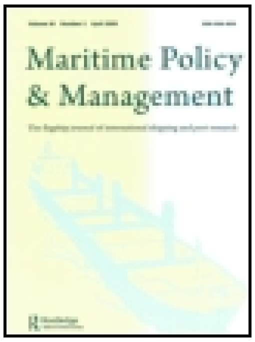

Routledge
Taylor & Francis Group

Maritime Policy & Management
The flagship journal of international shipping and port research

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tmpm20

Exploring the relationships between maritime connectivity, international trade and domestic production

Naima Saeed , Kevin Cullinane & Sigbjørn Sødal

To cite this article: Naima Saeed , Kevin Cullinane & Sigbjørn Sødal (2020): Exploring the relationships between maritime connectivity, international trade and domestic production, Maritime Policy & Management, DOI: 10.1080/03088839.2020.1802783

To link to this article: https://doi.org/10.1080/03088839.2020.1802783

Published online: 06 Aug 2020.

MARITIME POLICY & MANAGEMENT
https://doi.org/10.1080/03088839.2020.1802783

Exploring the relationships between maritime connectivity, international trade and domestic production

Naima Saeed[a], Kevin Cullinane[b] and Sigbjørn Sødal[c]

[a]School of Business and Law, University of Agder, Grimstad, Norway; [b]School of Business, Economics and Law, University of Gothenburg, Gothenburg, Sweden; [c]School of Business and Law, University of Agder, Kristiansand, Norway

ABSTRACT

The objective of this paper is to simultaneously analyse the complex relationships between bilateral maritime connectivity, bilateral trade and domestic production as measured by gross domestic product (GDP) per capita. This is achieved by applying non-recursive models and Path Analysis (PA). The top ten best maritime connected countries and their 155 trading partners are selected for the analysis. The components of maritime connectivity, maritime distance, and gravity variables are selected as instrumental variables to analyse the reciprocal relationship between export/import of ten countries and the GDP per capita of their 155 trading partners. The results confirm the reciprocal relationship between export values (that are the import values of trading partners) and GDP per capita, whereas a reciprocal relationship between import values (that are the export values of trading partners) and GDP per capita does not exist. The results also confirm the complexity of the relationships between maritime connectivity, trade and economic growth and that, compared to components of maritime connectivity, none of the gravity variables have a positive impact on bilateral trade. The results suggest that economic policy and trade policy at the global, regional, and national level should recognize the need for, and foster, better maritime connectivity.

KEYWORDS

Maritime connectivity; bilateral trade; economic growth; non-recursive models; path analysis; gravity variables

1. Introduction

Throughout the history of civilization, people that are located far apart, but sharing access to the sea, have mainly been connected via maritime transport. Road and rail are obviously required for inland transport and can provide an alternative to shipping in some domestic and international contexts but are often infeasible or too costly over long distance. Today, people move more rapidly by air and information flows more easily via telecommunications technology than aboard maritime vessels. However, shipping continues to dominate the long-distance transport of physical goods.

The relationship between the bilateral trade which exists between countries and the economic growth which they experience as a consequence is a complex one. Whilst it is widely acknowledged that greater connectivity between nations (in the widest use of the term, encompassing cultural and business connectivity) is likely to promote bilateral trade and, in so doing, contribute positively to economic growth (Frankel and Romer 1999; Irwin and Terviö 2002), the strive for a better understanding of the precise nature of the relationship between trade and growth has been a major research issue in international economics for decades. The objective of this article is to investigate

CONTACT Kevin Cullinane kevin.cullinane@gu.se School of Business, Economics and Law, University of Gothenburg, Gothenburg 40530, Sweden

the wider relationship between maritime connectivity, international trade and domestic production in terms of GDP per capita, but with no modelling of the time axis. The analysis is static, as it contains no explicit growth parameters. However, in some way or another, relatively high GDP today originates from growth in the past, so the results will still shed light on the relationships between maritime connectivity, trade and growth to the extent that patterns of trade and maritime connectivity are relatively stable over time. This is typically the case at the level of aggregation that has been chosen for this analysis.

An important part of the geographic concept of connectivity relates specifically to the connectivity of countries (as nodes) within physical networks. As such, while it is relatively obvious that physical infrastructure such as the ports and airports which are pivotal to trading activities need to have a high level of connectivity to domestic networks, such as domestic road and rail networks and even the electricity grid, the benefits of greater connectivity to international air and maritime networks cannot be perceived so obviously or directly. This is despite the fact that distance, as a proxy for transport costs, has long been deemed to be a critical determinant of the propensity for bilateral trade between nations (Clark, Dollar, and Micco 2004; Disdier and Head 2008).

The analysis is undertaken on the basis of the following assumptions: 1) an improvement in maritime connectivity between any two nations will facilitate an increase in the value of bilateral trade between those nations (both export and import values); 2) an increase in the aggregate value of trade for any given nation is positively related to domestic production and national output, which may also indicate that greater connectivity also spurs economic growth; 3) economic growth also affects trade.

Some previous work has analysed the impact of maritime connectivity and economic growth on trade (see, for example, Fugazza 2015; Fugazza and Hoffmann 2017; Hoffmann, Saeed, and Sødal 2019). The contributions of this study are as follows: (1) this is the first study in which the ten best connected countries (as measured by the maritime connectivity index) and their 155 trading partners are selected for the analysis; (2) this is the first study in which the relationship between different components of maritime connectivity, domestic production and trade are analysed simultaneously, in an attempt to unravel how maritime connectivity impacts trade, how this might affect domestic production which again will, in turn, have an impact on trade; (3) in terms of methodology, non-recursive models and path analysis models are applied, since they are considered the most suitable methodological tools for the analysis of complex and reciprocal relationships between variables.

The next section provides the theoretical background for the analysis, by elaborating on the specific form of maritime connectivity which will be utilised and setting this within the context of its theoretical relationship to trade and the economic growth of nations. The methodology for the analysis is described in section 3, where non-recursive models and path analysis is expounded, the models to be tested are specified and the data collection process outlined. The results of the analysis are presented in section 4, while conclusions are drawn in section 5.

