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► **To cite this version:**

Ping Hua. Impact of Maritime Connectivity on China's Exports of Manufactured Goods. 2024. halshs-04828238

**HAL Id: halshs-04828238**

**<https://shs.hal.science/halshs-04828238v1>**

Preprint submitted on 9 Dec 2024

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# **Impact of Maritime Connectivity on China's Exports of Manufactured Goods**

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<sup>a</sup> This work is supported by the Agence Nationale de la Recherche (ANR) AAPG 'MAGNETICS', Maritime Globalization, Network Externalities, and Transport Impacts on Cities, and presented in the first workshop on 25-26-27 March 2024 in Paris-Nanterre. I thank for the suggestions and the comments. The remaining errors are mine.

## Abstract

Owning the best maritime liner shipping connectivity has allowed China to rapidly become one of the leading centers for global value chains in manufactured goods, making it the largest exporter in the world. The strong development in China's exports has continually created pressure to improve the efficiency of its maritime connectivity. In light of this potential reverse causality, this paper examines the impact of the last one on China's exports of manufactured goods, most of which are transported by sea.

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, and estimated using the nonlinear Poisson Pseudo-Maximum Likelihood estimator which allows zero export values, controls multilateral resistance effects, and addresses endogeneity by including multiple fixed effects. The results indicate that efficient shipping connectivity has increased China's exports of manufactured goods. Its incorporation in the model has significantly reduced the coefficients of distance and common language but increased that of common borders, suggesting that enhanced maritime connectivity has alleviated the negative impacts of distance, mitigated the positive effects of a common language, and reinforced the positive impact of shared borders on exports. These findings underscore the essential role of efficient maritime connectivity for countries pursuing export-driven growth models.

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

## Résumé

La Chine, qui dispose de la meilleure connectivité maritime de ligne, est rapidement devenue l'un des principaux centres de la chaîne de valeur mondiale des produits manufacturés, ce qui en fait le plus grand exportateur au monde. Le fort développement des exportations chinoises a continuellement créé une pression pour améliorer l'efficacité de sa connectivité maritime. À la lumière de cette causalité inverse potentielle, cet article examine l'impact de cette dernière sur les exportations chinoises de produits manufacturés, dont la plupart sont transportés par voie maritime.

Un modèle de gravité des exportations augmenté de la connectivité maritime est appliqué aux données de panel de la Chine et de ses 149 partenaires d'importation côtiers de 2006 à 2020 et estimé en utilisant l'estimateur de pseudo-maximum de vraisemblance de Poisson non linéaire qui autorise des valeurs d'exportation nulles, contrôle les effets de résistance multilatérale et aborde l'endogénéité en incluant de multiples effets fixes.

Les résultats indiquent qu'une connectivité maritime efficace a augmenté les exportations chinoises de produits manufacturés. Son incorporation dans le modèle a considérablement réduit les coefficients de distance et de langue commune, mais a augmenté celui des frontières communes, suggérant qu'une connectivité maritime améliorée a atténué les impacts négatifs de la distance et les effets positifs d'une langue commune, et renforcé l'impact positif des frontières partagées sur les exportations. Ces résultats soulignent le rôle essentiel d'une connectivité maritime efficace pour les pays qui poursuivent des modèles de croissance axés sur les exportations des biens manufacturés.

Mots clés : Chine, connectivité maritime bilatérale, exportations de produits manufacturés

## 1. Introduction

Maritime transport is indispensable for a country to export, especially within global value chains in which fragmented intermediate manufactured products are often transported via sea several times before arriving at their final destination. Seaborne trade has increased quickly since the intensification of containerized transport services (Bernhofen et al., 2013; Hoffmann et al., 2017). It accounts for a dominant part of total trade in the world. 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<sup>1</sup> relative to world trade in volume from HS92 BACI CEPII<sup>2</sup> 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. Maritime transport plays therefore an essential role in trade.

Maritime trade between coastal countries is connected through the networks of global regular container shipping services with transshipments in hub ports. The naval shipping connectivity measures a country's capacity to join the global shipping networks;<sup>3</sup> and improves international seaborne export competitiveness (Hoffmann et al., 2017). The literature suggests that better maritime connectivity may enhance seaborne exports either directly by improving the efficiency and the quality of global shipping service networks, or indirectly by reducing distance constraints, improving market access, lowering shipping time, and thus decreasing export costs (Anderson and Wincoop, 2003; Hoffmann et al., 2020; Saeed and Cullinane, 2023).

