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Port Efficiency and International Trade: Port Efficiency as a Determinant of Maritime Transport Costs

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This paper examines the determinants of waterborne transport costs, with particular emphasis on the efficiency at port level. Its main contribution is (1) to generate statistically quantifiable measures of port efficiency from a survey of Latin American common user ports, and (2) to estimate a model of waterborne transport costs, including the previously generated port efficiency measures as explanatory variables. In order to incorporate different port efficiency measures from the survey, we use principal component analysis (PCA). Our estimations show that the specified variables in the model explain a great proportion of the change in waterborne transport costs. With regard to port efficiency, the result is especially important for one of the port efficiency measures obtained through PCA with an estimated elasticity equivalent to that of distance. Other explanatory variables which show to be statistically significant are the monthly liner service availability, distance, and the goods' value per ton. The conclusions are relevant for policy makers as they show and quantify that port efficiency is a relevant determinant of a country's competitiveness – and in this respect, there still exist big differences among Latin American countries. Unlike most other relevant variables, port efficiency can be influenced by public policies.
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INTRODUCTION: MARITIME TRANSPORT COSTS AND INTERNATIONAL TRADE

The paper is organised as follows: This chapter contains a general introduction that looks at the relation between transport costs and international trade. In the second chapter, principal components are computed from a Latin American Port survey. The third chapter describes the model and the estimation results, followed by the conclusion and interpretation of results.

The impact of the costs of transport on foreign trade and economic development

Improvements in international transport services are one of the main features of economic globalisation. Together with progress in telematics, standardisation and trade liberalisation, faster, more reliable and cheaper transport services are contributing to the integration of production processes at the global level.

International freight has an impact on trade similar to customs tariffs or the exchange rate: a reduction in the costs of transport directly stimulates exports and imports, just as an increase in the exchange rate (the rate at which the national currency may be exchanged against another) makes exports more competitive, and a reduction in national customs tariffs lowers the costs of imports. Spurred by trade liberalisation, customs tariffs have dropped to levels where in many cases any additional reduction would now no longer have a significant impact. It is perhaps for that reason that new and interesting studies have been published in recent years analysing the impact of transport costs on trade patterns and globalised production (see for example Kumar and Hoffmann (2002) for a literature overview).

The impact on trade

The price of the vast majority of traded goods is exogenous for developing countries. If the shipping of imports becomes more expensive, higher prices ensue as a result of the increased cost of imported goods; in the case of intermediate and capital goods, this also increases the costs of local production. If exports become dearer to ship, the result is a drop in earnings for the exporting country or simply the loss of a market, depending on the elasticity of demand and the availability of substitutes. Econometric estimates suggest that the doubling of an individual country's transport costs leads to a drop in its trade of 80% or even more (Hummels, 2000; Limao and Venables, 2001).

The impact on economic growth

Empirical studies have concluded that greater transport costs lead to lower levels of foreign investment, a lower savings ratio, reduced exports of services, reduced access to technology and knowledge, and a decline in employment. It is estimated that a doubling of transport costs leads to a drop in the rate of economic growth of more than half a percentage point (Radelet and Sachs, 1998). This impact may appear low, but it should be noted that lower growth over the long-term results in sizeable variation in per capita income. Geographical variables related to transport costs may account for 70% of the statistical variation in per capita income between countries (Redding and Venables, 2001).

The impact of transport costs is increasing

On average, 8.6% of the value of merchandise imported by the countries of Latin America and the Caribbean is spent on freight and insurance costs relating to their international carriage; this figure is 40% more than the world average. Major differences persist within the region, with the Caribbean economies recording the highest indices.

Compared to tariffs, transport costs have been increasing in relative importance for export competitiveness. For example, on average, exports from Latin America and the Caribbean to the United States attract customs duties of 1.86%, compared to the 4.45% share of their value accounted for by international carriage (Micco and Pérez, 2001).

Increasing component of GDP

The freight and insurance costs of international transport are also tending to increase as a percentage of Gross Domestic Product (GDP). The reason for this is that, both globally and in Latin America and the Caribbean, trade is growing at a faster pace than GDP. In the 1990s, the rate of growth of world exports was more than double that of GDP, and was triple in Latin America and the Caribbean (ECLAC, 2002). Therefore, although transport costs have fallen as a percentage of the value of trade, trade itself has expanded, and with it international freight's share of GDP.

Increasing component of logistics costs

Spending on transport is also increasing because improved quality of service is sought, especially greater dependability and 'just in time' delivery. As a result, the inventory component within the overall costs of logistics declines, while the transport component rises. In the case of the United States, for instance, it is estimated that during the 1990s spending on transport rose from 9.5% to 10% of GDP, while spending on inventories slipped from 4.3% to 3.5% (Gorman, 2002; includes domestic transport).