2. Theoretical background

2.1. Maritime connectivity, trade and growth

The UNCTAD bilateral connectivity index (LSBCI), which is defined as a normalized average of five container transport measures (Hoffmann, Saeed, and Sødal 2019), can be viewed as an index of not only maritime connections, but also of economic connections in a broader sense. The five component measures that are melded together to comprise the LSBCI are:

(1) The minimum number of transhipments needed for shipment between two countries i and j;
(2) The total number of common direct services that countries i and j have with third countries. Consequently, this is equal to the number of options at the disposal of a shipper for transferring cargo from country i to country j with one transhipment;

(3) The geometric average of the total number of direct connections. This variable expresses the average of the two countries' position in the international shipping network;
(4) The degree of competition, as reflected by the total number of carriers that provide services on the shipping connection between the two countries; and
(5) The size, measured in TEU, of the largest vessel operating on the shipping route between the country pair.

The components (i)-(v) are likely to correlate with trade and production due to the transport costs. Low numbers of transhipments (i) or high numbers of direct connections (ii) indicate scale economies at the level of the firm, as it implies a lower number of distance-independent (fixed) transaction costs in the cost function. This reduces average costs and puts a downward pressure on prices in a competitive market for most market structures of interest. As shipping is capacity driven and characterized by quantity competition of some kind, an increased number of service providers (iv) is also likely to push prices downward from the demand side, as greater competition is associated with less mark-up pricing. Increasing the number of direct connections (iii) lowers average costs for similar reasons, but a high number of direct connections also indicates market segmentation, which is associated with gains from product variation and market heterogeneity according to the new trade theory in the tradition of Krugman (1980). This is likely to spur information spillovers and self-reinforcing accumulation of knowledge according to the new growth theory in the tradition of Romer (1986). New growth theory suggests that knowledge spillovers can increase production and growth. To the extent that mutual exchange of goods is an indirect exchange of human capital, technology and other production factors, growth and bilateral connectivity can, therefore, be expected to correlate, and self-reinforcing, dynamic growth forces can come into play.

Does trade and growth cause lower cost and connectivity or is it the other way around? A specific answer is beyond the scope of this paper, but the history of shipping is a story of decreasing transport costs that encourage some general reflections. If the initial situation is a world with an uneven distribution of supply and demand but prohibitive transport costs, decreasing the costs will, at some point, enable connectivity and trade. As a consequence, therefore, increasing connectivity or decreasing transport costs by a certain percentage at high cost levels tends to induce trade. More generally, even if the relationships above hold in theory, are they strong enough to impact the world economy significantly in the future? This study argues that a reasonable measure of maritime connectivity is indeed suited to increasing our understanding of international trade and economic growth and the linkages between trade, economic growth and shipping.

Coastlines have always been the most attractive areas for human settlement, and they continue to dominate production and trade. This is due to the location of natural resources and easy access to maritime transport. Small and Nicholls (2003) estimated that 38% of the world population live in coastal areas within 100 kms of the shore. The container revolution from the 1960s onwards increased the role of sea access even further. Container shipping is by far the major carrier of global, intra-industry trade and global trade in value terms. Intra-industry (two-way) trade, and container shipping along with it, continues to grow much faster than the world economy. The value of trade that can be transported by sea increased from 50% to more than 56% of total trade over just seven years from 2006 to 2013, and pairwise correlation between total exports and containerizable exports is about 0.93 (Fugazza and Hoffmann 2017). This indicates that knowledge, production technologies and preferences that used to be localized, are spread in steadily more integrated international markets. Didier and Pinat (2017) find that an increase in the share of trade with core countries of the global trade network is also associated with higher growth. They also find that increased growth is associated with increased trade in differentiated and high-tech-intensive goods, which can be expected to correlate with maritime connectivity, as characterized by the LSBCI.

2.2. Research hypotheses

As initially proposed in Hoffmann (2005), the original Liner Shipping Bilateral Connectivity Index (LSBCI) utilised nine component variables. However, the index has been further developed and, as proposed by Hoffmann, Van Hoogenhuizen, and Wilmsmeier (2014), it is now created from five components. The index is generated for all countries in the world in pairs, while landlocked countries were excluded. As elucidated earlier, the first component of this maritime connectivity measure is the number of required transhipments. Fugazza (2015) explains this by pointing out that with greater distance between any two trading countries, the likelihood of requiring more transhipments in order to trade with each other is greater and that this, of course, means deviating from the shortest (direct) route as a consequence of those transhipments. Fugazza and Hoffmann (2017) point out that each transhipment entails additional costs, time and risk of delays and damage. A study conducted by Wilmsmeier and Hoffmann (2008) reveals that any transhipment has the equivalent impact on shipping freight rates as an increase in the distance between any two countries of 2,612 km and, consequently, will induce higher transport costs. Fugazza (2015) provides the first attempt to show the effect of shipping connections on the import and export of containerizable products. The results of their study point to a reduction in export value varying between 20 and 25% being associated with any additional transhipment.

Further, Fugazza, Hoffmann, and Razafinombana (2013) find a negative correlation between bilateral trade and the mean number of transhipments required to connect any pair of trading countries. They also point out that this negative association also increases the incidence of zero trade flows. The negative relationship between the number of transhipments and bilateral trade is confirmed by Fugazza and Hoffmann (2017) and Hoffmann, Saeed, and Sødal (2019).

On the basis of this empirical evidence, the following hypotheses are proposed:

H1a&b: There is a negative relationship between an additional required transhipment and the export and import value of a country.

The second and third components of the UNCTAD maritime connectivity measure are the total number of countries providing a direct service and the geometric average of the total number of direct connections. In contrast to the required number of transhipments, there is held to be a positive relationship between bilateral trade and the total number of countries providing a direct service to pairs of trading partners. Thus, a smaller number of zero trade flows are experienced by trading countries with a larger number of direct connections (Fugazza, Hoffmann, and Razafinombana 2013) and when two ports are connected by a direct liner shipping service. Asturias and Petty (2012) found that where two ports were directly connected by liner shipping services, the distance variable became statistically insignificant in models of trade. As with transhipments, Fugazza (2015) also estimates the impact of direct connections on bilateral trade flows, with the results suggesting that when a direct connection is absent, export values are reduced by somewhere between 42 and 55%. Similarly, for 14 developing countries in the Pacific, Helble (2014) concludes that the presence of a direct shipping connection more than doubles the trade in goods. The analyses conducted by Fugazza and Hoffmann (2017) and Hoffmann, Saeed, and Sødal (2019) also reveal a positive relationship between the number of direct connections and bilateral trade. In addition, Fugazza and Hoffmann (2017) argue that the geometric mean of the number of direct connections is a useful indicator of each paired trade partner's access to the network. It is expected, therefore, that the geometric average of the total number of direct connections also positively affects the trade of a country. Hence, on this basis, the following hypotheses are proposed:

H2a&b: There is a positive relationship between the total number of countries providing a direct service and the export and import value of a country.