The empirical studies on the trade impact of maritime connectivity have emerged following UNCTAD's publication of the liner shipping connectivity index (LSCI) in 2004, and particularly the liner shipping bilateral connectivity index (LSBCI) in 2006 (Fugazza and Hoffmann, 2017). The first index measures each coastal country's position within regular container shipping networks, while the second captures the bilateral connectivity between coastal countries. Most studies have found positive effects of liner shipping connectivity on

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<sup>1</sup> The United Nations Conference on Trade and Development

<sup>2</sup> Author's calculation using statistics of Harmonized System 1992 (HS92) obtained from the *Base pour l'Analyse du Commerce International* (BACI) of Le Centre d'études prospectives et d'informations internationales (CEPII).

<sup>3</sup> See Ducruet (2020) for a review of maritime networks.

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 using panel data from 138 coastal countries over the period from 2006 to 2013. Hoffmann et al. (2020) identified significant positive effects of LSBCI on South Africa's exports. Using disaggregated trade data from 2006 to 2019, Del Rosal (2024a) found positive effects of maritime connectivity on agricultural trade. Del Rosal (2024b) found that the trade effects of liner shipping are more pronounced in long-distance and interregional flows, especially between North America and Oceania, while they are significantly weaker in Africa and South America. Finally, Del Rosal and Moura (2022) found that better liner shipping connectivity enhanced containerized exports of EU countries to the rest of the world, while they showed a negative effect on non-containerized exports and statistically non-significant impacts on exports of manufactures.

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. Surprisingly, no studies 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. Existing literature has largely focused on the impact of China's One Belt One Road initiative on exports (Ramasamy et al., 2019; Dunford et al., 2020. Foo et al., 2020; Haralambides et al., 2020; Saeed, Cullinane, and Chhetri, 2021; Sharma, 2021, etc.). While China has been included in previous studies on exports using multi-trade country panel data, its inclusion may overestimate the world average impact of LSBCI on exports (Del Rosal, 2024b). China is an outlier; the effects of its maritime connectivity on exports should be analyzed separately.

This paper aims to fill this gap in the literature by examining the impact of maritime connectivity on China's exports of manufactured goods, which accounted for 97% of its total exports in 2021. We argue that better maritime connectivity may increase its exports 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). Hummels (2007) found that the cost of delayed shipping could outweigh traditional tariffs, particularly for high-value goods. We also argue that better

connectivity may improve market access and facilitate integration into global supply chains, where the timely movement of intermediate goods is crucial to meet the demands of parts and components (Xu et al., 2020). We further argue that better maritime connectivity 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 Martínez-Zarzoso (2010) in studies of intra-Caribbean and intra-Latin American trade respectively, and by Arvis et al. (2013) for agricultural and manufactured goods. Del Rosal (2024c) observed that the trade effect of distance on EU containerized exports is smaller than that on non-containerized ones. We finally argue that better liner shipping connectivity may increase exports by mitigating the importance of free trade agreements, shared borders, and common languages.

Ideally, the impact of the UNCTAD's liner shipping connectivity would be estimated on containerized seaborne export data, which measures the volume of international shipments, in metric tons in the world's seaports, and distinguishes the nature of transported goods and mode. 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 gravity model of manufactured exports augmented with LSBCI, applied to panel data including China as the sole exporter and its coastal trading partners as its importers from 2006 to 2022. The nonlinear Poisson pseudo maximum likelihood (PPML) estimator is applied to estimate coefficients with as little bias as possible. This mostly used estimator in gravity model allows for zero bilateral trade flows, is robust to heteroscedasticity, and controls for multilateral resistance terms (MRTs) by including multiple country-year fixed effects (Anderson and Wincoop, 2003; Santos Silva and Tenreyro, 2006; Olivero and Yotov, 2012) and accounts for potential biases from time-invariant gravity variables and reverse causality by including country pair fixed effects (Baier and Bergstrand, 2007). China-year fixed effects are thus included to control for unobservable aggregate trade costs faced by China. Importer-year fixed effects initially used led to excessive data loss due to singletons and strong collinearities. Instead, business-year fixed effects are added to capture trade costs faced by importers, where "business" represents the number of days and procedures to start a business in import countries. Finally, China-importer pair fixed effects were applied to address the reverse causality between liner shipping connectivity and exports of manufactured goods; China's good 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 all fixed effects; an increase of 0.1 in LSBCI is associated with a 23% growth in China's manufacturing exports. 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 MRTs with China-year fixed effects and endogeneity of shipping connectivity with China-importer fixed effects.

