The effect of shipping connectivity on seaborne containerised export flows

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Abstract:

Transport connectivity has increasing importance in the global economy. Using a gravity equation model, this paper investigates the effect of liner shipping connectivity on seaborne containerised exports. We use a dataset from the European Comext database that includes information about the transport mode and use of containers for trade flows between EU and non-EU countries. Measuring the dependent variable with the required accuracy and addressing the potential reverse causality between trade flows and shipping connectivity, we document a positive effect of liner shipping connectivity on seaborne containerised exports and a negative effect on seaborne non-containerised ones. The results of this paper support the policy recommendations of international institutions in terms of incentivizing liner shipping connectivity.

Keywords: Liner shipping connectivity, seaborne containerised trade, gravity equation, reverse causality.

1. Introduction

Goods in global markets are mainly transported by sea. According to the United Nations Conference on Trade and Development (UNCTAD), seaborne trade accounts for over 80% of the volume of international trade, and up to two thirds of its value (UNCTAD, 2016). Container shipping has a growing role in this seaborne traffic. Although the era of containerization began in the late 1950s (e.g. Stopford, 2009, Bernhofen et al., 2016; Rodrigue, 2020), containerised trade has multiplied sevenfold over the past three decades, fuelling growth in seaborne trade (UNCTAD, 2020).

As long as container shipping continues to grow in importance in maritime trade, access to liner shipping will become ever more crucial for countries' ability to participate in the global economy. To study coastal countries' positions within the global liner shipping network, the UNCTAD developed a synthetic indicator, the Liner Shipping Connectivity index (LSCI), using information about the world container shipping fleet (UNCTAD, 2017). More recently, the UNCTAD also developed a bilateral version of the LSCI, the Liner Shipping Bilateral Connectivity Index (LSBCI) (Fugazza and Hoffmann, 2016), an indicator of the bilateral connectivity of a coastal country with every other coastal country. The influence of the LSBCI on trade flows has been investigated by Fugazza and Hoffmann (2017) and Hoffmann et al. (2020), for example. As expected, these authors found that bilateral liner shipping connectivity impacts positively on trade flows.

The effect of bilateral liner shipping connectivity on seaborne trade is also explored in this paper. We add to previous literature by offering three potential empirical contributions. First, we take advantage of Eurostat's Comext database in order to take on one of the main challenges encountered in maritime literature, namely the proper measurement of the dependent variable. Second, we extend the analysis by examining the effects of bilateral liner shipping connectivity on different types of trade flows. And third, we estimate a theory-consistent gravity equation using the latest econometric methods found in the literature, thus enabling us to address the reverse causality between liner shipping connectivity and trade flows.

A recurring complaint in the literature relates to the absence of key information about trade flows such as the mode of transport in official statistics (e.g. Martínez-Zarzoso and Nowak-Lehmann, 2007; Guerrero et al., 2016; Fugazza and Hoffmann, 2017). This lack of information has led researchers in the maritime transport field to use several proxies for seaborne trade flows, such as total trade, trade in manufactured goods (e.g. Fugazza and Hoffmann, 2017; Martí and Puertas, 2017) or a specific list of 'highly containerisable' manufactured goods (e.g. Bernhofen et al., 2016; Guerrero et al., 2016; Hoffmann et al., 2020). In all these cases, the mode of transport is simply overlooked. In contrast, we do not have to proxy seaborne containerised flows. For the trade flows between EU and non-EU Rest-of-the-World (ROW) countries, Eurostat's Comext database offers information with two key details: the transport mode and the container mode (i.e. whether the cargo is containerised or not). According to Comext data for the study period 2013-18, 51% of the value of EU countries' trade with ROW countries was transported by sea. What's more, about 42% of this seaborne trade was containerised cargo, the rest (58%) being non-containerised cargo. We are thus able to accurately measure our dependent variable, seaborne containerised trade flows between EU and ROW countries. This is a key issue when analysing the effect of the LSBCI, since this index is generated from reported deployment of the container shipping fleet. In addition, we can compare our benchmark results with other results using different definitions of the dependent variable encountered in the literature, such as total manufactured trade flows. Furthermore, we can also look into the effect of liner shipping connectivity on seaborne non-containerised export flows, a link not yet explored in the literature. Here we found our most striking finding, namely the negative relationship between LSBCI and seaborne non-containerised export flows. The bottom line of our results is that the measurement of the dependent variable may have a crucial importance.

Reverse causality concerns are a key issue when studying the effects of transportation channels on trade (Baier et al., 2018). In our study case, better liner shipping connectivity may have a positive effect on seaborne containerised trade flows but is nonetheless actually the result of an already strong trade relationship. In the words of UNCTAD, "the liner shipping connectivity index is an indicator of the deployment of the world's container ship fleet. It is highly correlated with a country's port traffic. If there is more demand for the shipping of containerized cargo, liner companies will deploy more and larger ships, to achieve a higher level of total fleet deployment" (UNCTAD, 2020, p. 88). Previous studies (Fugazza and Hoffmann, 2017; Hoffmann et al., 2020) assume that liner shipping connectivity is exogenous. Our results show that reverse causality is indeed an issue that needs to be addressed.

We arrive at a properly measured and econometrically sound estimate of the positive effect of liner shipping connectivity on seaborne containerised export flows.

Our results suggest that an improvement in liner shipping connectivity increases containerised flows in seaborne trade[1]. Additionally, our novel results concerning the negative relationship between liner shipping connectivity and seaborne non-containerised trade flows suggest that non-containerised shipping would become less important when a country becomes better integrated into the global liner shipping network. Overall, these results support the policy recommendations of several international institutions, namely the UNCTAD, the World Trade Organization (WTO) and the Organisation for Economic Co-operation and Development (OECD),regarding promoting liner shipping connectivity (OECD/WTO, 2017; UNCTAD, 2017).

