Netw Spat Econ (2011) 11:555–576
DOI 10.1007/s11067-010-9128-5

"Special Issue on Latin-American Research" Maritime Networks, Services Structure and Maritime Trade

Laura Márquez-Ramos ·
Inmaculada Martínez-Zarzoso · Eva Pérez-García ·
Gordon Wilmsmeier

Abstract This paper aims at investigating the relationship between maritime trade and maritime freight rates at sectoral level. These rates and their effect on international trade will be estimated using highly disaggregated data of shipments from five Spanish ports to seventeen destinations, 78.34% of the tonnage exported by Spain. The paper focuses

---

Financial support from the Spanish Ministry of Public Works and the Spanish Ministry of Science and Technology is gratefully acknowledged (P21/08 and SEJ 2007-67548). We also would like to thank three anonymous reviewers, the participants of the II International Conference of Transport held in Castellón (Spain), the VII Congreso de Ingeniería de Transporte held in Ciudad Real (Spain), the IAME 2006 Conference held in Melbourne (Australia) and the participants of the XV Pan-American Conference of Traffic and Transportation Engineering held in Cartagena de Indias (Colombia), for their helpful comments and suggestions.

L. Márquez-Ramos (✉)
Department of Economics and Institute of International Economics, Universitat Jaume I, Campus del Riu Sec, 12071 Castellón, Spain
e-mail: lmarquez@eco.uji.es

I. Martínez-Zarzoso
Department of Economics and Institute of International Economics, Universitat Jaume I, Castellón, Spain
e-mail: martinei@eco.uji.es

I. Martínez-Zarzoso
Ibero-America Institute for Economic Research, University of Göttingen,
Platz der Göttinger Sieben 3, 37073 Göttingen, Germany

E. Pérez-García
Fundación Valenciaport, Nuevo Edificio APV, Av. Muelle Turia s/n, 46024 Valencia, Spain
e-mail: eperez@fundacion.valenciaport.com

G. Wilmsmeier
Transport Research Institute, Edinburgh Napier University, Merchiston Campus EH10 5DT, Edinburgh, Scotland
e-mail: g.wilmsmeier@napier.ac.uk

on the effect of maritime networks, services structure and port infrastructure variables on maritime freight rates. The relationship between freight rates and trade is then analysed by applying a gravity model for sectoral exports. We investigate the endogeneity of the trade and freight rate variables by estimating both equations by using instrumental variables methods. The main findings of this study should contribute significantly in explaining the variability of maritime freight rates and to quantifying the impact of maritime freight rates in maritime trade.

Keywords Maritime freight rates · Connectivity · Spanish exports

1 Introduction

Recent trends towards regionalisation and globalisation have led to a decreasing role of tariff and non-tariff barriers as an influencing factor on trade. Hence, the relative importance of transport costs has increased, and these costs have become a relevant determinant of trade patterns. Despite their importance, only a small number of studies have focused on transport costs. Existing research has mainly been carried out on an aggregate level. A wide range of articles consider only proxies for transport costs in their estimated models. For instance, gravity models use distance between country capital cities as a proxy for transport costs (Anderson and van Wincoop 2003). These gravity studies have found that geographical distance is a crucial determinant of trade. However, geographical distance may represent a series of factors such as cultural proximity, a shared history, a perception of closeness and information costs rather than acting exclusively as a proxy for transport costs. Anderson and van Wincoop (2004) emphasise the need to obtain better transport cost measures and to use these measures to expand gravity models and to deal with the endogeneity of the transport cost variable.

This investigation is concerned with maritime trade and freight rates. Given that maritime services are in most cases protected from competition and exempted from antitrust laws, shipping margins are important to many countries. The latter will probably gain more, in terms of welfare, from reducing shipping margins than from a further reduction in artificial trade barriers. The purpose of the paper is twofold. Firstly, the influence of maritime networks, services structure and port infrastructure variables on maritime freight rates is examined. Secondly, once the determinants of maritime freight rates are identified, the impact of maritime freight rates on international trade is quantified by estimating a gravity equation for trade with instrumental variables. This is, to the authors' knowledge, the first paper that investigates the relationship between maritime freight rates and trade for Spanish exports, representing 78.34% of tonnage exported by Spain, using highly disaggregated data and a well-specified model.

There are only three general published studies of the determinants of transportation rates for Spanish exports: Martínez-Zarzoso et al. (2003, 2007) and Martínez-Zarzoso and Nowak-Lehmann (2007). The first investigates the impact of freight rates on Spanish ceramic exports, the second includes the results of four sectors and the third analyses the differential effect of freight rates on trade for alternative transport modes.

The relationship between trade and transport costs is effectively investigated by Limao and Venables (2001). In their seminal paper, they analyse empirically the dependency of transport costs on geographical and infrastructural variables and estimate an elasticity of trade with respect to transport costs in the range 2–5. These authors also find that distance and landlocked status positively affect transport costs, but the effect of distance can be lessened by improving the infrastructure of the origin, transit and destination countries. More recently, Martínez-Zarzoso and Suárez-Burguet (2005) and Martínez-Zarzoso et al. (2007) found similar results using disaggregated data.

Jauernig and Roe (2001) examined the development of international transport and logistics in Lithuania. Although these authors only focused on transport related matters, they also stated that other logistics aspects such as quality attributes and logistic services should be considered. Clark et al (2004) indicate that geographical factors, transport insurance, transport conditions (i.e. refrigerated transport), trade imbalances, economies of scale, containerised transport, number of maritime lines, port efficiency and anti-competition legal and practical restrictions, all affect freight rates. Wilmsmeier and Sánchez (2009) analyse the impact of logistics sector development and the impact of informality and confirm that countries with higher levels of logistics competence have lower freight rates of imports, thus positively affecting food and all other containerised imports and relieving the burden of freight rates.

Wilmsmeier and Sánchez (2009) develop a port infrastructure endowment index based on a set of variables using principal components analysis: draught, berth length, storage capacity. Their results reveal that the more harmonious the development of port infrastructure, the lower the freight rates. Hoffmann et al. (2003) demonstrate that efficiency of port infrastructure also affects freight rates. They base their analysis on quantitative port performance measures. Hoffmann (2001) and Wilmsmeier (2003) analyse the determinants of port efficiency and find that the latter does not only depend on infrastructure, but also on institutional, administrative and political factors. Although a certain degree of regulation increases port efficiency and reduces maritime freight rates, crossing a certain threshold has the opposite effect—decreasing port efficiency and raising maritime freight rates. Wilmsmeier and Pérez (2005) analyse the effect of liner shipping network conditions on freight rates from different regions to South America. They show a decreasing effect of maritime services supply on freight rate and investigate to what extent the structure of the deployed fleet for directly connected regions contributes to the level of freight rates. Also in this line, Wilmsmeier and Hoffmann (2008) as well as Hummels et al. (2009) found that the exercise of market power drives much of the variation in shipping prices.