This study closely resembles those by Fugazza and Hoffmann (2017), Hoffmann et al. (2020), and Del Rosal and Moura (2022) in the sense that all of them estimated the impact of UNCTAD's shipping connectivity on exports. While this study and Fugazza and Hoffmann (2017), Hoffmann et al. (2020) found statistically significant positive effects, Del Rosal and



Moura (2022) found statistically non-significant effects on UE's exports of manufactured goods to the rest of the world, but a positive impact on UE's container exports, and a negative effect on UE's non-container exports. All studies except Hoffmann et al. (2020) adopt a gravity model with the PPML estimator, while Hoffmann et al. (2020) employed a purely statistical approach. Fugazza and Hoffmann (2017) moreover used the OLS estimator. This study aligns most closely with Del Rosal and Moura (2022) because both addressed the endogeneity of shipping connectivity, unlike Fugazza and Hoffmann (2017) and Hoffmann et al. (2020), who assumed that the last one is exogenous. This paper uniquely focuses on the special role of China; Fugazza and Hoffmann (2017), and Del Rosal and Moura (2022) included China in panel data, which may overestimate average shipping connectivity effects on exports. Additionally, this study controls for bilateral free trade agreements between China and its trading partners, and unilateral trade agreements involving European countries, while Del Rosal and Moura (2022) overlooked them. The omission of free trade agreements may bias estimates.

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 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**

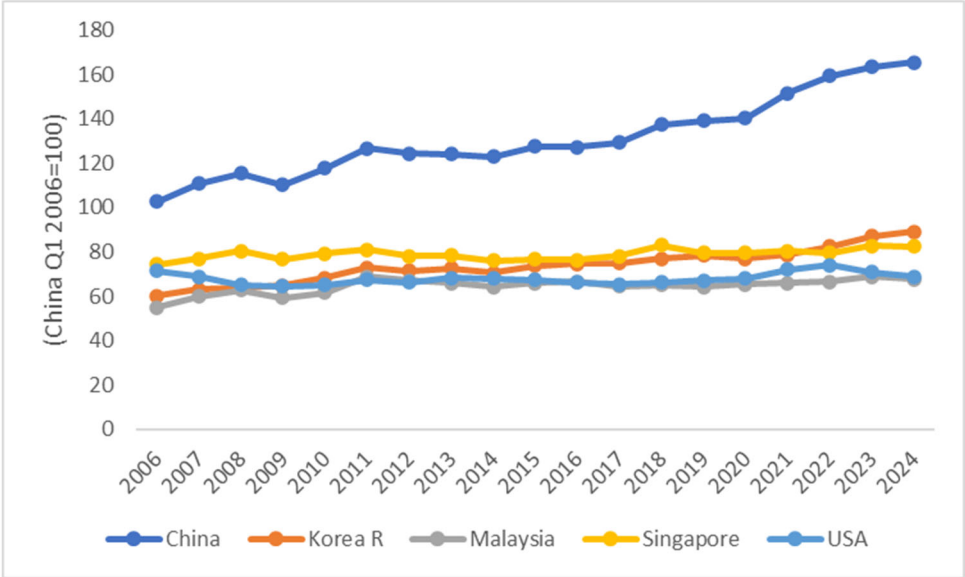
China's position in global maritime connectivity is exceptional. Since its "open door" policy launched at the end of 1978, the Chinese government has prioritized developing efficient seaports to support its export-led growth strategy.

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. China quickly became one of the most important GVC centers in the world. It accounted for a significant share of global maritime exports in manufactured goods, contributing to over 30% of global manufacturing output, much of which is exported via sea (UNCTAD, 2023).

