyze port efficiency.[6]

Following Serebrisky and others (2016), we use the following equation to characterize the technical efficiency in the stochastic frontier analysis methodology:

$$y_{it} = \exp(\alpha + x'_{it}\beta + v_{it} + u_{it}) \text{ for } t \in \tau(i); i = 1, 2, \dots, N, \quad (1)$$

where y_{it} is output; x_{it} is a vector of inputs for each port *i* and time period t; β is a vector of unknown parameters; and α is a constant. The term $\tau(i)$ is a set of years for which observations are available for the *i*th port; u_{it} captures technical inefficiency and is assumed to be a one-sided, independent, and identically distributed random variable; and v_{it} captures measurement errors and random effects and is assumed to be a two-sided, independent, and identically distributed normal $N(0, \sigma^v)$ variable. In keeping with the findings of Battese and Coelli (1995), a one-stage model may incorporate the explanatory factors of technical efficiency by fitting a conditional mean model to u_{it} in the estimation

$$u_{it} = \exp(z_{it}\delta + \mathrm{w_{it}}), \quad (2)$$

[6] This methodology has been constantly updated since the initial works by Farrel (1957), Aigner and others (1977), and Meeusen and van den Broeck (1977). Serebrisky and others (2016) explain the evolution of the stochastic frontier analysis methodology as well as recent applications in the port sector. Stochastic frontier analysis has also been used extensively in the water, telecommunications, and energy sectors.

where z_{it} is a vector of explanatory variables associated with technical inefficiency over time, δ is a vector of unknown parameters, and w_{it} is defined by truncating a normal distribution with mean zero and standard deviation σ^2.[7]

Once the assumptions are set, technical efficiency in each observation can be computed by comparing the observed output of each port against the output if there were no inefficiencies of production. These estimates are calculated using the following equation:

$$eff_{it} = \exp(-z_{it}\delta - w_{it}), \quad (3)$$

where eff_{it} (technical efficiency) is a variable ranging between 0 and 1, with the maximum value representing the technical-efficiency frontier.

Modeling Maritime Transport Costs

To determine the components of maritime transport costs, we use a standard reduced-form approach. The econometric model used is based on Fink, Mattoo, and Neagu (2002), who developed a pricing formula that links the cost of transporting goods from origin to destination country to a marginal cost-and-markup term

$$p_{jkt} = mc(j,k,t) + mu(j,k,t), \quad (4)$$

where p_{jkt} is the unit transport cost, in logarithm, for commodity *k* transported between exporter country *j* and the importer country in *year t; k* is the commodity transported in containers. The unit transport cost is the sum of marginal costs plus the markup. Following the literature[8] and the variables listed in table 1, the marginal cost term is expressed as

$$mc(j,k,t) = \alpha + \lambda_k + \beta_1 c_{jkt} + \beta_2 d_{jt} + \beta_3 q_{jt} + \beta_4 imb_{jt} + \beta_5 vw_{jkt} + \beta_6 gdp_{jt} + \beta_7 eff_{jt} \quad (5)$$

where

- α captures import country–specific characteristics, such as port and auxiliary services (which are not part of the dependent variable).
- λ_k captures differences in commodities shipped, considering heterogeneity across commodities.
- c_{jkt} is the percent of containerized shipments in country *j*, expressed as a ratio of the weight of containerized cargoes to the weight of all cargo. The expected sign is

[7] Following the literature on port efficiency, this paper opts for a truncated normal distribution. Cullinane and Song (2006) discuss alternatives within stochastic frontier analysis.

[8] Following Clark, Dollar, and Micco (2004); Wilmsmeier, Hoffmann, and Sanchez (2006); and Blonigen and Wilson (2008), we add the imbalance between imports and exports, value-weight, and GDP to Finks' model.

negative: The higher the level of containerization, the lower the maritime transport costs.

