

# How Does Port Efficiency Affect Maritime Transport Costs and Trade?

Evidence from Indian and Western Pacific Ocean  
Countries

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## Abstract

Would improvements in port performance increase trade in countries on the Indian and Western Pacific Oceans? Previous studies attempted to answer this question using ad hoc measures of port efficiency that do not control for the actual use of port assets or measures that can be very noisy. To avoid these problems, this paper builds a measure of economic efficiency based on the use of port

inputs to deliver port output. Using data envelop analysis, it ranks countries on the Indian and Western Pacific Oceans in terms of their port efficiency, and assesses the effect of increased efficiency. It finds that becoming as efficient as the country with the most efficient port sector would reduce their average maritime transport costs by up to 14 percent and increase their exports by up to 2.2 percent.

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# How Does Port Efficiency Affect Maritime Transport Costs and Trade?

## Evidence from Indian and Western Pacific Ocean Countries<sup>†</sup>

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## **Introduction**

Trade is critical to economic growth, and ports are critical to trade. Indeed, ports handle about 80 percent of global trade by volume and more than 70 percent by value (IMO, 2012). In a globalized world in which technology and know-how can be easily acquired and the constant search for the most efficient supply chain drives trade flows, the performance of a country's transport infrastructure relative to that of competing countries is a crucial determinant of global competitiveness and growth.

Transport costs (defined as all shipping expenses of internationally traded goods from origin to destination country) represent a major component of trade costs. 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 data set. 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.

The efficiency of port operations has a direct impact on the efficiency of the entire logistics chain along domestic and international freight corridors—and hence on transport costs. Efficient ports have shorter turnaround (loading and unloading) times and lower handling costs. Port efficiency is an important determinant of transportation costs: Doubling port efficiency reduces costs by as much as halving the distance between countries (Wilmsmeier, Hoffmann, and Sanchez 2006). A 0.1 increase in port efficiency decreases maritime transport costs by 0.9–3.8 percent (Micco and Pérez 2002; Clark, Dollar, and Micco 2004; Wilmsmeier, Hoffmann, and Sanchez 2006; Blonigen and Wilson 2008).

South Asia's trade almost doubled in the past decade, with trade as a percentage of GDP increasing by 18 percentage points between 2000 and 2014. Since 2000 the region has also enjoyed the second-highest economic growth in the world (after East Asia), growing at an average annual rate of 6.8 percent (World Development Indicators Database).

Despite this progress, trade accounted for a smaller share of GDP in South Asia (47 percent) than in East Asia (55 percent) in 2014, and South Asia's economic competitiveness continued to lag that of other regions. Global indicators, such as the Global Competitiveness Report, point to shortcomings in the infrastructure endowment in the region, with ports one of the weakest links. How much would improvements in port performance reduce transport costs and increase trade in South Asian countries?

The literature on maritime transport costs has struggled to identify a consistent measure of port efficiency, often resorting to ad hoc measures that, by construction, do not control for the actual use of port inputs (Fink, Mattoo, and Neagu 2002; Micco and Pérez 2002; Sanchez and others

2003; Clark, Dollar, and Micco 2004; Wilmsmeier, Hoffmann, and Sanchez 2006; Blonigen and Wilson 2006). A consistent efficiency measure would capture changes in port enhancements while keeping track of competing ports.

A strand of both the applied and theoretical literature measures port efficiency through in-depth research (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, however. This paper combines both approaches in order to quantify the cost of port inefficiency by showing what would have happened to transport costs and trade in countries in the Indian and Western Pacific Oceans, particularly in South Asia, had ports performed better.

The rest of this paper is organized as follows. The first section presents the drivers of maritime transport costs that previous studies have considered. The second section presents the empirical framework. The third section discusses the data. The fourth section presents the results. The last section summarizes the paper's main conclusion.

### **Determinants of Maritime Transport Costs**

The importance of transport costs for trade has led to a flurry of research that attempts to pin down the characteristics and determinants of transport costs. Despite the many data challenges, research has identified various factors that determine maritime transport costs (table 1).

Distance is historically one of the main variables used in analyzing barriers to trade. Transport costs are proportional to distance, albeit in a complex fashion.

Two main types of direct costs are associated with distance: time and fuel. Shipping operators require labor, for which the marginal cost (wages) is proportional to the time spent at sea. Longer times on ocean legs are associated with losses in productivity, as the same ship would be able to haul more merchandise over shorter distances.

Technological advances lead to an increase in the size of ships and a decrease in the overall time ships spend at sea. Bigger and faster ships allow more merchandise to be carried at lower cost. However, larger ships take more time at docks to unload, implying an inverse relationship between costs and size (OECD 2008).

Fuel costs are also higher for longer distances. They rose steadily after 2000, peaking in 2008. An unintended consequence of rising fuel costs was that ship operators tended to reduce vessel speeds to compensate for higher prices, reducing productivity. There is thus a feedback effect between time and fuel costs.

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

<i>Authors</i>	<i>Period studied</i>	<i>Determinant</i>							
		<i>Distance</i>		<i>Imbalance between imports and exports</i>	<i>Value-weight</i>	<i>Container</i>	<i>Weight</i>	<i>Volume</i>	<i>Efficiency</i>
Blonigen and Wilson (2008)	1991–2003	0.13***	-0.21***	Imports (-0.00) Exports (-0.00)	0.55***	-0.04***	0.91***	0.00***	-0.09 <sup>a</sup>
Fink, Mattoo, and Neagu (2001)	1998	0.33***				-0.07**		-0.02**	
Micco and Pérez (2002)	1995–99	0.17***			0.55***	-0.02		-0.04***	-0.07***
Sanchez and others (2003)	2002	0.09			0.54***	-0.02			0.03, -0.06, 0.00 <sup>b</sup>
Limao and Venables (2001)	1998	0.38**							
Wilmsmeier, Hoffmann, and Sanchez (2006)	2002	0.35***		0.00*	0.34***		-0.09***	-0.02*** <sup>c</sup>	-0.38***
Clark, Dollar, and Micco (2004)	1998	0.18***		-0.07***	0.55***	-0.03**		-0.04***	-0.06***

*Note:*

a. The first result compares the Port of Oakland with the most efficient port in the United States (Richmond-Petersburg), where port charges are about 9 percent lower. The second result compares the Port of Rotterdam with the most efficient port outside the United States in the sample considered by the authors (Zeebrugge, Belgium), where port charges are 6 percent lower.

b. Results are related to time inefficiency, productivity, and stay per vessel, respectively.

c. Result is for bilateral trade.