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

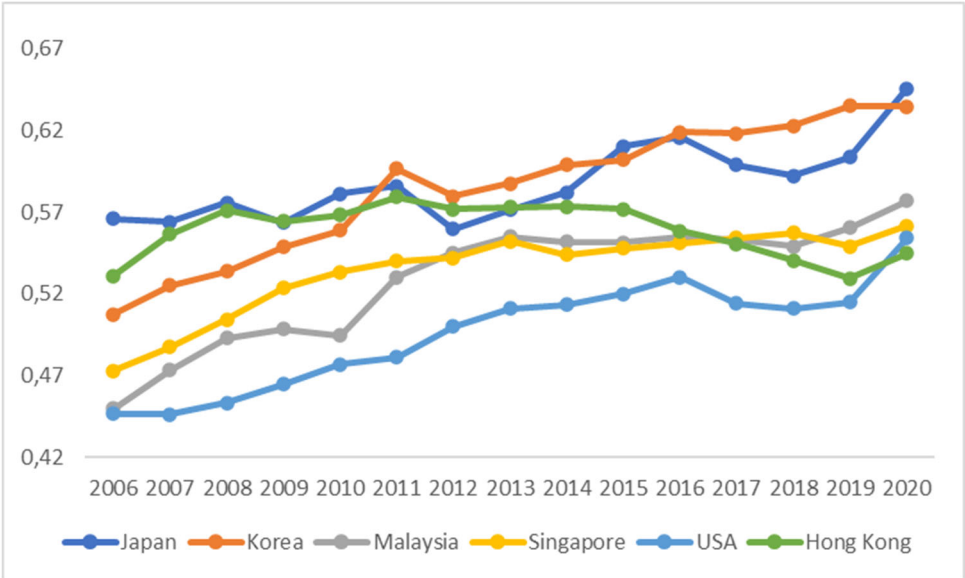
Source: UNCTAD Data Center

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 the 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



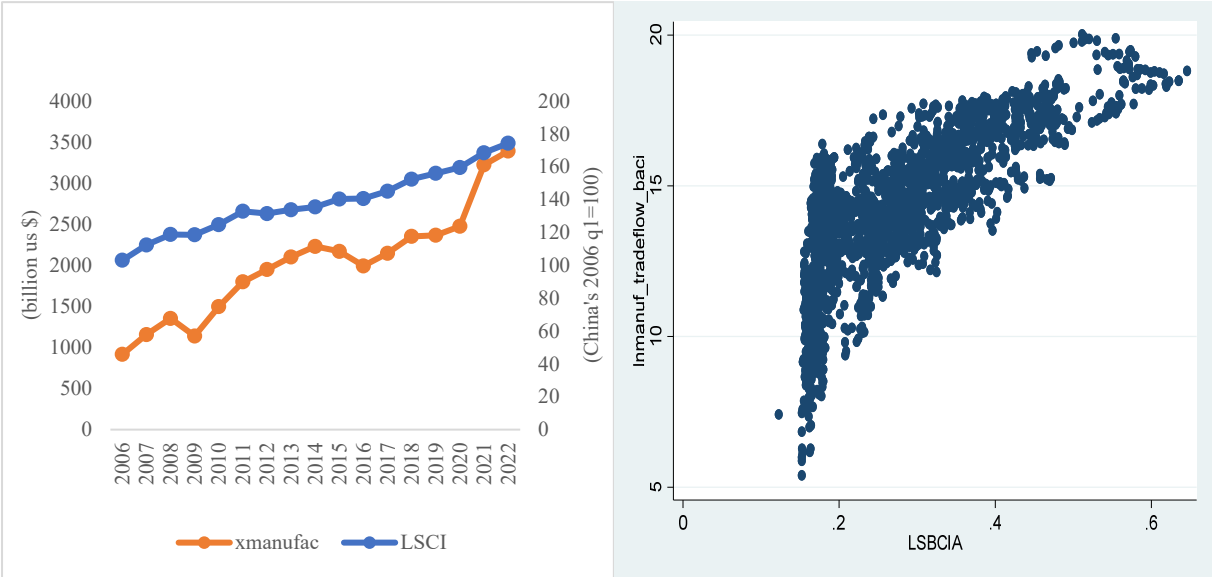
Source: UNCTAD data center

China has strongly contributed to global seaborne exports. While the volume of crude oil and other tangibles in the world remained stable from 1970 to 2021, dry cargo volumes grew at an annual rate of 4.2%, surpassing crude oil by the 1980s after China’s open-door policies launched at the end of 1978, and accelerated further after China joined the WTO in 2001. The share of crude oil in global maritime cargo decreased from 45% in 1979 to 15% in 2021, whereas the share of dry cargo, including bulk and containerized shipments, rose from 47% to 73%. Naturally, China is not the unique factor to explain this rise. The standardization of containers across developing countries (Bernhofen et al., 2013), the development of global

regular container shipping services with transshipment operations at hub ports, and the expansion of global value chains for intermediate goods have contributed.