The remainder of the paper is organised as follows: Section 2 reviews the literature, Section 3 presents the empirical strategy and the data used for the analysis, Section 4 presents and discusses the main results while the main conclusions and policy implications are presented in Section 5.

2. Literature Review

According to the literature on international trade, there are many reasons for trade between countries. Traditional theories place emphasis on differences between countries in technology and factor endowments, while modern theories emphasize the importance of economies of scale and monopolistic competition. However, most theories of international trade also consider the key role that impediments to trade play in shaping global trade flows. Broadly defined, trade costs refer to all those factors related to the degree of separation between countries (Anderson and van Wincoop, 2004; Arvis et al., 2013a), including transport costs (e.g. freight cost), policy barriers (tariffs), geographical barriers (distance) and so on. The study of trade costs and their effects on trade volumes has dominated the empirical literature on international trade, in great part due to the success of the gravity equation for analysing determinants of bilateral trade flows (e.g. Head and Mayer, 2014). The empirical analysis of trade costs has been also very common in the maritime literature.

However, a common problem in the literature is that reliable data on trade costs are difficult to obtain (Wilmsmeier and Martínez-Zarzoso, 2010; Tarasov and Felbermayr, 2014). If available, trade costs data are specific to a location, type of

[1] It is important to highlight that this article refers to the use of containers as a mode of shipping regardless of the specific type of cargo carried. Containers are used to carry a wide variety of cargo, including manufactured goods, commodities, chemical products etc. For a detailed discussion, see Rodrigue (2020).

commodity and other specific conditions (Martínez-Zarzoso and Nowak-Lehmann, 2007). For this reason, researchers have favoured the use of indirect measures for trade costs (Gervais, 2019). In general, factors considered important in influencing trade costs include, among others, transport cost, port infrastructure, liner shipping connectivity, sea distance, informational costs and policy barriers. For instance, Anderson and van Wincoop (2004) concluded that transport costs are equivalent to an average *ad valorem* tax of 21%. Limao and Venables (2001) pointed out that a country's geography and infrastructure are decisive for trade flows. In the case of maritime trade, (Clark et al., 2004) found port efficiency to be an important determinant of maritime transport costs. These studies opened up new lines of empirical research into the importance of infrastructure and transport cost in determining trade and access to international markets.

Some studies employ sea distance between countries as a proxy for transport costs. Bottasso et al. (2018), analysing Brazil's international trade flows, concluded that port endowment and distance, among other origin and destination related variables, are important in increasing trade flows. Artuc et al. (2014) found that the varying export performance of different Croatian counties could be explained by their proximity to border gates, ports, and other county-specific characteristics. However, according to Fugazza et al. (2013), distance can be a poor proxy for transport cost in seaborne trade when liner shipping services are considered[2]. These authors pointed out that sea distance (i.e. distance between countries' main ports) may not accurately reflect the incidence of transport cost when port connections require transhipments.

With the rise of the containerisation process, which affected the organisational and physical connectivity of the transport system, the quality of service in maritime transport became even more crucial (Hoffmann et al., 2014). Martínez-Zarzoso and Nowak-Lehmann (2007) found that transport conditions and quality of service are the main determinants of maritime trade cost. Bernhofen et al. (2016) discussed the role that the use of containers played in increasing world trade in the period between 1962 and 1990. They argued that containerisation was even more decisive in boosting trade flows than trade liberalisation. Indeed, container use fomented greater variety of cargoes across locations (Ducruet et al., 2015). The possibility of loads from different companies being transported in the same container and the expansion of the global shipping line network

[2]Liner shipping services are regular shipping services provided by a port to reach another point via a route. The service can be direct, even when the ship calls at other ports when in transit, or with transhipments (Fugazza et al., 2013).

have made it more economically viable for more actors of all sizes to participate in international trade. At the same time, due to the so-called hub ports, almost all countries in the world today are connected (Fugazza and Hoffmann, 2017).

Thus, a very important point emerges: what is of greater importance is not the distance between two points itself, but rather the liner shipping services between them. Good connectivity, that is, regular liner shipping services provided by a satisfactory number of competitors, leads to lower shipping costs and is therefore decisive in shaping trade patterns. Wilmsmeier et al. (2006) pointed out that connectivity leads to transport cost reductions because of increased competition between carriers and economies of scale. Wilmsmeier and Martínez-Zarzoso (2010) considered connectivity to be a determinant factor in maritime transport costs for intra-Latin American trade. They measured connectivity using several variables such as number of services, number of deployed vessels, shipping opportunities and average ship size. The more central the node is in the shipping network, the lower the transport costs. Wilmsmeier and Hoffmann (2008) concluded that each transhipment is equivalent to an increase in distance of 2,612 km between two countries. Guerrero et al. (2016) came to the conclusion that distance and frequency of containerised shipping services are critical for bilateral trade between countries. Lun and Hoffmann (2016) found that, when a new trade agreement such as the Association of Southeast Asian Nations (ASEAN) is signed, connectivity between partners improves and boosts intra and extra-regional trade. Saeed et al. (2021) and Michail et al. (2021) related maritime connectivity with trade and economic growth. Xu et al. (2020) proposed two indices to measure the integration of countries in the global liner shipping network and related the indices with the countries' participation in world trade. Finally, Lin et al. (2020) used a spatial lag model to analyse the spatial link between merchandise trade and maritime connectivity.