Other studies refer to alternative transport modes. For instance, Micco and Serebrisky (2004) analyse the determinants of air freight rates. Distance, unit values, trade imbalance, airport infrastructure, government effectiveness and regulatory quality are important determinants of air freight rates. Product unit value coefficients are higher than those obtained for maritime and road transport pointing towards the importance of transport insurance, whereas distance coefficients are lower than those obtained for other modes of transport (Wilmsmeier 2003). Martínez-Zarzoso and Nowak-Lehmann (2007) analyse transport cost determinants of Spanish exports to Poland and Turkey for door to door costs. Their results show that the quality of service and the transportation conditions influence short-sea-shipping freight rates, whereas the main determinants for road transport costs are transport conditions, distance and transit time.

The structure of the paper is as follows: Section 2 presents the theoretical background and the model specification. Section 3 describes the data used for the estimated freight rates and identifies the variables and the connectivity factors of the empirical analysis. Section 4 discusses the results of the estimated freight rates and trade equations. Finally, in Section 5 conclusions and policy implications are drawn from the results.

2 Model specification

2.1 Freight rates

In this section a reduced (form) model of liner transport prices for Spanish exports is presented. In the model the exported commodities are produced in Spain and then shipped at a cost to the import markets where the goods are sold. Due to the shipping costs (margin), the price paid by consumers in the destination exceeds the price paid by producers. Since the shipping margin depends on competitive conditions in the shipping industry, similar to Clark et al. (2004) the shipping firms are assumed to be profit-maximizing identical firms and behave as Cournot competitors. Within this framework a simple constant-elasticity pricing equation can be easily derived from a fully specified general-equilibrium model (Francois and Wooton 2001). The pricing equation relates the price of shipping commodity k disaggregated at 8-digit level of the (HS classification) from port i in Spain to destination port j, T_{ijk}, to the marginal cost of this service, mc(i,j,k), and a profit margin term, ψ (i,j,k),

$$T_{ijk} = mc(i,j,k)\,\psi(i,j,k) \tag{1}$$

Marginal costs and profit margin depend on transport service conditions, infrastructural variables of origin, transit and destination countries, the degree of competition existing in the market and factors inherent to the characteristics of the transported commodity. Assuming a multiplicative functional form the marginal cost equation is given by,

$$mc_{ijk} = \phi_k W_{ijk}^{\alpha_1} D_{ij}^{\alpha_2} Q_{ij}^{\alpha_3} C_{ij}^{\alpha_4} S_{ijk}^{\alpha_5} \tag{2}$$

where ϕ_k is a dummy variable referring to product k, W_{ijk} denotes the value per weight ratio (€ per ton), D_{ij} denotes distance between port i and port j, Q_{ij} is the volume of exports between port i and j. C_{ij} denotes connectivity between origin and destination, S_{ijk} denotes transport service quality. The profit margin equation is given by,

$$\psi_{ijk} = \gamma_k B_{ij}^{\alpha_6} L_{ij}^{\alpha_7} \tag{3}$$

where γ_k is a dummy variable referring to product k that can be a proxy of the different transport elasticities across sectors. B_{ij} denotes trade imbalance and L_{ij}

denotes number of lines between ports i and j. Substituting Eqs. (2) and (3), taking natural logs and adding an error term, the empirical model to be estimated is derived:

$$\ln T_{ijk} = \delta_k + \alpha_1 \ln W_{ijk} + \alpha_2 \ln D_{ij} + \alpha_3 \ln Q_{ij} + \alpha_4 \ln C_{ij} + \alpha_5 \ln S_{ijk} + \\ + \alpha_6 \ln B_{ij} + \alpha_7 \ln L_{ij} + \mu_{ijk} \tag{4}$$

$\delta_k = \phi_k + \gamma_k$ and ln are natural logarithms.

2.2 Trade equation

The second part of this study deals with a trade equation. This equation is derived from gravity models that in their most basic form include explanatory variables such as income of the country of origin and destination, population or income per capita of the two countries and geographical distance between the two points as a proxy for freight rates. The model was first used by Walter Isard in 1954.

The gravity model has been widely used as an empirical tool to analyse the determinants of bilateral trade flows since it provides a good fit to most data sets of regional and international trade flows. This model, in its basic form, assumes that trade between countries can be compared to the gravitational force between two objects: it is directly related to countries' size and inversely related to the distance between them. Exports from country i to country j are explained by their economic sizes, their populations, direct geographical distances and a set of dummies incorporating some characteristics common to specific flows. Theoretical support for the research in this field was originally very poor but since the second half of the 1970s several theoretical developments have appeared in support of the gravity model. Anderson (1979) made the first formal attempt to derive the gravity equation from a model that assumed product differentiation. Bergstrand (1985, 1989) also explored the theoretical determination of bilateral trade, in which gravity equations were associated with simple monopolistic competition models. Helpman and Krugman (1996) used a differentiated product framework with increasing returns to scale to justify the gravity model. Deardorff (1995) has proven that the gravity equation characterises many trade models and can also be justified from standard trade theories. Anderson and van Wincoop (2003) support the idea that the key aspect of the gravity model is the dependence of trade on a bilateral and multilateral resistance factor. These authors refer to price indices as "multilateral resistance" variables, since they depend on all bilateral resistances, including those not directly involving the exporting country.

The gravity model has also been theoretically justified and widely used in transport geography literature. Isard (1975) and Erlander and Stewart (1990) justified the use of the model and gave a detailed analysis of its various formulations and its underlying theory. More recently, Hesse and Rodrigue (2004) point out that logistics require a review of this multidimensional concept to include four core elements, the traditional transport costs, the organisation of the supply chain, and the transactional and physical environments in which freight distribution evolves, with maritime freight rates then being incorporated into the trade equation recognising that they are endogenously determined.

The gravity equation only includes income per capita and population of the destination country, since income per capita and population of Spain are constant[1]. The specified equation is:

$$\begin{aligned} \ln X_{ijk} &= \beta_k + \beta_1 \ln GDPPH_j + \beta_2 \ln Pop_j \\ &\quad + \beta_3 \ln d_{ij} + \beta_4 \ln T_{ijk} + \beta_5 Lang_{ij} + \beta_6 Island_j + \beta_7 FTA_{ij} + v_{ijk} \end{aligned} \tag{5}$$

where β_k are sectoral dummies, X_{ijk} are exports in volume of commodity k from port i in Spain to country j. $GDPPH_j$ is the GDP per capita of the importing country, Pop_j is the population of the importing country[2] and, d_{ij} is the distance between the two countries, T_{ijk} is the variable representing maritime freight rates, $Lang_{ij}$ is a dummy variable that takes value of one if the origin and destination country share a common language and zero otherwise, $Island_j$ is a dummy that takes the value of one if the destination country is an island and zero otherwise, FTA is a dummy that takes the value of one when the trading countries have a free trade agreement, zero otherwise, and v_{ijk} is the error term. Equation (5) has also been specified with country dummies for each destination instead of income variables, and the language and island dummies have been dropped in order to account for "multilateral resistance" as suggested by Anderson and van Wincoop (2003).