- d_{jt} is the logarithm of the product of oil prices (oil_t) and distance (ds_j). It captures the costs associated with distance that vary with the price of fuel.[9] The expected sign is positive: The greater the distance between countries or the price of oil, the higher the maritime transport costs.
- q_{jt} captures economies of scale, measured as the total weight of cargo carried by liners between exporter country *j* and the importer country. The expected sign is negative: A priori the weight variable is expected to reduce costs.
- imb_{jt} represents the trade imbalance. It is assumed to capture the imbalances in container shipping between the importer country and exporter country *j.* It is calculated as total exports from importer country to country *j* minus importer country imports from country *j* as a ratio of total trade between the countries. The expected sign is positive: A positive trade imbalance would imply an excess supply of containers; exporters would pay more than importers for similar merchandise.
- vw_{jkt} is the value per weight measure for commodity *k.* The expected sign is positive: The higher the value-weight, which control for differences within products, the higher the maritime transport costs.
- gdp_{jt} is the logarithm of exporting country GDP per capita, included as a proxy for infrastructure development of the exporting country. The expected sign is negative: The richer the country, the more developed the infrastructure and thus the lower the maritime transport costs.
- eff_{jt} represents the average intertemporal efficiency of container ports in the exporting country, calculated by weighting the efficiency variable from equation (3) by the port container throughput. The expected sign is negative: The more efficient the port, the lower the transport costs. Countries should see sizable reductions in transport costs when port performance improves.

Markups are expressed as

$$mu(j,k,t) = \delta_k + \beta_8 co_{jt}, \tag{6}$$

where the first term, δ_k, represents a product-specific effect that captures differences in transport demand elasticities across commodities and co_{jt} is a port connectivity index that should capture how well countries are connected to global shipping networks. It is based on five

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[9] Multiplying the distance between two points by the price of fuel not only introduces time and cross-sectional variation, it also captures the true underlying cost of distance (Herrera Dappe and Suárez-Alemán 2016).

components: the number of ships, the container-carrying capacity, the maximum vessel size, the number of services, and the number of countries that deploy container ships in a country's port.[10] The term co_{jt} should have a negative sign: The better connected to the network a port is, the more intense the price competition (lower markup), the lower the transport costs.

Substituting equations (5) and (6) into equation (4) yields the equation to be estimated:

$$p(j,k,t) = \alpha + \gamma_k + \beta_1 c_{jkt} + \beta_2 d_{jt} + \beta_3 q_{jt} + \beta_4 imb_{jt} + \beta_5 vw_{jkt} + \beta_6 gdp_{jt} + \beta_7 eff_{jt} + \beta_8 co_{jt} + \varepsilon_{jkt} \, , \quad (7)$$

where $\gamma_k = (\lambda_k + \delta_k)$ and ε_{jkt} is assumed to be i.i.d.

4. Data Description

Data on maritime transport costs, trade volume, and the level of containerization come from the OECD's Maritime Transport Cost database.[11] It includes (a) the total cost of transporting a given product in a given year, expressed in dollars; (b) the unit transport cost (cost per kilogram or cost in dollars required to transport 1 kilogram of merchandise); and (c) the ad valorem equivalent, or the transport cost divided by the total import value (that is, the share transport cost represents in the total import value of the product).[12] Total costs include freight, insurance, and other charges (excluding import duties or charges by specific ports). Other charges include the cost of bringing the merchandise alongside the carrier at the origin port and placing it alongside the carrier at the first port of entry from the importing country (OECD 2008). We use data only for container traffic and commodities transported in containers, which are disaggregated at the Harmonized System two-digit level for all 99 chapters for 2004–07[13].

Data on distance come from www.sea-distances.org, data on trade imbalance from the UN Comtrade database,[14] data on oil prices from BP energy statistics,[15] and data on the connectivity index and GDP from the World Bank database. Table 2 shows the descriptive statistics for variables used in the maritime transport costs estimations.

