

The effect of liner shipping connectivity on green export performance: heterogeneous evidence from higher-income and lower-income exporters

Journal of
International
Logistics and
Trade

Received 6 December 2025
Revised 8 May 2026
28 May 2026
Accepted 26 June 2026

Nguyen Thi Thu Huong
*Faculty of Economics, Vietnam Maritime University,
Haiphong, Vietnam*

Abstract

Purpose – This study examines the association between bilateral liner shipping connectivity and green export performance, with particular attention to the extensive and intensive margins of green trade across higher-income and lower-income exporters.

Design/methodology/approach – Drawing on lists of environmentally friendly products provided by the OECD, WTO and APEC, this study compiles a dataset of 485 green goods identified at the six-digit level under the HS2002 classification. The analysis employs the Poisson Pseudo-Maximum Likelihood (PPML) estimation within a gravity model framework, using bilateral data from 150 countries over 2006–2021.

Findings – The empirical results indicate that stronger bilateral liner shipping connectivity is positively associated with green export performance. Specifically, a one-unit increase in the rescaled bilateral liner shipping connectivity index is associated with approximately a 35.7% increase in green export market share and a 3.44% increase in bilateral green export value. The findings also reveal heterogeneous patterns across subsamples. For higher-income exporters, liner shipping connectivity is positively correlated with the intensive margin but negatively associated with the extensive margin. For lower-income exporters, connectivity shows positive associations with both trade margins. These results are robust after addressing endogeneity using a control-function PPML approach.

Originality/value – This study offers novel evidence on the association between liner shipping connectivity and green export performance through both the extensive and intensive margins of trade across higher-income and lower-income exporters, thereby providing valuable insights for targeted green trade and maritime policies.

Keywords Liner shipping connectivity, Green exports, Extensive margin, Intensive margin

Paper type Research article

1. Introduction

The increasing global environmental challenges have intensified the need to facilitate green trade as a key pathway toward sustainable economic development (Deere Birkbeck, 2021). Green trade refers to the international exchange of environmentally friendly goods and services that promote sustainable development. Specifically, it focuses on minimizing damage to the ecosystem by promoting products, technologies, and business practices that prioritize environmental protection and resource efficiency (Mahajan *et al.*, 2023; Razelan *et al.*, 2024). Encouraging the development and trade of products that use fewer resources and generate lower emissions can stimulate innovation, green investment, and access to environmentally conscious markets (Dangelico *et al.*, 2017; El-Kassar and Singh, 2019). As a result, green trade not only helps countries pursue economic progress but also achieves long-term environmental



© Nguyen Thi Thu Huong. Published in *Journal of International Logistics and Trade*. Published by Emerald Publishing Limited. This article is published under the Creative Commons Attribution (CC BY 4.0) licence. Anyone may reproduce, distribute, translate and create derivative works of this article (for both commercial and non-commercial purposes), subject to full attribution to the original publication and authors. The full terms of this licence may be seen at <http://creativecommons.org/licences/by/4.0/>

Journal of International Logistics and
Trade
Emerald Publishing Limited
e-ISSN: 2508-7592
p-ISSN: 1738-2122
DOI 10.1108/JILT-12-2025-0117

goals (Wei *et al.*, 2023). However, the potential of green trade depends on how efficiently firms can access global markets. Thus, strengthening logistics and shipping services is crucial to ensure green products reach international markets and support the global transition towards sustainable production and consumption.

Liner shipping remains the backbone of global merchandise trade, handling over 80% of international trade volume and 70% of trade value by sea (UNCTAD, 2023). Over the past 2 decades, the global shipping network has become denser and increasingly efficient. According to UNCTAD's Liner Shipping Connectivity Index (LSCI), most countries have seen an increase in maritime connectivity. Such improved connectivity is driven by the growth of containerization, enhancements to port infrastructure, and strategic collaborations among shipping companies (Kang *et al.*, 2022; Pan *et al.*, 2022; Tovar and Wall, 2022). Nevertheless, such connectivity remains highly uneven. Developed economies and major transshipment hubs, such as Singapore, China, and the Netherlands, maintain superior access to global shipping networks. In contrast, many developing and least developed countries still face limited integration and higher trade costs, which hinder their ability to participate effectively in international trade, including green exports.

Liner shipping connectivity has been widely recognized as a fundamental driver of international trade and economic performance. Higher connectivity can reduce transportation and transaction costs, shorten delivery times, and enhance the reliability of maritime logistics, thereby fostering export competitiveness, trade diversification, and economic growth (Chen and Hasan, 2023; Del Rosal, 2024b; Fugazza and Hoffmann, 2017; Munim and Schramm, 2018). Moreover, enhanced maritime connectivity not only facilitates more efficient access to global markets but also enables firms to participate in global value chains by improving access to intermediate goods, technologies, and foreign demand (Guedidi *et al.*, 2025; Li and Liu, 2022; Zakia *et al.*, 2024). Especially in countries with geographical disadvantages, improvements in liner shipping connectivity play a crucial role in mitigating infrastructure constraints and promoting industrial upgrading, export expansion, and integration into global production networks (Hoffmann *et al.*, 2020; Xu *et al.*, 2023).

Although prior research has recognized the link between liner shipping connectivity and trade outcomes, most studies have concentrated on overall trade performance, offering limited insights into its implications for green exports. This shortcoming highlights the importance of examining how liner shipping connectivity is associated with environmentally sustainable trade. Understanding this relationship is essential for designing transport and trade strategies that align with global sustainability objectives and the transition to low-carbon economies. To address this research gap, this study examines the relationship between liner shipping connectivity and green export performance. Using an unbalanced panel of 150 countries spanning the years 2006–2021, this study assesses green export performance across multiple dimensions, including total export value, extensive margins (the diversification of green products), and intensive margins (the export intensity of existing green goods). In addition, separate subsample estimations are conducted for higher-income and lower-income exporters to explore potential heterogeneity in the observed associations. The findings of this study contribute to the literature on sustainable trade and maritime transport by providing new empirical evidence on the maritime connectivity–green trade relationship and by offering valuable insights for both researchers and policymakers seeking to promote environmentally sustainable economic growth.

2. Literature review

Extant research has consistently highlighted the positive relationship between liner shipping connectivity and international trade performance. Existing studies generally agree that stronger maritime connectivity, reflected in better route quality, fewer transshipments, and greater carrier competition, contributes positively to bilateral trade flows. For example, Fugazza and Hoffmann (2017) analyze bilateral trade data for 138 countries between 2006 and

2013 and find that the strength and quality of shipping connections are key drivers of trade between nations. Specifically, the analysis discovers a strong adverse effect from additional transshipments, with each extra stop along the route being linked to about 40% lower value of bilateral exports. Focusing on trade data of 157 economies in 2016, [Lin et al. \(2020\)](#) similarly demonstrate that increases in liner shipping connectivity not only directly foster a country's merchandise trade but also generate positive spillover effects that enhance trade performance in neighboring economies. Likewise, [Hoffmann et al. \(2020\)](#) find that stronger direct shipping connections and greater competition among carriers significantly enhance trade between South Africa and its trading partners. More recently, [Guedidi et al. \(2025\)](#) show that maritime connectivity plays an important role in facilitating participation in global value chains, particularly in manufacturing and agricultural trade.

Another growing strand of literature has increasingly emphasized the importance of green trade for sustainable economic development. Previous studies suggest that green exports help reduce environmental degradation, encourage green innovation, and support the transition toward low-carbon growth models ([Lee et al., 2023](#); [Tariq et al., 2024](#)). Existing research has also identified several determinants of green export performance. For instance, [Brandi et al. \(2020\)](#) show that environmental provisions in preferential trade agreements can reduce environmentally harmful exports while promoting trade in green products, particularly in countries with stronger environmental regulations. [Mealy and Teytelboym \(2022\)](#) further demonstrate that countries with greater economic complexity, stronger environmental innovation, and stricter environmental policies tend to exhibit comparative advantages in exporting more sophisticated green goods. Other studies highlight the importance of technological similarity, institutional conditions, and macroeconomic stability. Specifically, [He et al. \(2024\)](#) show that technological similarity between trading partners facilitates trade in environmental goods by reducing information barriers, while [Huong \(2025\)](#) finds that exchange-rate volatility negatively affects Vietnam's green exports through both the extensive and intensive margins. Collectively, these studies suggest that green trade performance is shaped by a combination of technological, institutional, and economic factors. However, the role of maritime connectivity in supporting green exports remains relatively underexplored.