H3a&b: There is a positive association between the geometric average of direct connections and the export and import value of a country.

The fourth component of the maritime connectivity index is the degree of competition, as reflected by the total number of carriers that provide services on the shipping connection between the two countries. A higher number of service providers reflects a greater degree of competition (Wilmsmeier and Hoffmann 2008). Korinek and Sourdin (2010) argue that one of the reasons for higher transport costs to less developed countries is due to the lower level of competition on the shipping route. When facing greater competition on any shipping route, there is a tendency for shipping lines to economise on not only their costs, but also their margins on these routes (Hummels, Lugovskyy, and Skiba 2009). Ultimately, this results in lower transportation costs for shippers selecting that route (Fugazza and Hoffmann 2017). The analysis by Hoffmann, Saeed, and Sødal (2019) also confirms a positive association between the level of competition and bilateral trade. As such, the following hypotheses are proposed:

H4a&b: There is a positive association between the degree of competition and the export and import value of a country.

It is expected that costs at sea per TEU will decrease with increasing ship size (Pearson 1988). Because of this, the potential exists for reaping significant economies of scale from operating larger ships. It is widely recognized in the literature that, since 1995, the container shipping industry has once again shifted towards technological advancement and the associated importance of gaining the benefits of economies of scale in ship size (see McLellan 1997; Cullinane and Khanna 1999; Wijnolst, Scholtens, and Waals 1999). The study by Fugazza and Hoffmann (2017) indicates a positive relationship between ship size and bilateral exports. On the basis of this, the following hypotheses are proposed:

H5a&b: There is a positive association between ship size and the export and import value of a country.

In addition to the five components of maritime connectivity, the maritime distance between the two main container ports of bilateral trading partners has also been included as a potential variable of interest. It is expected that distance is negatively related to the value of bilateral trade; that is, countries trade less with partners that are farther away (Korinek and Sourdin 2010). Traditionally, sea distance is considered to be one of the crucial determinants of freight rates and thus also of transport costs and the trade competitiveness of countries (Fugazza 2015). A study by Martínez-Zarzoso (2013), for example, reveals that for exports from Germany to China in 2012, a reduction in the maritime distance of 3000 km (representing approximately a 30% decrease), brought about by using a route through the Arctic rather than the conventional route via the Suez Canal, would boost export value by 9.10 USD billion per year on average (about an 18% increase). The negative relationship between maritime distance and bilateral trade is confirmed by other empirical analyses (see for example Korinek and Sourdin 2010; Fugazza, Hoffmann, and Razafinombana 2013; Fugazza 2015; Fugazza and Hoffmann 2017; Hoffmann, Saeed, and Sødal 2019). Thus, the following hypotheses are proposed:

H6a&b: There is a negative relationship between maritime distance and the export and import value of a country.

To analyse the possible impact of trade on economic growth, the data for the gross domestic product (GDP) per capita of 155 trading partners of 10 countries in our sample has been collected. The GDP is a measure of the total production within a country and changes in its value over time reflects the economic growth of the country. The exports of sample countries which are the imports of their 155 trading partners can positively influence economic growth. For instance, Lawrence and Weinstein (2001) and Mazumdar (2001) argued that imports are the source through which foreign research and development is brought to importing countries. This is because the importation of cutting-edge technologies is normally closely associated, or even physically bundled, with the importation of related intermediate products, usually in the form of other equipment or more common technology, which provides an alternative source for a country's productivity growth. As a result, as suggested by endogenous growth models, long-run economic growth can be stimulated through the medium of imports (Grossman and Helpman 1991; Baldwin, Braconier, and Forslid 2005; Kim, Lim, and Park 2007; Awokuse 2008; Almeida and Fernandes 2008).

The underlying, assumed theoretical relationship between exports and economic growth is that, for several reasons, exports can enhance productivity and, thereby, economic growth. One reason might be that exports influence firms to learn and adopt advanced technologies in order to compete in foreign markets (Balassa 1978; Krueger 1980; Nishimizu and Robinson 1982). The firms also learn by doing, and the production and sale of export goods could enable them to emulate foreign rivals (Grossman and Helpman 1991). Furthermore, the increase in demand because of exports results in large scale production of the domestic product that reduces unit production prices, thus increasing productivity (Helpman and Krugman 1985). In addition to the above-mentioned benefits, as emphasized in new trade and growth theories, comes the traditional (neo)classical gains from trade, as exports are also a source of foreign exchange, which could be particularly critical for emerging economies that need to import capital and intermediate goods. Thus, exports can increase productivity growth via several economic channels (McKinnon 1964). On the basis of this, the following hypothesis is proposed:

H7a&b: The export value (import values of trading partners) and import value (export values of trading partners) have a positive impact on the GDP per capita of trading partners.

Theory suggests that it is not only the case that exports and imports impact economic growth, but also that economic growth has an impact on both exports and imports. In other words, a two-way relationship exists between these variables. The reverse causality from productivity growth to exports is a relatively straightforward relationship, as discussed by Kim, Lim, and Park (2007); by securing growth in its productivity levels, a nation will boost its competitiveness, in terms of both price and quality, in international markets and, as a consequence of this, the demand for its exports will rise. In the literature, empirical analysis typically supports either a one-way impact of economic growth on exports or indicates a two-way causal relationship between exports and economic growth (Awokuse 2008). The effect of economic growth on imports can be positive. For instance, an increase in productivity generates economic growth which, in turn will stimulates imports (Kim, Lim, and Park 2007). From this, the following hypotheses is proposed:

H8a&b: The GDP per capita of a trading partner has a positive effect on the export value of a country (or import values of trading partners) and on the import value of a country (or export values of trading partners).