Table 2 Descriptive statistics of variables used to estimate maritime transport costs

[10] http://data.worldbank.org/indicator/IS.SHP.GCNW.XQ
[11] The database contains data on bilateral maritime transport costs from 1991 through 2007 at the Harmonized System six-digit level.
[12] https://stats.oecd.org/Index.aspx?DataSetCode=MTC
[13] Unfortunately, this database has not been updated since 2007: https://stats.oecd.org/Index.aspx?DataSetCode=MTC
[14] https://comtrade.un.org/
[15] http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

Variable	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Unit cost (ln)	–1.37	1.19	–11.51	6.31
Ad valorem	0.08	0.06	0	0.89
Value-weight (ln)	1.55	1.33	–6.65	9.99
Weight (ln)	10.57	3.14	1.39	21.88
Imbalance	–0.23	0.34	–0.91	0.85
Oil*distance (ln)	12.3	0.7	10	13.59
Efficiency (variable returns to scale)	0.63	0.14	0.09	0.86
Connectivity	20.45	9.29	2.94	50.01
Containerization	0.411	0.33	0	1
Exporting GDP per capita (ln)	12.15	1.46	7.02	14.49

Our dataset includes information on 39 developing countries (see table A1 in annex A) and 115 container ports (see table A2). The analysis is constrained to one importing country, the United States, for which good-quality data are available.

Table 3 Descriptive statistics of ports in database, by region (averages for 2000–07)

Region	**Number of ports**	**Statistic**	**Annual throughput (TEUs)**	**Terminal area (square meters)**	**Berth length (meters)**	**Number of mobile cranes**	**Number of ship-to-shore gantry cranes**
Latin America and the Caribbean	50	Average	375,555	256,776	1,064	2.34	2.21
		Maximum	2,500,000	1,110,000	5,380	38	15
		Minimum	8,875	12,000	140	0	0
Europe and Central Asia	15	Average	374,490	449,110	1,247	7,01	4.03
		Maximum	1,900,000	1,100,000	5,090	31	21
		Minimum	18,387	16,248	211	0	0
South Asia	14	Average	659,525	265,445	1,108	3,03	5.28
		Maximum	4,100,000	1,200,000	3,176	23	26
		Minimum	17,890	3,200	168	0	0
Sub-Saharan Africa	7	Average	345,641	323,860	1,120	3.15	3.11
		Maximum	2,500,00	2,400,00	4,484	70	25
		Minimum	26,225	11,000	180	0	0
East Asia and Pacific	14	Average	1,031,472	631,200	1,907	4.8	8.6
		Maximum	7,100,000	4,300,000	10,300	47	73
		Minimum	25,532	3,600	100	0	0
Middle East and North Africa	15	Average	644,113	688,619	1,380	5.89	7.03
		Maximum	3,100,000	4,400,000	6,070	50	28
		Minimum	1,089	45,000	110	0	0
China	19	Average	3,412,778	1,052,290	3,371	2.54	16.02
		Maximum	26,000,000	8,600,000	9,142	24	113
		Minimum	27,000	11,000	180	0	0

Note: TEU = 20-foot equivalent unit.

Data on annual container throughput, total terminal area, total length of berths, number of mobile cranes with container-handling capacity, and number of ship-to-shore gantry cranes come from various editions of the *Containerization International Yearbooks* (2004–07).[16] Labor inputs are derived based on a predetermined relationship with the number of cranes (direct data are not available).

Port traffic in all regions increased sharply over the period of analysis. Port traffic in China grew from 22.4 million TEUs in 2000 to 91.6 million TEUs in 2007. Total traffic moved by the ports in the sample reached 206 million TEUs in 2007, up from 59.5 million in 2000. According to World Bank data, total container traffic worldwide was about 490 million TEUs in 2007. Our database thus includes about 42 percent of total movements in 2007. Table 3 shows port statistics by region.

The data show the overall supremacy of Chinese ports in the period of analysis. They are bigger and have more cranes than ports elsewhere and consequently move more cargo. A typical East Asian port has more than twice the capacity of Latin America and the Caribbean, South Asia, and Sub-Saharan Africa, in terms of both facilities and throughput.