From a theoretical perspective, maritime connectivity may influence green exports through several potential channels. First, greater maritime connectivity may reduce both transportation costs and shipping times, thereby improving the overall efficiency and predictability of international trade flows ([Chen and Hasan, 2023](#); [Fugazza and Hoffmann, 2017](#)). These reduced logistical barriers can enhance the competitiveness of green product exporters in global markets and expand their market access opportunities. Second, improved maritime links strengthen cross-border connections between firms and industries in global value chains, thereby facilitating the diffusion of knowledge, managerial expertise, and advanced technologies across countries ([Guedidi et al., 2025](#); [Li and Liu, 2022](#)). As a result, firms can adopt cleaner production techniques and incorporate green innovations into their production. For instance, improved shipping networks can facilitate the import of energy-efficient machinery or environmentally sustainable inputs, thereby supporting industrial upgrading and green transition at the firm level. Finally, by linking producers and consumers across various distances, liner shipping connectivity can stimulate competition among firms and industries worldwide. This competitive environment will encourage greater specialization according to each country's comparative advantage ([Hunt and Morgan, 1995](#)). In a well-connected maritime system, countries are likely to focus on sectors where they possess an environmental or technological edge. This process of specialization contributes to a structural shift toward higher-value and lower-emission productions. Nevertheless, these channels are discussed mainly at the conceptual level in the existing literature, while direct empirical evidence linking maritime connectivity and green export outcomes remains limited.

Another important limitation in the existing literature concerns the heterogeneous effects of maritime connectivity across countries. Previous studies suggest that the trade effects of connectivity depend heavily on infrastructure quality, logistics efficiency, and existing

shipping conditions. For example, [Liang and Liu \(2020\)](#) show that the benefits of port connectivity may weaken when port efficiency is low, suggesting that connectivity alone may not be sufficient to improve trade performance. Similarly, [Del Rosal \(2024a\)](#) finds that improvements in liner shipping connectivity generate stronger trade gains in lower-income economies, while [Del Rosal \(2024b\)](#) documents that the marginal trade benefits of connectivity improvements are particularly pronounced in structurally underconnected regions such as Africa and South America. These findings indicate that the relationship between maritime connectivity and trade outcomes may vary substantially across economic and logistical conditions. However, limited empirical attention has been devoted to whether such heterogeneous patterns also apply to green export performance, particularly across higher-income and lower-income exporters.

Collectively, the existing literature still leaves several important issues insufficiently explored. In particular, limited empirical evidence exists on how liner shipping connectivity relates specifically to green exports, how this relationship is reflected in the extensive and intensive margins of trade, and whether the observed patterns vary across subsamples classified by income levels. To address these gaps, this study examines the association between liner shipping connectivity and multiple dimensions of green export performance across 150 countries over the period 2006–2021. Particularly, by differentiating between higher-income and lower-income exporters, the study highlights heterogeneous patterns in how maritime connectivity is associated with green export performance across subsamples. The findings enrich the existing literature on sustainable trade and marine transport by providing empirical support for the maritime connectivity-green trade link, while also offering policy-relevant insights for supporting sustainable trade development.

3. Data and model specification

3.1 Liner shipping connectivity data

This study utilizes the Bilateral Liner Shipping Connectivity Index (BLSCI) compiled by the United Nations Conference on Trade and Development (UNCTAD), which quantifies the strength of both direct and indirect maritime links between countries. The index is constructed based on several factors, including the number of shared shipping routes, common transshipment connections, the size and frequency of vessel services, and the presence of major global carriers operating between ports. This index value ranges between 0 and 1. Higher BLSCI values indicate stronger maritime connectivity, reflecting greater accessibility and lower trade costs. The latest available dataset covers 157 countries for the period 2006–2021. Using the quarterly data provided by the UNCTAD, this study constructs annual BLSCI values by averaging the quarterly observations for each country pair within a given year. To make the values more interpretable, the resulting index is then multiplied by 10, resulting in an annual BLSCI that ranges from 0 to 10.

3.2 Green export performance

Green products are defined by production processes that utilize cleaner technologies to reduce pollution, preserve natural resources, and minimize environmental risks ([Bhardwaj et al., 2020](#); [Shamsi and Siddiqui, 2017](#)). Despite the growing importance of green trade, there is still no universally accepted classification of green products, as environmental characteristics can vary across technologies, production processes, and policy objectives ([Dong et al., 2023](#)). However, several international organizations have developed reference lists of environmentally friendly products. [Sauvage \(2014\)](#), on behalf of the OECD, identified 248 green commodities related to wastewater management, renewable energy monitoring, air pollution control, and environmental assessment. In a similar effort, the WTO compiled a list of 411 environmental goods consistent with the Doha Declaration's goal of reducing trade barriers for sustainable products ([WTO, 2011](#)), while the APEC proposed a smaller list of 48

products subject to tariff reductions to a maximum of 5% by 2015 (APEC, 2012). Drawing on the HS codes from these OECD, WTO, and APEC lists, this study constructs a comprehensive dataset of 485 green products classified at the 6-digit HS2002 level. This product list is then merged with bilateral trade data from the BACI database, developed by the Centre d'Études Prospectives et d'Informations Internationales (CEPII), to generate a detailed measure of bilateral green exports for empirical analysis.

Although these international classifications are widely used in empirical studies on green trade, several limitations should be acknowledged. First, the OECD, WTO, and APEC lists differ in their conceptual foundations and policy objectives, leading to differences in product coverage across classifications. Second, the HS-based classification system categorizes products according to customs codes rather than their actual production technologies or environmental performance. Consequently, certain products classified as green goods may also serve conventional industrial purposes, while the environmental impact of similar products may vary across countries and production methods. Nevertheless, these classifications provide a practical and internationally recognized framework for identifying environmentally related goods in cross-country trade analyses.

Traditionally, the extensive margin of trade is measured by counting the number of distinct products a country exports, while the intensive margin is represented by the average export value per product. However, these conventional measures overlook the relative importance of individual products within a country's export portfolio. For instance, consider a scenario in which country i exports only two products, k_1 and k_2 , to country j , with k_1 contributing 90% and k_2 only 10% of the total export value. Using standard indicators, both products would be weighted equally, thereby failing to reflect the dominant role of k_1 in the trade relationship between the two countries.

Building on the specifications from Baier *et al.* (2014) and Cheong *et al.* (2016), this study employs an alternative approach to overcome the aforementioned limitation. In particular, the extensive and intensive margins of bilateral green exports, represented by $EM_{i,j,t}$ and $IM_{i,j,t}$, are computed using the following set of equations:

$$EM_{i,j,t} = \frac{\sum_{k \in K_{i,j,t}} X_{W,j,t}^k}{\sum_{k \in K_{W,j,t}} X_{W,j,t}^k} \quad (1)$$

$$IM_{i,j,t} = \frac{\sum_{k \in K_{i,j,t}} X_{i,j,t}^k}{\sum_{k \in K_{i,j,t}} X_{W,j,t}^k} \quad (2)$$

where $X_{W,j,t}^k$ denotes the total value of global exports of green product k shipped to country j in year t , while $X_{i,j,t}^k$ represents the export value of green product k from country i to its trading partner j in the same year. $K_{W,j,t}$ refers to the set of all green products imported by country j from the rest of the world during year t , and $K_{i,j,t}$ indicates the subset of green products that country i exports to country j in year t .

The bilateral extensive margin of green exports from country i to destination j is defined as the ratio between the total value of global exports to j for the same set of products exported by i and the overall value of all green products imported by j from the world. This measure indicates the range of green products exported from i to j , weighting them according to their relative significance in the global green export portfolio to that destination. Similarly, the bilateral intensive margin represents the ratio of the total export value of green goods from country i to partner j to the aggregate value of global exports to j for those same green products. Consequently, the bilateral intensive margin reflects the share of country i 's green exports in world exports to j , within the subset of green products traded between the two countries.

Because the BACI database records only observed positive bilateral trade flows, the dataset employed in this study is an unbalanced panel with no zero-valued export observations. As a

result, the extensive margin reflects the breadth and diversification of green product categories within existing bilateral trade relationships, rather than the formation of entirely new trade links from zero to positive export flows. In this framework, the extensive margin captures the weighted coverage of green product categories exported by country i to destination j , while the intensive margin reflects the depth of exports within those existing product categories.

Both the extensive and intensive margins range from 0 to 1. The extensive margin measures the diversity and range of green products supplied by an exporting country to a specific partner, indicating the breadth of green product coverage within bilateral trade relationships. In contrast, the intensive margin reflects the depth or intensity of trade, indicating the magnitude of the export value for the green products already traded. These indicators provide a comprehensive view of both the breadth and intensity of green trade linkages between trading partners.

By multiplying the extensive and intensive margins of bilateral green exports, the resulting value represents country i 's share in total global green exports to partner j in year t , denoted by “*market_share_{i,j,t}*”:

$$\text{market_share}_{i,j,t} = \text{EM}_{i,j,t} \times \text{IM}_{i,j,t} = \frac{\sum_{k \in K_{i,j,t}} X_{i,j,t}^k}{\sum_{k \in K_{W,j,t}} X_{W,j,t}^k} \quad (3)$$

As a robustness test, this study also employs alternative indicators, including the total bilateral value of green exports (denoted by “*green_exp_value*”), the number of green products exported between partners (denoted by “*num_pro*”), and the average export value per green product (denoted by “*value_per_pro*”), to verify the consistency of the results derived from “*market_share*”, “*EM*”, and “*IM*”, respectively. In particular, “*num_pro*” serves as an alternative proxy for export scope and product diversification, while “*value_per_pro*” captures the average intensity of exports within traded product categories.