Equations (4) and (5) are estimated by using IV and TSLS since a number of authors have argued that problems could evolve from the endogeneity of trade volume in the freight rate equation and of the freight rate variable in the trade equation (Anderson and van Wincoop 2004).

3 Data, variables and connectivity factors

This section describes the variables used in the empirical analysis and discusses their expected signs in the freight rates equation. In addition, connectivity factors constructed using principal components analysis (PCA) are presented. The data used in this study were extracted from the database *TradeTrans—Spanish Trade and Transport Flows*, developed by Fundación Valenciaport.[3] Data for 36,152 shipments exported as containerised cargo by sea from 5 Spanish ports to 17 countries during 2003 were used for this model. The model represents all Spanish maritime export shipments to the 17 destination countries[4], excluding cases with a large proportion of missing values.[5]

---

[1] The constant term in equation (5) captures the influence of these variables on exports.

[2] Income per capita and population in the destination countries were finally added to the model instead of total income and income per capita since these two variables highly correlated (correlation=0.72).

[3] TradeTrans compiles export declaration forms and completes them with a series of variables providing information about the mode of transport, transport route followed by each export shipment and the costs and time associated with that transport service for each shipment leaving Spain with destinations in 23 countries.

[4] The 17 destination countries included in the study are: Algeria, Brazil, Chile, China, Dominican Republic, Greece, Israel, Japan, Mexico, Poland, Russia, South Africa, South Korea, Turkey, United Arab Emirates, United Kingdom and United States of America. The selection of countries includes all of Spain's major trade partners for maritime cargoes. Large trade counterparts such as France, Germany, Italy and other European countries were not included in this study as the percentage of shipments transported by sea is not representative of Spanish export flows to these countries. The United States of America is the most highly represented country, accounting for 18.7% of the total weight of the export flows considered.

[5] Excluded shipments represent only 0.3% of the total dataset.

The dependent variable in the freight rate model is the freight rate between the port of origin in Spain and the port of destination. This variable expresses the amount in Euros that the exporter or the importer, depending on the INCOTERM, had to pay for the export shipment to be transported in container(s) by sea from on-board the vessel moored at the port of origin to the port of destination (on-board the vessel). Transport insurance, terminal handling costs and inland freight rates are excluded. For every pair of origin and destination ports, 10 different quotes were obtained for the freight rates charged to transport a TEU (twenty equivalent unit container) and/or a FEU (forty equivalent unit container), for different transport conditions, refrigerated and non-refrigerated cargo, and cargo requiring consolidation or not. To obtain these freight rates, extensive fieldwork was carried out. During this fieldwork 2,000 telephone interviews with shipping agents, freight forwarders, customs agents, consolidation/deconsolidation companies and terminal operators based on structured questionnaires were conducted.

The variables incorporated into the estimated model and their a priori expected signs are:

Product value (€/Kg): ratio of value to weight (in Euros/kilograms) calculated for each specific export shipment. This variable as a determinant of maritime freight rates is expected to be positive, since goods with a higher value/weight ratio tend to choose transport services that offer a higher quality and better frequencies and speeds (Feo et al. 2003 and Wilmsmeier 2003). Despite this fact, this variable is not correlated with other quality variables (i.e. days between service departures and number of calls).

Volume exported: total weight in tonnes of the Spanish export flows shipped in containers to each specific country of destination. The expected effect on maritime freight rates is negative, since a larger volume would generate further economies of scale at the exporter level, producing an expected decrease in freight rate.

Distance: the average distance between the Spanish port of origin and the port of destination is calculated as the statistical mean of all the values of distances travelled by the various shipping lines offering the regular services, taking into account the port calls in their itineraries. The expected sign of this variable is positive. The source is *Lineport*[6].

Trade imbalance: international trade flows are heavily imbalanced between areas. This disequilibrium applies to both international trade in general and to containerised seaborne trade in particular. The trade imbalance in volume that influences the maritime freight rates correlates with the disequilibrium. It is calculated accordingly:

$$B_{ij} = \left(X_{ij} - M_{ji}\right) \tag{6}$$

B_{ij} is the trade balance, X_{ij} and M_{ij} are exports and imports from port *i* to destination *j*. If exports exceed imports, the larger the imbalance the higher the expected freight rates for Spanish exports will be. Trade imbalance is introduced into the transport model in absolute terms, B_{ij}, calculated according to Eq. (6). The expected sign for the variable is positive.

---

[6] Fundacion Valenciaport's Lineport database: *Lineport* collects vessel calls at Spanish ports for all lines (lines publicised on the port's website or in port community journals) operating between Spain and Europe since 2003. Due to the labour-intensive nature of this task, data on non-European countries is compiled using the same procedure, but only during three months of the year: March, July and October, and this information is then extrapolated to the rest of the year.

Refrigerated cargo: commodities that require special transport conditions, such as refrigerated cargo, would incur greater freight rates. A positive sign is expected for this variable.

Number of shipping lines: as a proxy for the degree of competition between lines offering the same service at a specific port, an increase in this variable would cause a decrease in freight rates. The source of this data is also the Lineport database.

Vessel capacity: economies of scale at vessel level could also apply in the market. A continuous increase in vessel size is observed over recent years (Jansson and Shneerson, 1982; Lim 1998; Tozer and Penfold 2000; and Lloyd's Register Technical Association 2002). The largest container vessel built in 1968 had the capacity to carry 1,700 TEUs, this figure increased to 2,900 TEUs in 1980, 4,000 TEUs in 1990, 8,000 TEU in 2004 and 11,000 TEU in 2007. Tozer and Penfold (2000) indicate that even if there are limits to scale economies, where further increases in vessel size provide only limited unit cost reductions, this inflexion point has not yet been reached. The expected sign of this variable is therefore negative, as larger vessel sizes would be associated with lower maritime freight rates.

Port container throughput: in recent studies container port traffic (container throughput) has been considered as an appropriate variable to measure economies of scale and port production (Wang et al. 2005). Economies of scale are also presented at port level. Larger volumes of containerised cargo loaded and unloaded at a port will enable the shipping lines to use larger containerships, as well as permitting the terminal operator to optimise the use of terminal equipment, infrastructure and stevedoring shifts. A more effective terminal can be expected to induce lower unit freight rates. The expected sign of this variable will hence be negative.