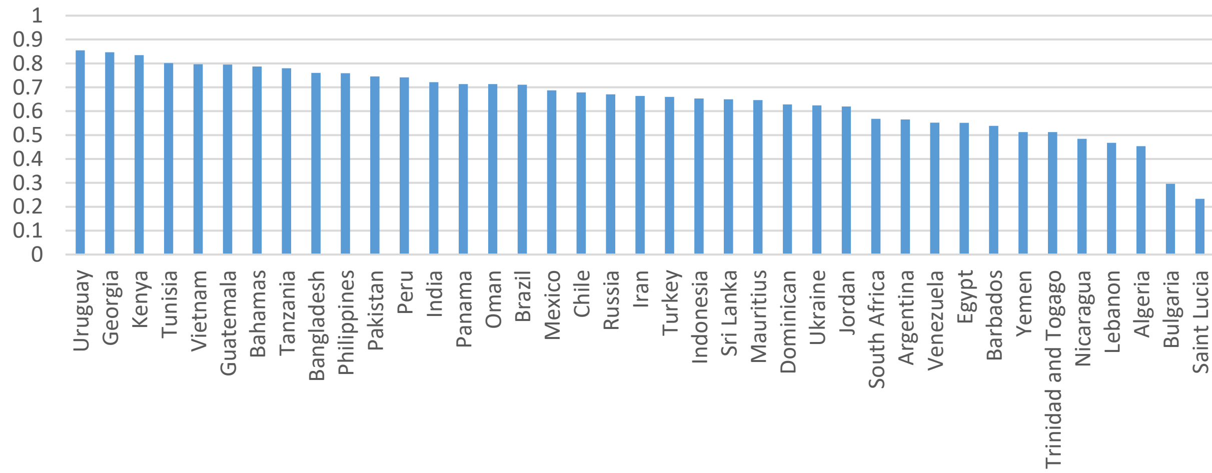
5. Empirical Results

Port Efficiency and its effect on Maritime Transport Costs

Figure 1 ranks average port efficiency by country, based on the maximum-likelihood estimations of equations 1–3 (figure B1 presents results by port). The stochastic frontier analysis efficiency scores and the ad hoc measure based on the World Bank's Global Competitiveness Report used in previous literature have a very low correlation of 0.05 (see figure B2).

[16] Following Serebrisky and others (2016), for each period we also identified ports that were privately operated, ports that had access to rail, and ports that were major transshipment hubs.

Figure 1 Country rankings based on port efficiency, 2007



Note: Results are based on stochastic frontier analysis. Averages are calculated by weighting each port in a country by its container throughput. 0 = most inefficient, 1 = most efficient.

Port efficiency measures from the time-varying relationship between the use of port assets and port throughput are considered in the estimation of the determinants of maritime transport costs (equation 7). Table 4 presents the estimation of the pricing formula that links the cost of transporting goods from origin to the destination country to a marginal cost (column 1). Column 2 adds the markup term. We follow Herrera Dappe and Suárez-Alemán (2016) to control for possible biases that might emerge from endogeneity or misspecification. We use terminal area, berth length, and the number of cranes as instruments and the standard Hausman test for endogeneity, the Hansen *J*-statistic for overidentification of instruments, and the identification test of Craig-Donald. All the tests favor ordinary least squares over an instrumental variable estimation (results available upon request).

Table 4 Determinants of maritime transport costs

Dependent variable: Unit transport cost (ln)	
Oil* distance (ln)	0.12***
Value-weight (ln)	0.60***
Containerization	–0.12**
Imbalance	0.03
Economies of scale	–0.07***
Efficiency	–0.23 **
GDP (ln)	–0.82***
Connectivity	0.00
N	34,055

Note: Significance level: ** = 5 percent, *** = 1 percent.

The results have the expected signs and are consistent with previous results in the literature. For example, Clark, Dollar, and Micco (2004) find that doubling the distance between two countries increases transport costs by 18 percent; Herrera Dappe and Suárez-Alemán (2016) find a 10 percent increase. Our results for the developing world between 2004 and 2007 show a 12 percent increase in transport costs.

It is also the case of the value-weight effect, which substantially increases transport costs. As Clark, Dollar, and Micco (2004) state, insurance fees are about 2 percent of the traded value, and they represent about 15 percent of total maritime charges. Due to the insurance component of transport costs, products with higher unit value have higher transport costs per unit of weight.