3.3 Model specification

The gravity model of trade is a well-established framework for analyzing the determinants of trade flows between countries. Originating from Newton's law of universal gravitation, the model suggests that trade volume between two nations increases with their economic size but decreases as the geographical distance between them grows (Yotov *et al.*, 2016). This study utilizes a gravity model for bilateral green trade exports, incorporating the BLSI, to examine the impact of maritime linkages on bilateral green export performance.

To derive unbiased estimates from the gravity model, it is essential to address several empirical issues that may distort the results. The first issue concerns multilateral resistance terms (MRTs). Bilateral trade is driven by both direct bilateral factors and external influences from trading partners (Yotov *et al.*, 2016). Following Olivero and Yotov (2012), this study includes importer-year and exporter-year fixed effects to control for MRTs. These high-dimensional fixed effects absorb all time-varying country-specific factors, such as economic conditions, trade policies, and infrastructure development, thereby isolating the bilateral variation of interest. As a result, the estimated coefficients are identified from within-country-pair variation over time.

The second issue relates to the heteroscedasticity of trade data. As emphasized by Silva and Tenreiro (2006), trade data frequently exhibits heteroscedasticity, which causes the estimated coefficients to be biased and inconsistent when the model is estimated in log-linear form using ordinary least squares (OLS). Thus, they propose the Poisson Pseudo Maximum Likelihood (PPML) estimator, which produces more reliable estimates under such conditions. In this study, the use of PPML is motivated primarily by its robustness to heteroscedasticity and its consistency with structural gravity specifications, rather than by the treatment of zero trade flows, since the BACI dataset only includes observed positive bilateral exports.

The third issue concerns the potential endogeneity of trade policy variables and macroeconomic indicators (Yotov *et al.*, 2016). To mitigate this problem, the study employs one-period lagged values of the potentially endogenous regressors, following the approach adopted in prior research such as Cho and Zheng (2021), Huong and Park (2023), and Huong and Nga (2026). This specification reduces concerns that contemporaneous trade outcomes influence explanatory variables. Accordingly, the baseline model is expressed as follows:

$$X_{i,j,t} = \exp(\alpha_0 + \alpha_1 BLSCI_{i,j,t-1} + \alpha_2 \ln DIST_{i,j} + \alpha_3 RTA_{i,j,t-1} + \alpha_4 COL_{i,j} + \alpha_5 COMLANG_{i,j} + \alpha_6 CONT_{i,j} + \gamma_{i,t} + \Omega_{j,t}) * \varepsilon_{i,j,t} \quad (4)$$

where $X_{i,j,t}$ denotes country i 's share in total global green exports to partner j in year t , denoted by “market_share”. $BLSCI_{i,j,t-1}$ represents the bilateral liner shipping connectivity between country i and country j in year $t-1$. $\ln DIST_{i,j}$ is the natural logarithm of the geographic distance separating the two countries, serving as a proxy for trade costs. $RTA_{i,j,t-1}$ is a binary variable that equals 1 if both nations participate in a regional trade agreement in year $t-1$, and 0 otherwise. $COL_{i,j}$ is a dummy variable that is set to 1 when a colonial or dependency relationship exists between the two countries, and 0 otherwise. $COMLANG_{i,j}$ equals 1 if the trading partners share an official or primary language, and 0 otherwise. $CONT_{i,j}$ takes the value of 1 if the countries share a common border, and 0 otherwise. $\gamma_{i,t}$ and $\Omega_{j,t}$ are exporter-year and importer-year fixed effects. The term $\varepsilon_{i,j,t}$ represents the error component.

Based on data availability, the study's final sample consists of 150 countries from 2006 to 2021. Table 1 reports the descriptive statistics and data sources of variables included in the analysis, while Appendix 1 lists the countries included in the empirical analysis.

Table 1. Summary statistics and data sources, 150 countries, 2006–2021

Variable	Obs	Mean	Std. dev.	Min	Max	Sources
market_share	212,720	0.011	0.039	0	0.933	The author's calculation using data from the BACI-CEPII database and green product lists proposed by Sauvage (2014), WTO (2011), and APEC (2012)
EM	212,720	0.265	0.296	0	1	
IM	212,720	0.027	0.086	0	1	
green_exp_value	212,720	227669.12	2253814.2	0.001	1.446e+08	
num_pro	212,720	76.803	110.946	1	483	
value_per_pro	212,720	1196.933	14657.99	0.001	2239341.3	The UNCTAD database
BLSCI	212,720	2.084	0.624	0.798	6.499	
RTA	212,720	0.329	0.47	0	1	Mario Larch's Regional Trade Agreements Database
ln(dist)	212,720	8.668	0.85	2.079	9.9	The CEPII's gravity dataset
COL	212,720	0.096	0.295	0	1	
COMLANG	212,720	0.175	0.38	0	1	
CONT	212,720	0.02	0.141	0	1	

Source(s): The author's calculation using Stata 14 software

3.4 Data analysis

Figure 1 illustrates the changes in the average green export value (line graph) and the average BLSCI (bar graph) across 150 countries from 2006 to 2021. In general, both indicators exhibit an upward trend, suggesting that maritime connectivity and the global trade in green products

have improved over time. However, the figure also shows several distinct fluctuations. To be more specific, the green export value initially surged before dropping sharply during the 2008–2009 global financial crisis. The recovery period from 2010 to 2014 saw a steady increase as governments implemented stimulus packages in response to the crisis. During 2014–2016, the value declined again, which may be due to slower economic growth in major economies such as China and weaker global demand for green goods. A similar downturn occurred between 2018 and 2020, likely due to heightened trade tensions, particularly the U.S.-China trade war, and the COVID-19 pandemic, which disrupted supply chains and temporarily dampened international trade flows. Nevertheless, green exports rebounded strongly in 2021, reflecting post-pandemic recovery and renewed commitments to green transitions. In terms of the BLSCI, the data shows a strong upward movement from 2006 to 2014, indicating significant improvements in maritime connectivity, infrastructure, and the expansion of global liner networks. This rise coincides with increasing globalization and port modernization efforts, especially in lower-income regions. However, after 2014, the index stabilized and exhibited slight fluctuations, suggesting that global connectivity had reached a mature phase.

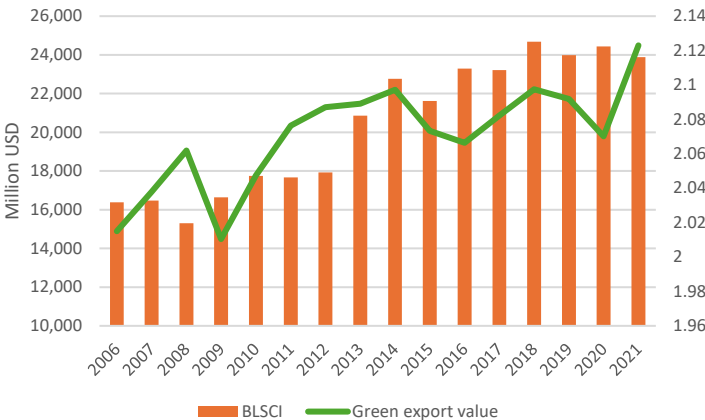


Figure 1. Green export value and bilateral liner shipping connectivity index across 150 countries, 2006–2021. Source: The author’s calculation based on data from the BACI-CEPII and the UNCTAD databases

4. Empirical results

4.1 Effects of liner shipping connectivity on green exports

This study begins by analyzing how liner shipping connectivity is associated with bilateral green trade using PPML estimators for the baseline model (4). The regression outcomes are reported in Table 2. Column (1) of Table 2 corresponds to the dependent variable “market_share”, whereas Column (2) uses “green_exp_value” for a robustness check. Given the inclusion of exporter–year and importer–year fixed effects, the estimates are identified from within-country-pair variation over time.

The estimation results reveal that the coefficients of the “BLSCP” variable remain positively significant across all model specifications. This consistent pattern indicates that stronger maritime connectivity between trading partners is positively associated with higher levels of bilateral green exports. Specifically, greater connectivity is linked to increases in both the total value of green exports and their relative market share in partner countries. The estimated

outcomes suggest that a one-unit increase in the BLSCI is associated with an approximate 35.7% rise in green export market share and a 3.44% increase in the bilateral green trade value. These findings are consistent with the view that improvements in maritime transport networks and shipping services may reduce trade costs (Chen and Hasan, 2023; Fugazza and Hoffmann, 2017), thereby improving access to foreign markets for environmentally friendly products. Furthermore, the positive associations observed for both green market share and green trade value suggest that connectivity improvements are associated not only with higher export volumes but also with a stronger competitive position in international markets of green products. These outcomes align with previous empirical studies emphasizing the role of maritime networks in promoting international trade. For instance, Fugazza and Hoffmann (2017), Lin *et al.* (2020), and Hoffmann *et al.* (2020) found that countries with stronger liner shipping connections experience higher levels of trade. In line with these findings, this study extends the literature by confirming that the benefits of maritime connectivity also apply to green exports, suggesting that maritime infrastructure development may serve as an important driver of sustainable trade.