In addition to maritime connectivity and maritime distance, gravity variables such as whether countries were formerly parts of the same country, share a common official language, have had a common colonizer after 1945 also potentially affect the bilateral trade of a country (Martínez-Zarzoso 2013; Fugazza and Hoffmann 2017). In consequence, the following hypotheses are proposed:

H9a&b: Gravity variables positively affect the export and import value of a country.

3. Methodology

3.1. Path analysis and non-recursive models

This study applies Path Analysis (PA) to test and assess the nature of the relationships between maritime connectivity, trade and economic growth. Path analysis is an extended form of multiple regression that is used to analyse the complex relationship among variables (see for example Gui et al. 2017; Kirk et al. 2019).

Since the two-way (reciprocal) relationship between export values/import values and GDP per capita is analysed, the models are non-recursive models. The non-recursive models are structural equation models (SEMs) that are bidirectional or have indirect feedback loops and are related to a larger group of path models (Finch. and French 2015; Price, Gonzalez, and Whittaker 2019). The reciprocal relationship causes the problem of endogeneity because of the endogenous regressor. To overcome the problem of endogeneity and to obtain consistent estimates, some assumptions need to be made. For instance, the exogenous variables must act as instrumental variables. In addition, the instrumental variable must have a direct and significant effect on the endogenous regressor, but should not have a direct effect on the outcome variable other than through the endogenous regressor. It should also be uncorrelated with the error term of the equation. For model identification, at least one instrumental variable must be assigned to each endogenous regressor (Paxton, Hipp, and Marquart-Pyatt 2011). However, if it is assumed that there is no covariance between two error terms, then a model can be identified by assigning the instrumental variable to only one endogenous regressor (Nagase and Kano 2017). For details about non-recursive models and their applications (see for example, Light et al. 2003; Price, Gonzalez, and Whittaker 2019).

3.2. Sample specification and data collection

For the purposes of analytical tractability, a sample of the top 10 best-connected countries according to UNCTAD (2018) was utilised as the basis for the analysis. These countries are: China, Singapore, Korea, Hong Kong, Malaysia, Netherlands, Germany, USA, Great Britain, and Belgium. Data was collected on their trading relationships with their 155 trading partners for the year 2016, yielding a total of 1550 observations as the basis for the ensuing PA. The data for the worldwide bilateral trade of 10 countries were extracted from the United Nation's website.[1] Following Hoffmann, Saeed, and Sødal (2019), only highly containerisable products were included. Data for the GDP per capita were collected from the UNCTAD website.[2] The data for the five components of the LSBCI and maritime distances were given by UNCTAD and the data for gravity variables were collected from the website of Research and Expertise on the World Economy (CEPII).[3]

The following variables are included in the models:

logexport = the natural logarithm of export values of 10 countries from their 155 trading partners

logimport = the natural logarithm of import values of 10 countries from their 155 trading partners

Position = the geometric average of the total number of direct connections

Common = the total number of countries providing a direct service to both countries i and j

Table 1. Descriptive statistics.

Variable	Mean	Standard Deviation	Minimum	Maximum	No. of observations
Position	47.669	19.030	8.717	102.401	N = 1550
Common	22.033	18.177	0	83	N = 1550
NCarriers	9.412	9.536	1	60	N = 1550
Size	5881.124	5703.128	221	19,224	N = 1550
Numtrans	0.46	0.501	0	2	N = 1550
Logdist	5691.181	3079.674	87	12,168	N = 1550
GDP per capita	14,779.76	17,951.45	92.056	99,363.36	N = 1520
Export (US$)	4,887,135	2.56e+07	3.3	5.08e+08	N = 1507
Import (US$)	4,166,646	2.51e+07	0.027	6.53e+08	N = 1458

NCarriers = the degree of competition, as reflected in the total number of carriers that provide services on the shipping connection between the two countries

Size = the size, measured in TEUs, of the largest vessel operating on the shipping route between the country pair

Numtrans = the minimum number of transhipments needed for shipment between two countries i and j

logdist = the natural logarithm of the maritime distance between 10 countries and their 155 trading partners

loggdp = the natural logarithm of the GDP per capita of 155 trading partners of the 10 countries

Smctry = whether the two countries were formerly parts of the same country (1 = same country; 0 otherwise)

Comlang = whether the two countries share a common official language (1 = common language; 0 otherwise)

Comcol = whether the two countries have had a common colonizer after 1945 (1 = common colonizer; 0 otherwise)

Table 1 provides a summary of the descriptive statistics for each of the variables for which data was collected.

4. Results

To test the nine hypotheses that are denoted as 1a and 1b through to 9a and 9b (see Table 4), the Models 1a and 1b are estimated. The correlation matrix[4] indicates a high value of correlation coefficient between the variables ‘Common’ and ‘Position’ (0.94) and also between ‘Common’ and ‘Size’ (correlation co-efficient = 0.80) which is why the variable Common is excluded from the models.[5]

4.1. Model 1a

The model 1a considers a reciprocal relationship between the export values of ten countries via maritime transportation and the GDP per capita of 155 trading partners. The components of maritime connectivity, maritime distance and gravity variables (Smctry, Comlang and Comcol) have been included as instrumental variables for the endogenous regressor (export value) because it is expected that these variables have a direct effect on trade, but do not directly affect GDP per capita, only indirectly through trade. The variable ‘the total number of carriers (NCarriers)’ might be influenced by the intensity of the trade between the two connected countries. However, the main factors that influence the selection of a particular route by a liner shipping company are the transportation costs and journey time for each route. The transportation costs include the operational costs of the vessel, such as fuel and port costs (Fagerholt 2004).

