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IMPACT OF MARITIME CONNECTIVITY ON CHINA'S EXPORTS OF MANUFACTURED GOODS

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Abstract: Owning the best maritime liner shipping connectivity has allowed China to become a major center for global value chains in manufactured goods, most of which are exported by sea worldwide. Using the nonlinear Poisson Pseudo-Maximum Likelihood estimator, a gravity model of exports augmented with maritime connectivity is applied to panel data for China and its 149 coastal import partners from 2006 to 2020. The results indicate that shipping connectivity has increased China's manufactured goods exports directly by improving efficiency, and indirectly by offsetting the negative effect of distance and reinforcing the positive impacts of common borders and free trade agreements. These findings underscore the essential role of maritime connectivity for developing countries pursuing export-driven growth models.

JEL classification codes: F14, F68, O53

Keywords: China, liner bilateral shipping connectivity, exports of manufactured goods

INTRODUCTION

Maritime trade between coastal countries is connected through regular container shipping services networks (Ducruet, 2020) indispensable for a country to export, especially within global value chains in which fragmented intermediate

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manufactured products are transported via sea several times across different countries before arriving at their final destination. The recent intensive use of modern containerized cargo has quickly increased seaborne trade, accounting for a dominant part of total trade (Bernhofen *et al.*, 2013; Hoffmann *et al.*, 2017). Rodrigue (2020) estimated that this part was as high as 90% in volume and 73% in value in 2008. We estimated that the share of seaborne trade in metric tons reported by UNCTAD[21] relative to world trade in volume from HS92 BACI CEPII[4] varied from 70% to 80% from 2006 to 2020. UNCTAD (2023) reported that more than 80% of the volume and 70% of the value of international trade in goods is carried by sea; with a higher share for most developing countries suggesting that maritime transport is more important for them than developed countries.

The shipping connectivity measures a country's capacity to join the networks, and impacts its international seaborne export competitiveness (Hoffmann *et al.*, 2017). It may influence seaborne exports directly by improving the efficiency and the quality of shipping service, or indirectly by reducing distance constraints and enhancing market access, thus lowering shipping time and decreasing export costs (Anderson and Wincoop, 2003; Saeed and Cullinane, 2023).

The empirical studies on the export impact of maritime connectivity have emerged following the UNCTAD's publication on the liner shipping connectivity index at an aggregate level (LSCI) published since 2004, and at a bilateral level (LSBCI) since 2006. The first measures each coastal country's position within regular container shipping service networks, while the second captures the bilateral connectivity between coastal countries. Most studies have found positive effects of liner shipping connectivity on exports. Lin *et al.* (2020) showed significant direct and spillover positive effects of LSCI on exports. Fugazza and Hoffmann (2017) found positive impacts of LSBCI on bilateral exports of containerizable goods for 138 coastal countries from 2006 to 2013. Hoffmann *et al.* (2020) identified significant positive effects of LSBCI on South Africa's exports. Del Rosal (2024a, b) found positive effects of maritime connectivity on agricultural trade from 2006 to 2019, and the effects are more pronounced in long-distance and interregional flows. On the contrary, Del Rosal and Moura (2022) did find statistically significant impacts of liner shipping connectivity on manufactured exports of EU countries to the rest of the world. The contrasted results suggest that the trade impact of connectivity may depend on the economic level of the studied countries.

One interesting question is, therefore, what impact maritime connectivity has exerted on China's exports of manufactured goods since developing efficient seaports to support its export-led growth strategy has been the priority of the Chinese government since the "open door" policies launched at the end of 1978, and particularly since its adhesion into the WTO in 2001. Surprisingly, few studies, to our knowledge, have estimated this impact, even though China has the best regular container shipping connectivity in the world, with its share in global container port throughput increasing from 26% in 2011 to 30% in 2021. The existing literature has largely focused on the export impact of the "Belt and Road Initiative" adopted by China in 2013 (Ramasamy *et al.*, 2019; Dunford *et al.*, 2020. Foo *et al.*, 2020; Haralambides *et al.*, 2020; Saeed *et al.*, 2021; Sharma, 2021). While China has been included in previous studies using multi-country panel data, its inclusion may overestimate the world average impact of LSBCI on exports. China is an outlier; the effects of its maritime connectivity on exports should be analyzed separately (Del Rosal and Moura, 2022).

This paper aims to fill this gap by examining the multiple, direct and indirect, impacts of maritime connectivity on China's exports of manufactured goods, which accounted for 97% of its total exports in 2021, most passed by sea. Maritime connectivity may increase exports directly by enhancing efficiency (Clark *et al.*, 2004; Tovar *et al.* 2022) and improving quality in global liner shipping services to avoid congested ports and inefficient logistics, thus reducing time-related costs and keeping international maritime exports competitiveness (Martínez-Zarzoso, 2007; Dappe *et al.*, 2017). The cost of delayed shipping could outweigh traditional tariffs, particularly for high-value goods (Hummels, 2007). Maritime connectivity may improve market access and facilitate integration into global supply chains, in which the timely movement of intermediate goods is crucial to meet the demands of parts and components (Xu *et al.*, 2020). It may indirectly facilitate exports by reducing the constraints imposed by distance through technological innovations in logistics and transport, thereby decreasing international shipping costs and times (Martínez-Zarzoso and Nowak-Lehmann, 2007; Guerrero *et al.*, 2016; Bommarito, 2022; Del Rosal, 2024c). This distance-reducing effect could mitigate the negative impact of distance on exports, as reported by Wilmsmeier and Hoffmann (2008) and Wilmsmeier and Martinez-Zarzoso (2010) on intra-Caribbean and intra-Latin American trade respectively. Liner shipping connectivity may finally influence exports by impacting the importance of free trade agreements, shared borders, and common languages.