Increasing incidence in the value of traded goods
Lastly, even as a percentage of the value of imported goods, the incidence of international transport costs is increasing. Whereas in the past exports consisted primarily of raw materials and manufactured goods, today trade is increasingly in intermediate goods. For example, the import price of a Mexican-made car imported into Peru includes not only the costs of transporting the vehicle from Veracruz, Mexico, to Callao, Peru, but also the transport costs of importing a number of inputs sourced from a wide range of countries that supply Mexico (Hoffmann, 2002).

Transport costs: Causes and effects

Analysis and reduction of transport costs is a quite complex issue. Demand for transport services is dependent on trade, which is influenced by a number of variables that also have an impact on the costs of transport.

Supply versus demand
The cost of transport is essentially the price of a service, and is determined by the supply and demand for that service. Lower transport costs reduce the final price, increasing trade. However, an expanding volume of trade also reduces the unit costs of transport, allowing for economies of scale and greater differentiation between different services in terms of speed, frequency, reliability and security.

Quality versus costs
As with goods, the production of transport services is also subject to the impact of technological advances. With the use of new information and communication technologies, improvements in infrastructure, and by taking advantage of the growing rate of containerisation, today the same freight and insurance per tonne of cargo can buy a quicker, more reliable service with less variation in delivery time than a decade ago.

In addition, it is worth noting that greater commercial demands as regards speed have at the same time given rise to an increase in the share of air transport as compared to maritime transport, and may entail an increase in the average cost of international transport. The fact that the average cost of freight and insurance rose worldwide in the 1990s (see Table 1) should not be interpreted as a worsening of the international transport system, but rather as a reflection of greater use of air transport and improvements in other transport services. Equivalently, when interpreting the regression results presented later in this paper, improved port efficiency does not necessarily imply lower transport costs, as the user may be required to pay for the improved service.

Table 1: Freight and insurance costs as a percentage of imports (c.i.f.), all modes of transport

Area	1980	1990	2000
Latin America and the Caribbean	8.85	8.17	8.58
World	6.64	5.22	6.21
Developing countries	10.44	8.60	8.83

Source: UNCTAD, Review of Maritime Transport, Geneva, 2002

Direct impacts versus indirect impacts

The distance separating countries impacts on trade between them in different ways. The main models used to explain international trade flows can be described as 'gravitational': countries trade with one another depending on their patterns of production, income, and whether they belong to economic blocs, with the distance between them also having some bearing. That gives an advantage to countries located in the 'center of gravity', and hence the name of the model. There is an assumption of a close link between distance and transport costs, which would explain why countries closer to one another trade more than with countries further away. In practice, distance may also have a bearing on other characteristics of countries, which leads them to trade more. For instance, countries located nearer to one another tend to have more similar histories, cultures and languages.

Most importantly, geographical closeness provides scope for alternative modes of transport to sea and air, thereby boosting competition and reducing prices for services. In other words, shorter distances entail lower costs and more trade. Increased trade in turn makes for economies of scale, leading to even further reductions in transport costs. In the case of intra-Latin American seaborne trade, a partial correlation coefficient of -0.463 is calculated between distance and the volume of bilateral trade, with a coefficient of $+0.178$ between distance and the costs of transport per ton. In other words, distance has its own bearings on trade and should not be taken only as a proxy for transport costs.

The modal split

Latin America's foreign trade

In terms of volume (tonnes), trade using air transport accounts for barely 0.1–0.6% of the foreign trade conducted by the countries of Latin America; in terms of value (USD), however, this mode represents anywhere between 8% and 21% (Table 2). The table also indicates that sea- and airborne transport are used particularly in foreign trade conducted by Argentina, Brazil, Chile, Colombia, and Peru, while in Mexico (significant trade with the United States) and

Table 2: Foreign trade of seven Latin American countries, 2000

	By water	By air	By land /other	% By water	% By air
Total volume of trade (in thousands of metric tons)					
Argentina	93,957	682	20,111	81.9%	0.6%
Brazil	324,991	694	12,138	96.2%	0.2%
Chile	88,924	514	9,690	89.7%	0.5%
Colombia	76,028	431	2,985	95.7%	0.5%
Mexico	198,857	1,031	885,890	18.3%	0.1%
Peru	25,376	153	699	96.8%	0.6%
Uruguay	6,121	20	2,330	72.2%	0.2%
Total value of trade (in millions USD)					
Argentina	30,803	6,610	12,847	61.3%	13.2%
Brazil	77,131	20,737	13,279	69.4%	18.7%
Chile	25,121	4,060	4,407	74.8%	12.1%
Colombia	16,320	5,004	2,573	68.3%	20.9%
Mexico	53,293	27,744	259,642	15.6%	8.1%
Peru	10,567	2,731	409	77.1%	19.9%
Uruguay	2,980	636	1,954	53.5%	11.4%
Cargoes value (in USD per ton)					
	By water	**By air**	**By land /Other**		
Argentina	328	9,687	639		
Brazil	237	29,869	1,094		
Chile	283	7,891	455		
Colombia	215	11,608	862		
Mexico	268	26,889	293		
Peru	416	17,837	586		
Uruguay	487	30,343	839		

Source: ECLAC, Maritime Profile 2002, www.eclac.cl/transporte/perfil

Uruguay (significant trade with Brazil and Argentina), the overland mode plays a relatively greater role.