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 geographical distance ( $D_{cj}$ ), 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 larger 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:

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

Where  $X_{cjt}$  represents exports from China to country  $j$  in year  $t$ ,  $\ln Y_{ct}$ , and  $\ln Y_{jt}$  are the GDPs of China and its destination countries in logarithms respectively in year  $t$ , and  $\ln D_{cj}$  is the bilateral distance between China and country  $j$  in logarithms. The coefficients  $\alpha_1$  and  $\alpha_2$  capture the elasticity of exports relative to the GDP of China and its import partners, respectively, and are expected to be positive.  $\alpha_3$  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 (2024b), giving us:

$$X_{cjt} = \exp[a_1 \ln Y_{ct} + a_2 \ln Y_{jt} + a_3 \ln D_{cj} + a_4 \text{LSBCI}_{cjt} + \varepsilon_{cjt}] \quad (2)$$

Where  $\text{LSBCI}_{cjt}$  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  $\text{LSBCI}_{cjt}$ , 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 the above equations is the absence of a theoretical basis and the potential omission of many 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 interdependence between trading countries and with the rest of the world. Following their theory, we write the structural gravity model by the following system.

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

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

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

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  $j$  ( $\tau_{cjt}$ ) (e.g., free trade agreements), unilateral time variant trade costs among importer  $j$  ( $\tau_{jt}$ ) (e.g., free trade agreements among importers, etc.), and individual aggregate trade costs faced by China and its import partners ( $\Pi_{ct}$  and  $P_{jt}$ ) respectively, named outward and inward multilateral resistance terms (MRTs). Equation b shows that the individual aggregate trade costs faced by China ( $\Pi_{ct}$ ) 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  $j$  and with China relative to China's aggregate trade cost and outputs of China relative to world output. Finally, the elasticity of substitution ( $\sigma$ ) determines how much trade flows respond to changes in trade costs. This structural gravity model extends trade costs from distance to all important observable and no observable trade costs, thus avoiding biased estimates. We can rewrite equations (1) and (2) as follows:

$$X_{cjt} = \exp [a_1 \ln Y_{ct} + a_2 \ln Y_{jt} + a_3 \ln D_{cj} + a_4 \text{contig}_{cj} + a_5 \text{comlang}_{cj} + a_6 \text{fta}_{cjt} + a_7 \text{eu}_{cjt} + \varepsilon_{ijt}] \quad (3)$$

$$X_{cjt} = \exp [a_1 \ln Y_{ct} + a_2 \ln Y_{jt} + a_3 \ln D_{cj} + a_4 \text{contig}_{cj} + a_5 \text{comlang}_{cj} + a_6 \text{fta}_{cjt} + a_7 \text{eu}_{cjt} + a_8 \text{LSBCI}_{cjt} + \varepsilon_{ijt}] \quad (4)$$

Where  $\text{Contig}_{cj}$  is a dummy variable that takes a value of 1 if China and country  $j$  share a border (0 otherwise).  $\text{comlang}_{cj}$  is 1 if China and country  $j$  share a common language (0 otherwise).  $\text{fta}_{cjt}$  is a dummy variable for regional trade agreements between China and the country  $j$  and  $\text{eu}_{jt}$  is a dummy variable if country  $j$  is an EU member.  $Y_{ct}$ ,  $Y_{jt}$ , and  $\text{eu}_{jt}$  are time-variant country-specific variables, and  $\text{fta}_{cjt}$  and  $\text{LSBCI}_{cjt}$  are time-variant bilateral variables.