In the early 2000s, increasing size and capacity in both ports and vessels resulted in gains from economies of scale. The results in table 4 confirm the presence of economies of scale. However, the uninterrupted trend of building bigger ships may have led to diseconomies in other aspects of container shipping, by, for example, requiring larger cranes and more land for container operations (Rodrigue, Comtois, and Slack 2017). The megaships-megacarriers-megaports equilibrium is being debated. As Merk (2017) notes, shippers have traditionally spread risks by using different ships, lines, and ports. They could now find all their cargo on one megaship operated by one mega-alliance calling on just a few megaports.[17]

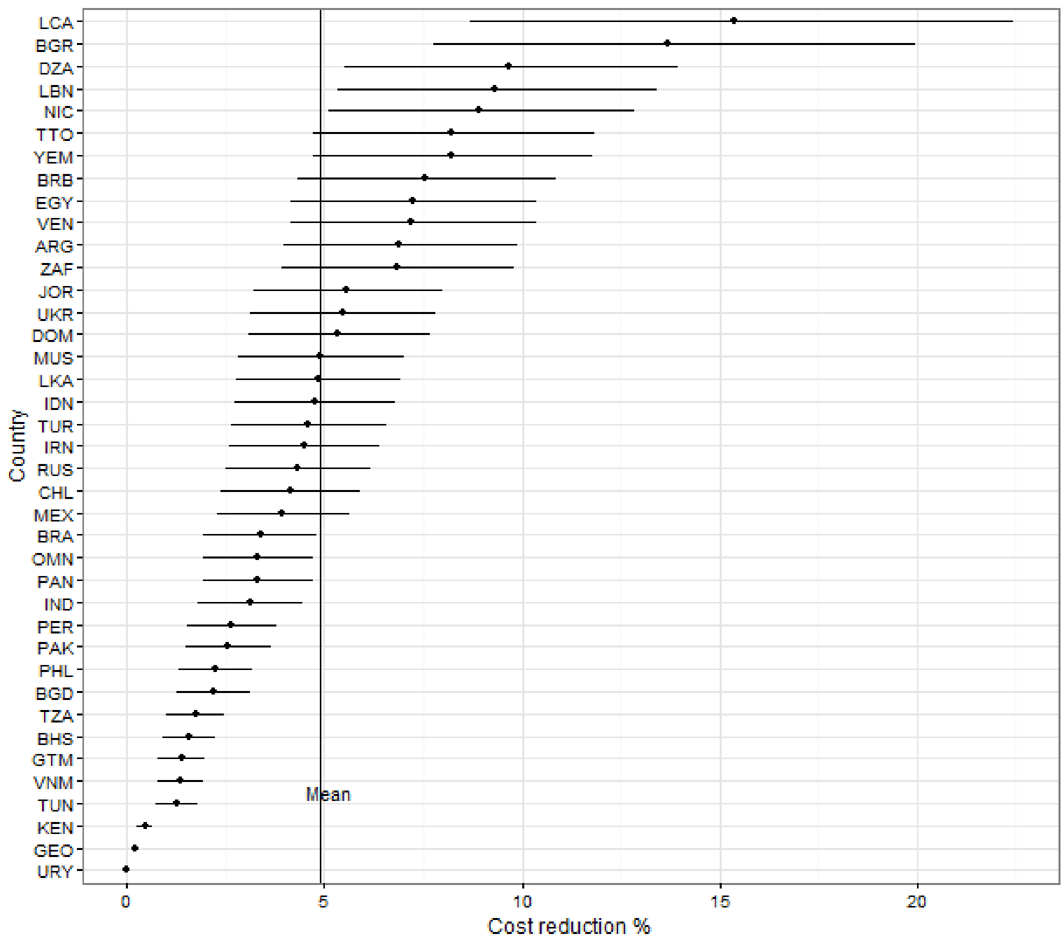
The result for the level of containerization is as expected. As Krugman (2009) has observed, container shipping is the technology that changed the world. Containerization has contributed mightily to the standardization of global trade.

The analysis indicates that differences in port performance explain differences in maritime transport costs: The more efficient the port, the lower the maritime transport costs. Efficiency levels range from 0 (most inefficient) to 1 (most efficient). A 0.1 increase in efficiency levels for the port sector in a country reduces the maritime transport costs of its exports to the United States by 2.3 percent. Raising port efficiency from the 25th to the 75th percentile reduces transport costs by about 4 percent. How ports employ their facilities thus has a direct effect on transport costs.