Air transport's share is higher in long-distance trade; accordingly, although total trade decreases with distance, there is virtually zero correlation (−0.001) between distance and the volume of airborne trade (estimate for intra-Latin American trade).

Transport costs of intra-Latin American trade

For the 10 countries included in Table 3, Chilean exports to Uruguay have the highest transport costs as a percentage of the value of trade, followed by Ecuador's exports to Uruguay and Paraguay's to Ecuador. On average, the country with the highest transport costs for its imports from other Latin American countries is Ecuador, followed by Chile. Trade between Paraguay and Uruguay has the lowest transport costs, followed by that between Argentina and Uruguay, and Argentina and Brazil.

It is not possible, using these figures, to reach hasty conclusions about the efficiency of the respective transport services, nor to conclude that transport in

Table 3: Intra-Latin American transport costs as a percentage of the value of imports, c.i.f., 2000

Destination	Origin										
	Argentina	**Brazil**	**Chile**	**Colombia**	**Ecuador**	**Mexico**	**Paraguay**	**Peru**	**Uruguay**	**Venezuela**	**Average**
Argentina		4.3	13.2	6.3	20.9	7.7	10.3	6.9	3.8	8.4	9.1
Brazil	4.1		5.9	6.0	7.5	6.2	4.1	5.6	9.0	9.2	6.4
Chile	10.2	7.9		6.0	15.8	6.9	8.7	6.7	9.4	9.9	9.1
Colombia	10.7	6.5	8.4		4.5	6.0	11.9	4.7	8.6	6.2	7.5
Ecuador	11.6	7.1	7.5	4.8		7.9	25.4	5.9	9.6	7.6	9.7
Mexico	5.4	5.7	6.9	4.7	9.6		5.2	8.6	7.0	7.6	6.7
Paraguay	6.3	14.0	10.5	6.5	7.6	10.2		15.6	3.4	9.2	9.3
Peru	13.2	8.2	5.6	5.6	3.9	6.3	11.0		9.4	8.1	7.9
Uruguay	4.9	7.3	38.8	5.2	31.3	13.1	2.1	7.8		7.5	13.1
Average (non-weighted)	8.3	7.6	12.1	5.6	12.6	8.0	9.8	7.7	7.5	8.2	

Source: ECLAC, based on data extracted from the International Transport Database (BTI), www.eclac.cl/transporte/perfil/bti.asp. Excludes oil and coal one country is more 'expensive' than in another. For example, the low density of regular shipping services (liner services), together with the natural barrier of the Andes, appear to be part of the reason why transport between countries on the west and east coasts of South America tends to be more expensive than transport along the same coast. It should be noted that the figures in Table 3 are averages that cover all modes of transport and many different types of goods.

The remainder of this paper will now look in more detail into the determinants of the maritime transport costs, with a special emphasis on the impact of port efficiency indicators for containerised cargo.

COMPONENTS OF PORT EFFICIENCY

The relationship between port efficiency and waterborne transport costs

In previous work about the relationship between transport costs, economic development and the determinants of international waterborne transport costs, several variables, such as distance, economies of scale, transport insurance components, access to maritime services and the type of market were incorporated (see for example Radelet and Sachs, 1998; Fink *et al*, 2000; Fuchsluger, 2000; Clark *et al*, 2001; Limao and Venables, 2001; Micco and Pérez, 2001; Redding and Venables, 2001; Hoffmann, 2002; Kumar and Hoffmann, 2002; Wang *et al*, 2002). Concerning port efficiency, however, these studies tend to work with proxies, such as GDP per capita, perception surveys, or general infrastructure indicators (ie Global Competitiveness Report), and use data on the national rather than port level. Australian Productivity Commission (1998) uses some partial productivity measures; Martinez *et al* (2002) allows for different port costs by incorporating dummy variables depending on the port of departure.

Far more detailed research on port efficiency uses stochastic frontiers models or the Data Envelopment Analysis (DEA) (see for example Roll and Hayuth, 1993; Baños *et al*, 1999; Martinez *et al*, 1999; Coto *et al*, 2000; Gosh and De, 2000; Estache *et al*, 2001; Tongzon, 2001; Valentine and Gray, 2001). The necessary information requirements to reach these measures tend to make a broad quantitative comparison difficult, and have – to our knowledge – not yet been linked to data on international transport costs.