\* Significant at the 10 percent level, \*\* Significant at the 5 percent level, \*\*\* significant at the 1 percent level.

Trade asymmetries have a large and significant effect on trade costs. Greece, for example, imports 60 percent more than it exports, whereas Ireland exports 40 percent more than it imports (Baldwin and Taglioni 2006). If country 1 exports to country 2 while importing nothing from country 2, ships may haul empty containers on one leg of the journey and return with full containers. The exporter that receives the empty containers and sends the containers back packed often bears a higher cost. For example, India has a favorable trade balance with the

United States. In the first half of 2008, hauling a container from the United States to India cost about \$1,500, whereas hauling it in the opposite direction cost about \$2,500 (Korinek and Sourdin 2009). Directional trade imbalances serve as a proxy for ships that carry empty containers on one leg of the journey (Clark, Dollar, and Micco 2004).

Value-weight coefficients are similar across studies, despite their use of different data sets: The higher the value-weight, the higher the maritime transport costs (Micco and Pérez 2002; Clark, Dollar, and Micco 2004; Wilmsmeier, Hoffmann, and Sanchez 2006; Blonigen and Wilson 2008). 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 volume of freight is used to capture economies of scale. Higher demand for goods (that is, an increase in the volume of trade) is associated with lower costs. 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.

A large share of goods traded is shipped in containers, as opposed to tankers and dry bulk. Containerization should reduce transport costs, because containers are easy to load and unload and result in a larger volume of goods shipped.

A number of empirical studies, however, suggest that ocean transportation costs did not decrease much as a consequence of containerization (Sanchez and others 2003; Hummels 2007; Bridgman 2014). One possible explanation is that transportation is not a conventionally competitive market, that cargo companies are able to exercise market power through legal cartels (Hummels, Lugovskyy, and Skiba 2009). For this reason, innovations and freight rates do not necessarily have a one-for-one relationship (Bridgman 2014).

Another possible explanation is that monetary costs do not fully capture the real gains from containerization, which might come from quality changes in transportation services, such as faster ships and quicker loading and unloading than with break bulk (Hummels 2007). The marginal gains from further containerization seem to be small if containerization is already high. The technological effects associated with containerization are thus once-off effects.

Markups in the shipping industry take many forms. They often fall when rival companies compete on trade routes. In contrast, on low-volume routes, shippers often operate as monopolies or cartels. Markups on these routes are higher, as a result of price-fixing or cooperation agreements among shipping lines.

Cargo reservation schemes still exist under the UN Liner Code, but regulation has reduced the extent of anticompetitive practices such as price-fixing agreements and maritime conferences.<sup>1</sup> Other forms of protection, such as barriers to investment in maritime transport service, still exist (one example is the limitations foreign investors face when establishing local offices). Bertho, Bochert, and Mattoo (2014) find that policy barriers reduce trade by 28–46 percent through higher transport costs.

Port efficiency has received attention in the literature as an important determinant of the level of and changes in transport costs. The evidence shows a strong negative link between port efficiency and shipping costs (Micco and Pérez 2002; Sanchez and others 2003; Clark, Dollar, and Micco 2004; Wilmsmeier, Hoffmann, and Sanchez 2006). However, there is no agreement on the measure of port efficiency. Consequently, the coefficient on efficiency in maritime transport cost 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 from survey responses of cargo handling firms 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, an increase in port efficiency from the 25th percentile to the 75th percentile reduces costs by about 10–15 percent, everything else equal. Wilmsmeier, Hoffmann, and Sanchez (2006) estimate the effects of port efficiency on transport costs for 16 Latin American countries in 2002 using data from the International Trade Database, which is maintained by the United Nations. They note that port efficiency need not lead to a reduction in freight rates (ports might charge higher rates if they provide faster or more reliable services). Based on port efficiency data from the 2004 World Economic Forum, however, they show that a 1 percent increase in port efficiency leads to a 0.38 percent reduction in trade costs. If a country with the lowest efficiency improved efficiency to the levels of the country with the highest efficiency, freight charges would decrease by 26 percent.

Sanchez and others (2003) uses a similar methodology to study the effects of using a different measure of port efficiency on transport costs. They derive their port efficiency measure from a 1999 survey of 41 port terminals. Based on the survey responses, they compile weights, using principal components analysis, to construct efficiency scores. Only their productivity factor—which included container handling capacity at port, the average number of containers per vessel, and the hourly container load rate—had a statistically significant impact on transport costs: A 1

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<sup>1</sup> Competition laws such as the United States' Ocean Shipping Reform Act of 1999, European regulation that abolished block exemptions from shipping conferences, and the emergence of large shipowners in the 1980s and 1990s weakened conferences (WTO 2010).

percent increase in port efficiency (from a productivity perspective) reduces trade costs by 0.06 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 transport cost data produced by the U.S. Department of Transportation for 1995–99 and an ad hoc port efficiency measure from the World Bank’s *Global Competitiveness Report*.

The importance of port efficiency on reducing costs and improving trade is also illustrated by Blonigen and Wilson (2008). They argue that for small, less-developed countries, port inefficiency has a larger trade-reducing effect than other trade frictions. They identify the costs associated with loading and unloading freight at ports, which are associated with efficiency, through fixed effects. They estimate the effects of port efficiency on transport costs between 1991 and 2003. However, their measure is likely to capture the effects of determinants unrelated to efficiency that are not controlled for in the regression.

All of 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 or measures that can be very noisy. 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 data envelop analysis (an input-output approach for measuring efficiency) to rank countries in terms of their port efficiency.