Regarding the control variables, the findings broadly support the predictions of the gravity model. Variables reflecting economic and cultural proximity, including regional trade agreements (RTA), common borders (CONT), shared language (COMLANG), and colonial ties (COL), exhibit positive and significant effects on bilateral green trade, while geographical distance remains negative and significant across most of the models. Specifically, based on the estimates in Columns (1) and (2), a 10% increase in distance between trading partners is associated with a 7.75% decline in green market share and a 5.95% drop in bilateral green export value. In contrast, joint participation in a regional trade agreement increases green market share and trade value by approximately 19.84 [1] and 48.14 [2] percent, respectively. These outcomes are consistent with previous gravity-based studies such as Anderson and Van Wincoop (2003) and Baier and Bergstrand (2007), which emphasize that trade diminishes with distance but strengthens through institutional integration. Likewise, the positive roles of common borders, shared language, and colonial ties support the arguments of Head and Mayer (2014), which suggest that cultural, historical linkages, and shared borders can reduce informational barriers and facilitate market access.

Table 2. Effects of liner shipping connectivity on green exports, 150 countries, 2006–2021

Variables	(1) market_share	(2) green_exp_value
$BLSCI_{i,j,t-1}$	0.357*** (0.0181)	0.0344* (0.0185)
$\ln DIST_{i,j}$	-0.775*** (0.0106)	-0.595*** (0.0130)
$RTA_{i,j,t-1}$	0.181*** (0.0153)	0.393*** (0.0215)
$CONT_{i,j}$	0.441*** (0.0246)	0.623*** (0.0240)
$COL_{i,j}$	0.267*** (0.0371)	0.453*** (0.0545)
$COMLANG_{i,j}$	0.565*** (0.0213)	0.0150 (0.0210)
Constant	2.264*** (0.122)	19.74*** (0.157)
Exporter-year FEs	YES	YES
Importer-year FEs	YES	YES
Observations	179,186	179,186

Note(s): Robust standard errors clustered at the country-pair level are shown in parentheses. Symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively

Next, to examine potential heterogeneity in the association between BLSCI and green exports, the sample of 150 exporting countries is divided into two subgroups based on their average GDP per capita. GDP per capita data are obtained from the World Bank’s World Development Indicators and measured in constant 2015 US dollars. Accordingly, the average GDP per capita for each country is computed over the 2006–2021 period, and the median (i.e. 50th percentile) value is used as the threshold for classification. As a result, 75 countries with an average GDP per capita above this threshold are categorized as higher-income countries, while the remaining 75 countries are classified as lower-income ones. Model (4) is then re-estimated separately for each subgroup of exporters, with the regression results presented in Table 3. In this table, Columns (1) and (3) report the estimates using “market_share” as the dependent variable, while Columns (2) and (4) employ “green_exp_value” for a robustness check.

As shown in Table 3, the estimated coefficients of the BLSCI variable appear larger in the subsample of lower-income exporters than in that of higher-income exporters, suggesting potential heterogeneity in the association between bilateral liner shipping connectivity and green export performance. This pattern indicates that, within country pairs over time, changes in connectivity are systematically associated with changes in green export outcomes, with the strength of this association potentially differing across subsamples. One possible interpretation of this pattern is that the role of maritime connectivity may vary across economic conditions, potentially reflecting differences in trade structures and the degree of integration into global shipping networks. These findings are broadly consistent with the literature that emphasizes the role of maritime connectivity in shaping trade performance, particularly in countries with lower initial levels of connectivity. For instance, Wilmsmeier and Hoffmann (2008) emphasize that connectivity is closely linked to trade competitiveness in developing regions, while Del Rosal (2024a, b) provide evidence that improvements in liner connectivity are associated with stronger trade responses in environments where baseline connectivity is relatively limited.

Table 3. Effects of liner shipping connectivity on green exports in subgroups of higher-income and lower-income exporters, 150 countries, 2006–2021

Exporters	Higher-income countries		Lower-income countries	
	(1) market_ share	(2) green_ exp_value	(3) market_ share	(4) green_ exp_value
Variables				
<i>BLSCI_{i,j,t-1}</i>	0.354*** (0.0201)	−0.0216 (0.0199)	0.743*** (0.0444)	0.363*** (0.0576)
<i>ln DIST_{i,j}</i>	−0.760*** (0.0110)	−0.584*** (0.0136)	−0.859*** (0.0301)	−0.999*** (0.0310)
<i>RTA_{i,j,t-1}</i>	0.177*** (0.0164)	0.426*** (0.0234)	0.395*** (0.0337)	0.322*** (0.0579)
<i>CONT_{i,j}</i>	0.279*** (0.0264)	0.655*** (0.0252)	0.927*** (0.0515)	0.700*** (0.0696)
<i>COL_{i,j}</i>	0.247*** (0.0435)	0.480*** (0.0665)	0.433*** (0.0488)	0.371*** (0.0562)
<i>COMLANG_{i,j}</i>	0.631*** (0.0227)	−0.0153 (0.0222)	0.110*** (0.0351)	0.236*** (0.0447)
Constant	2.322*** (0.131)	20.00*** (0.169)	0.802*** (0.309)	20.32*** (0.383)
Exporter-year FEs	YES	YES	YES	YES
Importer-year FEs	YES	YES	YES	YES
Observations	109,455	109,455	69,722	69,722

Note(s): Robust standard errors clustered at the country-pair level are shown in parentheses. Symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively

4.2 Effects of liner shipping connectivity on green export margins

This section examines the impact of BLSCI on the extensive and intensive margins of bilateral green trade. To achieve this, the baseline Model (4) is modified by replacing the dependent variable “*market_share*” with indicators representing the extensive and intensive margins. To examine potential heterogeneity in the association between BLSCI and green export margins, the extended Model (4) is estimated separately for the subsamples of higher-income and lower-income exporters. The regression findings are presented in Table 4. Columns (1)–(4) correspond to the higher-income exporters, while Columns (5)–(8) present those for the lower-income exporters. Columns (1), (2), (5), and (6) display results for the extensive margin, whereas Columns (3), (4), (7), and (8) report results for the intensive margin.

The regression results reported in Table 4 reveal distinct patterns in the association between liner shipping connectivity and the margins of green exports across subsamples. For higher-income exporters, liner shipping connectivity is positively associated with the intensive margin but negatively associated with the extensive margin. This pattern suggests that, within country pairs over time, improvements in connectivity are more closely related to increases in export intensity within existing product lines rather than to the expansion of the range of green products exported. One possible explanation is that higher-income economies are typically characterized by more advanced infrastructure and a stronger presence in higher-value green industries. Exporting firms in these economies often already operate with diversified green product portfolios and benefit from more efficient logistical and institutional environments, including well-functioning ports, streamlined customs procedures, and higher firm-level productivity. Under these conditions, further improvements in maritime connectivity may be associated with limited gains in expanding the range of green products and may exhibit diminishing returns in terms of product diversification. Instead, improvements in connectivity may allow firms to more efficiently utilize existing production capacity by increasing the reliability and efficiency of shipping services. This can facilitate the scaling up of exports within already established green product lines, thereby strengthening the association with the intensive margin. This interpretation is consistent with Fugazza and Hoffmann (2017), who argue that the trade-enhancing effects of shipping connectivity tend to be more pronounced in environments supported by efficient logistics and strong institutional frameworks. These conditions are commonly observed in higher-income economies.

For lower-income exporters, the results indicate a positive association between liner shipping connectivity and both the extensive and intensive margins of green exports. This result suggests that improvements in connectivity are linked to both a broader range of exported green products and higher export volumes within existing product lines. A plausible explanation lies in the structural conditions commonly observed in lower-income economies, where firms often face relatively high trade costs and limited access to efficient shipping services (Hummels, 2007; World Bank, 2023). In such environments, weak connectivity can restrict both the introduction of new green products and the expansion of existing export activities. Improvements in liner shipping connectivity are generally linked to lower transport costs, more reliable shipping schedules, and increased service availability (Chen and Hasan, 2023; Fugazza and Hoffmann, 2017). These changes may reduce barriers to exporting environmentally friendly goods. At the extensive margin, this could be reflected in a broader set of green products becoming feasible for export. At the same time, on the intensive margin, improved logistics conditions may support higher export volumes within existing product categories by facilitating more efficient production and delivery processes. This interpretation aligns with existing evidence highlighting the importance of logistics and connectivity in supporting export performance in developing regions. For example, Zakia *et al.* (2024) document that logistics infrastructure plays a crucial role in strengthening ASEAN countries’ access to global export markets. Especially, enhancements in the liner shipping connectivity index can raise export capacity by 2.82%.

