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The Green Logistics Impact on International Trade: Evidence from Developed and Developing Countries

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Abstract: Economic globalization promotes industrial division and forms a large stream of products between countries all over the world, which leads to serious environmental problems. The purpose of this study is to explore the relationship between green logistics and international trade. Heckman's two-stage procedure is employed to estimate an augmented gravity model that specifically includes green logistics variables with the data of 113 countries and regions over the period between 2007–2014. The findings show that the logistics performance index (LPI) of exporting and importing countries are positively correlated with trade volume, and that the LPI of exporting countries positively affects trade probability. Taking the entire sample into account, the green logistics performance of exporting countries positively affects export probability and volume. For trade flows between developing–developing countries, developed–developed countries, and developed–developing countries, the green logistics performance of importing countries has a negative impact on the export volume of exporting countries. In terms of trade flow between developing–developed countries, the green logistics performance of importing countries has a negative impact on export probability and a positive impact on export volume. The present research results will assist governments and exporters in understanding the relationship between green logistics and international trade, and help improve their policies and green operations toward sustainable development.

Keywords: green logistics; international trade; Heckman two-stage procedure; augmented gravity model

1. Introduction

Since 2005, the total volume of global merchandise and service trade nearly doubled [1], which led to a large stream of goods all over the world. The ever-increasing consumer demand, production, storage, and transportation of these goods have resulted in a large negative impact on the environment [2]. Logistics, which is the fundamental industry for national economic development, is a key determinant affecting international trade competitiveness [3]. Previous studies have found that the performance of logistics, such as logistics infrastructure, logistics quality, and competence, etc., positively influences international trade [3–6].

Logistics industry is a very complex industry that needs to meet the customer requirements efficiently through planning, organizing, implementing, and controlling the flow of goods and services from the point of origin to the point of consumption [7]. The functions of logistics involve the transportation, storage, material handling, packaging, and information processing of all the logistics operations. The World Economic Forum found that greenhouse gas (GHG) emissions from logistics account for 5.5% of global GHG emissions [8]. Inefficient logistics operations have negative externalities on the environment and human health [9,10], which will lead to many environmental problems including massive greenhouse gas emission, pollution, noise, waste, and substantial fuel consumption. In contrast, many researchers have found that effective and efficient green supply chain management and green logistics can positively influence companies' economic, environmental, operational, and social performance [9,11–18].

With the increase of global production and consumption, the supply chain is lengthened, and transportation intensity is increased all over the world to meet the requirements of economic globalization. Subsequently, the amount of GHG emissions will maintain the growth trend and aggravate global warming. It is a tremendous challenge to accomplish the goals of the Paris Agreement, one goal of which is to control the rise of global mean temperature at less than two degrees above the pre-industrial level, which will greatly reduce the risk and impact of climate change. In recent years, research on green logistics and sustainable development became a concern for academics, organizations, and governments. The research field of green logistics includes green procurement, green transportation, green packaging, green distribution, reverse logistics, green supply chain design and controlling, and closed-loop supply chains; the field aims to promote environmental preservation and reduce the environmental externalities of logistics operations [2,12,15,19]. Green logistics practices could efficiently decrease the negative environmental impact and maintain or improve cost reduction, energy conservation, and competitiveness [15,20,21]. Moreover, many researchers found that environmental regulation issued by the government is a critical factor in promoting the green logistics practices of different sectors [15,22–24]. Hence, stricter regulations are formulated to promote green logistics practices, decrease GHG emissions, and minimize the damage to the environment throughout the globe, such as the United States' implementation of the Transportation Equity Act for the 21st Century in 1998 to reduce the environmental pollution, promote employment, and construct a safe transportation system. Since the establishment of European Union (EU, Brussels, Belgium) in 1993, many member countries have issued policies on green packaging to reduce the packaging waste pollution. Companies from different industries have to comply with these regulations and maintain their competitiveness. These regulations have effectively improved environmental performance [25].