## **Empirical Framework**

By how much would improvements in port performance benefit countries in the Indian and Western Pacific Oceans? To answer this question, this paper (a) estimates port efficiency based on data envelop analysis (based on Herrera Dappe and Suárez-Alemán 2016); (b) presents a model of maritime transport costs that includes the impact of port efficiency (based on Fink, Mattoo, and Neagu 2002); and (c) uses a multilevel gravity model to test the impact of maritime transport costs on worldwide trade.

### ***Estimating Port Efficiency Using Data Envelop Analysis***

Data envelopment analysis (DEA) is the most frequently applied nonparametric methodology for estimating efficiency in the port industry as the relationship between inputs to the port production process and the outputs derived from it.<sup>2</sup> This deterministic method uses mathematical programming techniques to envelop the data as compactly as possible.

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<sup>2</sup> Most empirical analyses can be categorized as using either parametric or nonparametric models to estimate port efficiency. Parametric models assume that a specific function underpins the data; within this category, stochastic frontier analysis is the most commonly applied methodology. Nonparametric

Charnes, Cooper, and Rhodes (1978) were the first researchers to present DEA. Roll and Hayuth (1993) were the first to explicitly advocate its use to estimate port efficiency. By presenting a hypothetical application of DEA to a fictional set of container terminal data, they revealed the potential of the approach. Since then various researchers (including Cullinane and Wang 2010 and Serebrisky and others 2016) have used DEA to estimate port or terminal efficiency.

An output-oriented efficiency measurement problem can be written as a series of  $K$  linear programming problems (one for each port) with the constraints differentiating between DEA constant returns to scale (DEA-CCR) and DEA variable returns to scale (DEA-BCC) models. The objective is to maximize the proportional increase in output while remaining within the production possibility set ( $U$ ):

$$\begin{aligned}
 & \text{Max } U \\
 & U, z \\
 \text{subject to} & \\
 & U\mathbf{y}_h' - Y'\mathbf{z} \leq 0 \\
 & X'\mathbf{z} - \mathbf{x}_h' \leq 0 \\
 & \mathbf{z} \geq 0 \text{ (DEA-CCR)} \\
 & \mathbf{e}\mathbf{z}' = 1 \text{ (DEA-BCC)}
 \end{aligned} \tag{1}$$

where  $M$  inputs  $\mathbf{x}_h = (x_{1h}, x_{2h}, \dots, x_{Mh}) \in \mathbb{R}_+^M$  are used to produce  $N$  outputs  $\mathbf{y}_h = (y_{1h}, y_{2h}, \dots, y_{Nh}) \in \mathbb{R}_+^N$ . The row vectors  $\mathbf{x}_h$  and  $\mathbf{y}_h$  form the  $h_{th}$  rows of the data matrices  $X$  and  $Y$ , respectively. The term  $\mathbf{z} = (z_1, z_2, \dots, z_H) \in \mathbb{R}_+^H$  a nonnegative vector, which forms the linear combinations of the  $H$  ports or terminals;  $\mathbf{e} = (1, 1, \dots, 1)$  is a dimensioned vector of unity values.

A key factor in the efficiency estimations is the choice of inputs and outputs.<sup>3</sup> The choice of port facilities' follows the most commonly used approach in container port analysis. Capital is represented by the total port area and the length of all container and multipurpose berths in the port. Information on labor inputs is derived from a predetermined relationship to cranes. Following the approach used in the port literature (Notteboom, Coeck, and Van Den Broeck 2000; Cullinane, Ji, and Wang 2005; Cullinane and Wang 2010), the analysis includes the number of

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models make no such assumption; within this category, data envelop analysis is the most commonly applied methodology. Suárez-Alemán and others (2016) provide a detailed review of studies employing both approaches.

<sup>3</sup> The inputs usually selected for these analyses are physical facilities, such as the number or size of berths, gantry cranes and equipment, terminal yardage, and the labor force (Cullinane, Ji, and Wang 2005).

ship-to-shore or gantry cranes and the number of mobile or quay cranes with capacity of more than 15 tons as a proxy.<sup>4</sup> For outputs, it uses the number of 20-foot equivalent units (TEUs).

### **Modeling Maritime Transport Costs**

The seminal paper by Fink, Matto, and Neagu (2002) is used as a reference point in determining structural factors that affect transport costs. Fink, Matto, and Neagu (2002) propose a simple pricing formula that relates the cost of transporting goods from origin to destination country as a simple marginal cost (related to distance, the volume of trade, the value of trade, port efficiency, trade imbalances, the level of containerization, and other possible controls, such as oil prices and a markup term) proxied by various price-fixing agreements and variables that capture market power. The reduced-form equation to be estimated and tested following Fink, Matto, and Neagu (2002). The pricing formula, which is now standard, is specified as follows (all in logs):

$$p_{jkt} = mc(j, k, t) + mu(j, k, t), \quad (2)$$

where  $p_{jkt}$  is the unit transport cost, in logarithm, for commodity  $k$  transported between exporter country  $j$  and the United States in year  $t$ ;  $k$  is the commodity transported in containers. The unit transport cost is the sum of the marginal costs plus the markup. Following the literature<sup>5</sup> and the variables identified in table 1, the marginal cost term is expressed as follows:

$$mc(j, k, t) = \alpha + \lambda_k + \beta_1 c_{jkt} + \beta_2 d_{jt} + \beta_3 q_{jt} + \beta_4 imb_{jt} + \beta_5 vw_{jkt} + \beta_6 gdp_{jt} + \beta_7 eff_{jt} \quad (3)$$

where  $\alpha$  captures import country-specific characteristics, such as port and auxiliary services (which are not part of the dependent variable). Differences in the commodities shipped are captured by  $\lambda_k$ . The term  $c_{jkt}$  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 term  $d_{jt}$  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.<sup>6</sup> The term  $q_{jt}$  captures economies of scale, measured as the total weight of cargo carried by liners between exporter country  $j$  and the importer country. The term  $imb_{jt}$  represents the trade imbalance between the United States and exporter country  $j$ . It is calculated total country  $j$  imports from the United States minus country  $j$

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<sup>4</sup> In order to avoid overestimating container terminal facilities, this paper follows the assumption made in Serebrisky and others (2016) for Latin America, which considers only cranes that are able to manage containers.