Ideally, the impact of UNCTAD's liner shipping connectivity would be estimated on containerized seaborne exports. However, such data are challenging to obtain even today. UNCTAD compiles seaborne trade data from various sources for global aggregates and regional groups starting in 1970 but does not provide these data at an individual or bilateral level. The historical evolution of seaborne trade flows is calculated as a product of vessel counts and tonnage capacity using data from Lloyd's List Maritime Intelligence Unit (Yrjö, 2014; Kosowska-Stamirowska, 2020). However, this method may overestimate seaborne trade, because the calculation used maximum tonnage capacity instead of tonnage effectively transported, and Lloyd's statistics do not cover all seaborne trade. Recent advanced studies in Automatic Identification System-based vessel traffic data estimate real-time trade activity for crude oil exports (Adland *et al.*, 2017), Malta (Arslanalp *et al.*, 2019), Japan, and the Eurozone (Cerdeiro *et al.*, 2020). Eurostat's Comext database publishes the statistics between EU and non-EU countries according to the transport mode. UN Comtrade uses AIS-based nowcasts in the experimental phase to estimate global trade by transport modes and to identify the nature of goods transported.

China does not publish bilateral seaborne export data. However, with three of the world's five best-connected ports (Shanghai, Ningbo, and Qingdao) and a substantial share of global container export volume since the 1990s, it is reasonable to assume that most of China's manufactured goods are transported via sea. This assumption is more pertinent than previous studies using multi-trade countries panel data (Bernhofen *et al.*, 2016; Guerrero *et al.*, 2016; Fugazza and Hoffmann, 2017; Martí and Puertas, 2017; Hoffmann *et al.*, 2020, etc.).

This study proposes a manufactured export model augmented with LSBCI, applied to panel data including China and its coastal trading partners from 2006 to 2020. The nonlinear Poisson pseudo maximum likelihood (PPML) estimator is used. It has the advantage of allowing for zero bilateral trade flows and is robust to heteroscedasticity to avoid biased estimations. China-year fixed effects are included to control for unobservable time variant aggregate trade costs faced by China. China-importer pair fixed effects are applied to address the reverse causality between liner shipping connectivity and exports of manufactured goods; China's good maritime connectivity likely facilitates trade cost optimization and exports, while its strong export growth could pressure improving connectivity.

The results indicate that China's LSBCI increased the exports of manufactured goods. The estimated coefficient is 2.07 once including fixed effects. It is notably smaller than those in traditional gravity models (4.86) and structural models with or without China-year fixed effects (3.88 or 3.32 respectively). The observed difference suggests the importance of controlling Chinese resistance terms with China-year fixed effects and endogeneity of shipping connectivity with China-importer fixed effects. The results show that maritime connectivity has offset the negative effects of distance on exports, mitigated the positive effects of a common language, and reinforced the positive impact of shared borders and free trade agreements on exports.

The rest of this study is organized as follows. The second section presents the statistical relationship between maritime connectivity and exports of manufactured goods in China. The third section proposes a gravity model of bilateral exports augmented with maritime connectivity. The obtained results are presented in the fourth section. The economic and political implications are given in the conclusion.

2. STATISTICAL RELATIONSHIP ANALYSIS BETWEEN CHINA'S MARITIME CONNECTIVITY AND EXPORTS

China's position in global maritime connectivity is exceptional. Since its "open door" policy launched at the end of 1978, the Chinese government has prioritized developing efficient seaports to support its export-led growth strategy.

This policy has enabled China to become a central hub port in global sea exports, handling a substantial volume of its seaborne exports, particularly containerized manufactured goods everywhere. The goods loaded at its main ports increased by an average of 11% per year. They accounted for a significant share of global maritime exports in manufactured goods, contributing to over 30% of world manufacturing output, most of which is exported via sea

(UNCTAD, 2023). China quickly became one of the most important GVC centers in the world.

China is undoubtedly the world's best-connected economy. Figure 1 illustrates the evolution of the Liner Shipping Connectivity Index (LSCI) for the world's top five economies since its inception by the UNCTAD. According to the index, China has maintained the strongest connection to the global liner shipping network since 2006, the first year UNCTAD published the index. China's LSCI rose from 102.78 in 2006 to 163.56 in 2023, with an average annual growth rate of 2.29% (Q1 2006=100). The Republic of Korea ranked fourth in 2006 and moved to second in 2023, its LSCI rising from 60.28 to 89.21 at an average growth rate of 1.75%. Although Singapore was the second-best connected economy in 2006, its LSCI increased only slightly from 74.48 to 82.87 by 2023, with an average growth rate of 0.30%, and was overtaken by Korea in 2022. The gap between China's LSCI and the other top five economies has widened (Figure 1).

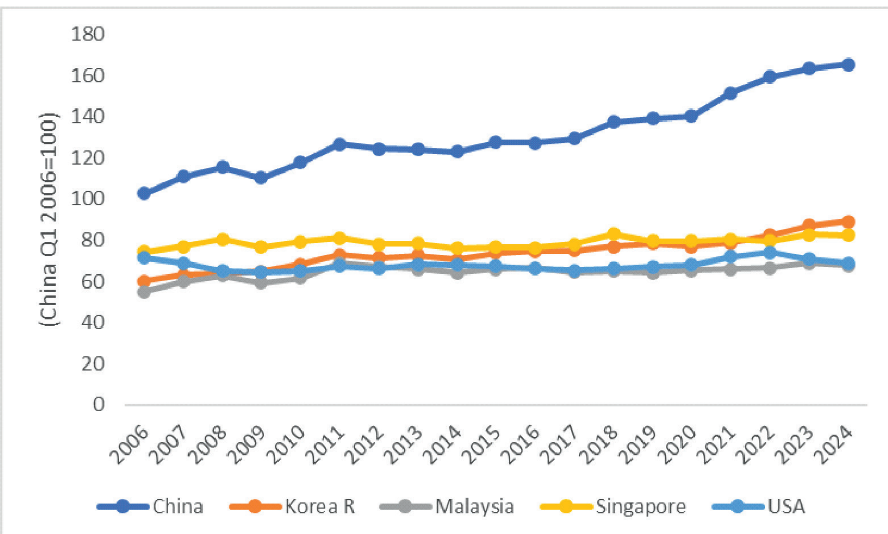

Figure 1: Evolution of liner shipping connectivity index, top five economies

Note: Annual LSCI is calculated as an average of four quarters with China Q1 2006=100

Source: UNCTAD Data Center

Figure 2 shows that Japan, the Republic of Korea, Malaysia, Singapore, the United States, and China's Hong Kong SAR were the top six economies most closely connected to China from 2006 to 2020. Except for the USA, all others are in the Asia region. Japan and the Republic of Korea have competed for the first rank. Japan ranked first from 2006 to 2010, 2014, and 2020, and was overtaken by Korea for the rest of the period. China's shipping connectivity with Korea has improved over the period. Hong Kong dropped from second in 2006 to sixth in 2020, likely due to the significant growth of the nearby modern Zhengsheng port. Malaysia moved up two spots to become the third-best connected economy with China in 2020, probably thanks to a free trade area with ASEAN launched in 2001. The United States was ranked the last one except for 2020 when it was classified fifth before Hong Kong.