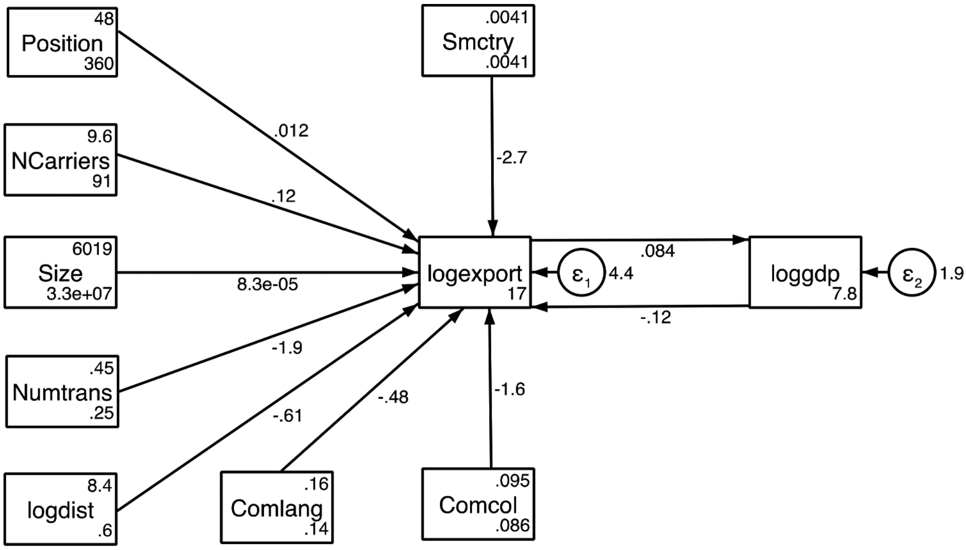

Figure 1. Representing the hypotheses and estimated values of coefficients of model 1a.

Table 2. Tests to check models' fit and validity of the instrumental variables.

Model fit statistics							
Models	Chi2	p-value	df	RMSEA	CFI	TLI	SRMR
Model 1a	11.098	0.134	7	0.020	0.997	0.993	0.010
Model 1b	8.431	0.296	7	0.012	0.999	0.997	0.009

Tests to check the validity of the instrumental variable.			
Model 1a	Chi2	df	p-value
Sargan test	11.056	7	0.136
Basmann test	11.072	7	0.135
Model 1b	Chi2	df	p-value
Sargan test	8.406	7	0.298
Basmann test	8.402	7	0.298

The estimation results are presented in Table 3 and again as a path diagram in Figure 1. The goodness-of-fit criteria are presented in Table 2. The results show insignificant chi-square statistics (χ^2 = 11.098, d.f. = 7, P = 0.134), indicating that the models have a good fit. Other fit indices also suggest that the model has an excellent fit. For instance, the root mean square error of approximation (RMSEA) is less than 0.07. The Comparative Fit Index (CFI) and the Tucker-Lewis index (TLI) are greater than 0.95, and the standardised root mean square residual (SRMR) is less than 0.05.

For over-identified models, Sargan (1958) and Basmann (1960) tests can be applied to check the validity of the instrumental variables. The results are presented in Table 2. P-values for both tests are 0.136 and 0.135, indicating that both tests give identical results that we can accept the null hypothesis that instrumental variables are valid.

4.2. Model 1b

In model 1b, the reciprocal relationship between import values via maritime transportation and GDP per capita is analysed by setting the eight exogenous variables as instrumental variables to the endogenous regressor (import values). Like the previous model, all the goodness-of-fit statistics presented in Table 2 confirm that the model has a good fit. The results of the estimated model 1b are

Table 3. Results of estimated models.

Model 1a		Model 1b	
Endogenous variable = logexport		Endogenous variable = logimport	
Exogenous variables	Co-efficients	Exogenous variables	Co-efficients
loggdp	−0.116** (0.052)	loggdp	−0.078 (0.084)
Position	0.011** (0.005)	Position	0.015** (0.007)
NCarriers	0.123*** (0.009)	NCarriers	0.167*** (0.013)
Size	0.000*** (0.000)	Size	0.000*** (0.000)
Numtrans	−1.927*** (0.156)	Numtrans	−2.195*** (0.230)
logdist	−0.605*** (0.084)	logdist	−0.225* (0.125)
Smctry	−2.696*** (0.922)	Smctry	−3.590*** (1.348)
Comlang	−0.484*** (0.158)	Comlang	−0.458* (0.235)
Comcol	−1.556*** (0.198)	Comcol	−1.832*** (0.304)
Constant	16.738*** (0.838)	Constant	10.423*** (1.270)
Endogenous variable = loggdp		Endogenous variable = loggdp	
Exogenous variable	Co-efficients	Exogenous variable	Co-efficients
logexport	0.083*** (0.014)	logimport	0.068*** (0.011)
Constant	7.834*** (0.172)	Constant	8.142*** (0.118)

****p* < 0.01, ** *p* < 0.05, * *p* < 0.10.*

Table 4. Results of hypotheses testing.

Hypotheses	Decision
H1a&b: There is a negative relationship between an additional required transshipment and the export and import value of a country.	Accepted
H2a&b: There is a positive relationship between the total number of countries providing a direct service and the export and import value of a country.	Not confirmed
H3a&b: There is a positive association between the geometric average and the export and import value of a country.	Accepted
H4a&b: There is a positive association between the degree of competition and the export and import value of a country.	Accepted
H5a&b: There is a positive association between ship size and the export and import value of a country.	Rejected
H6a&b: There is a negative relationship between the maritime distance and export and import value of a country.	Accepted
H7a&b: Gravity variables positively affect the export and import value of a country.	Rejected
H8a&b: The export via maritime transportation (imports of trading partners) and the import via maritime transportation (exports of trading partners) have a positive impact on GDP per capita of trading partners.	Accepted
H9a&b: The GDP per capita of a trading partner has a positive effect on the export value of a country (or import values of trading partners) and on the import value of a country (or export values of trading partners).	Rejected

presented in Table 3 and in the path diagram (see Figure 2). Sargan and Basmann tests also confirm that the instrumental variables are valid.