<sup>5</sup> 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 Fink's model.

<sup>6</sup> 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.

exports to the United States as a ratio of total trade between the countries. The term  $vw_{jkt}$  is the value per weight measure for commodity  $k$ . The term  $gdp_{jt}$  is the logarithm of exporting country GDP per capita, a proxy for infrastructure development in the exporting country. The term  $eff_{jt}$  represents the average intertemporal efficiency of container ports in the exporting country.

Markups are expressed as

$$mu(j, k, t) = \delta_k + \beta_8 co_{jt}, \quad (4)$$

where  $\delta_k$  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 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.<sup>7</sup> The term  $co_{jt}$  should have a negative sign: The better connected to the network a port is, the lower the transport costs.

Substituting equations (3) and (4) into equation (2) yields the equation to be estimated:

$$p(j, k, t) = \alpha + \gamma_k + \beta_1 c_{jkt} + \beta_2 d_{jt} + \beta_3 q_{jt} + \beta_4 imb_{jt} + \beta_5 vw_{jkt} + \beta_6 gdp_{jt} + \beta_7 eff_{jt} + \beta_8 co_{jt} + \varepsilon_{jkt}, \quad (5)$$

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

### ***Estimating the Impact of Maritime Transport Costs on Worldwide Trade***

We employ a traditional gravity model to study the effects of transport costs on trade.<sup>8</sup> The micro founded–gravity equation can be expressed as

$$NX_{jt} = \theta^{1-\sigma} GDP_{impt} GDP_{jt}, \quad (6)$$

where  $NX_{ijt}$  are exports from country  $j$  to importer country;  $\theta$  is a trade impedance factor that depends on distance and maritime transport costs;  $GDP_{impt}$  and  $GDP_{jt}$  are real GDP for the importer country and exporting countries  $j$  and a proxy for the expenditure of goods; and  $\sigma$  is the elasticity of substitution among commodities. The baseline gravity model also takes into account the gravitational constant by assuming that equation (6) takes the form of a hierarchical specification. It can be written (in logs) as

<sup>7</sup> <http://data.worldbank.org/indicator/IS.SHP.GCNW.XQ>.

<sup>8</sup> For a summary of the literature on the use of gravity models in trade and development, see Kepaptsoglou, Karlaftis, and Tsamboulas (2010); Gómez-Herrera (2013); and Baltagi, Egger, and Pfaffermayr and (2016).

$$nx_{jkt} = \alpha_k + \alpha_t + \alpha_j + \beta_1 p_{jkt} + \beta_2 ds_{jt} + \beta_3 gdp_{impt} gdp_{jt} + \varepsilon_t. \quad (7)$$

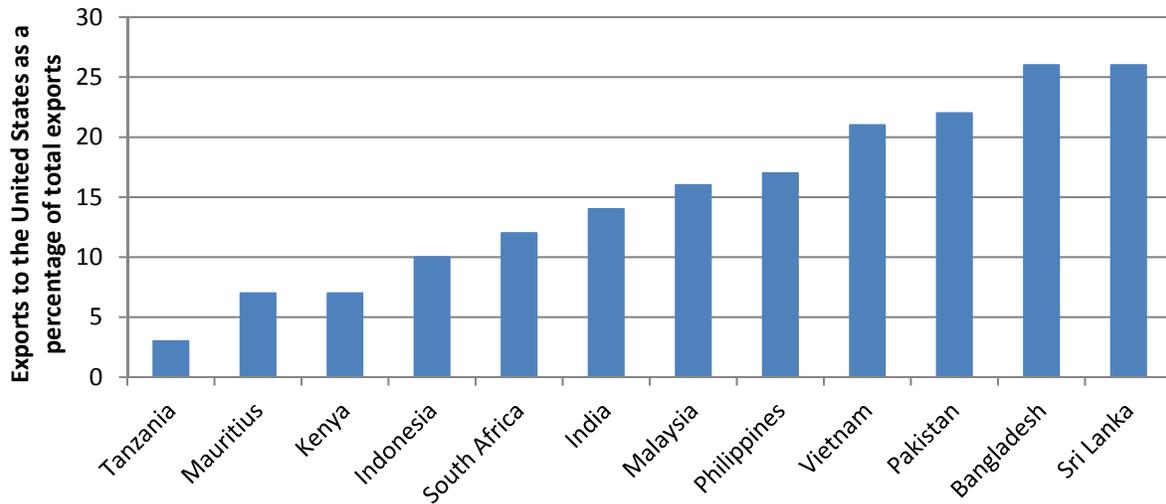
### Data Description

The data set includes information on 12 developing countries in the Indian and Western Pacific Oceans and 35 container ports (table 2). The analysis is constrained to one importing country, the United States, for which good-quality data are available. Figure 1 shows the importance of exports to the United States as a share of total exports from the countries considered in the analysis.

**Table 2 Container ports included in the analysis**

<i>Region</i>	<i>Ports</i>
Africa	Mombasa (Kenya); Port Louis (Mauritius); Cape Town, Durban, East London, Port Elizabeth (South Africa); Dar es Salaam (Tanzania)
East Asia and Pacific	Tanjung Perak, Tanjung Priok (Indonesia); Danang, Davao, Iloilo, Manula, Zamboanga (the Philippines); Kuantan, Kuching, Port Klang, Tanjung Pelepas (Malaysia); Haiphong, Ho Chi Minh (Vietnam)
South Asia	Chittagong (Bangladesh); Chennai, Cochin, Jawaharlal Nehru, Kandla, Kolkata, Mumbai, Mundra, Pipavav, Tuticorin, Visakhapatnam (India); Karachi, Mohammad Bin Qasim (Pakistan); Colombo (Sri Lanka)

**Figure 1 Exports to the United States to selected countries as a percentage of total exports, 2007**



Source: Data from UN Comtrade.

The data set is compiled from several sources. The primary source is the Maritime Transport Cost data set of the Organisation for Economic Co-operation and Development (OECD).<sup>9</sup> 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 (the share of transport cost in the total import value of the product).<sup>10</sup>

Actual costs include freight, insurance, and other charges (excluding import duties) associated with 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). Charges by specific ports are thus included. The value of imports (cost divided by ad valorem costs) and the volume of imports in kilograms (cost divided by unit cost) are calculated using these data. The value of shipped goods does not always factor in the cost of shipping when costs are based on containers or weight equivalents.