Figure 2 presents the average cost savings by country if ports had performed as well as the best performing port in our sample. Becoming as efficient as the most efficient port sector (Uruguay) reduced costs by as much as 15.4 percent. If, for example, ports in Trinidad and Tobago had been as efficient as ports in Uruguay, Trinidad and Tobago's maritime transport costs would have been about 8 percent lower than they were. On average countries in the sample could have achieved a 5 percent savings by becoming as efficient as Uruguay.

[17] http://shippingtoday.eu/economies-of-scale-shipping-model/

Figure 2 Average reduction in maritime transport costs associated with increasing port efficiency to level of most efficient country.



Note: Country codes are explained in table A1 in the annex. Bar widths represent 95 percent confidence intervals.

6. Conclusion

Many countries reduced tariff and nontariff barriers to trade in the last few decades. As a result, transport costs are now a more important determinant of the ability of a country to integrate into the global economy. Increasing the efficiency of ports is critical to reducing logistics costs. This paper concentrates on developing countries, as they need to "get closer" to high-demand markets and tend to lag behind in availability and performance of infrastructure assets when compared to advance countries.

Previous research developed efficiency measures from surveys that measure users' perception of quality of services or constructed ad hoc indexes that combine variables that are not strictly related to the use of port infrastructure. The innovation of this paper is that it uses objective data on ports to estimate how improving port performance could benefit developing countries by reducing maritime transport costs and increasing trade.

Relying on a measure of efficiency calculated using asset-based port infrastructure data for 39 developing countries, the results show that the more efficient the port sector in a country, the lower its maritime transport costs. The developing country ports in our sample are less than 60 percent as efficient as the average port. Having a port sector that uses its assets inefficiently comes at a cost.

The results have important policy implications. The public policy debate on infrastructure, particularly in developing countries, tends to focus exclusively on the need for more assets as the only means of providing more efficient services and increasing global competitiveness. This paper provides evidence that increasing the efficiency of existing assets can increase the competitiveness of countries.

Finally, these findings prove how important is to develop and maintain data sources that allow to improve public policy and the use of public resources. While we may expect that the established relationship between port efficiency and maritime transport costs holds over time, it is of the greatest interest of public sectors worldwide to collect and provide access to analyze infrastructure related data.

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Annex A Countries and Ports Included in the Analysis

Table A1 Countries included in the analysis, by region

East Asia and Pacific

Indonesia (IDN)
Philippines (PHL)
Vietnam (VNM)

Europe and Central Asia

Bulgaria (BGR)
Georgia (GEO)
Russian Fed. (RUS)
Turkey (TUR)
Ukraine (UKR)

Latin America and the Caribbean

Argentina (ARG)
Bahamas (BHS)
Barbados (BRB)
Brazil (BRA)
Chile (CHL)
Dominican Republic (DOM)
Guatemala (GTM)
Mexico (MEX)
Nicaragua (NIC)
Panama (PAN)
Peru (PER)
St. Lucia (LCA)
Trinidad and Tobago (TTO)
Uruguay (URY)
Venezuela, R.B. (VEN)

Middle East and North Africa

Algeria (DZA)
Egypt (EGY)
Iran (IRN)
Jordan (JOR)
Lebanon (LEB)
Oman (OMN)
Tunisia (TUN)
Yemen (YEM)

South Asia

Bangladesh (BGD)
India (IND)
Pakistan (PAK)
Sri Lanka (LKA)

Sub-Saharan Africa

Kenya (KEN)
Mauritius (MUS)
South Africa (ZAF)
Tanzania (TZA)