While environmental regulations promote the sustainable development of green logistics and reduce environmental problems, they are new non-tariff trade barriers that take the form of trade measures such as the Restriction of Hazardous Substances (RoHS), the End of Life Vehicle Directive (ELV), and eco-labeling [15,26]. These regulations are set by many countries, especially developed countries, on the grounds of protecting the ecological environment and the lives and health of humans, animals, and plants, to restrict or prohibit the access to products and services from outside regions. They may have a negative impact on international trade [27]. To our best knowledge, there is no study on the relationship between green logistics and international trade. Considering the important role of logistics in the process of international trade and tremendous GHG emissions of logistics activities, it is worthwhile and urgent to do an empirical study on the impact of green logistics on international trade.

This paper makes several contributions. First, it is the first empirical study on the relationship between green logistics and international trade. Second, we propose an augmented gravity model with green logistics proxies, named logistics CO_2 intensity (LCI) and the environmental logistics performance index (ELPI) to examine the relationship between green logistics and international trade. Third, the whole sample of 113 countries and regions are divided into two categories using the Human Development Index (HDI) to examine the heterogeneous effect of green logistics on international trade within four samples: developing–developing countries, developing–developed countries, developed–developing countries, and developed–developed counties. Fourth, Heckman's two-stage procedure is used to tackle the sample selection bias problem.

The rest of this paper is organized as follows. Section 2 presents an overall literature review and research framework. Section 3 presents the methodological framework and data sources. Section 4 presents empirical results. Section 5 presents the conclusion and discussion.

2. Literature Review and Research Framework

2.1. Logistics Performance and International Trade

In recent years, a number of papers explored the decisive impact of logistics on international trade. Many of these studies detected the effect of logistics components or functions on trade, most of which focused on transportation cost or logistics infrastructure [28,29]. Among these studies, Limão and Venables [30] found that an improvement of infrastructure decreases transportation costs and increases trade volume. Sánchez et al. [31] and Clark et al. [32] discussed the relationship between port efficiency, transportation costs, and bilateral trade volume. They found that port efficiency improvement can reduce transportation costs and increase bilateral trade volume. Bensassi et al. [3] studied the relationship between logistics infrastructure and trade in Spain and found that the number, size, and quality of logistics infrastructure positively affect export volume.

Other studies used comprehensive logistics indicators, such as the Logistics Performance Index (LPI), which is a proxy variable of trade facilitation [6], to evaluate the influence of logistics on international trade. Behar and Manner [33] analyzed the relationship between the logistics performance of importing, exporting countries, and bilateral exports. They found that the logistics performance of exporting countries has a significant positive impact on export volume. Marti et al. [6] analyzed the impact of LPI and its components on trade flow in developing countries; the results revealed that LPI and all of its components have a significant positive effect on trade flows in all of the regions. Puertas et al. [5] examined the effect of LPI and its components on export in European Union (EU, Brussels, Belgium) and found that LPI and all of its components have a significant positive effect on export. Chakraborty and Mukherjee [34] researched the influence of LPI on export orientation and found that LPI has a significant positive impact on trade orientation. Using LPI as a moderator, Uca et al. [35] found that LPI has a significant and positive impact on trade volume, and the moderating effect between corruption perceptions index and trade volume is statistically significant. Therefore, the first hypothesis is proposed:

Hypothesis 1. *The logistics performance of exporting and importing countries is positively correlated with international trade.*

2.2. Green Logistics and International Trade

The notion of "green logistics" could be traced from 1990 [20]. The main aim of green logistics is to reduce the environmental externalities of logistics operations, such as GHG emissions, noise, and waste, and obtain balanced development among the economy, society, and the environment. Distinguishing from logistics, the main aim of which is to minimize cost [19], green logistics activities are motivated by environmental considerations. Dekker et al. [2] systematically reviewed the operation research literature of green logistics, and found that environmental externalities could be significantly decreased from the optimization of logistics activities. The factors that influence the implementation of green logistics include government environmental regulations, customers, internal company management, supplier management, social factors, and competitiveness [21,22,36–38].