In consequence, in this paper we face the challenge to reach port efficiency measures that need to be statistically and analytically consistent, and be available on the port level for a relevant number of ports to be included in the waterborne transport cost equation. In the next section, we show the mechanism designed to obtain the necessary data (the direct survey) and the method used to generate port efficiency variables via principal component analysis (PCA).

Measuring port efficiency

Port of shipment efficiency was measured by using direct information gathered by way of extensive questionnaires as a part of this research. A number of potentially explanatory variables on port efficiency were measured, which were then grouped through the principal component analysis.

Through the survey, we obtained information about port activity for the year 1999. The questionnaires were sent to 55 port terminals. Responses were received from 41 port terminals mainly handling general containerised cargoes. These terminals handle over 90% of the containers exported from their respective countries. The responses corresponding to bulk items and pallet break-bulks were insufficient as regards statistical purposes, and had to be discarded. Other terminals had to be excluded due to insufficiently complete responses. Table 4 lists the 19 ports that were included in this study.

To avoid concerns about overparameterisation and spurious correlations between multiple variables, a PCA was conducted. The identified factors, which retained the patterns of the original variables, were to be introduced as new variables into the latter regression model. The correlations between the obtained port activity variables ranged from −0.295 to 0.969 (Table 5). As

Table 4: Ports included in PCA

Port	Country
Acajutla	El Salvador
Buenos Aires	Argentina
Campana	Argentina
Chacabuco	Chile
Coquimbo	Chile
Corinto	Nicaragua
Fortaleza	Brazil
La Guaira	Venezuela
La Plata	Argentina
Limon/Moin	Costa Rica
Panama-Atlantic	Panama
Maracaibo	Venezuela
Montevideo	Uruguay
Paranagua	Brazil
Rosario	Argentina
San Antonio	Chile
San Vicente	Chile
Santos	Brazil
Valparaíso	Chile

Table 5: Partial correlation matrix

Variable	Hourly container loading rate	General turn around time	Bureaucratic turn around time	Ship waiting time (Congestion period)	General ship waiting time	Average containers per vessel	Container handling capacity at port	Yearly congestion time	Average stay per vessel
Hourly container load rate[a]	1,000	−0.295	−0.309	−0.190	−0.257	0.520	0.524	0.093	0.028
General turn around time[b]		10.000	0.969	0.381	0.587	−0.082	0.145	0.593	−0.225
Bureaucratic turn around time[c]			1,000	0.428	0.624	−0.002	0.119	0.629	−0.235
Ship waiting time (Congestion period)[d]				1,000	0.693	−0.143	0.083	0.649	−0.152
General ship waiting time[e]					1,000	−0.007	0.034	0.571	−0.116
Average containers per vessel[f]						1,000	0.489	0.064	−0.053
Container handling capacity at port[g]							1,000	0.307	−0.201
Yearly congestion time[h]								1,000	−0.127
Average stay per vessel[i]									1,000

Source: Authors, based on Port Activity Survey, Austral University

[a]Hourly container load rate: Units of containers per hour.

[b]General turn around: The time—in hours—employed at the terminal/s to load or unload a container from the time of entry by land for exportation purposes, or until the container is released to the importer.

[c]Bureaucratic turn around: Average time—in hours—employed at the terminal/s to fulfill the arrangements required for exports and imports, including customs, health, safety and other procedures as might be required from the moment of cargo entry at the port, cargo release for vessel loading (exportation), or cargo entry into the warehouse for its subsequent release to the importer (importation).

[d]Ship waiting time (congestion period): the number of waiting hours at the roadstead in the periods of highest bunching each year according to regular terminal operation. This applies solely to vessels with commercial operations at the terminal/s.

[e]General ship waiting time: number of waiting hours at the roadstead during the rest of the year without bunching. This applies solely to vessels with commercial operations at the terminal/s.

[f]Average containers per vessel: Annual average of containers per vessel.

[g]Container handling capacity at port: Annual capacity for loading and unloading technology at the port.

[h]Yearly congestion time: Annual duration, measured in days, of the 'bunching' period (maritime, to the port).

[i]Average stay per vessel: Annual average time of ship stay at the port, expressed in hours.

anticipated, most of the nine variables are heavily correlated. The first three, out of nine components, account for more than 70% of the intrinsic variance of the data fulfilling the Kaiser criterion with eigenvalues over 1.

The Kaiser–Meyer–Olkin (KMO) overall statistic delivers 0.625 as a result for the sample of port efficiency variables, which indicates the sampling adequacy of the chosen variables. The PCA extracted three factors (Table 6). The first component, which accounted for more than 40% of the total variance, incorporates the bureaucratic turnaround of a container, the terminal turn-around for loading and unloading of a container, the average waiting time for ships during congestion time, the average waiting time for ships without congestion in the port, and the time of port congestion during the year. Together, these variables could be interpreted as representing port's time efficiency.