Over the studied period, China improved its bilateral connectivity with 129 countries in 2020 relative to 2006 but deteriorated with 20 countries. China improved its shipping connectivity to developing countries. Its bilateral connectivity increased greater than 0.2 in LBSCI with three developing countries (Morocco, Portugal, and Vietnam), and between 0.1 to 0.2 in LBSCI with eight countries, five of which are developing countries (Iraq, Portugal, Oman, Republic of Korea, Malaysia, Qatar, Sri Lanka, and the USA). Conversely, China's connectivity decreased with 20 countries, with the worst being -0.095 with Yemen.

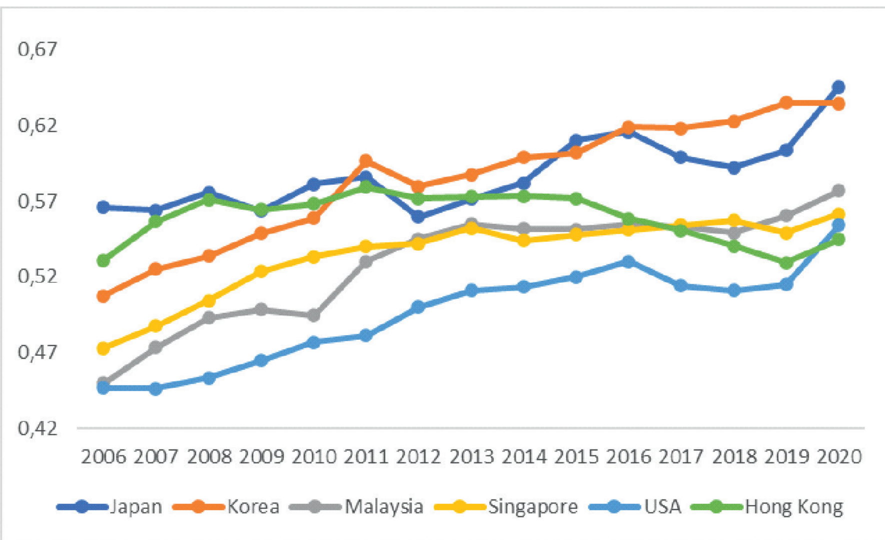

Figure 2: China's bilateral liner shipping connectivity with its top six economies

Source: UNCTAD data center

Finally, figure 3 illustrates a positive statistical correlation between China's shipping connectivity and exports of manufactured goods from 2006 to 2020, both at the aggregate and bilateral levels. This suggests that China's highly connected and efficient ports have enabled it to export manufactured goods globally. However, this correlation may be biased due to omitted variables that could influence trade. This omission problem is addressed in the following section by allowing non-positive values of exports, controlling for country-specific factors and China-importers pair fixed effects with the PPML estimator in estimating a gravity model augmented with shipping connectivity.

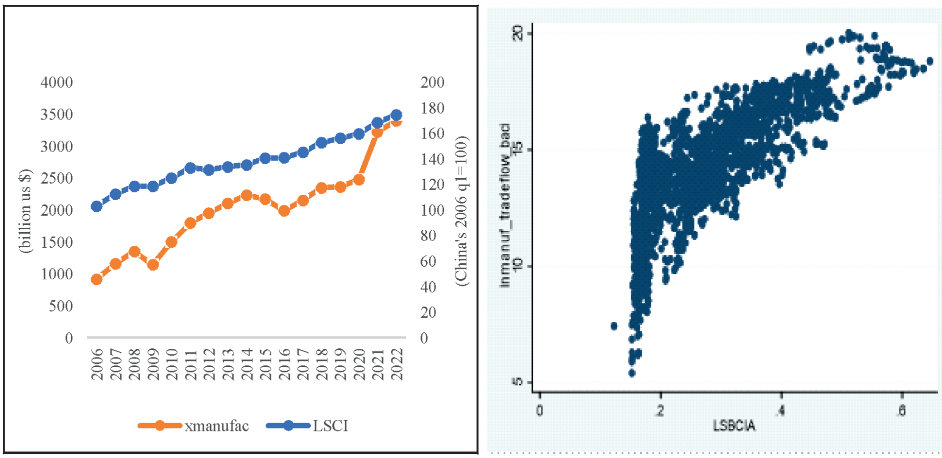

Figure 3: The statistical relationship between maritime connectivity and exports of manufactured goods in China over the 2006-2020 period

Source: CEPII and UNCTAD

3. A GRAVITY MODEL OF EXPORTS AUGMENTED WITH MARITIME CONNECTIVITY

The gravity model has been widely applied in studies on international trade (Capoani, 2023 for a review). Its specifications and estimation methods have drastically changed (Herman, 2023). According to the traditional gravity model (Tinbergen, 1962), China's bilateral exports to a destination country j in a given year t are supposed to increase with the economic sizes of China (Y_{ct}) and its import partners (Y_{jt}) but decrease with the geographical distance between China and its partner (D_{cj}), such as:

$$X_{cjt} = \frac{Y_{ct}Y_{jt}}{D_{cj}}$$

This intuitive model is traditionally estimated in logarithms and generally obtains good results. However, this estimation method has two potential problems, which may lead to biased estimates. First, since only positive export values can be calculated in logarithms, any zero value of China's exports to its import partners is overlooked. Secondly, estimating logged export values may encounter heteroscedasticity, as large export flows tend to exhibit greater variance of errors, which may be correlated with the dependent variable.