Table A2 Ports included in the analysis, by region and country

Port	*Country*	*Region*
Belawan	Indonesia	EAP
Makassar	Indonesia	EAP
Tanjung Perak	Indonesia	EAP
Tanjung Priok	Indonesia	EAP
Davao	Philippines	EAP
General Santos	Philippines	EAP
Iloilo	Philippines	EAP
Manila	Philippines	EAP
Subic Bay	Philippines	EAP
Zamboanga	Philippines	EAP
Danang	Vietnam	EAP
Haiphong	Vietnam	EAP
Ho Chi Minh	Vietnam	EAP
Qui Nhon	Vietnam	EAP
Varna	Bulgaria	ECA
Poti	Georgia	ECA
Kaliningrad	Russia	ECA
Novorossiysk	Russia	ECA
St. Petersburg	Russia	ECA
Vostochniy	Russia	ECA
Ambarli	Turkey	ECA
Antalya	Turkey	ECA
Diliskelesi	Turkey	ECA
Gemlik	Turkey	ECA
Haydarpasa	Turkey	ECA
Puerto Barrios	Guatemala	LAC
Puerto Quetzal	Guatemala	LAC
Santo Tomás de Castilla	Guatemala	LAC
Altamira	Mexico	LAC
Ensenada	Mexico	LAC
Lazaro Cardenas	Mexico	LAC
Manzanillo	Mexico	LAC
Progreso	Mexico	LAC
Veracruz	Mexico	LAC
Corinto	Nicaragua	LAC
Balboa	Panama	LAC
Colon CT	Panama	LAC
Puerto Manzanillo	Panama	LAC
Callao	Peru	LAC
Paita	Peru	LAC
Vieux Fort	Saint Lucia	LAC
Point Lisas	Trinidad and Tob.	LAC
Port of Spain	Trinidad and Tob.	LAC
Montevideo	Uruguay	LAC
La Guaira	Venezuela	LAC
Puerto Cabello	Venezuela	LAC
Port de Bejaia	Algeria	MENA
Alexandria Port Authority	Egypt	MENA
Damietta Port Authority	Egypt	MENA
El Dekheila Port Authority	Egypt	MENA

Izmir	Turkey	ECA	Port Said	Egypt	MENA
Mersin	Turkey	ECA	Sokhna Port Development Co	Egypt	MENA
Illichivsk	Ukraine	ECA	Iman Khomeini	Iran, Islamic Rep.	MENA
Odessa	Ukraine	ECA	Shahid Rajaee	Iran, Islamic Rep.	MENA
Buenos Aires (excl. Exolgan)	Argentina	LAC	Aqaba	Jordan	MENA
Exolgan	Argentina	LAC	Beirut	Lebanon	MENA
Ushuaia	Argentina	LAC	Port Sultan Qaboos	Oman	MENA
Zarate	Argentina	LAC	Salalah	Oman	MENA
Freeport	Bahamas	LAC	Rades	Tunisia	MENA
Bridgetown	Barbados	LAC	Aden	Yemen, Rep.	MENA
Belem	Brazil	LAC	Hodeidah	Yemen, Rep.	MENA
Fortaleza	Brazil	LAC	Chittagong	Bangladesh	SAR
Itajai	Brazil	LAC	Chennai	India	SAR
Manaus	Brazil	LAC	Jawaharlal Nehru	India	SAR
Paranagua	Brazil	LAC	Kandla	India	SAR
Pecem	Brazil	LAC	Kochi	India	SAR
Rio De Janeiro	Brazil	LAC	Kolkata	India	SAR
Rio Grande	Brazil	LAC	Mumbai	India	SAR
Salvador	Brazil	LAC	Mundra	India	SAR
Santos	Brazil	LAC	Pipavav	India	SAR
Sao Francisco Do Sul	Brazil	LAC	Tuticorin	India	SAR
Sepetiba	Brazil	LAC	Visakhapatnam	India	SAR
Suape	Brazil	LAC	Karachi	Pakistan	SAR
Vitoria	Brazil	LAC	Port Mohammad Bin Qasim	Pakistan	SAR
Antofagasta	Chile	LAC	Colombo	Sri Lanka	SAR
Arica	Chile	LAC	Mombasa	Kenya	SSA
Iquique	Chile	LAC	Port Louis	Mauritius	SSA
Lirquen	Chile	LAC	Cape Town	South Africa	SSA
San Antonio	Chile	LAC	Durban	South Africa	SSA
San Vicente	Chile	LAC	East London	South Africa	SSA
Valparaiso	Chile	LAC	Port Elizabeth	South Africa	SSA
Caucedo	Dominican Rep.	LAC	Dar es Salaam	Tanzania	SSA
Rio Haina	Dominican Rep.	LAC			