The importance of transport infrastructures, transport connectivity and institutional determinants has led to the development of synthetic indicators aimed at proxying the influence of these trade drivers. Two international institutions, the World Bank and the UNCTAD, are responsible for two of the most noteworthy indicators, the Logistic Performance Index (LPI) and the Liner Shipping Connectivity index (LSCI). The World Bank's LPI has been reporting every two years since 2007 and proxies logistics infrastructure, logistics services and cross-border trade facilitation (Arvis et al., 2018). The UNCTAD developed the LSCI in 2004 to study coastal countries' positions in the global liner shipping network, using information about the world container shipping fleet (UNCTAD, 2017). Over the years, several studies have investigated the usefulness of these synthetic indices when analysing the effects of trade costs on trade flows. Arvis et al. (2013b) found that the combined effect of the LSCI and LPI plays a greater role in determining trade cost than distance. Fugazza et al. (2013) pointed out that the LSCI and LPI are positively correlated. Behar et al. (2013) came to the conclusion that boosting logistics, measured by a bilateral index based on the LPI, is equivalent to a 14% reduction in distance. Bensassi et al. (2015) found that regional logistics (measured by the LPI) and infrastructure are important factors in determining trade flows for Spanish foreign and domestic trade. Martí and Puertas (2017) also found that increases in logistical infrastructure, proxied by the LPI and each of its components, improve the export competitiveness and trade of emerging economies. Hoffmann et al. (2014) proposed the LSBCI, a bilateral index for connectivity that measures the liner shipping distance between two countries within the global maritime network, widening the country-level concept of the LSCI. Analysing container flows, Fugazza and Hoffmann (2017) found that the LSBCI, port infrastructure endowment and liner shipping freight rates are significantly correlated and suggested using bilateral measures for the estimation of trade frictions as their absence can cause an overestimation of the distance effect. Applied to South Africa, Hoffmann et al. (2020) also analysed the positive impact of liner shipping connectivity, represented by the LSBCI, on trade flows. They went further and found that direct connections exert a significant and positive impact on trade flows, while more transhipments have a somewhat negative influence.

3. Methodology

3.1. Empirical strategy

Our empirical work builds on the gravity equation, the empirical workhorse of international trade comprehensively reviewed in Head and Mayer (2014), Yotov et al. (2016), and Baier et al. (2018), the latter being especially related to transportation economics. We start with the following general specification:

$$X_{ijt} = exp[\beta' W_{ijt} + \gamma LSBCI_{ijt}] + \vartheta_{ijt} \qquad (1)$$

where X_{ijt}denotes seaborne containerised exports from country *i* to country *j* in year *t*, measured in nominal values. Our main goal is to estimate γ, the coefficient for the Liner Shipping Bilateral Connectivity Index ($LSBCI_{ijt}$), our variable of interest. W_{ijt} is a vector of gravity covariates that can contain a wide array of regressors used in the literature, including regressors that change in the *i-t* or *j-t* dimensions, such as country populations and GDP, regressors that change in the *i-j* and *t* dimensions such as trade policy variables, and regressors that change across *i-j* but not *t*, i.e., time-invariant bilateral determinants of trade flows, such as distance. Finally, ϑ_{ijt} is an error term.

Several recommendations and best practices have emerged from the latest advances in gravity literature. The regressors enter (1) exponentially to estimate the gravity equation using the Poisson Pseudo Maximum Likelihood (PPML) estimator. Following Santos Silva and Tenreyro (2006), the PPML estimator is robust to different patterns of heteroscedasticity and provides a convenient way of dealing with zero bilateral trade flows. For these reasons, the PPML estimator can be considered the benchmark estimator of gravity equations. Moreover, it is well known from a theoretical point of view that robust estimation of the gravity equation has to deal with multilateral resistance terms (Anderson and Wincoop, 2003), since their omission may result in biased coefficient estimates. The multilateral resistance terms can be accounted for by exporter-time and importer-time fixed effects (Olivero and Yotov, 2012). The inclusion of these fixed effects will absorb any regressor that varies in the *i-t* or *j-t* dimensions, such as country GDP. This fact has important implications for maritime transport analysis. Proper specification of the gravity equation with exporter-time and importer-time fixed effects precludes the identification of the effects of country-level indicators such as the UNCTAD'S LSCI or the World Bank's LPI, as used in a number of studies. However, the inclusion of this set of fixed effects does not prevent the identification of the effect of our variable of interest, $LSBCI_{ijt}$, while a potential source of bias is eliminated.

With these considerations in mind, our first gravity model to be estimated is specified as follows:

$$X_{ijt} = exp[\delta_{it} + \varphi_{jt} + \beta_1 lnDistance_{ij} + \beta_2 Contiguity_{ij} + \beta_3 Language_{ij} + \beta_4 Colony_{ij} + \gamma LSBCI_{ijt}] + \vartheta_{ijt} \quad (2)$$

where δ_{it} and φ_{jt} respectively are exporter-year and importer-year fixed effects; $lnDistance_{ij}$ is the log of distance between countries i and j; $Contiguity_{ij}$ takes the value of 1 if countries *i* and *j* share a border; $Language_{ij}$ takes the value of 1 if countries *I* and *j* share a common language; $Colony_{ij}$ takes the value of 1 if countries *i* and *j* have colonial ties; and our variable of interest $LSBCI_{ijt}$ is the Liner Shipping Bilateral Connectivity Index between countries *i* and *j* in year *t*.

All right-hand variables in (2) must be exogenous, and the gravity controls included in (2) can be treated as exogenous. However, concerns about endogeneity may arise in the case of our variable of interest $LSBCI_{ijt}$, an indicator that is intended to reflect maritime connectivity. Baier et al. (2018, p. 47) warn that "reverse causality concerns would apply to transportation channels, which are built to facilitate trade but are often in response to an already strong and demanding existing trade relationship". These concerns about reverse causality are also mentioned in Fugazza and Hoffmann (2017). Maritime connectivity may influence export flows, but export flows could also influence maritime connectivity. To treat the endogeneity of any regressor in the gravity equation, Baier and Bergstrand (2007) advocate the inclusion of country-pair fixed effects. Furthermore, Agnosteva et al. (2014) and Egger and Nigai (2015) argue that country-pair fixed effects will control for any other time-invariant bilateral trade costs. In the current context, country-pair fixed effects will control for all observable and unobservable time-invariant bilateral factors that simultaneously influence liner shipping connectivity and trade flows. For instance, distance between countries, sharing a common border or an idiosyncratic bilateral relationship due to colonial ties may be simultaneously influencing $LSBCI_{ijt}$ and X_{ijt}, but there can also be other time-invariant bilateral factors that are not observable by the researcher. All these factors are likely correlated with $LSBCI_{ijt}$ and so can be best controlled for using country-pair fixed effects. The downside of including these fixed effects is that all the time-invariant gravity covariates are absorbed by the country-pair fixed effects and therefore cannot be identified.