The results show that eleven out of the eighteen hypotheses are accepted (see Table 4). Out of the five components of maritime connectivity, the geometric average (Position), the number of transhipments (Numtrans) and the degree of competition (NCarriers) have significant effects on both export and import values. The results indicate that with an increase in geometric average, export value increases by 1.1 percent and import value by 1.5%. The results show that additional

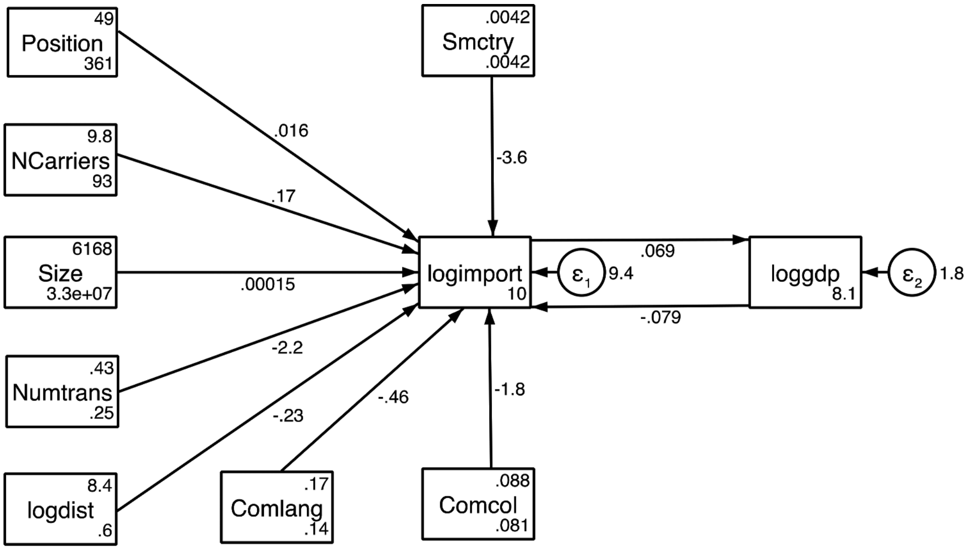

Figure 2. Representing the hypotheses and estimated values of coefficients of model 1b.

transhipment (Numtrans) reduces export value by 109% and import value by 201%. Similarly, an additional carrier increases export value by 12% and import value by 16%. The variable ship size (Size) has a significant but zero impact on both import and export values. These results are consistent with those obtained by Hoffmann, Saeed, and Sødal (2019) and suggest that diseconomies of scale have been reached in container shipping. A significantly negative effect is found to exist for the three gravity variables, which suggests that these ten countries trade less with countries that were formerly part of the same country (Smctry), share the same common official languages (Comlang) and have had a common colonizer after 1945 (Comcol).

The variable maritime distance (logdist) has a negative and significant impact on both export and import values, and this impact is in the form of elasticity. The coefficient of the variable maritime distance for Model 1a is −0.60, and for Model 1b −0.22, indicating that the export and import values of the ten countries are less elastic with respect to the maritime distance to their 155 trading partners. Similarly, the effect of export and import values on GDP per capita is also in the form of elasticity. The results show a positive and significant impact of trade (export and import values) on the GDP per capita of trading partners, but that elasticity is less than one—indicating a less elastic effect. Finally, the GDP per capita of a trading partner has a negative and significant effect on the export value of a country (or import values of trading partners). This finding supports the concept that in those circumstances where a country possesses an import-substituting industry, better productivity will displace potential imports into the domestic market and will exert a negative impact on imports (Kim, Lim, and Park 2007). GDP per capita has an insignificant impact on the import value of a country (or export values of trading partners).

Thus, a reciprocal relationship exists between the export values of ten countries (import values of trading partners) and the GDP per capita of their 155 trading partners. However, a reciprocal relationship between import values and GDP per capita does not exist.

5. Conclusions

From the perspective of an individual nation, an understanding of its maritime connectivity facilitates the formulation of policies which promote reduced transportation costs and higher service quality that, in turn, will enhance trade and national competitiveness (Jiang et al. 2015). It is important to recognise, however, that the concept of maritime connectivity should not be confused with the notion of simply providing the appropriate port and hinterland infrastructure. While this is, of course, a prerequisite for enhancing maritime connectivity, it is not a sufficient condition. As correctly pointed out by De Langen et al. (2016), the availability of scheduled maritime services, in the form of either container or ro-ro shipping, is a necessary and defining characteristic of maritime connectivity. All these aspects are implicitly recognised in the annual publication by the United Nations Conference on Trade and Development (UNCTAD) of the Liner Shipping Bilateral Connectivity Index (LSBCI), as originally formulated by Hoffmann (2005), to provide a snapshot of the differences in maritime connectivity between nations.

This work applies path analysis modelling with the objective of unravelling the nature of the complex relationships which might exist between maritime connectivity, trade and economic growth. Two specifications of path analysis models are applied, and the results of the analysis suggest that the following conclusions can be drawn:

- The GDP per capita of the trading partners has a positive and significant effect on the export value of ten countries, while it has an insignificant impact on the import value of these ten best connected countries.
- A reciprocal relationship exists between the export values of ten countries, which is the import values of their trading partners, with the GDP per capita of trading partners. However, a reciprocal relationship does not exist between the import values of ten countries, which is the export values of their trading partners, with the GDP per capita of trading partners.
- The number of transhipments required for the movement of cargoes between trading partners, the degree of competition on the maritime trade route and the geometric average of the total number of direct connections are the most important composite elements of maritime connectivity.
- The maritime distance between trading partners has a negative and significant impact on both import and export value.
- When considering the impact of gravity variables, the countries analyzed trade less with countries that were formerly part of the same country, share the same common official languages and have had a common colonizer after 1945.

Overall, these conclusions highlight the complexity of the interrelationships that exist between maritime connectivity, trade and economic growth. However, more specifically, they certainly emphasize the pivotal importance of maritime connectivity. Implicitly, therefore, this suggests that economic and trade policies at global, regional and national levels should recognize the need for, and to foster, better maritime connectivity. Obviously, this may have implications for many policy decisions, such as those relating to domestic and international transport, port infrastructure and governance and transport market regulation for instance. In all cases, however, the potential outcomes of such policy decisions can be economically evaluated by utilizing the sort of quantified relationships between fundamental variables that have been estimated within this work and which have been presented within the various path diagrams presented herein.

The main limitation of this study is that export and import models have been separately estimated. If the standard gravity model is applied, then it considers bilateral trade flows, and within the same estimation, countries could appear both as an exporter and importer. However, the non-recursive models cannot be solved by applying the gravity model. For this purpose, 'path analysis' has been used. Since path analysis does not combine the two models (export and import) like the gravity model, both models have to be estimated separately.