Number of days between service departures: this variable reports the average time in days between two consecutive calls of vessels deployed in services between the port of origin and destination (according to the dates advertised by each line). The variable is therefore expected to be negative and directly related to frequency. The effect of the number of days between service departures on the average service freight rate is uncertain: on the one hand frequency is seen as a proxy for service quality, as a more frequent port to port service reduces the shipper's overall transit time from door to door on average and increases its flexibility to programme its shipments. Hence, the impact of frequency perceived as quality on the freight rate will then be positive. On the other hand an increase in the number of days between service departures indicates lower competition between shipping lines. In this case, a longer time interval between departures will decrease competition and increase freight rates.

Number of calls: this variable reflects the average number of ports a shipping line calls at between the ports of origin and destination. It is a proxy for service quality, and its expected sign will be negative, as a higher number of calls would imply a reduction in service quality and a decrease in the freight rate that the shipping line could charge.

Table A.1 in the Appendix shows a summary of the explanatory variables used in the estimation of freight rates in Section 4.[7]

---

[7] Column 1 in Table A.1 lists the variables, column 2 shows their description, and columns 3 and 4 the expected and obtained signs in the freight rate estimation respectively.

Port infrastructure variables: number of cranes, maximum draught and storage area at origin and destination ports. The interaction of the three above-mentioned variables is considered an appropriate proxy for quayside operation performance.

Following Bendall and Stent (1987) and Wilmsmeier and Pérez (2005), this study introduces vessel specific variables, age of the newest vessel in each specific service, average capacity (in TEUs) and speed (in knots). It is expected that greater performance, higher speed, larger capacities and newer vessels will contribute to changes in freight rates, due to higher productivity.

Connectivity: a number of variables describe connectivity in maritime transport. The previously mentioned variables relating to infrastructure endowment in ports and the characteristics of maritime services provide simple connectivity proxies, but do not reflect the system-inherent interrelations in the supply of transport services and transport infrastructure. The issue of connectivity and the impact on freight rates is here addressed in a broad sense[8], encompassing physical characteristics of the network, features of the services and cooperation of ship operators in conferences and strategic alliances. Port performance is essential for the efficiency and effectiveness of the maritime network. The functioning of the network and its structure involve complex interaction patterns that subsequently influence the cost of transport in the relation between two countries. Conceptually, PCA is used to calculate non collinear variables from the set of variables described above. The following variables were introduced in the PCA analysis: percentage of transhipment lines on that route, transit time, maximum and minimum number of calls on the route, distance between ports, number of services, time lag between shipping opportunities, vessel speed, fleet age, average capacity. The variables related to port infrastructure are: number of cranes, maximum water depth and storage area.

Three PCA models were constructed based on different sets of 16 variables. The first model (Model A) is based on 16 variables; five factors are extracted to be introduced in the regression model.[9] The first factor, *maritime route structure*, constructed using the variables transit time, minimum and maximum number of calls, distance between ports and percentage of transhipment lines, explains 22.8% of the total variance. The second factor is *port infrastructure supply A,* including maximum draught, number of cranes and storage area in the port of origin, and explains 21.9% of the variance. The third factor is *port infrastructure supply B,* including the same variables in the port of destination, and explains 13.3% of the variance. The age of ships, their average capacity (TEUs) and speed determine the fourth factor, *characteristics of deployed ships*, explaining 10.3% of the total variance. The fifth factor, *structure of liner services*, uses minimum frequency, number of liner services and maximum number of ports of call and explains 7.0% of the total variance.

In Model B, port infrastructure variables were omitted in order to construct a pure connectivity measure based exclusively on the mobile elements of the maritime transport network. Three factors were extracted. *Maritime route structure* including

---

[8] In a narrow sense, connectivity is limited to the physical properties of the network.

[9] The results of the construction of the connectivity indices with PCA are available upon request from the authors.

the variables: transit time, minimum and maximum number of calls, distance between ports and percentage of transhipment lines, which explains 34.0% of the total variance. *Characteristics of deployed ships* uses the age of ships, their average capacity (TEUs) and speed, and explains 21.7% of the total variance. Finally, *structure of liner services* uses the minimum frequency, number of liner services and maximum number of ports of call and it explains 15.7% of the total variance.

In Model C the distance variable was omitted, since it tended to be a significant single determinant in freight rate regressions in prior studies (Hoffmann 2002; Wilmsmeier 2003). The three components extracted are: *Maritime route structure, characteristics of deployed ships* and *structure of liner services,* explaining respectively 24.4, 29.4 and 17.6% of the total variance. The results from the PCA analysis are used in the regressions to investigate the specific impact of the constructed variables on freight rates. These variables are presented as connectivity indexes.

4 Empirics

4.1 Results

In this section, estimates of different factors influencing maritime freight rates and maritime exports from 5 Spanish ports to 17 destinations in the year 2003 are reported. Commodities were defined using the combined nomenclature (Harmonised System) at an 8-digit disaggregation level and only freight rates for containerised cargoes were considered.

First, the basic specification, given by Eq. (4) in Section 2, is estimated. Three variables are included to proxy for connectivity: number of lines, vessel capacity and port throughput; another two variables are used as proxies for service quality: number of days between service departures, and number of calls. Finally, the dummy refrigerated cargo is used for controlling specific cargo conditions. Equation (4) was initially estimated by OLS, but since a Hausman test indicates that the trade volume variable is endogenous, the estimation method for all the results reported in Table 1 is one of instrumental variables. We only have one excluded instrument which is population, since the variable trade volume is the total volume exported to a given country and this is highly correlated with population.

Second, instead of single variables, the connectivity factors derived from the PCA are included in Model (4) in order to measure their specific effect on the dependent variable. Also in this case Model (4) is estimated by using instrumental variables and testing for endogeneity.

Table 1 shows results from the first estimation. The product value has the expected positive sign and is significant. A 10% increase in the unit value increases freight rates by 0.2%.

The volume of exports from Spain to the included destination countries shows the expected negative sign and is significant, indicating that a larger trade volume has a reducing effect on freight rates, due to scale economies. However, the explanatory power of this variable and the magnitude of its coefficient decrease as new variables are added to the basic specification in Models 2–6. These results indicate a great variability in the freight rates offered for the same service depending on the volume exported. This variability points towards the cost advantage of high volume shippers over small and medium size shippers. The results also illustrate the advantage of high volume shippers to negotiate lower rates for their cargoes.

Average real distance from port to port is significant and has the expected sign. Longer distances increase maritime freight rates. The estimated distance elasticity ranges from 0.06 to 0.23. These elasticities are slightly lower than those published in earlier studies. Hoffmann (2002) calculates elasticities between 0.23 and 0.28 for intra-Latin American maritime trade (see also Hoffmann and Kumar 2002). Hummels (1999) estimates the distance coefficient as between 0.2 and 0.3 for different commodities.