To address these problems, Santos Silva and Tenreyro (2006) proposed a nonlinear Poisson Pseudo Maximum Likelihood (PPML) estimator which allows zero export values in the dependent variable and is moreover robust to heteroscedasticity issues. Thus, instead of estimating the model in logarithmic form, we write the traditional gravity model in exponential form as suggested by the above authors as follows:

$$X_{cjt} = \exp[a_1 \ln Y_{ct} + a_2 \ln Y_{jt} + a_3 \ln D_{cj} + \varepsilon_{cjt}] \tag{1}$$

Where X_{cjt} represents exports from China to country j in year t, lnY_{ct}, and lnY_{jt} are the GDPs of China and its destination countries in logarithms respectively in year t, and lnD_{cj} is the bilateral distance between China and country *j* in logarithms. The coefficients α_1 and α_2 capture the elasticity of exports relative to the GDP of China and its import partners, respectively, and are expected to be positive; that of α_3 captures the elasticity of exports to distance and is waited to be negative.

The gravity model is also used to study the impact of shipping connectivity on trade in transportation economics (Baier *et al.*, 2018). Literature suggests that improved shipping connectivity can increase the efficiency and quality of global shipping line networks, reduce distance constraints, and decrease shipping time, and transportation costs, thereby facilitating trade (Anderson & Wincoop, 2003; Guerrero *et al.*, 2016; Borchert and Yotov, 2017; Del Rosal, 2024c). To capture these effects, the Liner Shipping Bilateral Connectivity Index (LSBCI) is added to the above equation as in Fugazza and Hoffmann (2017) and Del Rosal (2022), giving us:

$$X_{cjt} = \exp[a_1 \ln Y_{ct} + a_2 \ln Y_{jt} + a_3 \ln D_{cj} + a_4 LSBCI_{cjt} + \varepsilon_{cjt}] \tag{2}$$

Where $LSBCI_{cjt}$ represents the liner Shipping Bilateral Connectivity Index between China and country j in year t. Its coefficient a_4 is a semi-elasticity and is expected to be positive. The coefficient of $\ln D_{cj}$ in equation 2 including $LSBCI_{cjt}$ is expected to be smaller than that in the previous equation 1 if there is a reduced distance cost effect of connectivity on exports.

The inconvenient of above equations is the absence of a theoretical basis and the potential omission of variables leading to biased estimates. To remedy this, Anderson (1979) and Anderson and van Wincoop (2003) provided theoretical foundations for the intuitive gravity model, incorporating preferences with constant elasticity of substitution and differentiation of goods by origin and destination countries to take into account the interactions and interdependences between trading countries and with the rest of the world. Following their theory, we write the structural gravity model by the following system.

$$X_{cjt} = \frac{Y_{ct} Y_{jt}}{Y_{wt}} \left(\frac{\tau_{cj} \tau_{cjt} \tau_{jt}}{\Pi_{ct} P_{jt}} \right)^{1-\sigma} \tag{a}$$

$$\prod\nolimits_{ct}^{1-\sigma} \sum_{j} \left(\frac{\tau_{cj} \tau_{cjt} \tau_{jt}}{P_{jt}} \right)^{1-\sigma} \frac{Y_{jt}}{Y_{wt}} \tag{b}$$

$$P_{jt}^{1-\sigma} = \left(\frac{\tau_{cj} \tau_{cjt} \tau_{jt}}{\Pi_{ct}} \right)^{1-\sigma} \frac{Y_{ct}}{Y_{wt}} \tag{c}$$

Equation (a) corresponds to the gravity model. It supposes that the bilateral exports from China to its importer j in year t are in function of economic sizes of China (Y_{ct}) and its import partners (Y_{jt}), relative to world output (Y_{wt}), and multiple trade costs. The last ones include bilateral time-invariant factors between China and its importer $j(\tau_{cj})$ (distance, shared borders, or common language, etc.); bilateral time-variant trade factors between China and importer j (τ_{cjt}) (e.g., free trade agreements), unilateral time variant trade costs among importers j (τ_{jt}) (e.g., free trade agreements

among importers, etc.), and individual aggregate trade costs faced by China and its import partners ($\prod_{ct}$ and P_{jt}) respectively. This model allows trade between China and importers j to be potentially affected by the free trade agreements among importers. Equation b shows that the individual aggregate trade costs faced by China ($\prod_{ct}$) are a function of multiple trade costs between China and its importers and only among importers relative to aggregate trade costs supported by all importers, and outputs of its trading partners relative to world output. It allows trade between China and importer j to be potentially affected by the world trade. Equation c shows that the individual aggregate trade costs faced by China's importer j are a function of multiple trade costs of importer j with China relative to China's aggregate trade cost and outputs of China relative to world output. Finally, the elasticity of substitution (σ) determines how much China's exports respond to variations in trade costs. This structural gravity model extends trade costs from distance to all important observable and non-observable trade costs, thus avoiding biased estimates. We can rewrite equations (1) and (2) as follows:
rewrite equations (1) and (2) as follows:

$$X_{cjt} = \exp[a_1\, lnY_{ct} + a_2\, lnY_{jt} + a_3\, lnD_{cj} + a_4\, contig_{cj} + a_5\, comlang_{cj} + a_6\, fta_{cjt} + a_7 eu_{cjt} + \varepsilon_{ijt}] \tag{3}$$

$$X_{cjt} = \exp[a_1\, lnY_{ct} + a_2\, lnY_{jt} + a_3\, lnD_{cj} + a_4\, contig_{cj} + a_5\, comlang_{cj} + a_6\, fta_{cjt} + a_7 eu_{cjt} + a_8 LSBCI_{cjt} + \varepsilon_{ijt}] \tag{4}$$

Where $Contig_{cj}$ is a dummy variable that takes a value of 1 if China and country *j* share a border (0 otherwise). $comlang_{cj}$ is 1 if China and country *j* share a common language (0 otherwise). They are time-invariant variables. fta_{cjt} is a dummy variable for regional trade agreements between China and the country *j* and eu_{jt} is a dummy variable if country *j* is an EU member. Y_{ct}, Y_{jt}, and eu_{jt} are time-variant country-specific variables, and fta_{cjt} and $LSBCI_{cjt}$ are time-variant bilateral variables.