A further limitation of this study is that a sample of only the top ten best connected countries has been used. In future research, in order to cater for potential sample bias, a larger sample covering best, medium and low connected countries can be analysed to see the effect of maritime connectivity on economies with different levels of connectivity with the rest of the world. In addition, the impact of connectivity components can be analysed by using gravity models with the Poisson pseudo-maximum-likelihood (PPML) estimator (Santos Silva and Tenreyro 2011) in order to take advantage of the information contained in the zero trade flows, which is not considered in this study. Finally, instead of estimating a two-way relationship between bilateral trade and GDP, following Anderson, Mario, and Yotov (2018), the gravity model can be applied to investigate the effect on real GDP of changes in trade in response to reduced trade costs and the removal of borders.

Notes

1. See https://comtrade.un.org/data/accessed in October 2018.
2. See https://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx accessed in November 2018.
3. See http://www.cepii.fr/CEPII/fr/bdd_modele/presentation.asp?id=8 accessed in November 2018.
4. The results can be provided upon request.
5. After excluding the variable Common, we performed the variance inflation factor and tolerance value tests. The results confirm that multicollinearity does not exist.

Acknowledgments

The authors are grateful to two anonymous reviewers and an associate editor of Maritime Policy & Management for their productive feedback that led to improvements in the paper.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Kevin Cullinane http://orcid.org/0000-0002-4031-3453

References

Almeida, R., and A. Fernandes. 2008. "Openness and Technological Innovations in Developing Countries: Evidence from Firm-level Surveys." *The Journal of Development Studies* 44 (5): 701–727. doi:10.1080/00220380802009217.

Anderson, J. E., L. Mario, and Y. V. Yotov. 2018. "GEPPML: General Equilibrium Analysis with PPML." *The World Economy* 41: 2750–2782. doi:10.1111/twec.12664.

Asturias, J., and S. Petty. 2012. "A Model of Trade with Endogenous Transportation Costs". Accessed 20 July 2018. https://www.economicdynamics.org/meetpapers/2012/paper_1095.pdf

Awokuse, T. O. 2008. "Trade Openness and Economic Growth: Is Growth Export-led or Import-led?" *Applied Economics* 40 (2): 161–173. doi:10.1080/00036840600749490.

Balassa, B. 1978. "Exports and Economic Growth." *Journal of Development Economics* 23: 181–189. doi:10.1016/0304-3878(78)90006-8.

Baldwin, R., H. Braconier, and R. Forslid. 2005. "Multinationals, Endogenous Growth, and Technological Spillovers: Theory and Evidence." *Review of International Economics* 13 (5): 945–963. doi:10.1111/j.1467-9396.2005.00546.x.

Basmann, R. L. 1960. "On Finite Sample Distributions of Generalized Classical Linear Identifiability Test Statistics." *Journal of the American Statistical Association* 55: 650–659. doi:10.1080/01621459.1960.10483365.

Clark, X., D. Dollar, and A. Micco. 2004. "Port Efficiency, Maritime Transport Costs, and Bilateral Trade." *Journal of Development Economics* 75 (2): 417–450. doi:10.1016/j.jdeveco.2004.06.005.

Cullinane, K. P. B., and M. Khanna. 1999. "Economies of Scale in Large Containerships." *Journal of Transport Economics and Policy* 33 (2): 185–208.

De Langen, P. W., M. Udenio, J. C. Fransoo, and R. Helminen. 2016. "Port Connectivity Indices: An Application to European RoRo Shipping." *Journal of Shipping and Trade* 1 (1): 6. doi:10.1186/s41072-016-0008-0.

Didier, T., and M. Pinat. 2017. "The Nature of Trade and Growth Linkages". Policy Research Working Paper 8168, Washington: World Bank Group.

Disdier, A. C., and K. Head. 2008. "The Puzzling Persistence of the Distance Effect on Bilateral Trade." *The Review of Economics and Statistics* 90 (1): 37–48. doi:10.1162/rest.90.1.37.

Fagerholt, K. 2004. “Designing Optimal Routes in a Liner Shipping Problem.” *Maritime Policy & Management* 31 (4): 259–268. doi:10.1080/0308883042000259819.

Finch., W. H., and B. F. French. 2015. “Modeling of Non-recursive Structural Equation Models with Categorical Indicators.” *Structural Equation Modeling: A Multidisciplinary Journal* 22 (3): 416–428. doi:10.1080/10705511.2014.937380.

Frankel, J. A., and D. H. Romer. 1999. “Does Trade Cause Growth?” *American Economic Review* 89 (3): 379–399. doi:10.1257/aer.89.3.379.

Fugazza, M. 2015. “Maritime Connectivity and Trade. Policy Issues in International Trade and Commodities”. Research study series no. 70, Geneva: United Nations Conference on Trade and Development (UNCTAD).

Fugazza, M., and J. Hoffmann. 2017. “Liner Shipping Connectivity as Determinant of Trade.” *Journal of Shipping and Trade* 2 (1): 2–18. doi:10.1186/s41072-017-0019-5.

Fugazza, M., J. Hoffmann, and R. Razafinombana, 2013. “Building a Dataset for Bilateral Maritime Connectivity”. No. 61, [online], Geneva: UNCTAD Policy Issues in International Trade and Commodities. https://unctad.org/en/PublicationsLibrary/itcdtab63_en.pdf

Grossman, G., and E. Helpman. 1991. *Innovation and Growth in the Global Economy*. Cambridge: MIT Press.

Gui, S., C. Wu, Y. Qu, and L. Guo. 2017. “Path Analysis of Factors Impacting China’s CO2 Emission Intensity: Viewpoint on Energy.” *Energy Policy* 109: 650–658. doi:10.1016/j.enpol.2017.07.034.

Helble, M. 2014. “The Pacific’s Connectivity and Its Trade Implications”. ADBI Working Paper 499. Manila: Asian Development Bank.

Helpman, E., and P. Krugman. 1985. *Market Structure and Foreign Trade*. Cambridge: MIT Press.