MTRs are not written in equations because they are unobservable variables capturing any time-invariant or bilateral trade costs. The first difficulty in estimating equations 3 and 4 is just controlling these outward and inward multilateral resistance terms. Not being able to properly account for the last ones to control for the country-level determinants of trade could bias estimates because of omitted variables (Anderson and van Wincoop, 2003). One efficient solution is substituting GDP and any other country-level variables with exporter-year and importer-year fixed effects (Feenstra, 2022). These substitutions mitigate bias problems due to omitted variables, as the fixed effects eliminate almost all country-specific, observable, and unobservable factors that vary over time for each exporter and importer respectively, isolating the bilateral time-invariant factors affecting trade (e.g., distance).

In panel data with a single exporter (China) and multiple importers, the China-year fixed effect controls all time-variant factors specific to China regardless of its trading partners to mitigate omitted variable bias, thus dropping China's GDP. However, using importer-year fixed effects initially led to significant collinearity issues; dropping almost all explanatory variables

due to singleton groups and collinearity. In this study, only two observations were kept. This problem is common in regressions with multiple fixed effects and should be dropped to avoid underestimating the standard errors (Correia, 2015). We substitute importer-year fixed effects with business-year fixed effects to capture the business costs faced by importers, where “business” represents the days required to start a business and the number of procedures to start a business. This substitution partially mitigates the omitted variables bias problem that the importer-year fixed effects would control for any import country-level determinants, whether observed or not. It does not therefore necessitate dropping the importer’s GDP. Using China-year and business-year fixed effects, we simplify the model keeping key variables and making the results more interpretable and robust. This approach is moreover justified by economic theory and previous literature, which emphasize the role of exporter-specific factors in determining export flows (Marquez-Ramos et al., 2011; Arvis et al., 2013).

We thus add China-year and business-year fixed effects to the above equations, which drop China’s GDP, but not the GDP of the importer because, probably, business-year fixed effects do not capture all characteristics of importer-year fixed effects. We obtain the following equations:

$$X_{cjt} = \exp [\delta_{ct} + \gamma_{jt} + a_2 \ln Y_{jt} + a_3 \ln dist_{cj} + a_4 contig_{cj} + a_5 comlang_{cj} + a_6 fta_{cjt} + a_7 eu_{cjt} + \varepsilon_{cjt}] \quad (5)$$

$$X_{cjt} = \exp [\delta_{ct} + \gamma_{jt} + a_2 \ln Y_{jt} + a_3 \ln dist_{cj} + a_4 contig_{cj} + a_5 comlang_{cj} + a_6 fta_{cjt} + a_7 eu_{cjt} + a_8 LSBCI_{cjt} + \varepsilon_{cjt}] \quad (6)$$

Where  $\delta_{ct}$  is China-year fixed effects;  $\gamma_{jt}$  is importer business-year fixed effects.

Second, bilateral trade costs are generally approximated by specific trade costs such as distance, shared contiguity, common language, free trade agreements, etc., as in equations 5 and 6. These approximations may not capture all factors influencing trade costs, especially unobservable ones, and thus cause problematic biases in estimations (Baier and Bergstrand, 2007).

Moreover, bilateral trade variables may pose endogeneity problems due to omitted variables and selection bias, simultaneity bias, and measurement error bias. In this study, our key variable LSBCI is probably endogenous. Maritime connectivity may influence export flows, which could influence shipping connectivity (Fugazza and Hoffmann, 2017; Baier et al., 2018; Del Rosal and Moura, 2022). This causality may be even stronger in China. 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, country-pair fixed effects should be included in gravity estimation with panel trade data (Baier and Bergstrand, 2007). This inclusion also controls any observable time-invariant (distance, common border, and language) and non-observable bilateral factors (Agnosteva et al. 2014; Egger and Nigai 2015). The drawback 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. The above equations can be written in a nonlinear form such as:

$$X_{cjt} = \exp [a_0 + \delta_{ct} + \gamma_{jt} + \vartheta_{cj} + a_2 \ln Y_{jt} + a_6 \text{fta}_{cjt} + a_7 eu_{jt} + a_8 \text{LSBCI}_{cjt} + \varepsilon_{cjt}] \quad (7)$$

where  $\vartheta_{cj}$  is China-importer fixed effect.