Table 4. Effects of liner shipping connectivity on green export margins in subsamples of higher-income and lower-income exporters, 2006–2021

Variables	Higher-income exporters				Lower-income exporters			
	Extensive margin		Intensive margin		Extensive margin		Intensive margin	
	(1) EM	(2) num_pro	(3) IM	(4) value_per_pro	(5) EM	(6) num_pro	(7) IM	(8) value_per_pro
$BLSCI_{ij,t-1}$	−0.225*** (0.00464)	−0.181*** (0.00518)	0.623*** (0.0198)	0.0128 (0.0382)	0.0884*** (0.0109)	0.153*** (0.0119)	0.385*** (0.0570)	0.388*** (0.0927)
$\ln DIST_{ij}$	−0.395*** (0.00319)	−0.440*** (0.00382)	−0.222*** (0.0124)	−0.419*** (0.0282)	−0.470*** (0.00626)	−0.612*** (0.00698)	−0.0924*** (0.0291)	−0.574*** (0.0469)
$RTA_{ij,t-1}$	0.0120*** (0.00451)	0.00375 (0.00522)	0.165*** (0.0163)	0.378*** (0.0426)	0.173*** (0.00742)	0.166*** (0.00829)	0.190*** (0.0427)	−0.0519 (0.0638)
$CONT_{ij}$	−0.188*** (0.0154)	−0.172*** (0.0173)	0.582*** (0.0294)	0.934*** (0.0496)	0.252*** (0.0168)	0.249*** (0.0192)	0.732*** (0.0656)	0.741*** (0.0946)
COL_{ij}	0.105*** (0.0102)	0.134*** (0.0137)	0.0642 (0.0439)	0.0363 (0.107)	0.203*** (0.0122)	0.191*** (0.0144)	−0.141*** (0.0487)	0.383*** (0.0884)
$COMLANG_{ij}$	0.343*** (0.00560)	0.400*** (0.00689)	0.186*** (0.0212)	−0.148*** (0.0446)	0.345*** (0.00885)	0.383*** (0.0105)	−0.146*** (0.0422)	−0.428*** (0.0677)
Constant	3.164*** (0.0323)	9.353*** (0.0387)	−2.291*** (0.138)	12.90*** (0.322)	2.222*** (0.0719)	8.975*** (0.0803)	−2.918*** (0.319)	13.65*** (0.577)
Exporter-year FEs	YES	YES	YES	YES	YES	YES	YES	YES
Importer-year FEs	YES	YES	YES	YES	YES	YES	YES	YES
Observations	109,455	109,455	109,455	109,455	69,722	69,722	69,722	69,722

Note(s): Robust standard errors clustered at the country-pair level are shown in parentheses. Symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively

4.3 Addressing endogeneity

A key empirical challenge in estimating the effects of liner shipping connectivity on green export performance is the potential endogeneity of the BLSCI variable. Reverse causality may arise if stronger bilateral trade flows lead shipping lines to adjust routes, capacity, and service frequency, thereby improving connectivity. At the same time, omitted factors, such as port infrastructure quality, logistics efficiency, or institutional capacity, may jointly influence both maritime connectivity and trade outcomes, resulting in biased estimates.

To address these concerns, this study employs a control-function approach within the PPML framework. Building on the foundational work of Heckman (1979) and its extensions to nonlinear models by Rivers and Vuong (1988) and Wooldridge (2015), this method isolates the endogenous component of the explanatory variable in a first-stage regression and incorporates it directly into the structural equation. In this study, the component of bilateral liner shipping connectivity correlated with unobserved trade determinants is extracted through the first stage, and the resulting residual is subsequently included as an additional regressor in the PPML estimation.

To identify exogenous variation in liner shipping connectivity, this study constructs instrumental variables based on third-country connectivity dynamics using a shift-share design. Following the logic of Bartik (1991), the instruments combine predetermined exposure shares with time-varying external shocks. By relying on connectivity patterns from a base year, this approach exploits variation in global shipping conditions while limiting the risk that current trade outcomes influence the construction of the instruments. Specifically, two instruments are developed to capture exporter-side and importer-side exposure to global shipping network changes, as follows:

$$Z_{i,t}^{(x)} = \sum_{k \neq j} w_{ik}^{2006} x LSCI_{k,t} \quad (5)$$

$$Z_{j,t}^{(m)} = \sum_{k \neq i} w_{kj}^{2006} x LSCI_{k,t} \quad (6)$$

where $LSCI_{k,t}$ denotes the liner shipping connectivity index of the third country k at time t . This variable, obtained from the UNCTAD database, is a country-level indicator capturing the extent to which a country is integrated into global liner shipping networks. It is constructed from multiple components, including the number of scheduled shipping services, deployed container capacity, vessel size, and the number of shipping companies operating at national ports, thereby providing a comprehensive measure of maritime connectivity.

The exporter-side and importer-side weights w_{ik}^{2006} and w_{kj}^{2006} are constructed using bilateral liner shipping connectivity observed in a predetermined base year (2006), as follows:

$$w_{ik}^{2006} = \frac{BLSCI_{ik}^{2006}}{\sum_k BLSCI_{ik}^{2006}} \quad (7)$$

$$w_{kj}^{2006} = \frac{BLSCI_{kj}^{2006}}{\sum_k BLSCI_{kj}^{2006}} \quad (8)$$

where $BLSCI_{ik}^{2006}$ and $BLSCI_{kj}^{2006}$ denote bilateral liner shipping connectivity between country i and third country k , and between third country k and country j , respectively, measured in the base year. These weights represent normalized connectivity shares that reflect the relative importance of third countries within each country's shipping network.

Countries more strongly linked to major transshipment hubs receive larger weights, indicating greater exposure to connectivity shocks originating from these hubs. Normalization ensures that the weights sum to unity, allowing the instruments to be interpreted as weighted averages of third-country shocks while avoiding scale distortions and improving comparability across country pairs.

The rationale for employing third-country connectivity as an instrument lies in the network structure of maritime transport. Bilateral connectivity between two countries is influenced not only by their direct shipping links but also by their connections to intermediary countries functioning as hubs within global shipping networks. Changes in the connectivity of these third countries, driven by factors such as port expansion, technological upgrading, or network reconfiguration by shipping lines, may alter bilateral liner shipping connectivity through indirect channels.

The validity of these instruments relies on the exclusion restriction that third-country connectivity shocks affect bilateral green exports only through their impact on bilateral liner shipping connectivity, rather than through a direct channel. The plausibility of this assumption is strengthened by several features of the instrument construction and model specification. First, the instruments are constructed from connectivity changes occurring outside the exporter–importer pair, thereby reducing the likelihood that they directly capture bilateral trade dynamics. Second, the exposure weights are fixed in a predetermined base year and are therefore not influenced by contemporaneous trade outcomes or current shipping conditions. Third, the second-stage PPML specification incorporates exporter-year and importer-year fixed effects, which absorb time-varying country-specific factors such as infrastructure development, institutional quality, and macroeconomic conditions that may simultaneously influence maritime connectivity and export performance. Consequently, identification is derived from variation in external network shocks interacting with predetermined exposure patterns.

In the first stage, lagged bilateral liner shipping connectivity is regressed on the lagged values of the two instruments and the control variables from Model (4), while incorporating exporter–importer and year fixed effects. This specification is adopted because the shift-share instruments vary at the exporter–year and importer–year levels. Including exporter-year and importer-year fixed effects at this stage would absorb the identifying variation contained in the instruments and render them collinear with the fixed effects. The residual from this regression, denoted by “ $BLSCI_RESID_{i,j,t-1}$ ”, captures the endogenous component of bilateral liner shipping connectivity after conditioning on the instruments and exogenous covariates and serves as the control-function term in the second-stage estimation. In the second stage, this residual term is included in the PPML gravity model as an additional covariate. By doing so, the estimation helps account for potential endogeneity in liner shipping connectivity. To assess the relevance of the proposed instruments, additional first-stage and weak-identification diagnostics are conducted using an IV framework, and the results are reported in Table 5.

As shown in Table 5, the joint significance test rejects the null hypothesis that the coefficients on the exporter-side and importer-side instruments are simultaneously equal to zero ($F = 19.88, p < 0.001$), indicating that the instruments possess substantial explanatory power in predicting bilateral liner shipping connectivity. In addition, the Kleibergen–Paap rk LM statistic rejects the null hypothesis of underidentification ($LM = 36.53, p < 0.001$), suggesting that the instruments are sufficiently correlated with the endogenous regressor. Furthermore, the Kleibergen–Paap rk Wald F statistic equals 19.88, which exceeds the conventional Stock–Yogo critical value associated with a 15% maximal IV size and is very close to the more stringent 10% threshold (19.93). These findings indicate that the proposed instruments possess sufficient explanatory power and suggest that weak-instrument problems are unlikely to undermine the identification strategy.