The loading and unloading rate per hour, the handling capacity, and the average number of containers per ship handled in the terminals loaded high in the second component, which can be referred to as the productivity of the terminal.

Finally, the average port stay of the ships was found as a single variable loaded on the third component.

The original, unrotated principal components solution maximises the sum of squared factors loadings, efficiently creating the set of factors in the table above. However, unrotated solutions are hard to interpret because variables tend to load on multiple factors. Using the Varimax rotation realises an orthogonal rotation of the factor axes to maximise the variance of the squared factor loadings of a factor on all the variables (Table 7).

From the above, three 'Factors', which correspond to the three generated components, were calculated and standardized to be used as variables in the posterior regressions. It was observed that that a great share of the ports is working at the same level in regard to 'time efficiency' (Factor1), while there are great differences in terms of 'productivity' (Factor2) (Table 8).

Table 6: Component loadings

	Initial eigenvalues			Extraction sums of squared loadings		
Component	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	3,620	40,218	40,218	3,620	40,218	40,218
2	2,107	23,415	63,633	2,107	23,415	63,633
3	1,006	11,177	74,810	1,006	11,177	74,810

Source: Port Activity Survey, Austral University

Table 7: Rotated component matrix

Variable	Component		
	1	2	3
General ship waiting time	0.851	−9.513E-02	3.612E-02
Yearly congestion time	0.851	0.249	3.262E-02
Ship waiting time (congestion period)	0.813	−6.359E-02	−0.113
Bureaucratic turn around	0.780	−9.531E-02	0.482
General turn around	0.746	−0.114	0.498
Hourly container load rate	−0.182	0.849	−0.193
Container handling capacity at port	0.166	0.813	0.208
Annual average of containers loaded per vessel	−3.926E-02	0.787	6.148E-02
Average stay per vessel	−2.396E-02	−9.832E-02	−0.842
Extraction method: principal component analysis.			
Rotation method: varimax with kaiser normalisation.			
a rotation converged in five iterations.			

Source: Processed from the Port Activity Survey, Austral University

Table 8: Port efficiency factors

Factor	Description
Factor1 'time inefficiency'	Based on YEARLY CONGESTION TIME, SHIP WAITING TIME (CONGESTION PERIOD), GENERAL SHIP WAITING TIME and BUREAUCRATIC TURN AROUND variables. These are related to the time of the ship in the port. The GENERAL TURNAROUND was excluded, as it is too closely correlated with the BUREAUCRATIC TURN AROUND.
Factor2 'productivity'	Based on CONTAINER HANDLING CAPACITY AT PORT, AVERAGE CONTAINERS PER VESSEL, and HOURLY CONTAINER LOAD RATE variables; it reflects efficiency in the terminals plus scale economies and container handling effectiveness.
Factor3 'stay per vessel'	Based on AVERAGE STAY PER VESSEL variable.

REGRESSION RESULTS FOR LATIN AMERICAN EXPORTS TO THE UNITED STATES

Model and approach

What follows is a cost equation, where the waterborne transport cost (the model-dependent variable) is assumed as equal to the marginal cost of service, multiplied by the markup of shipping companies. This reflects the costs in US dollars of transporting 1 ton of product *k* from foreign port *i*, located in country *I*, to port *j* in the US, located in customs district *J*. The markup is a function of the elasticity of demand faced by liner companies covering sea lines between country *I* and customs district *J* for product *k*.

$$\rho ijk = \phi(I, J, k) + mc(i, j, k) \tag{1}$$

where ρ_{ijk} is the cost of maritime transport per unit of weight of product *k* as transported between points *i* and *j*, in log; *i* is the port of origin located in country I; j is the port of destination in the US, located in district J; k is the product, defined at the six-digit Harmonised System Aggregation; ϕ is the markup, in log; and mc is the marginal costs, in log,

As may be observed in equation (1), both marginal costs and markup need to be a function of factors dependent on the port of origin (i, I), the district of destination in the US (j, J), and the specific characteristics of product k. In particular, it is assumed that the marginal cost is as follows:

$$mc_{ijk} = \alpha_j CD_j + \lambda_k HS_k + \psi WV_{ijk} + \gamma T_{ijk} + \partial_{iJ} + \rho FI_{iUS} + \omega PE_i \qquad (2)$$

where α_j is a specific effect of each customs district in the US. It reflects potential efficiency differences between ports in the various US customs districts. CD_j is the corresponding dummy variable. λ_k is the a specific effect of each product type, as classified by the Harmonised System. HS_k is the corresponding dummy variable. ψWV_{ijk} reflects the impact of the weight-value ratio for product k transported from foreign port i to US transport district j, in log. It represents the insurance component of maritime transport costs and also of the care and protection required to transport goods with a higher value per ton. γ T_{ijk} is the impact of the fraction of product k transported in containers. γ is expected to be negative. ∂d_{iJ} reflects the impact of the maritime distance between foreign port i and the main port in customs district J in the US, in log. It should be positive. ρFI_{iUS} is the monthly frequency of regular services between country I and the US, in log. It should be negative. ωPE_i captures the port efficiency of port i. In the past, port efficiency was considered on a country level. This is one contribution made in this model, as opposed to the models preceding it.