Hoffmann, J. 2005. “Liner Shipping Connectivity.” *Geneva: UNCTAD Transport Newsletter* 27 (1): 4–12.

Hoffmann, J., N. Saeed, and S. Sødal. 2019. “Liner Shipping Bilateral Connectivity and Its Impact on South Africa’s Bilateral Trade Flows.” *Maritime Economics & Logistics*. doi:10.1057/s41278-019-00124-8.

Hoffmann, J., J.-W. Van Hoogenhuizen, and G. Wilmsmeier. 2014. “Developing an Index for Bilateral Liner Shipping Connectivity”. Proceedings of the International Association of Maritime Economists (IAME) conference, Norfolk, United States, July 1518.

Hummels, D., V. Lugovskyy, and A. Skiba. 2009. “The Trade Reducing Effects of Market Power in International Shipping.” *Journal of Development Economics* 89 (1): 84–97. doi:10.1016/j.jdeveco.2008.05.001.

Irwin, D. A., and M. Terviö. 2002. “Does Trade Raise Income?: Evidence from the Twentieth Century.” *Journal of International Economics* 58 (1): 1–18. doi:10.1016/S0022-1996(01)00164-7.

Jiang, J., L. H. Lee, E. P. Chew, and C. C. Gan. 2015. “Port Connectivity Study: An Analysis Framework from a Global Container Liner Shipping Network Perspective.” *Transportation Research Part E: Logistics and Transportation Review* 73: 47–64. doi:10.1016/j.tre.2014.10.012.

Kim, S., H. Lim, and D. Park. 2007. “Could Imports Be Beneficial for Economic Growth: Some Evidence from Republic of Korea”. Manila: Asian Development Bank, Economic and Research Department Working paper no. 103: 1–33.

Kirk, A., J. M. Meyer, M. A. Whisman, B. J. Deacon, and J. J. Arch. 2019. “Safety Behaviors, Experiential Avoidance, and Anxiety: A Path Analysis Approach.” *Journal of Anxiety Disorders* 64: 9–15. doi:10.1016/j.janxdis.2019.03.002.

Korinek, J., and P. Sourdin. 2010. “Clarifying Trade Costs: Maritime Transport and Its Effect on Agricultural Trade.” *Applied Economic Perspectives and Policy* 32 (3): 417–435. doi:10.1093/aepp/ppq007.

Krueger, A. 1980. “Trade Policy as an Input to Development.” *American Economic Review* 70 (2): 288–292.

Krugman, P. 1980. “Scale Economies, Product Differentiation, and the Pattern of Trade.” *The American Economic Review* 70 (5): 950–959.

Lawrence, R. Z., and D. E. Weinstein. 2001. “Trade and Growth: Import-led or Export-led? Evidence from Japan and Korea.” In *Rethinking the East Asian Miracle*, edited by J. E. Stiglitz and S. Yusuf, 379–408. New York: Oxford University Press and the World Bank.

Light, J. M., J. W. Grube, P. A. Madden, and J. Gover. 2003. “Adolescent Use and Suicidal Ideation: A Nonrecursive Model.” *Addictive Behaviors* 28: 705–724. doi:10.1016/S0306-4603(01)00270-2.

Martínez-Zarzoso, I. 2013. “Alternative Sea Routes: What Effects on Maritime Trade?” *SAIS Review* XXXIII (2): 61–74.

Mazumdar, J. 2001. “Imported Machinery and Growth in LDCs.” *Journal of Development Economics* 65: 209–224. doi:10.1016/S0304-3878(01)00134-1.

McKinnon, R. 1964. “Foreign Exchange Constraint in Economic Development and Efficient Aid Allocation.” *Economic Journal* 74: 388–409. doi:10.2307/2228486.

McLellan, R. G. 1997. “Bigger Vessels: How Big Is Too Big?” *Maritime Policy & Management* 24 (2): 193–211. doi:10.1080/03088839700000070.

Nagase, M., and Y. Kano. 2017. “Identifiability of Nonrecursive Structural Equation Models.” *Statistics and Probability Letters* 122: 109–117. doi:10.1016/j.spl.2016.11.010.

Nishimizu, M., and S. Robinson. 1982. “Trade Polices and Productivity Change in Semi-Industrialized Countries.” *Journal of Development Economics* 16: 177–206. doi:10.1016/0304-3878(84)90106-8.

Paxton, P. M., J. R. Hipp, and S. Marquart-Pyatt. 2011. *Nonrecursive Models: Endogeneity, Reciprocal Relationships, and Feedback Loops*. Newbury Park: Sage.
Pearson, R. 1988. *Container Ships and Shipping*. London: Fairplay Publications.
Price, L. R., D. P. Gonzalez, and T. A. Whittaker. 2019. "Performance of Nonrecursive Latent Variable Model under Misspecification." *Structural Equation Modeling: A Multidisciplinary Journal* 26 (1): 12–23. doi:10.1080/10705511.2018.1463164.
Romer, P. M. 1986. "Increasing Returns and Long-run Growth." *Journal of Political Economy* 94 (5): 1002–1037. doi:10.1086/261420.
Santos Silva, J. M. C., and S. Tenreyro. 2011. "Further Simulation Evidence on the Performance of the Poisson Pseudo-maximum Likelihood Estimator." *Economics Letters* 112 (2): 220–222. doi:10.1016/j.econlet.2011.05.008.
Sargan, J. D. 1958. "The Estimation of Economic Relationships Using Instrumental Variables." *Econometrica* 26: 393–415. doi:10.2307/1907619.
Small, C., and R. J. Nicholls. 2003. "A Global Analysis of Human Settlements in Coastal Zones." *Journal of Coastal Research* 19 (3): 584–599.
UNCTAD. 2018. *Review of Maritime Transport 2018*. Geneva: United Nations Conference on Trade and Development.
Wijnolst, N., M. Scholtens, and F. Waals. 1999. *Malacca-max: The Ultimate Container Carrier*. Delft: Delft University Press.
Wilmsmeier, G., and J. Hoffmann. 2008. "Liner Shipping Connectivity and Port Infrastructure as Determinants of Freight Rates in the Caribbean." *Maritime Economics & Logistics* 10 (1–2): 130–151. doi:10.1057/palgrave.mel.9100195.