Finally, to compare the results with Del Rosal and Moura (2022), which is the most similar to this paper, we estimate the following equation:

$$X_{cjt} = \exp [a_0 + \delta_{ct} + \gamma_{jt} + \vartheta_{cj} + a_8 \text{LSBCI}_{cjt} + \varepsilon_{cjt}] \quad (8)$$

Baier et al. (2018) argued that the presence of reverse causality between exports and  $\text{LSBCI}_{cjt}$  would lead to an upwardly biased estimation of the impact of maritime connectivity. We expect that the coefficients of  $a_8$  in equations (7 and 8) will be sensibly smaller than that obtained in equations (4, and 6).

#### 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, ensuring ample variation within each exporter-year group. The statistics are sourced from the Base Analytique du Commerce International (BACI) database maintained by the Centre d'Etudes Prospectives et d'Informations Internationales (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 and computed by UNCTAD. 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<sup>4</sup>.

UNCTAD publishes quarterly LSBCI data, which were downloaded in March 2024. Annual LSBCI values in this study 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 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 `ppmlhdfc` command developed by Correia et al. (2020) for STATA is used to implement the PPML estimator, widely considered the standard estimator for gravity models in international trade. The estimator accounts for multi-way error clustering by exporter, importer, and year, in line with Egger and Tarlea (2015), Larch et al. (2019), and Cameron et al. (2011), who emphasize the importance of accounting for multi-way clustering of errors in panel data gravity models for a more conservative inference.

To demonstrate 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 and business-year fixed effects to control MRTs, and China-importer pair fixed effects to control endogeneity, all without and with our key variable of LSBCI.

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<sup>4</sup> See the calculation and normalization methodologies on the website of UNCTAD's data center.

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), China-year and business-year fixed effects (columns 7 and 8), and finally adding China-importer fixed effects (columns 9 and 10).

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, with the distance coefficient decreasing from 0.59 (column 1) to 0.24 (column 2), showing LSBCI's direct positive effect on exports of manufactured goods, and an indirect effect 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. The 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 3.46, and distance stayed insignificant. columns 7 and 8 reported the results with both China-year and business-year fixed effects, LSBCI's coefficient is 3.38. The distance coefficient is again significant at -0.26 without LSBCI (column 7) and -0.10 with LSBCI (column 8). Finally, China-importer fixed effects yield an LSBCI coefficient from 1.99 when the trade agreement and importer's GDP are kept, to 2.07 (columns 9 and 10). These estimated coefficients are lower than those obtained in the previous estimations because of the suspected reverse causality and the potential upward-biasing effects.

We observe that the distance coefficient decreased sensibly from -0.59 in column 1 to 0.10 in column 8, suggesting a distance-reducing effect of maritime connectivity. In the same way, the common language coefficient reduced significantly from 1.48 in column 3 to 0.33 in column 8, 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 1.35 in column 8, suggesting maritime connectivity reinforced the trade relationship among neighboring countries. Finally, free trade agreements discouraged China's exports if they were limited among European countries, while they increased if with China.

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

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

Here,  $\Delta X$  represents a change in bilateral exports,  $\Delta LSBCI$  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.

Our results are consistent with Fugazza and Hoffmann (2017) and Hoffmann et al. (2020): all studies found positive LSBCI effects on exports. However, both papers did not address reverse causality contrary to our paper. Fugazza and Hoffmann (2017) analyzed the impact of the LSBCI on manufactured trade flows by estimating a gravity model augmented with LSBCI, using both Ordinary Least Squares (OLS) and PPML estimators without controlling for country-year or country-pair fixed effects. The obtained coefficient estimate for the LSBCI equals 3.123 for OLS and 0.029 for the PPML estimator. Hoffmann et al. (2020) adopted a purely statistical approach to analyze the short and long-term impact of the LSBCI on South Africa's trade flows assuming that the bilateral liner shipping connectivity of South Africa was exogenous. The estimated effect of the LSBCI on trade flows ranges between 2.44% and 16.67%. The econometric approaches in our study are similar to Del Rosal and Moura (2022), but the obtained results are different. Their estimated coefficient of LSBCI was not

statistically significant for UE's manufactured goods to the rest of the world.<sup>5</sup> It is estimated at 2.07 and is statistically significant in our study. The difference in the estimated coefficients supports the need for a separate analysis of China.

## 5. Conclusions

Building world-leading maritime connectivity has been a priority in supporting China's export-led growth strategy since the "open door" policy was 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 increased sensibly, leading to the largest exporter.