To estimate equations 3 and 4, China-year fixed effects are added to capture all time-variant factors specific to China regardless of its trading partners, whether observed or not. If they effectively capture all time-varying factors, China's GDP and other country-level variables are drop-down. Moreover, bilateral trade variables may pose endogeneity problems due to omitted variables and selection bias, simultaneity bias, and measurement error bias. Our key variable LSBCI is probably endogenous (Baier *et al.*, 2018). The Chinese seaports were built primarily to facilitate the exports of manufactured goods in line with China's export promotion strategy launched at the end of 1978, while the strong development of these exports has pushed China to increase port throughput and improve shipping connectivity. To deal with the endogeneity problems of LSBCI, China-importer pair fixed effects are added (Baier and Bergstrand, 2007). This addition also controls any observable time-invariant (distance, common border, and language) and non-observable bilateral factors, and thus has the drawback of absorbing all the time-invariant gravity variables (Agnosteva *et al.* 2014; Egger and Nigai 2015). Equations 3 and 4 can be written in a nonlinear form such as:

$$X_{cjt} = \exp[a_0 + \delta_{ct} + \vartheta_{cj} + a_1 \ln Y_{ct} + a_2 \ln Y_{jt} + a_3 \ln D_{cj} + a_4 contig_{cj} + a_5 comlang_{cj} + a_6 fta_{cjt} + a_7 eu_{jt} + \varepsilon_{cjt}] \tag{5}$$

$$X_{cjt} = \exp[a_0 + \delta_{ct} + \vartheta_{cj} + a_1 \ln Y_{ct} + a_2 \ln Y_{jt} + a_3 \ln D_{cj} + a_4 contig_{cj} + a_5 comlang_{cj} + a_6 fta_{cjt} + a_7 eu_{jt} + a_8 LSBCI_{cjt} + \varepsilon_{cjt}] \tag{6}$$

Where δ_{ct} is China-year fixed effects. ϑ_{cj} is China-importer fixed effect.

Baier *et al.* (2018) argued that the presence of reverse causality between exports and $LSBCI_{cjt}$ would lead to an upwardly biased estimation of the impact of maritime connectivity. We expect that the coefficients of a_8 in equation 6 will be sensibly smaller than that obtained in equations 2 and 4.

4. DATA AND EMPIRICAL RESULTS

The dependent variable is China's bilateral exports of manufactured goods to its 149 coastal import partner countries from 2006 to 2020. The statistics are sourced from BACI, CEPII (Conte *et al.*, 2023). The maximum number of observations is 2170, with 65 zero values recorded across 14 countries, representing only 3% of observations. This is significantly lower than the 38% found by Fugazza and Hoffmann (2017), using panel data from 138 coastal countries over the period from 2006 to 2013. This suggests that China exports to nearly all countries.

The key independent variable, China's Liner Shipping Bilateral Connectivity Index (LSBCI), has been available since 2006. It is calculated using the number of transshipments needed to move goods from China to its importer j, the number of direct shipping routes shared between China and importer j, the number of common connections with one transshipment between the country pair, the service competition, and the ship Size on Weakest Route[5]. UNCTAD publishes quarterly LSBCI data, which were downloaded in March 2024. Annual LSBCI values are calculated as the average of four quarters within each year. The study period ends in 2020 due to the availability of LSBCI data. Other variables, including the GDP of China and its trading partners, distance, free trade agreements, common borders, and shared languages, are sourced from the CEPII gravity database (Conte *et al.*, 2023). Table A1 in the Appendix details the definition of variables and sources. Table A2 describes the characters of variables.

Unlike Fugazza and Hoffmann (2017), who only used positive trade flows to estimate gravity models, this study uses the Poisson pseudo-maximum likelihood (PPML) estimator to retain zero values and avoid bias. The ppmlhdfe command developed by Correia *et al.* (2020) for STATA is used to implement the PPML estimator, widely now considered the standard estimator for gravity models in international trade. The estimator accounts for multi-way error clustering by exporter, importer, and year for a more conservative inference (Egger and Tarlea, 2015; Larch *et al.*, 2019; Cameron *et al.*, 2011).

To see the importance of controlling all kinds of trade costs and multiple fixed effects to obtain unbiased estimates of LSBCI, we have estimated the equations from 1 to 8 successively, progressing from a traditional intuitive model with only distance to include other trade cost variables such as common borders and language, regional trade agreement, etc., to a structural gravity model successively adding China-year fixed effects to control its resistance terms, and China-importer pair fixed effects to control endogeneity, all without and with our key variable of LSBCI.

Table 1 presents the econometric results. We begin by estimating a traditional gravity model without and with LSBCI (columns 1 and 2), then adding other trade costs variables (columns 3 and 4), controlling for China-year fixed effects (columns 5 and 6), and finally adding China-importer fixed effects (columns 7 and 8).

The estimated coefficients of our key variable vary considerably, confirming the necessity of controlling for different fixed effects to mitigate estimation biases. Column 1 shows the coefficients of GDP and distance of traditional gravity models, which are statistically significant as expected. In column 2, the coefficient of LSBCI is estimated at 4.86; the distance coefficient decreased from - 0.59 (column 1) to -0.24 (column 2), suggesting LSBCI's direct positive effect on exports of manufactured goods, and an indirect impact via reducing distance costs.

Additional gravity variables, such as European membership, free trade agreements, common borders, and shared languages are introduced in column 3, while LSBCI is included in column 4. All are statistically significant with waited signs. LSBCI coefficient remains positive and statistically significant but decreases to 3.32, and the distance coefficient becomes insignificant. Controlling for China-year fixed effects (columns 5 and 6), LSBCI is estimated at 3.38, and distance stayed insignificant (column 6). Columns 7 and 8 reported the results with China-year and China-importer pair fixed effects. LSBCI coefficient is estimated to be 2.07 (column 8). These estimated coefficients are lower than those obtained in the previous estimations because of the suspected reverse causality and the potential upward-biasing effects (Baier *et al.*, 2018).

These results conform to the results obtained in previous studies (Fugazza and Hoffmann, 2017; Hoffmann *et al.*, 2020; Lin *et al.*, 2020), all found positive effects of LSBCI on exports, but contrary to Del Rosal and Moura (2022), who did not find a statistically significant impact of LSBCI on manufactured exports of UE's countries to the rest of the world. This suggests that having better maritime connectivity is particularly important for developing countries with an export-led growth strategy focusing on low-value-added labor-intensity exports.