With these additional considerations in mind, our baseline gravity model is as follows:

$$X_{ijt} = exp[\delta_{it} + \varphi_{jt} + \pi_{ij} + \gamma LSBCI_{ijt}] + \vartheta_{ijt} \quad (3)$$

where π_{ij} are country-pair fixed effects. We are especially interested in comparing the PPML coefficient estimates for $LSBCI_{ijt}$ in models (2) and (3). In principle, the presence of reverse causality between trade flows and $LSBCI_{ijt}$ would lead to an upwardly biased estimation of the impact of maritime connectivity (Baier et al., 2018). Comparing these estimations may lead to the conclusion that reverse causality is an issue to be addressed in maritime connectivity studies.

3.2. Data

We now discuss the data used for our estimations. We take advantage of the EU international trade data provided by Eurostat's Comext database. Comext offers data on trade flows for every reporting EU country with its respective partners in diverse data collections and formats and with different levels of detail (see Eurostat, 2020). For the objectives of this paper, we are especially interested in the 'Transport_NSTR' dataset that collects data on trade flows between EU and third-party countries (i.e., extra-EU trade), provided according to the NSTR (Nomenclature uniforme des marchandises pour les Statistiques de Transport, Révisée) product classification. More importantly, this dataset contains information on whether the goods are containerised and which transport mode is used. Thus, we can measure with the required accuracy our dependent variable, seaborne containerised trade flows between EU and Rest-of-the-World (ROW) countries. The required information on transport and container modes is available for the 23 EU coastal countries from 2013 onwards, so the sample period is 2013-2018. EU partner countries with rather sporadic data are excluded[3], and the sample comprises 23 EU coastal countries and 132 ROW countries. Table A1 in Appendix A lists the countries in the sample.

Some basic figures from the Comext database illustrate the importance of seaborne transport and the use of containers in this mode of transport. In value terms, 51.01% of EU countries' trade with third countries in 2013-2018 was transported by sea, but in volume terms the share is considerable larger, accounting for 78.3% of total volume handled in the same period. These figures are in line with UNCTAD (2016) and

[3]The Republic of Palau, with zero export flows to the EU, and the Northern Mariana Islands, with one export flow, have been dropped from the sample because these countries are excluded in some regressions (see also footnote 5). The results do not change if these countries are kept in the sample (results available upon request from the authors).

Rodrigue (2020), showing a somewhat less significant role for seaborne transport in EU external trade. Regarding the use of containers in seaborne trade, containerised cargo represented 41.53% of the value of EU trade by sea, but only 15.24% in volume terms.

These figures for EU countries trade point to the importance of having data that allow proper measurement of the dependent variable. Moreover, an important contribution of our paper is that we can experiment with different measures of the dependent variable. The absence of information regarding the use of containers or even about the transport mode in widely used databases, such as the United Nations' Commodity Trade Statistics Database (COMTRADE), has led researchers in maritime transport to use several proxies for containerised seaborne trade. Total trade or trade in manufactured goods is the most frequently used solution (e.g. Fugazza and Hoffmann, 2017 or Martí and Puertas, 2017), and sometimes a specific list of 'highly containerisable' manufactured goods is used instead (e.g. Bernhofen et al., 2016; Guerrero et al., 2016 or Hoffmann et al., 2020). Thus, it is very interesting to use the value of manufactured goods exports for X_{ijt} in equations (2) and (3) and compare the estimation results. The NSTR product classification relates to the EU Statistical Classification of Economic Activities (NACE), so we can measure the volume of total manufactured trade flows without discriminating by transport and container modes (as is usual in previous literature). In addition, our data also allow us to use another option for X_{ijt}. We can measure the seaborne non-containerised trade flows between EU and ROW coastal countries, making it interesting to test the effects of the LSBCI on these non-containerised seaborne trade flows. To the best of our knowledge, this link has yet to be explored in the literature.

LSBCI data were retrieved from the UNCTADstat (2021) platform. This bilateral indicator, available since 2006, can be considered an extension of the UNCTAD's already existing country-level LSCI[4]. The LSBCI is computed at the country-pair level using information about the number of transhipments between a pair of countries, the number of direct connections of both countries, the number of direct connections common to both countries, the level of competition in services that connect the pair of countries and the size of the largest ships on the weakest route connecting both countries

[4]In 2004, the UNCTAD began to collect and systematise information at the country level in order to create the LSCI. The index was proposed in order to be able to measure the level of connectivity of coastal countries with maritime transport services for container cargo (UNCTAD, 2017). For a complete description of the components, see Hoffmann (2012).

as a proxy of port infrastructure and economies of scale (Fugazza and Hoffmann, 2016). Finally, data on gravity variables were obtained from the CEPII gravity dataset (see Head et al., 2010). LSBCI and CEPII data are complete for the 23 EU and 132 ROW countries in the sample period (2013-2018). Table A2 in Appendix A shows the descriptive statistics for the variables used in the estimations.