The trade imbalance variable is significant and has the expected sign. The estimated sign of trade imbalance in absolute terms is positive, hence higher trade disequilibrium increases freight rates. Indeed, the volume of Spain's exports to the USA is greater than its imports. Trade imbalance in absolute terms is highly significant, thus explaining its high influence on the freight rate fixing processes. Recurrently on one of the legs of the turnaround trip, the percentage of vessel capacity utilisation will be lower, and therefore shipping lines adapt their pricing scheme to the direction of the trip and to its corresponding expected cargo. Freight rates will be higher for the shipments transported on the leg of the trip with more traffic, as the total amount charged for this leg must compensate the relatively reduced income from the return trip, when part of the vessel's capacity will inevitably be taken up with repositioned empty containers. Excess capacity on the return trip will increase the competition between the various liner services, and as a result freight rates will tend to be lower.

In Models 2, 3 and 4 three connectivity variables were added, reflecting the influence of infrastructure endowment and services on freight rates. The models show that better connectivity based on a greater number of lines (Model 2), vessel capacity (Model 3) and port throughput (Model 4) between the origin and destination ports lowers freight rates. The importance of connectivity will be studied in more detail in Models 7 to 9, in which the earlier estimated connectivity indices based on the PCA analysis are introduced into the regressions.

Model 5 adds a dummy variable to consider whether goods are transported in refrigerated containers. A higher percentage of refrigerated cargo has a positive effect on the dependent variable. Therefore, the variable has the expected sign, since freight rates are higher for products with special transport requirements.

Model 6 show the importance of service-quality variables in maritime transport. It adds number of days between two consecutive departures for the same destination country and number of calls. The estimated coefficient for the first variable is not statistically significant and presents a positive sign. The longer the number of days between two consecutive departures of vessels, the higher the freight rates. This variable could be viewed as a proxy for the degree of competition present in the market instead of as a proxy for service quality. Number of calls is significant and shows the expected negative sign. A higher number of calls indicates a lower service quality since the transit time that goods use to reach their final destination is higher. The value of the R^2 in Model 6 explains 49% of the variability of maritime freight rates, similar values are obtained in other papers where freight rate functions are estimated (see Clark et al. 2004).

In what follows, the influence of variables related to connectivity is investigated by using the connectivity indices described in the previous section, constructed with

Table 1 Determinants of maritime freight rates

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Product value	0.024*** (12.902)	0.024*** (12.649)	0.021*** (11.262)	0.021*** (13.119)	0.025*** (16.441)	0.023*** (15.154)
Volume exported	−0.565*** (−72.955)	−0.571*** (−59.617)	−0.585*** (−61.739)	−0.047*** (−2.727)	−0.055*** (−3.242)	−0.073*** (−4.535)
Distance	0.064*** (21.735)	0.061*** (19.226)	0.072*** (22.103)	0.197*** (45.432)	0.195*** (46.557)	0.234*** (39.094)
Trade imbalance	0.105*** (121.138)	0.106*** (108.569)	0.106*** (107.921)	0.043*** (22.784)	0.043*** (22.542)	0.043*** (23.487)
Dummy Island	0.592*** (82.933)	0.595*** (83.223)	0.584*** (78.335)	0.379*** (46.433)	0.380*** (47.375)	0.373*** (52.664)
Dummy refrigerated cargo					0.700*** (37.878)	0.711*** (38.666)
Connectivity:						
Number of lines		0.014** (2.335)	0.029*** (4.773)	−0.126*** (−18.693)	−0.110*** (−16.744)	−0.095*** (−11.955)
Vessel capacity (TEUS)			−0.109*** (−25.379)	−0.125*** (−36.184)	−0.127*** (−37.434)	−0.118*** (−32.079)
Port throughput (TEUS)				−0.203*** (−40.198)	−0.205*** (−41.261)	−0.217*** (−44.156)
Quality:						
Number of days between service departures						0.005 (0.939)

Number of calls						−0.064*** (−8.704)
Constant Term	14.101*** (88.127)	14.231*** (72.851)	15.212*** (79.789)	6.824*** (23.379)	7.001*** (24.534)	7.154*** (27.094)
R-squared	0.273	0.269	0.278	0.462	0.486	0.49
Number of Observations	34151	34151	34151	34151	34151	33987
ll	−19797.53	−19882.84	−19671.55	−14641.24	−13870.77	−13710.39
rmse	0.432	0.433	0.430	0.371	0.363	0.362
estat	1563.728	1628.101	1982.900	15.492	11.434	6.021
estatp	0.000	0.000	0.000	0.000	0.001	0.014
archi2	4624.273	3521.539	4038.154	7.507	10.640	20.980
archi2p	0.000	0.000	0.000	0.006	0.001	0.000

***, **, * indicate significance at 1%, 5% and 10%, respectively. T-statistics are given in brackets. P-values are zero for all explanatory variables apart from number of days between service departures in model 6. The dependent variable is the freight rate (euros per tonne) of transporting good *k* from the exporting country *i* (Spain) to the importing country *j* in natural logarithms. All explanatory variables, excluding trade imbalance and dummies, are also in natural logarithms. Models 1–6 were estimated by Instrumental Variables. Volume exported is considered as endogenous and the instrument used is the population of the importing country. The estimations use STATA command ivreg2. Estimates are efficient for arbitrary heteroskedasticity and reported statistics are robust to heteroskedasticity. Data is for the year 2003. Estat is a test of endogenous regressors and the p-value attached to it indicates that the volume exported is endogenous. Archi2 is the result of the Anderson-Rubin Wald test, rejection of the null (weak instruments) indicates that the instruments are valid the PCA analysis. Earlier studies have used only single indicators (Micco and Pérez 2002). Table 2 shows the results. Models 7, 8 and 9 incorporate the connectivity indices of Model A, Model B and Model C, respectively.

Model 7 indicates that the interaction between a greater number of ports of call, a longer total distance, longer transit times and the need for transhipment (maritime route structure) lead to higher freight rates. The effect of infrastructure supply is higher for the destination port than for the origin since differences among ports are lower within the

Table 2 Determinants of maritime freight rates: estimation of the importance of connectivity measures

	Model 7	Model 8	Model 9
Product value	0.035*** (21.537)	0.031*** (17.635)	0.030*** (17.289)
Volume exported	−0.120*** (−8.883)	−0.473*** (−48.154)	−0.479*** (−50.167)
Trade Imbalance	0.033*** (21.145)	0.090*** (92.255)	0.091*** (91.996)
Dummy Island	0.279*** (33.741)	0.583*** (93.774)	0.581*** (92.26)
Dummy refrigerated cargo	0.675*** (37.965)	0.643*** (32.363)	0.637*** (31.497)
Connectivity index:			
Maritime route structure	0.051*** (17.72)	0.040*** (14.323)	0.062*** (23.174)
Port of origin infrastructure supply	−0.060*** (−29.711)		
Port of destination infrastructure supply	−0.194*** (−56.289)		
Equipment structure	−0.078*** (−32.024)	−0.086*** (−29.498)	−0.080*** (−28.064)
Service structure	−0.071*** (−19.229)	0.005 (1.728)	−0.001 (−0.491)
Constant term	6.072*** (23.13)	12.881*** (66.951)	12.992*** (69.588)
R-squared	0.454	0.352	0.354
Number of observations	34151	34151	34151
ll	−14899.68	−17832.15	−17770.1
rmse	0.3743177	0.4078799	0.4071395
estat	47.62425	788.752	861.9715
estatp	5.16E-12	1.50E-173	1.80E-189
archi2	76.24416	2186.236	2378.207
archi2p	2.51E-18	0	0