We observe that the distance coefficient in the traditional gravity model decreased sensibly from -0.59 (column 1) to -0.24 when maritime connectivity is added (column 2), and becomes statistically insignificant when other gravity variables are added without and with China year fixed effects (columns 4 and 6), suggesting a distance-reducing effect of maritime connectivity. In the same way, the common language coefficient reduced from 1.48 in column 3 to 0.93 in column 6, indicating a common language-mitigating effect of connectivity in facilitating trade. On the contrary, the coefficient of contiguous countries increased from 0.53 in column 3 to 0.75 in column 6, suggesting maritime connectivity reinforced the trade relationship among neighboring countries, as in Lin *et al.* (2020). Finally, free trade agreements discouraged China's exports if they were limited among European countries, while they increased if with China.

We follow Yotov *et al.* (2016) to calculate the effect of a change in LSBCI on bilateral exports using the PPML estimator such as:

$$\Delta X_{cj}\% = (e^{a_8 * \Delta LSBCI} - 1) * 100$$

Here, ΔX represents a change in bilateral exports, ΔLSBCI represents a change in our key variable of interest, and a_8 is its estimated coefficient reported in column 10.

The LSBCI takes values between 0 and 1. An increase of 0.1 in China's LSBCI in 2020 relative to 2006 would increase its exports by 23%. Over the studied period, Morocco, Poland, and Vietnam are the three economies with which China's LSBCI in 2020, relative to 2006, increased the most, with values of 0.277, 0.218, and 0.212, respectively. This rise in bilateral connectivity could increase China's exports to Morocco by 78%, Poland by 57%, and Vietnam by 55%. China's LSBCI with eight countries (Iraq, Portugal, Oman, Korea, Malaysia Qatar, Sri Lanka, United States) increased by between 0.10 and 0.17, yielding an increase from 23% to 42% in their exports. In contrast, relative to 2006 China's LSBCI with 20 countries in 2020 decreased from -0.001 for Cuba to -0.095 for Yemen, decreasing their exports from 0.1% to 17.78% for the two countries respectively. These results suggest the importance of having good shipping connectivity for countries that hope to be integrated into global value chains and adopt an export-led growth strategy.

5. CONCLUSIONS

Building world-leading maritime connectivity has been a priority of the Chinese government in supporting its export-led growth strategy since the "open door" policy launched in 1978, particularly with its accession to the WTO in 2001. This strategy has allowed China to quickly become the best-connected maritime shipping country and a central hub in global sea ports. During the same period, the exports of manufactured goods in China increased significantly, making it the largest exporter.

A gravity model of exports augmented with maritime connectivity is applied to panel data of China's exports of manufactured goods to 149 coastal importers. PPML estimator is applied to allow zero value of exports; China-year and China-importer fixed effects are included to control omission variables and endogeneity of maritime connectivity. We found a positive direct impact of maritime connectivity on China's exports due to improved connectivity efficiency. This positive effect is strengthened indirectly by mitigating distance's adverse effects and increasing FTAs and common borders' positive effects, but reduced by decreasing the role of common language.

The Chinese successful experience showed the essential role of efficient maritime connectivity for developing countries pursuing an export-driven growth model. This positive role may be less important for higher value-added exports of developed economies, in such a way that Del Rosal and Moura

Table 1: The impact of LSBCI on China's exports of manufactured goods, PPML estimator

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
LBSCI		4.86*** (9.09)		3.32*** (10.30)		3.38*** (10.40)		2.07*** (5.28)
LnD	-0.59*** (-8.64)	-0.24*** (-4.73)	-0.28*** (-11.21)	-0.04 (-1.17)	-0.28*** (-11.5)	-0.03 (-1.03)		
Eu			-0.14*** (-3.48)	-0.21*** (-5.37)	-0.14*** (-3.37)	-0.21*** (-5.33)	-0.23*** (-3.23)	-0.21*** (-2.94)
Fta_wto			0.40*** (7.23)	0.46*** (7.92)	0.41*** (7.54)	0.48*** (8.22)		-0.01 (-0.32)
Contig			0.53*** (7.09)	0.75*** (10.11)	0.53*** (7.17)	0.75*** (10.27)		
Comlang			1.48*** (15.74)	0.94*** (8.56)	1.47*** (15.96)	0.93*** (8.44)		
lnYc	0.31*** (3.83)	0.15* (1.79)	0.22*** (5.46)	0.12*** (2.89)	0.26*** (2.73)	0.10 (1.21)	0.29*** (5.95)	0.17*** (3.44)
lnYd	0.76*** (26.79)	0.56*** (14.30)	0.88*** (68.49)	0.73*** (40.44)	0.88*** (66.9)	0.73*** (41.3)	0.72*** (15.6)	0.71*** (17.4))
R^2	0.8334	0.8605	0.9365	0.9438	0.9363	0.9444	0.9942	0.9946
observations	2052	2052	2052	2052	2052	2052	2052	2052
Estimator	PPML	PPML	PPML	PPML	PPML	PPML	PPML	PPML
exp#year	no	no	No	no	yes	yes	yes	yes
exp#imp	no	no	No	no	no	no	yes	yes

Notes: - t-statistics are reported in brackets.

-*, ** and *** indicate significance at the 10%, 5%, and 1% levels of confidence, respectively.

(2022) did not find significant effects of shipping connectivity on European countries' exports of manufactures to the rest of the world.

Future research to extend this study is numerous. I will include domestic demand to refine trade cost estimates (Yotov, 2022; Masood & Martínez-Zarzoso, 2024). I will use updated data from UNCTAD and Lloyd's cargo ship records to estimate a structural gravity model to examine whether it exerts a differential impact on upstream and downstream participation and different sectors (such as agriculture, manufacturing, etc.). I will analyze the effects of China's New Maritime Silk Road and Arctic routes on global maritime networks and bilateral trade flows. Finally, I will examine how maritime connectivity influences growth, inequality, employment, and the environment.

NOTES

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1. The United Nations Conference on Trade and Development
2. Author's calculation using statistics from the *Base pour l'Analyse du Commerce International* (BACI) of *Centre d'études prospectives et d'informations internationales* (CEPII).
3. See the calculation and normalization methodologies on the website of UNCTAD's data center.