Table 5. First-stage diagnostics for shift–share instruments

Statistic	Value
Joint instrument F-statistic	19.88
Prob > F	0
Kleibergen–Paap rk LM statistic	36.53
Kleibergen–Paap rk LM <i>p</i> -value	0
Kleibergen–Paap rk Wald F statistic	19.88
Stock–Yogo critical value (10%)	19.93
Stock–Yogo critical value (15%)	11.59
Exporter-importer FE	Yes
Year FE	Yes

Table 6 presents the PPML estimation results for Model (4), incorporating “ $BLSCI_RESID_{i,j,t-1}$ ”, to address the potential endogeneity of BLSCI. Column (1) reports estimates for the full sample, while Columns (2) and (3) correspond to subsamples of higher-income and lower-income exporters, respectively. Consistent with the baseline findings, lagged bilateral liner shipping connectivity remains positively and statistically significantly associated with green export performance across all specifications. The estimated coefficients also continue to suggest heterogeneous patterns across subsamples. In addition, the coefficient of “ $BLSCI_RESID_{i,j,t-1}$ ” is statistically significant, indicating the presence of endogeneity in bilateral liner shipping connectivity and supporting the need for the control-function correction.

Table 6. Effects of liner shipping connectivity on green exports with endogeneity correction

Exporters	Full sample	Higher-income countries	Lower-income countries
Variables	(1) market_share	(2) market_share	(3) market_share
$BLSCI_{i,j,t-1}$	0.434*** (0.0209)	0.439*** (0.0234)	0.946*** (0.0535)
$BLSCI_RESID_{i,j,t-1}$	−0.454*** (0.0440)	−0.479*** (0.0474)	−0.813*** (0.0960)
$\ln DIST_{i,j}$	−0.753*** (0.0108)	−0.732*** (0.0115)	−0.816*** (0.0317)
$RTA_{i,j,t-1}$	0.179*** (0.0153)	0.175*** (0.0164)	0.386*** (0.0334)
$CONT_{i,j}$	0.245*** (0.0358)	0.243*** (0.0436)	0.386*** (0.0486)
$COL_{i,j}$	0.548*** (0.0212)	0.614*** (0.0225)	0.101*** (0.0351)
$COMLANG_{i,j}$	0.439*** (0.0245)	0.280*** (0.0263)	0.900*** (0.0513)
Constant	1.891*** (0.131)	1.878*** (0.144)	0.0174 (0.341)
Exporter-year FEs	YES	YES	YES
Importer-year FEs	YES	YES	YES
Observations	175,539	108,002	67,526

Note(s): Endogeneity is addressed using a control-function approach with residuals constructed from first-stage regressions. Robust standard errors clustered at the country-pair level are shown in parentheses. Symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively

Table 7 presents the PPML estimates of the extended Model (4), where the dependent variable “*market_share*” is replaced by indicators of the extensive and intensive margins, and the control-function term “*BLSCI_RESID_{ij,t-1}*” is included to address potential endogeneity. The model is estimated separately for higher-income and lower-income exporters to examine the potential heterogeneous effects. Columns (1)–(2) and (3)–(4) report results for the higher-income and lower-income exporters, respectively. Columns (1) and (3) refer to the extensive margin, and Columns (2) and (4) correspond to the intensive margin. Consistent with the earlier findings, liner shipping connectivity remains positively associated with both trade margins in the subsample of lower-income exporters. In the subsample of higher-income exporters, connectivity continues to show a positive association with the intensive margin but a negative association with the extensive margin. The coefficient on the control-function residual remains statistically significant, further indicating the presence of endogeneity in bilateral liner shipping connectivity and supporting the need for the control-function correction.

Table 7. Effects of liner shipping connectivity on green export margins in subsamples of higher-income and lower-income exporters with endogeneity correction

Exporters	Higher-income countries		Lower-income countries	
Variables	(1) EM	(2) IM	(3) EM	(4) IM
<i>BLSCI_{ij,t-1}</i>	−0.261*** (0.00515)	0.734*** (0.0223)	0.124*** (0.0129)	0.521*** (0.0644)
<i>BLSCI_RESID_{ij,t-1}</i>	0.238*** (0.0112)	−0.669*** (0.0523)	−0.144*** (0.0245)	−0.469*** (0.119)
<i>ln DIST_{ij}</i>	−0.406*** (0.00318)	−0.190*** (0.0129)	−0.461*** (0.00660)	−0.0886*** (0.0296)
<i>RTA_{ij,t-1}</i>	0.00734 (0.00449)	0.165*** (0.0164)	0.171*** (0.00746)	0.172*** (0.0431)
<i>CONT_{ij}</i>	−0.184*** (0.0153)	0.577*** (0.0293)	0.242*** (0.0168)	0.696*** (0.0663)
<i>COL_{ij}</i>	0.105*** (0.0103)	0.0686 (0.0442)	0.198*** (0.0123)	−0.196*** (0.0492)
<i>COMLANG_{ij}</i>	0.339*** (0.00555)	0.177*** (0.0211)	0.340*** (0.00890)	−0.124*** (0.0422)
Constant	3.350*** (0.0334)	−2.812*** (0.147)	2.080*** (0.0793)	−3.215*** (0.336)
Exporter-year FEs	YES	YES	YES	YES
Importer-year FEs	YES	YES	YES	YES
Observations	108,002	108,002	67,526	67,526

Note(s): Endogeneity is addressed using a control-function approach with residuals constructed from first-stage regressions. Robust standard errors clustered at the country-pair level are shown in parentheses. Symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively

5. Conclusion and implications

This study examines the association between liner shipping connectivity and green export performance across 150 countries over the period 2006–2021. Employing a PPML gravity framework with exporter–year and importer–year fixed effects, the analysis identifies the relationship from within-country-pair variation over time. The empirical results show that stronger bilateral liner shipping connectivity is positively associated with both the market share and export value of green products. The findings also suggest potential heterogeneity

across subsamples, as the estimated association appears stronger in the subsample of lower-income exporters than in that of higher-income exporters.

Further analysis of trade margins reveals distinct patterns across subsamples. For higher-income exporters, liner shipping connectivity is positively associated with the intensive margin but negatively related to the extensive margin, suggesting that improvements in connectivity are more closely linked to strengthening export intensity within existing green product lines than to expanding the range of products exported. For lower-income exporters, liner shipping connectivity is positively associated with both the extensive and intensive margins of green exports, indicating that improvements in connectivity may be related to both broader participation in green product markets and stronger export performance within existing product categories. The results remain broadly robust after addressing potential endogeneity through a control-function PPML approach based on shift-share instruments constructed from third-country connectivity dynamics.

The results of this study carry several important policy implications. First, the baseline findings consistently show that bilateral liner shipping connectivity is positively associated with green export performance. Since the estimates are identified from within-country-pair variation over time, the results suggest that changes in maritime connectivity within existing trade relationships are systematically associated with changes in green export outcomes. From a policy perspective, this pattern highlights the potential relevance of improving the efficiency, reliability, and sustainability of maritime transport networks. Measures such as expanding direct liner shipping services, improving shipping frequency and schedule reliability, reducing transshipment dependence, and strengthening coordination between ports and customs authorities may contribute to more stable green trade flows. In addition, governments may consider developing green shipping corridors with major trading partners through coordinated investments in cleaner marine fuels, energy-efficient vessels, and harmonized environmental standards across ports and shipping operators.

Second, the differences observed across subsample estimations suggest that policies aimed at strengthening maritime connectivity may benefit from being tailored to country-specific economic and logistical conditions rather than adopting a uniform approach. For lower-income exporters, the positive association between liner shipping connectivity and both the extensive and intensive margins of green exports suggests that improvements in connectivity may support broader participation in green product markets as well as stronger export performance within existing product categories. Thus, policies focused on expanding direct shipping services, improving port connectivity, reducing customs clearance delays, and increasing regular liner services may contribute to alleviating logistics constraints on green exports. Investments in port modernization and digital trade facilitation systems, including digital customs systems, electronic cargo-tracking platforms, and paperless trade procedures, may also help reduce administrative costs and improve the predictability of cross-border green trade flows.

For higher-income exporters, the results indicate that improvements in connectivity are more strongly associated with the intensive margin than with the extensive margin. This pattern suggests that, in more established export systems, further gains from connectivity may be more closely linked to strengthening export performance within existing green product segments rather than expanding the range of exported products. Accordingly, policies aimed at improving shipping reliability, reducing congestion at major ports, enhancing intermodal transport coordination, and strengthening integration with high-value supply chains may be particularly relevant. At the same time, port decarbonization strategies, such as investments in energy-efficient port infrastructure, shore-side electrification, smart-port technologies, and low-carbon cargo-handling systems, may help improve both operational efficiency and environmental sustainability. In addition, stronger regional maritime integration strategies, including coordinated port development, harmonized logistics regulations, and enhanced cooperation among neighboring economies, may improve connectivity to global green value chains and support the long-term expansion of environmentally related trade.