Finally, following the formulation of Fink *et al*, (2000), the potential effect of shipping company markups is evaluated by using

$$\phi(\mathrm{I}, J, k) = \mu_k + \psi^{PA} A_{IJ}^{PA} + \psi^{CA} A_{IJ}^{CA} \qquad (3)$$

where μ_k HS_k is a product-specific effect capturing the differences between products in transport demand elasticity. Transport demand elasticity derives from the final demand of product k in the US. ψ^{PA} A_{IJ}^{PA} represents the existence of price-fixing agreements on sea line IJ. ψ^{PA} is expected to be positive. ψ^{CA} A_{IJ}^{CA} equivalently, the existence of cooperative working agreements (no price-fixing type) on sea line IJ. ψ^{CA} should be positive, and it is expected that $\psi^{PA} > \psi^{CA}$. An agreement usually covers a line between a port in a foreign country and one or more coastal districts in the US, which are comprised of several customs districts, which in turn consist of several ports. This is the official classification of the US Maritime Administration, and is used in the trade statistics on which these equations are applied.

Substituting equation (1) for equations (2) and (3), we obtain:

$$\rho_{ijk} = \alpha_j CD_j + \beta_k HS_k + \psi WV_{ijk} + \gamma T_{ijk} + \partial d_{iJ} + \rho FI_{iUS} + \omega PE_i + \psi^{PA} A_{ij}^{PA} + \psi^{CA} A^{CA} IJ + \epsilon_{ijk} \quad (4)$$

where $\beta_k = \lambda_k + \mu_k$ and ε_{ijk} is the error term.

The dependent variable is defined as the per-ton cost of waterborne transport for the products exported from Latin America to the US in 1999.[1] It corresponds to total aggregated costs, including freight, insurance and other charges from the port of origin (port of export) up to the arrival of the cargo at the first port within the US, excluding import duties. Commercial information pertains to the US Import Waterborne Databank of the US Department of Commerce. The observations of this database that have not been taken into account are those where the country of origin of the merchandise is different from the country of their port of departure, that is, trade with landlocked countries is disregarded together with 'in-transit' merchandise. Extreme values that could correspond to measurement errors or bad accounting at Customs where also excluded.

Regression results

OLS regressions were undertaken using the factors generated by the above-described PCA (Table 9), a port survey on the country level (Table 10), and some selected individual productivity measures (Table 11).

Table 9: Transport costs determinants

Variable	Model I		Model II		Model III	
	Coefficient	***t***	**Coefficient**	***t***	**Coefficient**	***t***
Distance (ln)	0.096968	2.22	0.056329	1.12	0.060829	1.13
Value per weight (ln)	0.542058	14.50	0.535265	14.01	0.536632	14.38
Frequencies (ln)	−0.182408	−2.04	−0.117146	−1.64	−0.092485	−1.43
Containerisation (ln)	−0.025043	−0.23	−0.024177	−0.22	−0.022543	−0.20
Price−fixing agreements	−0.083535	−0.26	−0.114585	−0.37	−0.090948	−0.29
Coop. working agreements	0.070133	1.47	0.061185	0.54	0.043433	0.92
Factor1, 'time inefficiency'					0.034831	1.13
Factor2, 'productivity'	−0.062132	−3.02				
Factor3, 'stay per vessel'			0.001371	0.04		
	Number of obs=6203 $F(7, 4484)$=19.50 Prob>F=0.0000 R^2=0.5762 Adj R^2=0.4139 Root MSE=0.98683		Number of obs=6203 $F(7, 4484)$=643,97 Prob>F=0.0000 R^2=0.5752 Adj R^2=0.4124 Root MSE=0.98804		Number of obs=6203 $F(7, 4484)$=14.66 Prob>F=0.0000 R^2=0.5754 Adj R^2=0.4128 Root MSE=0.98774	

Source: Author's calculation based on Port Activity Survey, Austral University, 2002 *Notes*: All estimations in all tables include fixed effects for products and destination port districts. Regressions with robust standard errors (standard errors adjusted for clustering)

Table 10: Port modernisation on the country level

	Model IV	
Variable	**Coefficient**	***t***
Distance (ln)	0.097949	2.16
Value per weight (ln)	0.537766	14.25
Frequencies (ln)	−0.057082	−1.11
Price-fixing agreements	−0.094535	−0.30
Coop. working agreements	0.023243	0.57
Port reform survey	−0.029844	−2.00
	Number of obs=6203	
	$F(7, 4484)$=622,00	
	Prob>F=0.0000	
	R^2=0.5757	
	Adj R^2=0.4131	
	Root MSE=0.98746	

Regressions using variables generated from PCA

The distance coefficient in all three models has the expected positive sign, although only in Model I it is significant at 5%. A 1% increase in distance increases transport costs by 0.09%. This estimated distance elasticity is lower to those found in other studies. The reason may be that distances are relatively large, and Hummels (2000) suggests that the effect of the distance factor on transport costs becomes less important when larger distances are involved. Also, the differences in distance are not too big in our sample.