Results

Prior to discussing the results, several comments regarding the empirical estimations are in order. We perform the PPML estimation procedure, including zero trade flows (e.g., 24.2% of observations of the benchmark dependent variable)[5]. Our sample comprises export flows between 23 EU coastal countries and 132 ROW coastal countries for the 2013-2018 period, so the maximum number of observations is 36,432 (23x132x2x6). We will see that the number of included observations differs across estimations due to the presence of 'singleton' groups, i.e., fixed effect groups with only one observation[6]. Regarding statistical inference, recent papers (Egger and Tarlea, 2015; Larch et al., 2019) emphasise the importance of accounting for multi-way clustering of errors in panel-data gravity models. Multi-way clustering along the lines of Cameron et al. (2011) usually leads to a more conservative inference. We follow this advice, and all standard errors are three-way, clustered by exporter, importer and year.

Using the data described in Section 3.2., we estimated the parameters of gravity equations (2) and (3) using PPML. Table 1 provides the estimates of both equations with our benchmark dependent variable (seaborne containerised exports) and the two alternative dependent variables (manufactured exports and seaborne non-containerised exports). We first comment on the results of estimating gravity Equation (2), i.e., without country-pair fixed effects, which is provided in columns (1) – (3). The coefficient estimates on the gravity controls mostly have the expected sign. Distance has a powerful and statistically significant negative effect on trade, whereas cultural and colonial ties appear to be important drivers of trade flows. The effect of a common language is not

[5]The regression results shown in this section do no change if the observations are restricted to non-zero trade flows (results available upon request from the authors).
[6]Singleton groups are common in regressions with multiple levels of fixed effects and should be dropped to avoid underestimating the standard errors (Correia, 2015).

precisely estimated for seaborne non-containerised exports. The effect of sharing a common border is positive and statistically significant for manufactured exports, but negative for seaborne containerised and non-containerised exports, and not statistically significant in the latter case. We relate this unexpected result with the sample under study, comprising deep-sea trade flows between EU and ROW countries. Turning to the variable of interest, all LSBCI estimates in columns (1) – (3) are positive, statistically significant and significant in magnitude, although the estimate is smaller and marginally significant (at a level of 10%) for seaborne containerised exports. These results suggest that an increase in the LSBCI would have a positive effect on trade flows between EU and ROW coastal countries. This effect is more significant for manufactured exports, and even more so for seaborne non-containerised exports.

Table 1 - Estimation of Parameters

	(1) Benchmark (Container)	*(2) Manufactures*	*(3) No container*	*(4) Benchmark (Container)*	*(5) Manufactures*	*(6) No container*
$\boldsymbol{lnDistance_{ij}}$	*-1.417*** (0.301)*	*-1.782*** (0.161)*	*-1.969*** (0.176)*			
$\boldsymbol{Contiguity_{ij}}$	*-1.016*** (0.337)*	*0.449** (0.181)*	*-0.267 (0.345)*			
$\boldsymbol{Language_{ij}}$	*0.472*** (0.114)*	*0.392*** (0.070)*	*0.226 (0.166)*			
$\boldsymbol{Colony_{ij}}$	*0.364** (0.158)*	*0.509*** (0.144)*	*0.667*** (0.140)*			
$\boldsymbol{LSBCI_{ijt}}$	*1.285* (0.732)*	*2.070*** (0.557)*	*2.730*** (0.915)*	*0.501** (0.222)*	*0.218 (0.230)*	*-0.717** (0.357)*
$\boldsymbol{\delta_{it}}$	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
$\boldsymbol{\varphi_{jt}}$	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
$\boldsymbol{\pi_{ij}}$	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*
Observations	*36,317*	*36,363*	*36,139*	*31,655*	*34,131*	*30,603*
Pseudo-R^2	*0.969*	*0.958*	*0.921*	*0.998*	*0.996*	*0.989*

Three-way standard errors clustered by exporter, importer and year in parentheses.
Level of significance: *10%, **5%, ***1%.

However, the coefficient estimates shown in columns (1) – (3) of Table 1 may be biased due to the potential endogeneity of right-hand variables. Columns (4) – (6) provide the results of estimating Equation (3), i.e., the gravity model with country-pair fixed effects. Time-invariant gravity covariates cannot be identified with this configuration. The inclusion of country-pair fixed effects has a notable effect on the results. The estimates on the LSBCI decrease in magnitude, in line with the suspected reverse causality and its potential upward-biasing effects. With our benchmark dependent variable, seaborne containerised exports, the LSBCI coefficient estimate measures 0.501, but becomes statistically significant at the level of 5%. The estimated effect of the LSBCI on manufactured exports is much smaller and loses statistical significance. This result makes sense since the effect of the LSBCI on seaborne containerised trade flows is more imprecisely estimated if the dependent variable is proxied by manufactured trade. Finally, we found an unexpected result: the coefficient estimate for the effects of the LSBCI on seaborne non-containerised exports is negative and statistically significant (at 5% level). To the best of our knowledge, this is a new result in the literature. Before discussing this finding in more detail, we focus on the interpretation of the coefficient estimates of columns (4) and (6).

The coefficient estimate for $LSBCI_{ijt}$ can be interpreted as a semi-elasticity, the usual interpretation of the effect of continuous regressors in exponential models such as (3), our baseline gravity model. The LSBCI takes values between 0 and 1, so an increase of 0.1 in $LSBCI_{ijt}$ would lead to a predicted increase of 5% in seaborne containerised trade or a predicted decrease of 7.1% in seaborne non-containerised trade. Given the sample variation of $LSBCI_{ijt}$ (see Table A2 in Appendix A), this interpretation makes sense for cross-section (country pair) comparison. $LSBCI_{ijt}$ ranges from 0.006 (the bilateral liner shipping connectivity between Bulgaria and Paraguay in 2014) to 0.729 (Belgium and China in 2016), with a mean of 0,259 and a standard deviation of 0.114. The *within* country-pair variation, however, is lower than the *between* variation. The mean variation of $LSBCI_{ijt}$ within country pairs is 0.019, so an increase of 0.1 in the LSBCI for a particular country pair is not the most realistic scenario, especially for the country pairs with worse liner shipping connectivity. For this reason, the analysis of the regression results for our baseline gravity model can be refined by reporting the elasticity of seaborne trade with respect to $LSBCI_{ijt}$, measured in our exponential gravity model with $\gamma \times LSBCI_{ijt}$. Table 2 shows the estimates for the elasticity of containerised and non-containerised seaborne trade flows with respect to $LSBCI_{ijt}$ for different values of $LSBCI_{ijt}$.