**Table 3 Descriptive statistics of variables used to estimate maritime transport costs**

<i>Variable</i>	<i>Mean</i>	<i>Standard deviation</i>	<i>Minimum</i>	<i>Maximum</i>
Unit cost (ln)	-1.30	0.94	-9.21	4.95
Ad valorem	0.09	0.06	0.00	0.71
Value-weight (ln)	1.38	1.09	-2.82	7.83
Weight (ln)	12.93	3.43	1.39	20.57
Imbalance	-0.44	0.31	-0.85	0.66
Oil*Distance (ln)	12.81	0.44	12.04	13.61
Efficiency (variable returns to scale)	0.27	0.12	0.00	1.00
Connectivity	26.33	16.92	5.07	81.58
Containerization	0.63	0.28	0.16	1.00
Exporting GDP per capita (ln)	7.06	0.86	5.72	8.88

*Note:* Sample summary statistics exclude the omitted data.

We use data only for container traffic and commodities transported in containers, which are disaggregated at the two-digit Harmonized System level for all 99 chapters for 2000–07. Data on distance come from [www.sea-distances.org](http://www.sea-distances.org), data on trade imbalance from the UN Comtrade

<sup>9</sup> The database contains data on bilateral maritime transport costs from 1991 through 2007 at the six-digit level of the Harmonized System (HS), an international nomenclature for the classification of products developed by the United Nations that allows participating countries to classify traded goods on a common basis for customs purposes. The first two digits identify the chapter in which the goods are classified.

<sup>10</sup> <https://stats.oecd.org/Index.aspx?DataSetCode=MTC>.

database,<sup>11</sup> data on oil prices from BP energy statistics,<sup>12</sup> and data on the connectivity index and GDP from the World Bank database. Table 3 displays the descriptive statistics for variables used in the maritime transport costs and gravity estimations.

Data on annual container throughput, total terminal area, total length of berths, the number of mobile cranes with container-handling capacity, and the number of ship-to-shore gantry cranes come from various editions of the *Containerization International Yearbooks* (2002–09).

Table 4 presents descriptive statistics by region. The average port in the sample moves about 900,000 TEUs annually. It has a terminal area of about 475,000 square meters, a total berth length of 1,501 meters, 7 gantry cranes, and 4 mobile cranes. The summary statistics show that East Asian and Pacific ports handle considerably more containers (by employing larger facilities) than African and South Asian ports.

**Table 4 Descriptive statistics of ports in database, by region**

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
Africa	7	Average	531,338	457,002	1,254	0.31	5.84
		Standard deviation	570,609	457,779	757	0.83	5.42
		Maximum	2,511,704	1,940,000	2,854	4	25
		Minimum	26,225	22,000	549	0	0
East Asia and Pacific	14	Average	1,339,226	716,762	2,156	6.78	10.52
		Standard deviation	1,696,850	693,046	2,143	10.57	13.48
		Maximum	7,118,714	2,061,530	8,382	47	52
		Minimum	26,303	7,118,714	342	0	0
South Asia	14	Average	638,236	243,865	979	2.98	5.06
		Standard deviation	820,798	212,101	756	5.91	7.04
		Maximum	4,059,843	1,208,400	3,176	23	26
		Minimum	17,890	3,200	168	0	0
Total	35	Average	900,964	476,658	1,501	3.99	7.42
		Standard deviation	1,273,409	544,606	1,576	8.07	10.25
		Maximum	7,118,714	2,061,530	8382	47	52
		Minimum	17,890	3,200	100	0	0

Note: TEU = 20-foot equivalent unit. Figures are averages for 2000–07.

<sup>11</sup> <https://comtrade.un.org/>.

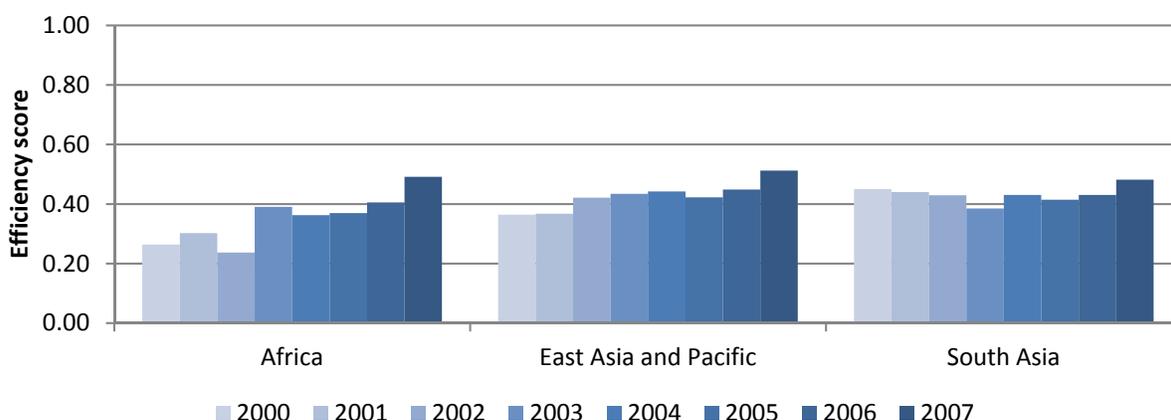
<sup>12</sup> <http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>.

## Empirical Results

### *Impact of Port Efficiency on Maritime Transport Costs*

Figure 2 displays the results of an output-oriented intertemporal DEA. In 2000 the average efficiency score for the 35 ports in the dataset was 0.37 (on a 0–1 scale). By 2007, the end of the period of analysis, average port efficiency had risen to 0.49. Average scores for the period as a whole indicate that ports in East Asia and Pacific (0.42), excluding China and Singapore, and South Asia (0.43) were much more efficient than ports in Africa (0.35), although there is room for improvement in all regions.