***, **, * indicate significance at 1%, 5% and 10%, respectively. T-statistics are given in brackets. P-values are zero for all explanatory variables. The dependent variable is the freight rate (euros per tonne) of transporting good k from the exporting country i (Spain) to the importing country j in natural logarithms. All explanatory variables, excluding trade imbalance, dummies and connectivity measures are also in natural logarithms. Models 7, 8 and 9 were estimated by Instrumental Variables. Volume exported is considered as endogenous and the instrument used is the population of the importing country. The estimations use STATA command ivreg2. Estimates are efficient for arbitrary heteroskedasticity and reported statistics are robust to heteroskedasticity. Data is for the year 2003. Estat is a test of endogenous regressors and the p-value attached to it indicates that the volume exported is endogenous. Archi2 is the result of the Anderson-Rubin Wald test, rejection of the null (weak instruments) indicates that the instruments are valid. Models 7, 8 and 9 incorporate the connectivity indices of Model A, Model B and Model C, respectively as described in Section 3 single origin country. If the ships, deployed on a certain route, are newer, with a higher average ship speed and greater capacity per vessel, freight rates will be lower. Furthermore, a high degree of competition on certain routes combined with a greater number of opportunities to ship cargo lead to a reduction of freight rates (service structure). The results concerning maritime route and equipment structure hold even when port infrastructure measures (Models 8 and 9) are excluded from the model.

The obtained results are especially interesting when compared with the main findings on the impact of connectivity measures on freight rates in other regions. Wilmsmeier and Pérez (2005) show similar results on the importance of connectivity in maritime networks for trade with South America and particularly for intra South American trade (Wilmsmeier 2003).

The increasingly important role of freight rates on international trade has been mentioned in previous sections. Several authors have shown that the effect of freight rates on trade flows are important (e.g. Martínez-Zarzoso and Suárez-Burguet 2005), especially when transportation rates are considered as endogenously determined. Table 3 shows the estimation results of Eq. (5) by OLS and Instrumental Variables (IV).

In Models 10 to 13 a trade equation is estimated. Variables traditionally included in gravity models are considered (income per capita, population, geographical distance, being an island, sharing a language, having a free trade agreement). In addition, ad-valorem freight rates are incorporated in the models. Results show that all variables included are significant and have the expected sign. Income per capita and population in the destination countries were finally added to the model instead of total income and income per capita since the latter two variables are highly correlated. The coefficient on per capita income is positive, indicating that the larger the income per capita of an importing country the larger the volume exported by Spain. The population coefficient is negative, thus pointing towards the existence of an absorption effect for more populated countries that tend to import less.

The positive coefficient of the dummy variable “sharing a language” indicates stronger trade relations between Spain and Latin-American countries, where the population speaks the same language (Chile, Mexico and the Dominican Republic). Two countries that speak Spanish trade more than the rest of the country pairs. Nonetheless, this result indicates a lower influence of a common language compared with similar studies with data for previous years (Martínez-Zarzoso and Suárez-Burguet 2005 show a coefficient of 0.94 and Martínez-Zarzoso and Nowak-Lehmann 2003 of 0.86). The coefficient for island is also positive, indicating that, other things being equal, countries that are an island (UK, the Dominican Republic) trade more, and also those countries sharing a free trade agreement (FTA) trade more.

Geographical distance has the expected sign and may reflect other trade influencing factors than maritime freight rates (e.g. cultural similarities, common history and information barriers), since the estimated coefficient remains the same when freight rates are added to the list of explanatory variables.

The coefficient of maritime freight rates has the expected negative sign and is highly significant. A 10% decrease in ad-valorem freight rates fosters international trade by 4.4%, as indicated by models 11–13. We find that this variable is endogenously related to trade values. All variables included in Models 6 and 7 were alternatively used as freight rates instruments. If this endogeneity is not taken into account, the elasticity of trade with respect to freight rates is underestimated as

Table 3 Determinants of international trade

	OLS Model 10	IV Model 8 Model 11	IV Model 6 Model 12	IV Model 6 Model 13
Maritime freight rates	−0.262*** (−30.618)	−0.442*** (−50.197)	−0.438*** (−49.599)	−0.447*** (−51.512)
Income per capita	0.082*** (10.309)	0.055*** (6.93)	0.057*** (7.122)	
Population	−0.153*** (−18.516)	−0.143*** (−17.273)	−0.147*** (−17.403)	
Distance	−0.100*** (−8.882)	−0.133*** (−11.757)	−0.132*** (−11.474)	
Dummy language	0.065** (2.386)	0.159*** (5.756)	0.149*** (5.37)	
Dummy Island	0.203*** (5.526)	0.272*** (7.5)	0.310*** (8.203)	
Free trade area	0.202*** (8.202)	0.187*** (7.528)	0.205*** (8.089)	
Dummy Brazil				−0.138*** (−3.209)
Dummy Chile				−0.109*** (−2.968)
Dummy China				−0.080* (−1.792)
Dummy Dominican Republic				−0.295*** (−8.149)
Dummy Greece				0.084 (1.624)
Dummy Japan				−0.116*** (−2.71)
Dummy Korea				−0.442*** (−8.191)
Dummy Israel				−0.347*** (−9.161)
Dummy Mexico				0.159*** (5.075)
Dummy Poland				0.1 (0.792)
Dummy Russia				0.132 (1.312)

Dummy South Africa				0.049 (1.121)
Dummy Turkey				−0.005 (−0.112)
Dummy United Arab Emirates				−0.295*** (−7.365)
Dummy United Kingdom				0.673*** (8.237)
Dummy United States				0.154*** (4.815)
Constant term	12.213*** (66.124)	12.551*** (68.408)	12.459*** (67.209)	14.513*** (150.546)
R-squared	0.13	0.114	0.115	0.113
Number of Observations	34151	34151	33987	35874
ll	−61959.920	−62264.480	−61943.180	−65223.910
rmse	1.487	1.498	1.497	1.491
estat		4214.651	4076.014	4932.948
estatp		0.000	0.000	0.000
archi2		3302.093	3120.552	3317.107
archi2p		0.000	0.000	0.000
j		423.628	330.250	322.613
jp		0.000	0.000	0.000