Despite its meaningful contributions, this study is not without limitations. First, although the analysis employs exporter–year and importer–year fixed effects together with a control-function PPML approach to address potential endogeneity concerns, the estimated relationships should still be interpreted as associations identified from within-country-pair variation over time rather than as definitive causal effects. Second, the heterogeneity analysis is based on separate subsample estimations for higher-income and lower-income exporters using average GDP per capita classifications. Accordingly, the results should be interpreted as indicative of heterogeneous patterns across subsamples rather than as direct comparisons between groups. Third, while the study examines the extensive and intensive margins of green exports, the empirical framework does not directly identify the specific mechanisms through which improvements in maritime connectivity are associated with changes in green trade performance. Future research could strengthen causal identification by applying alternative empirical strategies or using quasi-experimental settings to further examine the relationship between maritime connectivity and green exports. Moreover, the heterogeneity analysis may be extended through the use of continuous indicators capturing economic development, logistics performance, or shipping connectivity conditions. In addition, future research could investigate the transmission channels through which liner shipping connectivity is associated with green trade margins, such as transport costs, shipping reliability, logistics efficiency, and integration into global value chains.

Notes

1. $(e^{0.181}-1)*100 = 19.84$.
2. $(e^{0.393}-1)*100 = 48.14$.

Supplementary material

The supplementary material for this article can be found online.

References

- Anderson, J.E. and Van Wincoop, E. (2003), “Gravity with gravitas: a solution to the border puzzle”, *American Economic Review*, Vol. 93 No. 1, pp. 170-192, doi: [10.1257/00028280321455214](https://doi.org/10.1257/00028280321455214).
- APEC (2012), “2012 leaders’ declaration: Annex C - APEC list of environmental goods”, available at: https://www.apec.org/meeting-papers/leaders-declarations/2012/2012_aelm/2012_aelm_annexc (accessed 20 September 2025).
- Baier, S.L. and Bergstrand, J.H. (2007), “Do free trade agreements actually increase members’ international trade?”, *Journal of International Economics*, Vol. 71 No. 1, pp. 72-95, doi: [10.1016/j.jinteco.2006.02.005](https://doi.org/10.1016/j.jinteco.2006.02.005).
- Baier, S.L., Bergstrand, J.H. and Feng, M. (2014), “Economic integration agreements and the margins of international trade”, *Journal of International Economics*, Vol. 93 No. 2, pp. 339-350, doi: [10.1016/j.jinteco.2014.03.005](https://doi.org/10.1016/j.jinteco.2014.03.005).
- Bartik, T.J. (1991), *Who Benefits from State and Local Economic Development Policies?*, W.E. Upjohn Institute for Employment Research, Kalamazoo, MI, available at: <https://doi.org/10.17848/9780585223940> (accessed 1 May 2026).
- Bhardwaj, A.K., Garg, A., Ram, S., Gajpal, Y. and Zheng, C. (2020), “Research trends in green product for environment: a bibliometric perspective”, *International Journal of Environmental Research and Public Health*, Vol. 17 No. 22, pp. 1-21, doi: [10.3390/ijerph17228469](https://doi.org/10.3390/ijerph17228469).
- Brandi, C., Schwab, J., Berger, A. and Morin, J.-F. (2020), “Do environmental provisions in trade agreements make exports from developing countries greener?”, *World Development*, Vol. 129, 104899, doi: [10.1016/j.worlddev.2020.104899](https://doi.org/10.1016/j.worlddev.2020.104899).

- Chen, Y.-C. and Hasan, M.K. (2023), "Impacts of liner shipping connectivity and global competitiveness on logistics performance: the mediating role of the quality of port and infrastructure", *Transport*, Vol. 38 No. 2, pp. 87-104, doi: [10.3846/transport.2023.19372](https://doi.org/10.3846/transport.2023.19372).
- Cheong, J., Kwak, D.W. and Tang, K.K. (2016), "The distance effects on the intensive and extensive margins of trade over time", *Empirical Economics*, Vol. 50 No. 2, pp. 253-278, doi: [10.1007/s00181-015-0927-x](https://doi.org/10.1007/s00181-015-0927-x).
- Cho, M. and Zheng, X. (2021), "Bayesian estimation of dynamic panel data gravity model", *Econometric Reviews*, Vol. 40 No. 7, pp. 607-634, doi: [10.1080/07474938.2021.1889203](https://doi.org/10.1080/07474938.2021.1889203).
- Dangelico, R.M., Pujari, D. and Pontrandolfo, P. (2017), "Green product innovation in manufacturing firms: a sustainability-oriented dynamic capability perspective", *Business Strategy and the Environment*, Vol. 26 No. 4, pp. 490-506, doi: [10.1002/bse.1932](https://doi.org/10.1002/bse.1932).
- Deere Birkbeck, C. (2021), *Greening International Trade: Pathways Forward*, Global Governance Centre and the Forum on Trade, Environment & the SDGs (TESS), Geneva.
- Del Rosal, I. (2024a), "Maritime connectivity and agricultural trade", *Journal of Agricultural Economics*, Vol. 75 No. 1, pp. 153-168, doi: [10.1111/1477-9552.12548](https://doi.org/10.1111/1477-9552.12548).
- Del Rosal, I. (2024b), "Trade effects of liner shipping across world regions", *Maritime Business Review*, Vol. 9 No. 1, pp. 2-16, doi: [10.1108/MABR-06-2023-0040](https://doi.org/10.1108/MABR-06-2023-0040).
- Dong, K., Li, J. and Dong, X. (2023), "How do green product exports affect carbon emissions? Evidence from China", *Chinese Journal of Population, Resources and Environment*, Vol. 21 No. 2, pp. 43-51, doi: [10.1016/j.cjpre.2023.06.001](https://doi.org/10.1016/j.cjpre.2023.06.001).
- El-Kassar, A.-N. and Singh, S.K. (2019), "Green innovation and organizational performance: the influence of big data and the moderating role of management commitment and HR practices", *Technological Forecasting and Social Change*, Vol. 144, pp. 483-498, doi: [10.1016/j.techfore.2017.12.016](https://doi.org/10.1016/j.techfore.2017.12.016).
- Fugazza, M. and Hoffmann, J. (2017), "Liner shipping connectivity as determinant of trade", *Journal of Shipping and Trade*, Vol. 2 No. 1, 1, doi: [10.1186/s41072-017-0019-5](https://doi.org/10.1186/s41072-017-0019-5).
- Guedidi, I., Baghdadi, L. and Martínez-Zarzoso, I. (2025), "Trade facilitation in global value chains: assessing the role of maritime connectivity and trading across borders", *Journal of International Trade and Economic Development*, Vol. 34 No. 2, pp. 309-339, doi: [10.1080/09638199.2024.2399597](https://doi.org/10.1080/09638199.2024.2399597).
- He, S., Dai, X. and He, C. (2024), "Symphony of sustainability: how technology similarity impacts international trade patterns in environmental goods", *Environmental Science and Pollution Research*, Vol. 31 No. 16, pp. 23747-23765, doi: [10.1007/s11356-024-32634-1](https://doi.org/10.1007/s11356-024-32634-1).
- Head, K., Mayer, T. (2014), "Gravity equations: workhorse, toolkit, and cookbook", in Gopinath, G., Helpman, E. and Rogoff, K. (Eds), *Handbook of International Economics*, Vol. 4, pp. 131-195, doi: [10.1016/B978-0-444-54314-1.00003-3](https://doi.org/10.1016/B978-0-444-54314-1.00003-3).
- Heckman, J.J. (1979), "Sample selection bias as a specification error", *Econometrica*, Vol. 47 No. 1, pp. 153-161, doi: [10.2307/1912352](https://doi.org/10.2307/1912352).
- Hoffmann, J., Saeed, N. and Sødal, S. (2020), "Liner shipping bilateral connectivity and its impact on South Africa's bilateral trade flows", *Maritime Economics and Logistics*, Vol. 22 No. 3, pp. 473-499, doi: [10.1057/s41278-019-00124-8](https://doi.org/10.1057/s41278-019-00124-8).
- Hummels, D. (2007), "Transportation costs and international trade in the second era of globalization", *Journal of Economic Perspectives*, Vol. 21 No. 3, pp. 131-154, doi: [10.1257/jep.21.3.131](https://doi.org/10.1257/jep.21.3.131).
- Hunt, S.D. and Morgan, R.M. (1995), "The comparative advantage theory of competition", *Journal of Marketing*, Vol. 59 No. 2, pp. 1-15, doi: [10.1177/002224299505900201](https://doi.org/10.1177/002224299505900201).
- Huong, N.T.T. (2025), "Impact of exchange rate volatility on green export margins of Vietnam: a gravity approach", *Journal of International Economics and Management*, Vol. 25 No. 1, pp. 33-46, doi: [10.1108/JIEM-04-2025-0019](https://doi.org/10.1108/JIEM-04-2025-0019).
- Huong, N.T.T. and Nga, B.T.T. (2026), "Does aid for trade promote green product exports in recipient countries?", *Development Studies Research*, Vol. 13 No. 1, pp. 1-16, doi: [10.1080/21665095.2026.2654094](https://doi.org/10.1080/21665095.2026.2654094).