**Figure 2 Technical efficiency of ports, by region, 2000–07**



Note: Efficiency scores range from 0 (most inefficient) to 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 5). Table 5 presents the estimation of the pricing formula that links the cost of transporting goods from origin to the destination country to a marginal cost (columns 1 and 2). Column 3 adds the markup term. We control for possible biases that might emerge from endogeneity or misspecification. We use port throughput, 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 variables estimation (results available upon request). Alternating or combining instruments does not improve the overall test statistics, primarily the model fit.

Censoring observations and omitting outliers leaves 5,906 observations. We include only countries and commodities with observations available for the entire sample period (2000–07). The within-transformation is used to estimate equation (5). The fixed-effects model controls for

commodity heterogeneity (the fact that not all commodity costs share similar features). A set of trade-pair dummies is included to control for differences between countries, and time dummies are included to control for time-specific effects.<sup>13</sup>

Distance, economies of scale, and value-weight have substantial effects on transport costs, as expected. Our results for the countries in the Indian and Western Pacific Oceans show that doubling distance increase transport costs by 10 percent. This estimate falls in the lower range of estimates obtained by other studies (see table 1). In the early 2000s, increasing size and capacity in both ports and vessels resulted in gains from economies of scale. The results in table 5 confirm the presence of economies of scale: Unit costs decrease with weight. As Clark, Dollar, and Micco (2004) note, insurance fees are about 2 percent of the traded value, and they represent about 15 percent of total maritime charges. Because of the insurance component of transport costs, products with higher unit value have higher transport costs per unit of weight.

**Table 5 Determinants of maritime transport costs**

Dependent variable: Unit transport cost (ln)			
<i>Variable</i>	<i>(1)</i>	<i>(2)</i>	<i>(3)</i>
Oil prices*distance (ln)	0.02 (0.02)	0.10** (0.04)	0.10** (0.04)
Value-weight (ln)	0.60*** (0.03)	0.60*** (0.03)	0.60*** (0.02)
Containerization (percent)	0.19 (0.13)	0.24 (0.15)	0.25 (0.16)
Directional imbalance (percent)	-0.17* (0.09)	-0.22** (0.09)	-0.22** (0.09)
Weight (ln)	-0.07*** (0.01)	-0.07*** (0.01)	-0.07*** (0.01)
Port efficiency	-0.22** (0.08)	-0.24*** (0.10)	-0.23*** (0.10)
Exporting country GDP per capita (ln)		-0.17** (0.07)	-0.17** (0.07)
Connectivity index			-0.20 (0.34)
$R^2$	0.26	0.26	0.26
F-statistic	362.94	312.20	273.18
Number of observations	5,906	5,906	5,906

Note: Standard errors in parenthesis.

\*\* Significant at the 5 percent level, \*\*\* significant at the 1 percent level.

<sup>13</sup> Including these dummies controls for port-specific costs (average by country) over time. The time dummies are not always significant.

The effect of containerization on transport costs is not significant, a result similar to that in Sanchez and others (2003). There are two potential explanations for why this might be. First, most shipped cargo is already in containers, so the rate of containerization does not capture technological changes, as it did in the past (previous studies included it as a proxy for technology). Second, containerization may not be the most reliable proxy for changes in technology. If the data were available, better proxies would be the carrying capacity of liners, the use of fuel-efficient technologies, and on-ship facilities to organize cargo.

Our results on trade imbalance indicate that the availability of empty containers at the exporting port determines maritime transport costs. Larger flows of exports to the United States relative to imports from the United States mean that empty containers come to pick up exports, raising maritime transport costs. A 10 percent decrease in the trade imbalance, calculated as total country  $j$  imports from the U.S. minus country  $j$  exports to the U.S. as a ratio of total trade between the countries, increases maritime transport costs by about 2 percent. Exporting countries with higher GDP per capita face lower maritime transport costs for their exports, as a consequence of better trade infrastructure and services.

The proxy for markups (liner shipping connectivity) is not significant, although it has the correct sign. Identifying proper markups of maritime transport costs and finding reasonable and statistically significant estimates is a challenge. The markup variables do not always yield the expected result and are sensitive to omitted variables (see Clark, Dollar, and Micco 2004 for a discussion). It would have been ideal to control for other policy measures that affect liner shipping services, as Bertho, Bochert, and Mattoo (2014) do. Although the World Bank's Services Trade Restriction Database is a rich resource for maritime cost studies, it includes only a single year entry for various countries.<sup>14</sup> We tested the effects of services trade restrictions in our panel set-up but decided to drop it because of the limited variation over time.

The analysis indicates that differences in port performance in the Indian and Western Pacific Oceans explain differences in maritime transport costs: The more efficient the port, the lower the maritime transport costs. 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 3.6 percent.<sup>15</sup> How ports employ their facilities thus has a direct effect on transport costs.

Figure 3 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 country (Sri Lanka)

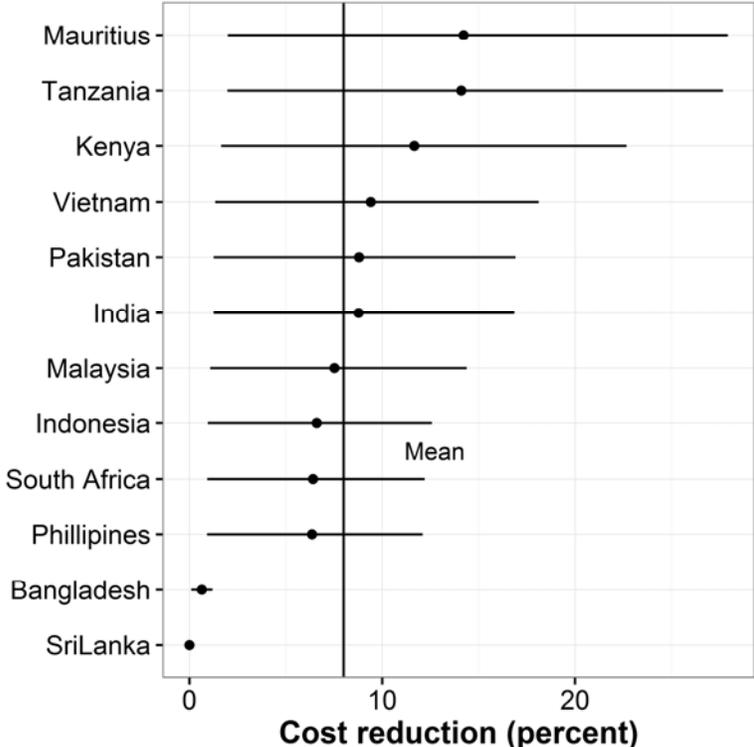
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<sup>14</sup> <http://iresearch.worldbank.org/servicetrade/aboutData.htm>.