***, **, * indicate significance at 1%, 5% and 10%, respectively. T-statistics are given in brackets. P-values are zero for all explanatory variables. The dependent variable is the exported value in natural logarithms. All explanatory variables, excluding dummies, are also in natural logarithms. Model 10 was estimated by OLS, whereas Models 11–13 are estimated by TSLS. Maritime freight rates are ad valorem. Maritime freight rate is considered as endogenous and the instruments used are the exogenous variables included in Models 8 and 6. The TSLS estimations use STATA command ivreg2. Estimates are efficient for arbitrary heteroskedasticity and reported statistics are robust to heteroskedasticity. Data is for the year 2003. Estat is a test of endogenous regressors and the p-value attached to it indicates that the volume exported is endogenous. Archi2 is the result of the Anderson-Rubin Wald test, rejection of the null (weak instruments) indicates that the instruments are valid. J is the result of the Hansen test of over identifying restrictions, rejection of the null indicates that the overidentifying restrictions are valid indicated by Model 10. Judging from these results, it could be argued that the negative impact of maritime freight rates on trade flows has been traditionally underestimated by the economic literature.

4.2 Robustness

Adding country dummies to the trade equation instead of income and population variables and the set of dummies (language, island and FTA) is a way to control for the robustness of our results. Several authors, among them Feenstra (2004), have stated that this is also a way to control for "multilateral resistance" as proposed by the theoretically-justified gravity model of Anderson and van Wincoop (2003). The results are reported in Model 13 (Table 3). The same coefficient is obtained for the freight rate variable indicating that controlling for all developments that are destination-specific gives us the same elasticity of trade with respect to freight rates that was obtained by adding real variables into the trade equation, which is reassuring and indicates that the estimate is unbiased.

5 Conclusions and policy implications

The objective of this paper was to investigate the determinants of maritime freight rates and their effect on international trade flows. A freight rate equation was estimated using highly disaggregated data on maritime freight rates and highlighted the importance of connectivity and service quality variables as explanatory variables. A gravity equation was also estimated for Spanish exports augmented with the above-mentioned maritime freight rate variables.

Results from the first estimation show that all of the variables included in the estimated freight rate equation are significant and have the expected signs. The explanatory power of the freight rate model increases when connectivity and service quality measures are included in the model.

The subsequent estimation of the trade equation shows that the validity of using distance as a proxy variable for freight rates is questionable, since the variable maritime freight rates is significant and its coefficient is higher in magnitude than the estimated distance coefficient. The magnitude, sign and significance of the distance coefficient remains unchanged when freight rates are considered endogenous. Hence, distance may capture trade barriers other than transport costs such as cultural similarities, common history, proximity perception and information barriers.

The effect of maritime freight rates on exports provides a more accurate estimation when this variable is considered as endogenous. A reduction of the freight rate could act as a facilitator of exports by increasing the competitiveness of the exported products in the destination country. A secondary effect could be an increase in exported goods to the markets with lower freight rates and a reduced barrier to enter the destination market for products that previously were not exported to this destination.

Since the international competitiveness of many Spanish exporting sectors is based on prices, these sectors are highly sensitive to small variations in any component of the final price of the goods: production, transportation and distribution costs. If transport costs are considered as an endogenous variable to trade, the results indicate that it is not transport costs per se, but the underlying structure of variables that determine transport costs that are important determinants of export flows. Hence, further improvements in maritime services (i.e. direct services and low transit times) and in connectivity will promote exports.

The coefficient and sign estimated for the port variable show that the larger the size of a port, the lower the freight rates. Moreover, this study has also proved that the higher the number of shipping lines, competing on a route, the lower the freight rates. These results emphasize the relevance of port policy and port investment planning in a country. Although concentrating investments in a few ports and promoting their role as import-export gateways may be difficult from a political point of view in large countries with many kilometres of coast, as it is the case in Spain, investing in several small or medium-sized ports all aiming at the same container segment of the market may not be a strategy that leads to increasing the competitiveness of the country's exports.

While it is almost impossible to move a centre of consumption, the time and cost needed to reach and serve certain locations can be influenced through improved accessibility (including variables related to economies of scale and scope in service provision and infrastructural barriers). The recognition of governments that all of these internal variables might only interact effectively if they are accompanied by a fitting legal and institutional framework is a basic requirement for policy development and implementation.

Our findings open the important discussion on the 'cost of trading with peripheral countries' as they show that transport costs on more central trade routes of the maritime liner service network are significantly lower than on peripheral ones. The elasticities found in the study show that the impact of being peripheral in the maritime network is higher than the impact of distance. Spain's exports to network peripheral countries pay higher prices which also influences the competitiveness of Spanish exports in these markets, particularly if these are less peripheral for competing exporters.

Additionally, the results underline the fact that the position within the network has a more significant impact than the notion of distance, the latter only expressing the geographical distance between the trading partners, but not the level of quality to breach that distance.

This important finding needs to be seen in the context of the influencing variables of liner network connectivity such as ship size (Jansson and Shneerson 1982; Lim 1998) and frequency, which are determined by the overall level of trade, the geographic position and, last but not least, port infrastructure endowment and development options. While the volume of trade is especially decisive, it can only be influenced indirectly by governments.

Consequently, it could be argued that the negative impact of the maritime network and services structures on maritime freight rates and consequently trade flows has traditionally been underestimated by the economic literature and requires further exploration. In an environment where shipping lines are actively seeking out ways to reduce their costs, particularly by aiming for economies of scale and scope, this process results in a continued change of liner services at particular ports. Ports attempt to accommodate this effect by providing incentives to ocean carriers and by making substantial infrastructure investments on the waterfront in an attempt to increase their productivity. The result is an extremely dynamic network that reinforces processes of agglomeration in some places, but at the same time provides an economic advantage that can improve the competitive position of a region in the global market. The relationship between ports and carriers in the context of this dynamic network can leave little doubt that the structure of transportation networks is an important variable for the structure of transport costs. However, the full comparative advantages of improving infrastructure and networks can only be captured if this development is of comparable and equal level throughout the network. Changes and shifts in economic development can induce significant shifts in maritime transport service networks. From a policy perspective, however, it is important to be aware that liner service network development is driven by private sector decision making.

The findings thus highlight the importance of implementing proactive policies for port infrastructure development and management in order to create a suitable a environment for the demands and requirements of shipping lines, but also illustrate the importance of understanding the contextuality of shipping, trade and port development.

Finally, as containerisation further expands, liner transportation is becoming a point-to-point or door-to-door rather than a port-to-port business, and freight rates are established to cover the entire movement. Further research on this issue would therefore be desirable.