- Huong, N.T.T. and Park, D. (2023), "Impact of ICT development on bilateral intermediate input trade: considering cross-country heterogeneity", *The Journal of International Trade and Economic Development*, Vol. 32 No. 8, pp. 1291-1311, doi: [10.1080/09638199.2023.2255700](https://doi.org/10.1080/09638199.2023.2255700).
- Kang, L., Wu, W., Yu, H. and Su, F. (2022), "Global container port network linkages and topology in 2021", *Sensors*, Vol. 22 No. 15, 5889, doi: [10.3390/s22155889](https://doi.org/10.3390/s22155889).
- Lee, C.C., Olasehinde-Williams, G. and Gyamfi, B.A. (2023), "The synergistic effect of green trade and economic complexity on sustainable environment", *Sustainable Development*, Vol. 31 No. 2, pp. 976-989, doi: [10.1002/sd.2433](https://doi.org/10.1002/sd.2433).
- Li, D. and Liu, S. (2022), "The value of connectivity: evolution of global shipping services networks and the dynamics of global value chains", *Frontiers in Business, Economics and Management*, Vol. 4 No. 3, pp. 90-93, doi: [10.54097/fbem.v4i3.1144](https://doi.org/10.54097/fbem.v4i3.1144).
- Liang, R. and Liu, Z. (2020), "Port infrastructure connectivity, logistics performance and seaborne trade on economic growth: an empirical analysis on '21st-century maritime silk road'", *Journal of Coastal Research*, Vol. 106 No. sp1, pp. 319-324, doi: [10.2112/S1106-074.1](https://doi.org/10.2112/S1106-074.1).
- Lin, P.-C., Kuo, S.-Y. and Chang, J.-H. (2020), "The direct and spillover effects of liner shipping connectivity on merchandise trade", *Maritime Business Review*, Vol. 5 No. 2, pp. 159-173, doi: [10.1108/MABR-12-2019-0055](https://doi.org/10.1108/MABR-12-2019-0055).
- Mahajan, N., Kaur, N., Singh, V., Gupta, A. and Garg, N. (2023), "Green trade: transition towards a sustainable economy", *IOP Conference Series: Earth and Environmental Science*, Vol. 1279 No. 1, doi: [10.1088/1755-1315/1279/1/012023](https://doi.org/10.1088/1755-1315/1279/1/012023).
- Mealy, P. and Teytelboym, A. (2022), "Economic complexity and the green economy", *Research Policy*, Vol. 51 No. 8, 103948, doi: [10.1016/j.respol.2020.103948](https://doi.org/10.1016/j.respol.2020.103948).
- Munim, Z.H. and Schramm, H.-J. (2018), "The impacts of port infrastructure and logistics performance on economic growth: the mediating role of seaborne trade", *Journal of Shipping and Trade*, Vol. 3 No. 1, 1, doi: [10.1186/s41072-018-0027-0](https://doi.org/10.1186/s41072-018-0027-0).
- Olivero, M.P. and Yotov, Y.V. (2012), "Dynamic gravity: endogenous country size and asset accumulation", *Canadian Journal of Economics*, Vol. 45 No. 1, pp. 64-92, doi: [10.1111/j.1540-5982.2011.01687.x](https://doi.org/10.1111/j.1540-5982.2011.01687.x).
- Pan, J.-J., Zhang, Y.-F. and Fan, B. (2022), "Strengthening container shipping network connectivity during COVID-19: a graph theory approach", *Ocean and Coastal Management*, Vol. 229, 106338, doi: [10.1016/j.ocecoaman.2022.106338](https://doi.org/10.1016/j.ocecoaman.2022.106338).
- Razelan, N.D., Hamidi, H.N.A., Zainuddin, M.R.K., Khairuddin, N.A. and Zulkifli, M.S. (2024), "Impact of green trade on green growth in Malaysia: a dynamic ARDL simulation", *International Journal of Renewable Energy Development*, Vol. 13 No. 6, pp. 1015-1024, doi: [10.61435/ijred.2024.60413](https://doi.org/10.61435/ijred.2024.60413).
- Rivers, D. and Vuong, Q.H. (1988), "Limited information estimators and exogeneity tests for simultaneous probit models", *Journal of Econometrics*, Vol. 39 No. 3, pp. 347-366, doi: [10.1016/0304-4076\(88\)90063-2](https://doi.org/10.1016/0304-4076(88)90063-2).
- Sauvage, J. (2014), "The stringency of environmental regulations and trade in environmental goods", OECD Trade and Environment Working Papers, No. 2014/03, OECD Publishing, Paris.
- Shamsi, M. and Siddiqui, Z. (2017), "Green product and consumer behavior: an analytical study", *Pertanika Journal of Social Sciences and Humanities*, Vol. 25 No. 4, pp. 1545-1554, available at: [http://psasir.upm.edu.my/id/eprint/58330/1/JSSH%20Vol.%202025%20\(4\)%20Dec.%202017%20\(View%20Full%20Journal\).pdf](http://psasir.upm.edu.my/id/eprint/58330/1/JSSH%20Vol.%202025%20(4)%20Dec.%202017%20(View%20Full%20Journal).pdf) (accessed 20 September 2025).
- Silva, J.S. and Tenreiro, S. (2006), "The log of gravity", *The Review of Economics and Statistics*, Vol. 88 No. 4, pp. 641-658, doi: [10.1162/rest.88.4.641](https://doi.org/10.1162/rest.88.4.641).
- Tariq, M., Xu, Y., Ullah, K. and Dong, B. (2024), "Toward low-carbon emissions and green growth for sustainable development in emerging economies", *Sustainable Development*, Vol. 32 No. 1, pp. 959-978, doi: [10.1002/sd.2711](https://doi.org/10.1002/sd.2711).
- Tovar, B. and Wall, A. (2022), "The relationship between port-level maritime connectivity and efficiency", *Journal of Transport Geography*, Vol. 98, 103213, doi: [10.1016/j.jtrangeo.2021.103213](https://doi.org/10.1016/j.jtrangeo.2021.103213).

-
- UNCTAD (2023), *Review of Maritime Transport 2023: Towards a Green and Just Transition*, United Nations, Geneva.
- Wei, S., Jiandong, W. and Saleem, H. (2023), “The impact of renewable energy transition, green growth, green trade and green innovation on environmental quality”, *Frontiers in Environmental Science*, Vol. 10, 1076859, doi: [10.3389/fenvs.2022.1076859](https://doi.org/10.3389/fenvs.2022.1076859).
- Wilmsmeier, G. and Hoffmann, J. (2008), “Liner shipping connectivity and port infrastructure as determinants of freight rates in the Caribbean”, *Maritime Economics and Logistics*, Vol. 10 No. 1, pp. 130-151, doi: [10.1057/palgrave.mel.9100195](https://doi.org/10.1057/palgrave.mel.9100195).
- Wooldridge, J.M. (2015), “Control function methods in applied econometrics”, *Journal of Human Resources*, Vol. 50 No. 2, pp. 420-445, doi: [10.3368/jhr.50.2.420](https://doi.org/10.3368/jhr.50.2.420).
- World Bank (2023), *Connecting to Compete 2023: Trade Logistics in an Uncertain Global Economy – The Logistics Performance Index and its Indicators*, World Bank Group, Washington, DC, available at: <http://documents.worldbank.org/curated/en/099042123145531599> (accessed 20 September 2025).
- WTO (2011), *Report by the Chairman, Ambassador Manuel A. J. Teehankee, to the Trade Negotiations Committee: Committee on Trade and Environment in Special Session (TN/TE/20)*, WTO, Geneva, available at: <https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=Q:/TN/TE/20.pdf&Open=True> (accessed 20 September 2025).
- Xu, M., Deng, W., Zhu, Y. and Lü, L. (2023), “Assessing and improving the structural robustness of global liner shipping system: a motif-based network science approach”, *Reliability Engineering and System Safety*, Vol. 240, 109576, doi: [10.1016/j.res.2023.109576](https://doi.org/10.1016/j.res.2023.109576).
- Yotov, Y.V., Piermartini, R., Monteiro, J.-A. and Larch, M. (2016), *An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model*, WTO/UNCTAD, Geneva, doi: [10.30875/abc0167e-en](https://doi.org/10.30875/abc0167e-en).
- Zakia, M., Hanene, B., Samir, A. and Soumeia, D. (2024), “The impact of logistics performance on export market penetration: an econometric study using GMM”, *Financial Markets, Institutions and Risks*, Vol. 8 No. 4, pp. 51-63, doi: [10.61093/fmir.8\(4\).51-63.2024](https://doi.org/10.61093/fmir.8(4).51-63.2024).
-

Corresponding author

Nguyen Thi Thu Huong can be contacted at: huongntt.ktb@vimaru.edu.vn