<sup>15</sup> The 75th percentile and 25th percentiles equal 0.513 and 0.357, respectively. The size effect is  $e^{\beta(0.513-0.357)} - 1$ .

reduced costs by as much as 14 percent. If, for example, ports in Mauritius had been as efficient as ports in Sri Lanka, Mauritius' maritime transport costs would have been about 14 percent lower than they were. On average countries in the sample could have achieved an 8.5 percent savings by becoming as efficient as Sri Lanka.

**Figure 3 Average reduction in maritime transport costs associated with increasing port efficiency to the level of the most efficient country**



Note: Bar widths represent 95 percent confidence intervals

These results are robust to several changes in variables and samples. As a robustness checks, we used various substitutes for port efficiency, including the time ships are idle at the ports, the pre-berthing time, and turnaround time. Results remain stable when countries or a group of countries are picked at random and removed from the data set. The robustness checks also include a smaller sample that excludes countries in East Asia and Pacific, to study the stability and robustness of the slope estimates.

**Impact of Port Efficiency and Transport Costs on Trade**

Table 6 shows the results from the estimation of the gravity equation (7). Column 1 summarizes the results if only commodity heterogeneity is controlled for; column 2 controls for both commodity and time heterogeneity; and column 3 controls for commodity, time, and country

heterogeneity. Estimations are robust to the inclusion of the usual controls for language, colony, and religion (results are in the appendix).

**Table 6 Estimation results of multilevel gravity model for trade**

Dependent variable: bilateral trade (ln)			
<i>Variable</i>	<i>(1)</i>	<i>(2)</i>	<i>(3)</i>
Distance (ln)	−0.24** (0.07)	−0.29* (0.11)	0.17 (0.15)
GDP <sub>us</sub> GDP <sub>exp</sub> (ln)	0.86*** (0.06)	0.97*** (0.07)	0.40** (0.14)
Unit costs (ln)	−0.16*** (0.02)	−0.16*** (0.02)	−0.16*** (0.02)
Intercept variation			
Commodity	2.89	2.88	2.77
Exporting country			1.31
Year		0.10	0.08
Residual	0.97	0.96	0.97

\* Significant at the 10 percent level, \*\* significant at the 5 percent level, \*\*\* significant at the 1 percent level.

In the first two specifications, the GDP product coefficient is close to 1 (that is, close to what the theory predicts). The distance variable has the expected sign and is statistically significant. The unit cost measure on bilateral trade is constant across all three specifications. A 1 percent reduction in shipping costs increases trade by approximately 0.16 percent. The coefficient on unit costs is smaller than in Korinek and Sourdin (2006): −0.16 versus −0.26. The difference reflects the fact that we use only containerized cargo in our estimations, whereas Korinek and Sourdin (2006) use data on other types of cargo as well.

An increase in port efficiency from the 25th percentile to the 75th percentile reduces transport costs by about 3.5 percent and increase the value of exports to the United States by 0.56 percent. If countries became as efficient as Sri Lanka, maritime transport costs would fall by up to 14 percent, which translates into an increase of exports to the United States of up to 2.2 percent.

## Conclusion

Many countries that want to become more competitive in global markets tend to jump to the conclusion that they need to invest more in infrastructure, particularly in transport sectors like ports. Although many developing countries do face important infrastructure gaps, massive new investments are not the only way to improve competitiveness. Countries have significant

potential to make more efficient use of the infrastructure they already have. Improving the performance of existing ports, enabling them to handle higher levels of cargo with the same facilities and in a shorter time, can be a truly cost-effective approach to reducing transport and trade costs. Doing so can significantly increase the volume of trade.

This paper is the first to focus on ports on the Indian and Western Pacific Oceans and the first to use efficiency measures based on port input and output data, which serve as international benchmarks. The findings show that countries on the Indian and Western Pacific Oceans can significantly benefit from increased efficiency in the use of existing container port facilities. The estimated potential gains for each country help policy makers assessing the importance of improving port performance, and hence prioritizing interventions.

Future research should expand the analysis to all developing regions, in order to understand whether differences in port performance explain difference in maritime transport costs and exports across the developing world. If port level transport costs and trade data were available, future research could also control for heterogeneities among ports and help countries to prioritize interventions in their port sector by identifying ports where efficiency improvements can yield higher reductions in transport costs, and increases in exports.

## References

- Baldwin, R., and D. Taglioni. 2006. "Gravity for Dummies and Dummies for Gravity Equations." NBER Working Paper 12516, National Bureau of Economic Research, Cambridge, MA.
- Baltagi, B.H., Egger, P.H. and Pfaffermayr, M., 2016. "Special issue on the estimation of gravity models of bilateral trade: Editors' introduction". *Empirical Economics*, 50(1), pp.1-4.
- Bertho, F., I. Bochart, and A. Mattoo. 2014. "The Trade-Reducing Effects of Restrictions on Liner Shipping." Policy Research Working Paper WPS6921, World Bank, Washington, DC.
- Blonigen, B.A. and Wilson, W.W., 2006. "New Measures of Port Efficiency Using International Trade Data." NBER Working Paper 12052, National Bureau of Economic Research Cambridge, MA.
- Blonigen, B.A. and Wilson, W.W., 2008. Port efficiency and trade flows. *Review of International Economics*, 16(1), pp.21-36.
- Bridgman, B., 2014. *Why Containerization Did Not Reduce Ocean Trade Shipping Costs*. Working Paper.
- Charnes, A., W. W. Cooper, and E. Rhodes. 1978. "Measuring the Efficiency of Decision Making Units." *European Journal of Operational Research* 2 (6): 429–44.
- Clark, X., D. Dollar, and A. Micco. 2004. "Port Efficiency, Maritime Transport Costs, and Bilateral Trade." *Journal of Development Economics* 75, no. 2: 417-450.
- Cullinane, K., Wang, T.F., Song, D.W. and Ji, P., 2006. "The technical efficiency of container ports: comparing data envelopment analysis and stochastic frontier analysis". *Transportation Research Part A: Policy and Practice*, 40(4), pp.354-374.
- Cullinane, K. P. B., and T. Wang. 2010. "The Efficiency Analysis of Container Port Production Using DEA Panel Data Approaches." *Or Spectrum* 32 (3): 717–38.