A gravity model augmented with maritime connectivity is applied to panel data of China's exports of manufactured goods to 149 coastal importers and estimated using the PPML estimator controlling multiple fixed effects. We found a positive impact of maritime connectivity on China's exports due to improved connectivity efficiency. This positive effect is strengthened by mitigating distance's adverse effects and increasing common borders' positive effects, but reduced by the decreasing 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 (2022) did not find significant effects of shipping connectivity on European countries' exports of manufactures to the rest of the world.

Future research could examine the individual contributions of each LSBCI component, revisit the model once comprehensive data on containerized manufactured goods becomes available, include China's domestic trade to explore how domestic production might influence export prices, especially given concerns over industrial overcapacity, and investigate its social and environmental effects.

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<sup>5</sup>Del Rosal and Moura (2022) found that the coefficients of the container and non-container exports are both statistically significant but with contrasted coefficients (0.501 and -0.717 respectively).

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

	1	2	3	4	5	6	7	8	9	10
LBSCI		4.86*** (9.09)		3.32*** (10.30)		3.46*** (10.35)		3.38*** (5.70)	1.99*** (4.23)	2.07*** (4.43)
LnD	-0.59*** (-8.64)	-0.24*** (-4.73)	-0.28*** (-11.21)	-0.04 (-1.17)	-0.28*** (-11.48)	-0.03 (-0.83)	-0.26*** (-4.91)	-0.10** (-1.93)		
Eu			-0.14*** (-3.48)	-0.21*** (-5.37)	-0.14*** (-3.41)	-0.21*** (-5.43)	-0.17* (-1.92)	-0.19** (-2.41)	-0.55*** (-3.06)	
Fta			0.40*** (7.23)	0.46*** (7.92)	0.42*** (7.38)	0.48*** (8.20)	0.38*** (3.49)	0.31*** (2.85)	0.14*** (4.07)	
Contig			0.53*** (7.09)	0.75*** (10.11)	0.53*** (7.17)	0.76*** (10.27)	1.23*** (9.54)	1.35*** (10.98)		
Comlang			1.48*** (15.74)	0.94*** (8.56)	1.47*** (15.75)	0.91*** (8.16)	0.94*** (6.99)	0.33* (1.82)		
lnYc	0.31*** (3.83)	0.15* (1.79)	0.22*** (5.46)	0.12*** (2.89)						
lnYd	0.76*** (26.79)	0.56*** (14.30)	0.88*** (68.49)	0.73*** (40.44)	0.88*** (67.79)	0.73*** (40.45)	0.78*** (29.08)	0.62*** (19.57)	0.55*** (5.40)	
R <sup>2</sup>	0.8334	0.8605	0.9365	0.9438	0.9363	0.9444	0.9763	0.9795	0.9986	0.9983
No. of observations	2052	2052	2052	2052	2052	2052	1047	1047	1036	1068
Estimator	PPML	PPML	PPML	PPML	PPML	PPML	PPML	PPML	PPML	PPML
Exports	Level	Level	level	Level	Level	Level	Level	level	level	Level
exp#year	No	no	no	No	yes	Yes	yes	yes	yes	Yes
business#year	No	no	no	No	no	No	Yes	yes	yes	Yes
exp#imp	No	no	no	No	no	No	No	no	yes	yes

Notes: imp#year fixed effects are not included because the estimation on panel data with China as the original exporter towards its import partners has dropped down almost all variables due to collinearities.

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Appendix Table A1: Definitions and sources of variables

variable Name	Content	Sources	Level
X	exports of manufactured goods, 1000 US\$	BACI, CEPII	bilateral
LSBCI	Liner Shipping Bilateral Connectivity Index	UNCTAD	Level
Yd	GDP of importers, 1000 US\$	CEPII	unilateral
Yc	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	CEPII	unilateral
Fta	1 if pair is currently engaged in a regional trade agreement (source: WTO supplemented by Thierry Mayer)	CEPII	bilateral
Contig	Dummy equal to 1 if countries are contiguous	CEPII	bilateral
Comlang	1 if countries share a common language spoken by at least 9% of the population	CEPII	bilateral
Business	Days required to start a business + number of procedures to start a business in China’s import partners	CEPII	unilateral

Appendix 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.