The estimated coefficient of the value per weight variable is also positive and highly significant. An increase of 1% in the value per weight of the merchandise carried generates a 0.54% increase in transport costs.

The frequency of services presents a significant negative effect on transport costs. The coefficient reflects that a 1 percent increase in the frequency or number of available liner services per month, which goes through a particular maritime route to each port, causes lower transport costs of between roughly 0.1 and 0.2 percent.

The level of containerisation, used as an indicator for the technological change at port level and in vessels is not significant at 5%. If Model I is estimated using only 100% containerised cargo, the estimated parameters remain practically the same.

With regard to the variables referring to agreements between liners companies, none of them turns out to be significant at 5%, and neither are the estimated signs coherent.

The coefficient related to Factor2, 'port productivity', is negative and significant at 1% showing that increasing port efficiency implies a reduction in

Table 11: Regression results, using single productivity indicators

	Model Va		Model Vb		Model Vc		Model Vd		Model Ve	
Variable	**Coefficient**	***t***	**Coefficient**	***t***	**Coefficient**	***t***	**Coefficient**	***t***	**Coefficient**	***t***
Distance (ln)	0.1832231	3.06	0.0503733	0.77	−0.000034	0.07	−0.010484	−0.28	0.056934	0.85
Value per weight (ln)	0.5426152	14.83	0.5412454	14.53	0.533837	13.9	0.5469166	13.75	0.536086	13.40
Frequencies (ln)	−0.183436	−2.52	−0.121445	−1.86	−0.011102	−0.15	0.0305314	0.41	−0.163577	−1.55
Containerisation (ln)	−0.024045	−0.23	−0.027260	−0.25	−0.012247	−0.11	0.0088335	0.08	0.008852	0.18
Price fixing agr.	−0.083383	−0.26	−0.113553	−0.38	−0.088744	−0.27	−0.385625	−3.55	−0.113383	−0.35
Coop. working agreements	0.123126	2.86	0.069817	1.35	−0.047366	−0.66	−0.085891	−1.33	0.083982	0.99
Container hourly loading rate	−0.168628	−4.96								
Container handling capacity at port			−0.170510	−2.82						
Port ship stay					0.079101	1.95				
Bureaucratic turn around							−0.001951	−0.16		
Container waiting time at port									0.052517	0.81
	Number of obs=6203		Number of obs=6203		Number of obs=6203		Number of obs=5945		Number of obs=5984	
	$F(7, 4484)$=19.21		$F(7, 4484)$=19.09		$F(7, 4484)$=12.51		$F(6, 4259)$=5.41		$F(6, 4291)$=474.03	
	Prob >F=0.0000		Prob >F=0.0000		Prob >F=0.0000		Prob >F=0.0000		Prob >F=0.0000	
	R^2=0.5773		R^2=0.5761		R^2=0.5759		R^2=0.5891		R^2=0.5777	
	Adj R^2=0.4153		Adj R^2=0.4136		Adj R^2=0.4135		Adj R^2=0.4265		Adj R^2=0.4112	
	Root MSE=0.98558		Root MSE=0.98703		Root MSE=0.98716		Root MSE=0.95424		Root MSE=0.99498	

transport costs; that is, the greater the efficiency at port level, the lower the transport costs.

The coefficient for Factor1, 'time inefficiency' has the expected sign, although it is not significant at the 5% level.

The coefficient for Factor3, which is based on just one variable – the average stay per vessel – appears to be irrelevant to transport costs. Ships may stay longer because the port is less efficient, but also because their operators choose so in order to move more cargo or benefit from other services.

In all the estimations, the dummies for the US destination districts had largely significant *t* values, exceeding 2.2, with only one exception. This result indicates important differences between them, implying relevant productivity and efficiency differences among US ports.

Regressions using results of a satisfaction survey

Table 10 shows the estimation results using the proxy for port efficiency variable obtained by a Satisfaction Survey (Hoffmann, 2001). The survey reports the average opinion of 60 consultants, port users and port operators about successful advances in private sector participation in port operations and investment, on a scale of 1–10. That is, unlike the new Port Survey undertaken specifically for this study, it does not include actual data on the port level, but can be considered as a proxy for user satisfaction, albeit on the country level.