- Cullinane, K. P. B., P. Ji, and T. Wang. 2005. "The Relationship Between Privatization and DEA Estimates of Efficiency in the Container Port Industry." *Journal of Economics and Business* 57 (5): 433–62.
- Fink, C., A. Mattoo, and I. C. Neagu. 2002. "Trade in International Maritime Services: How Much Does Policy Matter?" *World Bank Economic Review* 16 (1): 81–108.
- Gómez-Herrera, E., 2013. "Comparing alternative methods to estimate gravity models of bilateral trade". *Empirical Economics*, 44(3), pp.1087-1111.
- González, M. M., and L. Trujillo. 2009. "Efficiency Measurement in the Port Industry: A Survey of the Empirical Evidence." *Journal of Transport Economics and Policy* 43 (2): 157–92.
- Herrera Dappe, M., and A. Suárez-Alemán. 2016. *Competitiveness of South Asian Container Ports: A Comprehensive Assessment of Performance, Drivers, and Costs*. Directions in Development, Infrastructure. Washington, DC: World Bank.
- Hummels, D. 2007. "Transportation Costs and International Trade in the Second Era of Globalization." *Journal of Economic Perspectives* 21 (3): 131–54.
- Hummels, D., V. Lugovskyy, and A. Skiba. 2009. "The Trade Reducing Effects of Market Power in International Shipping." *Journal of Development Economics* 89 (1): 84–97.
- IMO (International Maritime Organization). 2012. International Shipping Facts and Figures: Information Resources on Trade, Safety, Security and Environment. Maritime Knowledge Center. London.
- Kepaptsoglou, K., Karlaftis, M.G. and Tsamboulas, D., 2010. "The gravity model specification for modeling international trade flows and free trade agreement effects: a 10-year review of empirical studies". *The open economics journal*, 3(1).
- Korinek, J., and P. Sourdin. 2009. "Maritime Transport Costs and Their Impact on Trade." <http://www.etsg.org/ETSG2009/papers/korinek.pdf>.
- Limao, N., and A. J. Venables. 2001. "Infrastructure, Geographical Disadvantage, Transport Costs and Trade." *World Bank Economic Review* 15 (3): 451–79.
- Micco, A., and N. Pérez. 2002. "Determinants of Maritime Transport Costs." Working Paper 441, Inter-American Development Bank, Washington, DC.
- Notteboom, T., C. Coeck, and J. Van Den Broeck. 2000. "Measuring and Explaining the Relative Efficiency of Container Terminals By Means of Bayesian Stochastic Frontier Models." *International Journal of Maritime Economics* 2 (2): 83–106.
- OECD (Organisation for Economic Co-operation and Development). 2003. *The Sources of Economic Growth in OECD Countries*. Paris.
- . 2008. *Clarifying Trade Costs in Maritime Transport*. Paris.
- Roll, Y., and Y. Hayuth. 1993. "Port Performance Comparison Applying Data Envelopment Analysis." *Maritime Policy and Management* 20 (2): 153–61.
- Sanchez, R. J., J. Hoffmann, A. Micco, G. A. Pizzolitto, M. Sgut, and G. Wilmsmeier. 2003. "Port Efficiency and International Trade: Port Efficiency as a Determinant of Maritime Transport Costs." *Maritime Economics and Logistics* 5: 199–218.
- Serebrisky, T., J. M. Sarriera, A. Suárez-Alemán, G. Araya, C. Briceño-Garmendía, and J. Schwartz. 2016. "Exploring the Drivers of Port Efficiency in Latin America and the Caribbean." *Transport Policy* 45: 31–45.
- Suárez-Alemán, A., J. Morales Sarriera, T. Serebrisky, and L. Trujillo. 2016. "When It Comes to Container Port Efficiency, Are All Developing Regions Equal?" *Transportation Research Part A* 86: 56–77.

Wilmsmeier, G., J. Hoffmann, and R. Sanchez. 2006. "The Impact of Port Characteristics on International Maritime Transport Costs." In *Port Economics. Research in Transportation Economics*, vol. 16, ed. K. Cullinane and W. Talley. Amsterdam: Elsevier.

WTO (World Trade Organization). 2010. "Maritime Transport Services." Background note by the Secretariat, S/C/W/315, WTO, Geneva.

## Appendix

**Table A.1 Estimation results of multilevel gravity model for trade with usual dummies**

Dependent variable: bilateral trade (ln)			
<i>Variable</i>	<i>(1)</i>	<i>(2)</i>	<i>(3)</i>
Distance (ln)	-0.21** (0.07)	-0.29* (0.11)	0.11 (0.14)
GDP <sub>us</sub> GDP <sub>exp</sub> (ln)	0.80*** (0.06)	0.89*** (0.07)	0.46** (0.13)
Unit costs (ln)	-0.16*** (0.02)	-0.16*** (0.02)	-0.16*** (0.02)
Language	1.37** (0.31)	1.34** (0.32)	1.42 (0.95)
Colonization	-2.14*** (0.27)	-2.10*** (0.27)	-2.43* (0.83)
Religion	-0.82** (0.25)	-0.79** (0.25)	-1.00 (0.75)
Intercept variation			
Commodity	2.89	2.88	2.77
Exporting country			1.31
Year		0.10	0.08
Residual	0.97	0.96	0.97

\* Significant at the 10 percent level, \*\* significant at the 5 percent level, \*\*\* significant at the 1 percent level.