Table 2. Estimates of the elasticity of seaborne trade with respect to the LSBCI

	(1) ***Containerised trade flows***	***(2)*** ***Non-containerised trade flows***
$\boldsymbol{LSBCI_{ijt}}$ **= 0.1**	*0.050*** *(0.022)*	*-0.0717*** *(0.037)*
$\boldsymbol{LSBCI_{ijt}}$ **= 0.3**	*0.150*** *(0.066)*	*-0.215*** *(0.107)*
$\boldsymbol{LSBCI_{ijt}}$ **= 0.6**	*0.301*** *(0.133)*	*-0.430*** *(0.214)*

Three-way standard errors clustered by exporter, importer and year in parentheses.

Level of significance: **5%.

The estimates of Table 2 show that the larger the value of $LSBCI_{ijt}$, the larger the value of the elasticity. For instance, for a country pair with a low level in the LSBCI ($LSBCI_{ijt}$ = 0.1), a 10% increase in the LSBCI would lead to a predicted increase of 0.5% in seaborne containerised trade and also a predicted decrease of 0.7% in non-containerised trade. These effects appear to be modest but would be induced by an increase of one hundredth in the index. For a country pair with a high level of liner shipping connectivity, such as $LSBCI_{ijt}$ = 0.6, a 10% increase in the LSBCI (an increase of 0.06 in the index) would lead to a predicted increase of 3% in seaborne containerised trade and a predicted decrease of 4.3% in non-containerised trade.

With this negative relationship between the LSBCI and seaborne non-containerised exports we venture into previously unchartered waters. A possible explanation can be outlined. The results would indicate that both shipping options are affected when liner shipping connectivity improves, suggesting a substitution effect between containerised and non-containerised shipping in seaborne trade. It appears that, at least to some extent, the exporters and the importers of a country substitute non-containerised for containerised shipping when liner shipping connectivity improves. Thus, the negative effect of the LSBCI on non-containerised seaborne trade flows can be seen as a photographic negative of the effect of the LSBCI on containerised flows. This is an interesting finding that needs further investigation.

The bottom line of this analysis is methodological: the measurement of the dependent variable is an important issue. Our results show that it is important to differentiate between modes of transport, as Fugazza and Hoffmann (2017) recognise, but knowing the container mode is also crucial. After controlling for reverse causality, the effect of the LSBCI on seaborne containerised exports is positive but negative on non-containerised ones. Consequently, these results may help to explain why the estimated effect of the LSBCI on manufactured exports is smaller and insignificant. Without information about transport and container modes, manufactured trade flows include non-containerised flows, so this mismeasurement of the dependent variable may cause a downward bias in the estimates.

Finally, our results show that reverse causality is a potential problem that needs to be addressed. Better liner shipping connectivity may have a positive effect on export flows but also reflect the existence of a previously intense trade relationship. The inclusion of country-pair fixed effects, along the lines of Baier and Bergstrand (2007), appears to be an econometric method appropriate for accounting for reverse causality issues. To confirm this, we perform the test of strict exogeneity suggested by Wooldridge (2010, chap. 10) in the context of panel data models. To perform this test, we add the future level of LSBCI, $LSBCI_{ijt+1}$, to Equations (2) and (3). Under strict exogeneity, $LSBCI_{ijt+1}$should be uncorrelated with X_{ijt}, i.e., the parameter associated with the variable $LSBCI_{ijt+1}$ should be statistically insignificant. We repeat the regressions of Table 1, including the future level of the LSBCI. The results are shown in Table 3. As can be seen, the coefficient estimates of$LSBCI_{ijt+1}$are not statistically significant with the gravity equation that includes country-pair fixed effects [columns (4) – (6)]. We are especially interested in the results for our benchmark dependent variable, seaborne containerised exports, which show that $LSBCI_{ijt+1}$ is not statistically different from zero. This is a formal test that rejects reverse causation. Turning to the results with no country-pair fixed effects shown in columns (1) – (3) of Table 3, coefficient estimates of $LSBCI_{ijt+1}$ are larger, becoming statistically significant in the case of manufactured exports. These results confirm the suspicion that reverse causality may be present in the gravity model without country-pair fixed effects.

Table 3 - Estimation of Parameters, including the Future Level of LSBCI

	(1) Benchmark (Container)	*(2) Manufactures*	*(3) No container*	*(4) Benchmark (Container)*	*(5) Manufactures*	*(6) No container*
$\boldsymbol{lnDistance_{ij}}$	*-1.395*** (0.294)*	*-1.783*** (0.158)*	*-1.936*** (0.178)*			
$\boldsymbol{Contiguity_{ij}}$	*-0.979*** (0.341)*	*0.421** (0.185)*	*-0.301 (0.344)*			
$\boldsymbol{Language_{ij}}$	*0.472*** (0.118)*	*0.395*** (0.069)*	*0.211 (0.176)*			
$\boldsymbol{Colony_{ij}}$	*0.379** (0.161)*	*0.515*** (0.140)*	*0.672*** (0.146)*			
$\boldsymbol{LSBCI_{ijt}}$	*0.362 (1.104)*	*1.107*** (0.297)*	*0.104 (2.392)*	*0.395** (0.201)*	*0.317 (0.249)*	*-0.634 (0.411)*
$\boldsymbol{LSBCI_{ijt+1}}$	*1.040 (1.077)*	*1.129*** (0.324)*	*2.927 (2.163)*	*0.065 (0.117)*	*0.113 (0.118)*	*-0.302 (0.411)*
$\boldsymbol{\delta_{it}}$	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
$\boldsymbol{\varphi_{jt}}$	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
$\boldsymbol{\pi_{ij}}$	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*
Observations	*30,291*	*30,314*	*30,090*	*25,975*	*28,089*	*25,086*
Pseudo-R^2	*0.968*	*0.958*	*0.921*	*0.998*	*0.996*	*0.989*

Three-way standard errors clustered by exporter, importer and year in parentheses.
Level of significance: *10%, **5%, ***1%.