Appendix

Table A.1

Variable	Description	Expected sign	Obtained sign
Product value	Ratio of value/weight (euro/kg) calculated for each specific export shipment	+	+
Volume exported	Total weight in tonnes of the Spanish export flows shipped in containers to each specific country of destination	−	−
Distance	Average distance in kilometres between the Spanish port of origin and the port of destination.	+	+
Trade imbalance	Absolute difference between exports and imports from port i to destination j.	+	+
Island	Dummy variable that takes the value of one if the destination country is an island and zero otherwise	+	+
Refrigerated cargo	Dummy variable which takes the value of one when commodities require refrigerated cargo	+	+
Number of lines	Connectivity measure: Proxy of the degree of competition between lines offering the same maritime transport service at a specific port	−	−
Vessel capacity	Connectivity measure: Indicates the existence of economies of scale at vessel level	−	−
Port container throughput	Connectivity measure: Involves economies of scale and production and efficiency	−	−
Number of days between service departures	It is a quality measure or reflects a lack of competition between shipping lines	−/+	+
Number of calls	Quality measure: Average number of ports a shipping line calls at between the ports of origin and destination	−	−

References

Anderson JE (1979) A theoretical foundation for the gravity equation. Am Econ Rev 69(1):106–116

Anderson JE, Van Wincoop E (2003) Gravity with gravitas: a solution to the border puzzle. Am Econ Rev 93:170–192

Anderson JE, Van Wincoop E (2004) Trade costs. J Econ Lit 42:691–751

Bendall H, Stent A (1987) On measuring cargo handling productivity. Marit Policy Manage 14(4):337–343

Bergstrand JH (1985) The gravity equation in international trade: some microeconomic foundations and empirical evidence. Review Econ Stat 67(3):474–481

Bergstrand JH (1989) The generalized gravity equation, monopolistic competition, and the factor-proportions theory in international trade. Rev Econ Stat 71(1):143–153

Clark X, Dollar D, Micco A (2004) Port efficiency, maritime transport costs, and bilateral trade. J Dev Econ 75:417–450

Deardorff AV (1995) Determinants of bilateral trade: does gravity work in a Neo-classical word?, NBER Working Paper 5377

Erlander S, Stewart NF (1990) The gravity model in transportation analysis—theory and extensions. *Topics in Transportation,* VSC Utrecht. The Nertherlands, 1–226

Feenstra RC (2004) Advanced international trade: Theory and evidence, Princeton University Press

Feo M, García L, Martínez I, Pérez E (2003) Determinants of modal choice for freight transport: consequences for the development of short sea shipping between Spain and Europe. In *Maritime Transport II. Second International Conference on Maritime Transport and Maritime History.* Volume I, 767-669. SCI UPC 2003. Barcelona, Spain

Francois JF, Wooton I (2001) Trade in international transport services: the role of competition, *Review of International Economics*, Blackwell Publishing, 9(2), 249–261

Helpman E, Krugman PR (1996) Market structure and foreign trade. Increasing returns, imperfect competition, and the international economy. MIT, Cambridge

Hesse M, Rodrigue J-P (2004) The transport geography of logistics and freight distribution. J Transp Geogr 12(3):171–184

Hoffmann J (2001) Latin American ports: results and determinants of private sector participation. Int J Marit Econ 3:221–241

Hoffmann J (2002) El costo del transporte internacional y la integración y competitividad de América Latina y el Caribe. Boletín FAL, 191, ECLAC

Hoffmann J, Kumar S (2002) Globalisation: the maritime nexus, in Handbook of Maritime Economics, Chapter 3. London, 2002. 35–62

Hoffmann J, Micco A, Pizzolotti G, Sánchez R, Sgut M, Wilmsmeier G (2003) Port efficiency and international trade: port efficiency as a determinant of maritime transport costs. Marit Econ Logist 5 (2)

Hummels D (1999) Have international transport costs declined? Department of Economics Working Paper, Purdue University

Hummels D, Lugovskyy V, Skiba A (2009) The trade reducing effects of market power in international shipping. J Dev Econ 89(1):84–97

Isard W (1954) Location theory and trade theory: short-run analysis. Q J Econ 68:305–322

Isard W (1975) A simple rationale for gravity model type behavior. Pap Reg Sci Assoc 35:25–30

Jansson JO, Shneerson D (1982) The optimal ship size. J Transp Econ Policy 16(3):217–238

Jauernig C, Roe MS (2001) International logistics in Lithuania at a time of transition. Transp Rev 21 (1):117–135

Lim SM (1998) Economies of scale in container shipping. Marit Policy Manage 25(4):361–373

Limao N, Venables AJ (2001) Infrastructure, geographical disadvantage, transport costs and trade. World Bank Econ Rev 15(3):451–479

Lloyd’s Register Technical Association (2002) Ultra-large container ships (ULCS): designing to the limit of current and projected terminal infrastructure capabilities

Martínez-Zarzoso I, Nowak-Lehman F (2003) Augmented gravity model: an empirical application to Mercosur-European union trade flows. J Appl Econ 6(2):269–294

Martínez-Zarzoso I, Suárez-Burguet C (2005) Transport costs and trade: empirical evidence for Latin American imports from the European Union. J Int Trade Econ Dev 14(3):227–245

Martínez-Zarzoso I, Nowak-Lehmann F (2007) Is distance a good proxy for transport costs?: The case of competing transport modes. Journal of International Trade and Economic Development, forthcoming

Martínez-Zarzoso I, García-Menéndez L, Suárez-Burguet C (2003) The impact of transport cost on international trade: the case of Spanish ceramic exports. Marit Econ Logist 5(2):179–198

Martínez-Zarzoso I, Pérez-García E, Suárez-Burguet C (2007) Do transport costs have a differential effect on trade at the sectoral level? Appl Econ 40(24):3145–3157

Micco A, Pérez N (2002) Determinants of maritime transport costs. WP-441, Inter-American Development Bank

Micco A, Serebrisky T (2004) Infrastructure, competition regimes and air transport costs: cross country evidence, research Dep. Working Papers WP-510, Iber-American Development Bank

Tozer DR, Penfold A (2000) Container ships: design aspects of larger vessels, Lloyd's Register and Ocean Shipping Consultants Ltd., RINA/IMarE Presentation, London, UK

Wang T, Cullinane K, Song D (2005) Container port production and economic efficiency. Palgrave, London

Wilmsmeier G (2003) Modal choice in freight transport—influencing analysis of constraint variables and a perspective for diversified modal participation in South America. Dresden University, Mimeo

Wilmsmeier G, Pérez G (2005) Maritime transport costs and connectivity on maritime routes to South America. 13th Annual Congress of the International Association of Maritime Economists (IAME), Cyprus

Wilmsmeier G, Hoffmann J (2008) Liner shipping connectivity and port infrastructure as determinants of freight rates in the Caribbean. Marit Econ Logist 10:130–151

Wilmsmeier G, Sánchez R (2009) The relevance of international transport costs on food prices: endogenous and exogenous effects. Res Transp Econ 25(1):56–66