REFERENCES

Adland, R., H. Jia and S. P. Strandenes, 2017. "Are AIS-based Trade Volume Estimates Reliable? The Case of Crude Oil Exports," *Maritime Policy & Management,* 44(5), 657-665, http://dx.doi.org/10.1080/03088839.2017.1309470.

Agnosteva, D. E., J. E. Anderson, & Y.V. Yotov. 2014. Intra-national trade costs: Measurement and aggregation (No. w19872). *National Bureau of Economic Research.*

Anderson, J. E. 1979. "A theoretical foundation for the gravity equation," *The American Economic Review* 69(1), 106–116. https://www.jstor.org/stable/1802501.

Anderson, J. E. and E. van Wincoop. 2003. "Gravity with gravitas: A solution to the border problem," *American Economic Review* 93, 170–192. https://doi.org/10.1257/000282803321455214

Arslanalp, S., M. Marini and P. Tumbarello. 2019. Big Data on Vessel Traffic: Nowcasting Trade Flows in Real Time. IMF Working Paper 19/275.

Baier, S. L. and J. H. Bergstrand. 2007. "Do trade agreements actually increase members' international trade?" *Journal of International Economics* 71(1), 72–95. https://doi.org/10.1016/j.jinteco.2006.02.005.

Baier, S. L., A. Kerr, and Y. V. Yotov. 2018. Gravity, Distance, and International Trade. in Handbook of International Trade and Transportation, B. A. Blonigen and W. W. Wilson (editor), 15–78. Cheltenham (UK): Edward Elgar.

Bernhofen, D.M., Z. El-Sahli and R. Kneller. 2016. Estimating the effects of the container revolution on world trade. *Journal of International Economics.* 98, 36–50. https://doi.org/10.1016/j. jinteco.2015.09.001.

Bommarito J. 2022. Maritime Connectivity and International Trade: Distance in a Globalized World. World Trade Institute, University of Bern.

Borchert P. and Y. V. Yotov. 2017. "Distance, globalization, and international trade," Economics Letters, 153, 32-38.

Cameron, A.C., J. B. Gelbach, and D.L. Miller. 2011. Robust inference with multiway clustering. Journal of Business & Economic Statistics. 29, 238–249. https://doi.org/10.1198/jbes.2010.07136.

Capoani L. 2023. "Review of the gravity model: origins and critical analysis of its theoretical development," SN Business & Economics 3(5), DOI: 10.1007/s43546-023-00461-0

Cerdeiro, M. D. A., A. Komaromi, Y. Liu, & M. Saeed. 2020. World seaborne trade in real time: A proof of concept for building ais-based nowcasts from scratch: Technical report, IMF working papers 2020/057.

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.

Conte, M., P. Cotterlaz and T. Mayer. 2023. The CEPII Gravity database. CEPII Working Paper N°2022-05, October 12.

Correia, S. 2015. Singletons, cluster-robust standard errors and fixed effects: A bad mix. Technical Note, Duke University, 7.

Correia, S., P. Guimarães, and T. Zylkin. 2020. Fast Poisson estimation with high-dimensional fixed effects. The Stata Journal, 20(1), 95-115. https://doi.org/10.1177/1536867X20909691

Dappe M. H., C. Jooste and A.S. Aleman. 2017. How Does Port Efficiency Affect Maritime Transport Costs and Trade? Evidence from Indian and Western Pacific Ocean Countries. September 25. World Bank Policy Research Working Paper No. 8204, https://ssrn.com/abstract=3042911

Del Rosal, I. and T.G.Z. Moura. 2022. The effect of shipping connectivity on seaborne containerized export flows. Transport Policy, 118, 143-151, https://doi.org/10.1016/j.tranpol.2022.01.020

Del Rosal I. 2024a. "Maritime connectivity and agricultural trade," journal of agricultural economics. 75 (1), 153-168, February. https://doi.org/10.1111/1477-9552.12548

Del Rosal, I. 2024b. "Trade effects of liner shipping across world regions." Maritime Business Review, 9(1), 2-16. https://doi.org/10.1108/MABR-06-2023-0040

Del Rosal, I. 2024c. "Does containerisation reduce the constraints imposed by distance in seaborne trade?" *Maritime Policy & Management,* 51(1), 35-49.

Ducruet, C. 2020. "The Geography of Maritime Networks: A Critical Review." Journal of Transport Geography, 88: 102824. doi: 10.1016/j.jtrangeo.2020.102824.

Dunford, M., Z. Liu, and J. Xue. 2020. "Chinese Overseas Ports: Market Potential, Supply Capacity and Access to Imports." Journal of Geographical Sciences 30 (10): 1681–1701. doi:10.1007/s11442-020-1807-7.

Egger, P. H., and F. Tarlea. 2015. "Multi-Way Clustering Estimation of Standard Errors in Gravity Models." *Economics Letters* 134: 144–147. doi:10.1016/j.econlet.2015.06.023

Feenstra, R. C. 2002. "Border effects and the gravity equation: Consistent methods for estimation." *Scottish Journal of Political Economy* 49(5), 491–506. https://doi.org/10.1111/1467-9485.00244.

Foo N., Lean H.H. and Salim R. 2020. "The impact of China's One Belt One Road initiative on international trade in the ASEAN region." *The North American Journal of Economics and Finance,* 54, November, 101089, https://doi.org/10.1016/j.najef.2019.101089

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

Guerrero, D., C. Grasland, and C. Ducruet. 2016. Explaining International Trade Flows with Shipping-Based Distances. In Maritime Networks: Spatial Structures and Time Dynamics, edited by C. Ducruet, 302–320. New York: Routledge.

Haralambides, H. and O. Merk. 2020. The Belt and Road Initiative: Impacts on Global Maritime Trade Flows. Documents de travail du Forum international des transports, n° 2020/02, Éditions OCDE, Paris, https://doi.org/10.1787/2281f06f-en.

Herman P.R. 2023. Gravity Estimation: Best Practices and Useful Approaches. Working Paper 2023–10–C, U.S. International Trade Commission, October.