Our results are in line with the estimates of Fugazza and Hoffmann (2017) and Hoffmann et al. (2020), in the sense that the LSBCI may have a positive effect on (containerised) trade flows. However, there are differences between these papers in terms of econometric strategy, leading to differences in estimated effects. Fugazza and Hoffmann (2017) analyse the effect of the LSBCI on manufactured trade flows with a gravity model, using both Ordinary Least Squares (OLS) and PPML estimators. Their OLS coefficient estimate for the LSBCI equals 3.123. Using our previous reasoning for this semi-elasticity, an increase of 0.1 in the LSBCI would increase trade flows by 31%. Based on our results, this effect would be significantly overestimated. The OLS estimator leads to inconsistent estimates(Santos Silva and Tenreyro, 2006). Moreover, reverse causality is not addressed in Fugazza and Hoffmann (2017). Their PPML coefficient estimate for the LSBCI is 0.029. In this case, we think that this result underestimates the impact of the LSBCI on trade flows. Neither country-year nor country-pair fixed effects are included in their specification. Furthermore, our results concerning the mismeasurement of the dependent variable may help to explain their fragile PPML estimate. Hoffmann et al. (2020) adopt a pure statistical approach to analysing the short and long-term impact of the LSBCI on South Africa’s trade flows. The authors assume that the bilateral liner shipping connectivity of South Africa is exogenous. The estimated effect of the LSBCI on trade flows ranges between 2.44% and 16.67%. Although our results are not directly comparable, reverse causality issues would suggest overestimation, whereas mismeasurement of the dependent variable would lead to underestimation.

We are highly confident about our estimated effect of the LSBCI on seaborne containerised trade flows. According to our benchmark results, an increase of 0.1 in the LSBCI would increase seaborne containerised exports by 5%. We reach this conclusion after a PPML estimation of a theory-consistent gravity equation, addressing the reverse causality of the LSBCI. In addition, our conservative inferences are based on three-way clustered standard errors. Furthermore, our dependent variable is finely measured, and we believe that this constitutes an important novelty in the literature and may guide future work in this area.

5. Conclusions and Policy Implications

Trade opportunities are crucial for a country’s participation in the world economy. Since the majority of world trade is transported by sea, it is natural to be curious about the importance of maritime transport connectivity. Does better liner shipping connectivity increase trade between countries? The main purpose of this paper was to provide convincing empirical evidence about the effect of liner shipping connectivity on trade. This research question poses two main challenges, both related to how liner shipping connectivity is measured.

As in previous studies, we take advantage of the UNCTAD's Liner Shipping Bilateral Connectivity Index (LSBCI). This index is generated from information about the world's container shipping fleet, which in turn has two methodological implications. First, the effect of the LSBCI on trade should ideally be analysed using data on seaborne containerised trade flows. Second, the simultaneity between the reported deployment of container ships and actual containerised trade flows raises concerns about reverse causality that may lead to biased estimates. These methodological implications have not been addressed in previous studies.

Using Eurostat's Comext data, we estimated a gravity equation in order to assess the effect of liner shipping connectivity on seaborne containerised trade flows between EU and Rest-of-the-World countries. Our contributions can be summarised as follows: First, using a proper measurement of the dependent variable and controlling for the reverse causality between the LSBCI and trade flows, we find convincing empirical evidence for a positive effect of the LSBCI on containerised trade flows. An increase of approximately one standard deviation in the LSBCI raises the level of exports by 5%. Second, we take advantage of Eurostat's Comext database and are able to measure the dependent variable with the required accuracy. Thus, the results above refer to the precise relationship coveted in the literature: the effect of the LSBCI on seaborne containerised flows. Third, we also looked at the effect of liner shipping connectivity on other types of trade flows. We found the first empirical evidence for a negative effect of the LSBCI on seaborne non-containerised exports: the higher the liner shipping connectivity, the lower the volume of seaborne non-containerised exports, and vice versa. This novel evidence, which can be seen as a photographic negative of the effect of the LSBCI on containerised flows, also has a clear methodological implication. Our results show that using other generic measures of the dependent variable encountered in the literature, such as manufactured trade flows, may dilute the effect. We believe that this finding opens new avenues for research. And third, we verified that reverse causality is a key issue that has to be addressed. Liner shipping connectivity may boost trade, but liner shipping connectivity is usually the reflection of an already strong trade relationship. Using simple and well-known econometric techniques, the results suggest that reverse causality may lead to an overestimation of the effect of the LSBCI on trade. Our case study of liner shipping connectivity constitutes an illustrative example of how reverse causality can be addressed when analysing the effects of trade drivers.

The main findings of this paper have clear policy implications. Our estimate of the effect of the LSBCI on seaborne trade supports policy recommendations regarding liner shipping connectivity raised by some of the main international institutions (OECD/WTO, 2017; UNCTAD, 2017). Some of the key determinants of shipping connectivity such as geographical position and port throughput are difficult for national-level policymakers to change, but a number of determinants offer policy lines on which to work. The policy lines suggested by the UNCTAD include the promotion of linkages between national, regional and international shipping services to improve cabotage markets, the coordination of port investment in countries of the same region, investment in seaports and intermodal infrastructure to expand hinterlands, implementation of trade facilitation reforms and the facilitation of transit and cross-border trade (UNCTAD, 2017). The WTO and OECD highlight the benefits of becoming transhipment centres, although this is not a realistic objective for every country (OECD/WTO, 2017). These institutions insist on the importance of expanding the hinterlands, investing in modern seaports with intermodal infrastructure and encouraging competitive trade logistics markets in gateway countries.