The estimated coefficient for port efficiency is also negative and significant at 5%. For more detailed regressions with country-level data see Hoffmann (2002). Concerning port modernisation, he concludes that for intra-Latin American trade the difference between the most advanced country (Panama) and the least advanced (El Salvador) in this survey implies a difference of 25% of international transport costs.

The coefficients for Distance and Value per weight remain stable, and they continue to be significant. However, the frequency of services variable, the percentage of containerised cargoes (Containerisation (ln)) and the variables referring to the existing agreements, result not to be significant at 5%.

Regressions using individual port productivity indicators

Table 11 presents the results using single productivity indicators which had previously been grouped together as Factor2.

The results of individual variables that were of significance (Models Va and Vb) approximately match those obtained through the multivariate analysis with Factor2 in Model I. In several other cases, however, coefficients with low significance vary strongly in their values, indicating a high multicollinearity. For models Vd and Ve fewer observations were available, and the exclusion of a number of ports may explain the instability in the values and even signs of some variables.

The hourly container loading rate, which is actually one of the most common and straightforward productivity indicators of container terminals, is highly significant. Actually, the R^2 in Model Va is higher than that of Model I.

INTERPRETATION OF RESULTS AND CONCLUSIONS

The goals of this paper were, first, to obtain direct measures of port efficiency for a range of comparable Latin American ports, and, second, to estimate a model of waterborne transport costs, including the previously generated port efficiency measures as explanatory variables. Estimations are satisfactory in the fulfillment of those goals, because they show wide differences of port efficiency variables and their influence over the total waterborne transport costs.

We found that more efficient seaports are clearly associated with lower freight costs after controlling for distance, type of product, liner services availability, and insurance costs, among others. Different port efficiency measures are statistically significant, and are estimated with the expected signs in the regressions. Most other considered explanatory variables were also statistically significant and with the expected sign. These included the monthly service availability, distance and the goods' value per ton. The containerisation rate and the dummies for the existence of liner companies shipping agreements generally show not to be statistically significant. The coefficient for Factor 1 ('time efficiency'), which correspond to the first generated component, is the most important according to the PCA and is statistically significant, but at a lower level with regard to Factor 2.

Pending questions

The overall impact of port productivity on trade is higher than might be suggested by the estimated impact on international transport costs. The different indicators measured in the survey not only lead to a reduction in costs – as shown by the regressions – but also improve the quality of service, including reliability, security, and speed, which encourage trade further, but have not been a topic of this paper. It also needs to be pointed out that the measured international transport costs do not include a proportion of the port costs which may be charged directly to the shipper. We do not know – at least not from the data used in this paper – if more productive ports are more expensive or not. Experience suggests that modernised ports may charge higher prices, for example, per ship hour, but that the improved speed reduces costs per cargo unit.

Several indicators used in the regressions are not only a potential cause for lower transport costs, but they may also be the result of better services. Carriers may choose a particularly efficient or inexpensive port, causing congestion, which can thus not be interpreted as a 'cause' for higher transport costs. Similarly, they may stay longer to bunker because unit costs are lower. Similarly, one could argue that high liner frequencies might be a response to low transport costs, and are not necessarily their cause. However, liner services tend to cover long routes, including many ports, and at least in the short term are practically exogenous to freight rates.

Policy implications

In spite of these notes of caution, the paper's results are relevant for Latin American ports, the policy-makers, and for researchers. The work leaves an important set of matters to be investigated in the future, such as the depth of efficiency measures for large sets of ports; the consequences over the LAC international trade, competitiveness and regional integration processes, the institutional and economic determinants of port efficiency, the regulatory implications, and the influence of inland-port connection over the waterborne transport costs.

Port efficiency factors are easily observable in any terminal. Variables considered in this paper include the container hourly loading rate, the annual average of containers loaded per vessel, waiting times, and several others. Especially for low-value export commodities, small changes in port costs and productivity may make the difference between being or not competitive in the global market. The estimated elasticity for port efficiency is similar to that of distance.

Given the large pertaining differences in productivity among Latin American ports, these conclusions are relevant for policy-makers, for the ports and for researchers. Unlike distance, economies of scale, and most other determinants of transport costs, port efficiency is within the scope of national policies. Again, readers are reminded that this paper only looked at transport costs, identifying a clear impact of port efficiency on those cost. The overall impact of port efficiency on trade goes beyond this correlation.

ENDNOTE

[1] Published information on US imports of merchandise is compiled primarily from automated data submitted through the US Customs' Automated Commercial System. Data are compiled also from import entry summary forms, warehouse withdrawal forms and Foreign Trade Zone documents as required by law to be filed with the US Customs Service. Import charges represent the aggregate costs of all freight, insurance, and other charges (excluding US import duties) incurred in bringing the merchandise from alongside the carrier at the port of exportation in the country of exportation and placing it alongside the carrier at the first port of entry in the United States.

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