Hoffmann, J., G. Wilmsmeier, Y.V. Lun. 2017. "Connecting the world through global shipping networks." J. Ship. Trade 2, 2. https://doi.org/10.1186/s41072-017-0020-z.

Hoffmann, J., N. Saeed, and S. Sødal. 2020. "Liner Shipping Bilateral Connectivity and Its Impact on South Africa's Bilateral Trade Flows." Maritime Economics and Logistics 22 (3): 473–499. doi:10.1057/s41278-019-00124-8.

Hummels, D. 2007. "Transportation Costs and International Trade in the Second Era of Globalization." *Journal of Economic Perspectives,* 21(3), 131-154.

Kosowska-Stamirowska Z. 2020. "Network effects govern the evolution of maritime trade." PNAS, May 26, 117 (23), https://doi.org/10.1073/pnas.1906670117

Larch, M., Wanner, J., Yotov, Y.V., Zylkin, T., 2019. Currency unions and trade: a PPML Re-assessment with high-dimensional fixed effects. Oxf. Bull. Econ. Stat. 81, 487–510. https://doi.org/10.1111/obes.12283.

Lin, P. C., S. Y. Kuo, and J. H. Chang. 2020. "The direct and spillover effects of liner shipping connectivity on merchandise trade." *Maritime Business Review,* 5(2), 159-173. https://doi.org/10.1108/MABR-12-2019-0055

Martí, L., and R. Puertas. 2017. "The Importance of Export Logistics and Trade Costs in Emerging Economies." *Maritime Economics and Logistics* 19 (2): 315–333. doi:10.1057/mel.2015.31.

Martínez-Zarzoso, I., and F. D. Nowak-Lehmann. 2007. Is distance a good proxy for transport costs? The case of competing transport modes. *The Journal of International Trade & Economic Development.* 16, 411–434. https://doi.org/10.1080/09638190701527186.

Olivero, M.P., Y.V. Yotov. 2012. "Dynamic gravity: endogenous country size and asset accumulation." Canadian Journal of Economics/Revue canadienne d'économique, 45, 64–92. https://doi.org/10.1111/j.1540-5982.2011.01687.x.

Ramasamy B. and M. C. H. Yeung. 2019. "China's One Belt One Road Initiative: The impact of trade facilitation versus physical infrastructure on exports." The World Economy, 42 (6) June, 1673-1694.

Rodrigue, J.-P. 2020. The Geography of Transport Systems. 5th ed. New York: Routledge.

Saeed N., K. Cullinane, V. Gekara and P. Chhetri. 2021. "Reconfiguring maritime networks due to the Belt and Road Initiative: impact on bilateral trade flows." Maritime Economics & Logistics 23:381–400.

Saeed N. & K. Cullinane. 2023. "Identifying the characteristics of China's maritime trading partners on the basis of bilateral shipping connectivity: a cluster analysis." Maritime Policy & Management, 50:1, 42-57, DOI: 10.1080/03088839.2021.1954256

Santos Silva, J.M.C. and S. Tenreyro. 2006. "The log of Gravity." Review of Economics and Statistics. 88(4). November, 641–658.

Sharma A. 2021. "China's Polar Silk Road: Implications for the Arctic Region." Journal of Indo-Pacific Affairs, Air University Press.

Tinbergen, J. 1962. Shaping the world economy: suggestions for an international economic policy. [s.l.] New York: Twentieth Century Fund.

Tovar B. and A. Wall. 2022. "The relationship between port-level maritime connectivity and efficiency, Author links open overlay panel." *Journal of Transport Geography,* 98. https://doi.org/10.1016/j.jtrangeo.2021.103213

UNCTAD. 2023. Review of Maritime Transport. Geneva: United Nations Publication

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.

Wilmsmeier, G., and I. Martínez-Zarzoso. 2010. "Determinants of Maritime Transport Costs - A Panel Data Analysis for Latin American Trade." Transportation Planning and Technology 33 (1): 105–121. doi:10.1080/03081060903429447.

Xu, M., Pan, Q., Xia, H., Masuda, N., 2020. Estimating international trade status of countries from global liner shipping networks. Royal Society Open Science. 7, 200386. https://doi.org/10.1098/rsos.200386.

Yotov, Y., M. Larch, J.A. Monteiro, R. Piermartini. 2016. An Advanced Guide to Trade Policy Analysis: the Structural Gravity Model. UNCTAD and WTO, Geneva. https:// doi.org/10.30875/abc0167e-en.

Yrjö K. 2014. "The role of shipping in the 'second stage of globalisation." *The International Journal of Maritime History,* 26(1) 64–81, DOI: 10.1177/0843871413514505

Table A1: Definitions and sources of variables

variable names	*Content*	*Sources*	*Level*
X	exports of manufactured goods, 1000 US$	BACI, CEPII	bilateral
LSBCI	Liner Shipping Bilateral Connectivity Index	UNCTAD	Level
Y_d	GDP of importers, 1000 US$	CEPII	unilateral
Y_c	GDP of China, 1000 US$	CEPII	unilateral
D	Geodesic distance between most populated cities	CEPII	unilateral
Eu	1 if the country currently is an EU member, zero for others	CEPII	unilateral
Fta	1 if both countries are engaged in a regional trade agreement, zero for others	CEPII	bilateral
Contig	1 if countries are contiguous, zero for others	CEPII	bilateral
Comlang	1 if countries share a common language spoken by at least 9% of the population, zero for others	CEPII	bilateral
Business	Days and number of procedures required to start a business in China's import partners	CEPII	unilateral

Table A2: Summary of variables

Variables	*Obs*	*Mean*	*Std. dev.*	*Min*	*Max*
X	2 170	1.31e+07	4.07e+07	220.708	4.98e+08
LSBCI	2 235	.2715447	.1050471	.1227552	.6456275
lnYd	2 106	17.45026	2.47522	11.81438	23.78537
lnYc	2 235	22.79826	.5171201	21.7213	23.41027
LnD	2 235	9.083927	.5389681	6.765039	9.884764
Eu	2 235	.1498881	.3570416	0	1
Fta	2 235	.1020134	.3027337	0	1
Contig	2 235	.0402685	.1966322	0	1
Comlang	2 235	.0201342	.1404908	0	1

Sources: CEPII, UNCTAD.