Our novel evidence about the negative effect of the LSBCI on seaborne non-containerised trade reinforces these policy recommendations by demonstrating that the effect of better liner shipping connectivity may be more greater than it seemed. It appears that there is some kind of substitution effect between containerised and non-containerised trade flows when liner shipping connectivity improves. Thus, remote and/or less-developed countries may be suffering from poor liner shipping connectivity restricting their trade opportunities, a potential obstacle to their industrial and economic development which must be addressed. However, for small, remote island countries it is difficult to improve their liner shipping connectivity (UNCTAD, 2020). Again, attracting transhipment services may constitute a way of improving the connectivity of their own importers and exporters.

Finally, the UNCTAD also recommends that further research should be carried out into shipping connectivity (UNCTAD, 2017). We hope that this paper has contributed to fulfilling this recommendation and thus improving how the effects of liner shipping connectivity are estimated. That is a first step to establishing, overseeing and evaluating policy initiatives.

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APPENDIX A

TABLE A1 – List of countries

Albania	Gabon	Norway
Algeria	Gambia	Oman
Angola	Georgia	Pakistan
Antigua and Barbuda	Germany	Panama
Argentina	Ghana	Papua New Guinea
Aruba	Gibraltar	Paraguay
Australia	Greece	Peru
Bahamas	Grenada	Philippines
Bahrain	Guatemala	Poland
Bangladesh	Guinea	Portugal
Barbados	Guinea-Bissau	Qatar
Belgium	Guyana	Romania
Belize	Haiti	Russian Federation
Benin	Honduras	Saint Kitts and Nevis
Bermuda	Iceland	Saint Lucia
Brazil	India	Saint Vincent and the Grenadines
British Virgin Islands	Indonesia	Samoa
Brunei Darussalam	Iran (Islamic Republic of)	Sao Tome and Principe
Bulgaria	Iraq	Saudi Arabia
Cabo Verde	Ireland	Senegal
Cambodia	Israel	Seychelles
Cameroon	Italy	Sierra Leone
Canada	Jamaica	Singapore
Cayman Islands	Japan	Slovenia
Chile	Jordan	Solomon Islands
China	Kenya	Somalia
China, Hong Kong SAR	Korea, Republic of	South Africa
China, Taiwan Province of	Kuwait	Spain
Colombia	Latvia	Sri Lanka
Comoros	Lebanon	Sudan
Congo	Liberia	Suriname
Cook Islands	Libya	Sweden
Costa Rica	Lithuania	Syrian Arab Republic
Croatia	Madagascar	Thailand
Cuba	Malaysia	Timor-Leste
Cyprus	Maldives	Togo
Côte d'Ivoire	Malta	Tonga
Dem. Rep. of the Congo	Marshall Islands	Trinidad and Tobago
Denmark	Mauritania	Tunisia
Djibouti	Mauritius	Turkey
Dominica	Mexico	Ukraine
Dominican Republic	Micronesia (Federated States of)	United Arab Emirates
Ecuador	Morocco	United Kingdom
Egypt	Mozambique	United Republic of Tanzania
El Salvador	Myanmar	United States of America
Equatorial Guinea	Namibia	Uruguay
Estonia	Netherlands	Vanuatu
Faroe Islands	New Caledonia	Venezuela (Bolivarian Rep. of)
Fiji	New Zealand	Viet Nam

Finland	Nicaragua	Wallis and Futuna Islands
France	Nigeria	Yemen
French Polynesia	Norfolk Island	

TABLE A2 – Descriptive statistics

Variable	Variation	Mean	Std. Dev.	Min	Max	Obs.
X_{ijt} (Container) (€)	overall	1.16E+08	9.03E+08	0	3.73E+10	N = 36432
	between		8.92E+08	0	3.48E+10	n = 6072
	within		1.41E+08	-8.37E+09	8.59E+09	T = 6
X_{ijt}(Manufactures) (€)	overall	1.71E+08	1.09E+09	0	3.36E+10	N = 36432
	between		1.09E+09	0	3.00E+10	n = 6072
	within		1.19E+08	-4.77E+09	4.90E+09	T = 6
X_{ijt} (No container) (€)	overall	1.61E+08	1.06E+09	0	4.83E+10	N = 36432
	between		1.02E+09	0	4.33E+10	n = 6072
	within		2.82E+08	-2.23E+10	2.29E+10	T = 6
$lnDistance_{ij}$	overall	8.786186	0.6269637	5.511348	9.880192	N = 36432
	between		0.6270067	5.511348	9.880192	n = 6072
	within		0	8.786186	8.786186	T = 6
$Contiguity_{ij}$	overall	0.0042819	0.0652973	0	1	N = 36432
	between		0.0653017	0	1	n = 6072
	within		0	0.0042819	0.0042819	T = 6
$Language_{ij}$	overall	0.0767457	0.2661912	0	1	N = 36432
	between		0.2662095	0	1	n = 6072
	within		0	0.0767457	0.0767457	T = 6
$Colony_{ij}$	overall	0.0283267	0.1659069	0	1	N = 36432
	between		0.1659183	0	1	n = 6072
	within		0	0.0283267	0.0283267	T = 6
$LCBCI_{ijt}$	overall	0.2597119	0.1148389	0.0068	0.7296	N = 36432
	between		0.1132335	0.0304	0.7078333	n = 6072
	within		0.0191808	0.1402786	0.4001452	T = 6

Sources: Comext, CEPII, UNCTADstat (2021).