Annex B Port Efficiency Scores

Figure B1 Port efficiency scores from stochastic frontier analysis, 2007

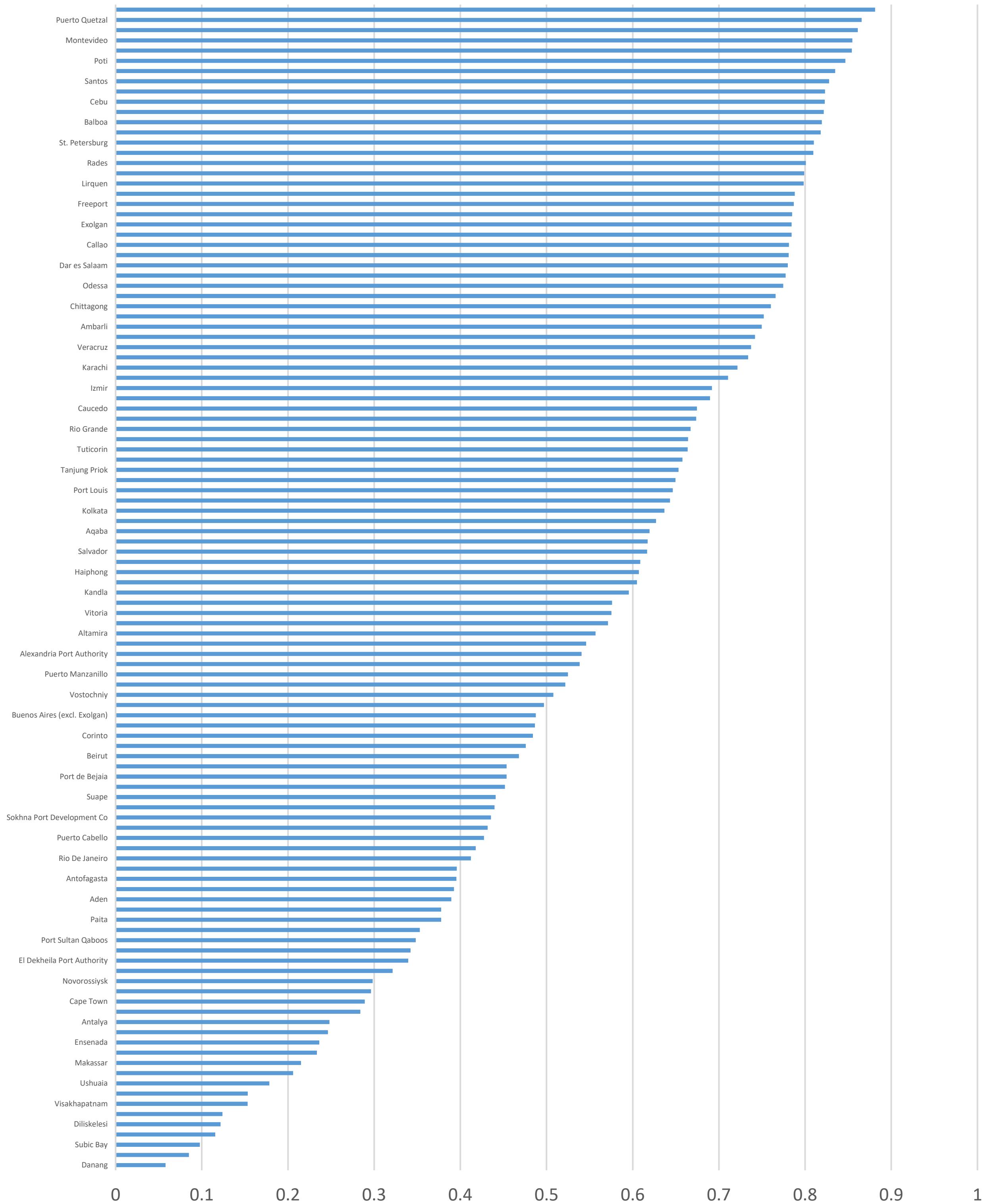

Figure B2 Correlation between estimated stochastic frontier analysis efficiency scores and quality of port infrastructure based on ad hoc indicator