As for papers on the effects of green logistics, many studies have tested the effects at the micro level, such as the relationship between green logistics, green supply chain management (GSCM), and firm performance. Studies that focused on this field have had mixed results, most of which suggested a positive relationship between GSCM performance and green logistics performance [14,16,39], while others found that the link between GSCM performance and green logistics performance was neutral or negative [40,41]. The probable reason for the conflicting results is that in the early stage of

GSCM or green logistics, companies had to invest tremendous resources, which increased cost and negatively affected the economic performance. The representative study from Lai and Wong [15] studied the influence of green logistics on the environmental and operational performance for Chinese manufacturing exporters and found that green logistics management positively correlated with the exporters' environmental and operational performance in reducing CO_2 emission, waste, and increasing productivity, which enhance the competitiveness of exporters. In order to gain more insights, Geng et al. [12] used the meta-analysis method to systematically review the link between GSCM and firm performance in Asian emerging economies and found that the relationships between GSCM and firms' economic, environmental, operational, and social performance are positive and significant. Moreover, many studies found environmental regulations to be a critical factor for the promotion of green logistics practices in different sectors [15,22,23]. Companies from different sectors have to comply with environmental regulations to maintain their competitiveness [25].

So, under pressure from environmental regulations, customers, other stakeholders, and internal management, exporters have to implement green logistics practices, such as green purchasing, green transportation, green packaging, obtaining ISO14000 certification, and reverse logistics, to mitigate the harm to the environment and promote their economic, operational, environmental, and social performance. In addition, green logistics practices that comply with the domestic or overseas environmental regulations can strengthen the competitiveness of exporters and increase the export volume. Therefore, the second hypothesis is proposed:

Hypothesis 2. *The green logistics level of exporting countries is positively correlated with the export volume.*

For the critical factors influencing the adoption of green practices, many researchers found environmental regulations to be the most important determinant in promoting green logistics practices [22,42]. While environmental regulations promote domestic green logistics environmental and operational performance and decrease the negative externalities of logistics [12,15], new environmental-based trade barriers are formed for foreign exporters. Numerous researchers studied the relationship between international trade and environment; however, the empirical literature on the relationship between the environmental regulations of importing countries and international trade is relatively scarce [43]. Some researchers have discovered a negative relationship between environmental regulations and international trade [29,44]. The probable reason for this result is that the environmental regulations of the importing countries, such as the End of Life Vehicle Directive (ELV) or Restriction of Hazardous Substances (RoHS), form new green trade barriers, which increase the technology threshold and lead to a decreased export volume for foreign exporters. Among these studies, the research of Van Beers and Van den Bergh is the most representative. Based on the Organization for Economic Co-operation and Development (OECD) data and using the gravity model, they found that the stringent environmental regulations of importing countries significantly and negatively affect the OECD country's export. The import volume of importing countries is negatively affected by the environmental regulations of the importing countries. Therefore, the third hypothesis is proposed:

Hypothesis 3. *The green logistics level of importing countries is negatively correlated with the export volume of exporting countries.*

3. Methodological Framework and Data Sources

3.1. Methodological Framework

In order to estimate the impact of logistics on international trade, the augmented gravity model, including logistics variables, was generally used in the former studies [3]. Generally, there are three determinative variables affecting trade flows between any two economies:

(1) the export volume of a country depends on its economic size (i.e., its GDP);
(2) the consumption volume of a country, which affects trade volume, varies with the size of the country's market (i.e., GDP of the importing country);
(3) the amount of trade is affected by the transportation costs, which correspond to the geographical distance between the pair of trading countries.

The simplest form of the gravity model used in international trade research is written as follows:

$$Exp_{ij} = \alpha_0 GDP_i^{\alpha_1} GDP_j^{\alpha_2} D_{ij}^{\alpha_3} \tag{1}$$

where Exp_{ij} denotes the export volume from country i to country j; GDP_i and GDP_j denote the GDP of countries i and j, respectively; D_{ij} denotes the geographical distance between country i and j; α_0 denotes a constant; and $\alpha_1, \alpha_2, \alpha_3$ denote parameters of variables.

Equation (1) shows that the export volume depends upon the *GDP* of country *i*, the *GDP* of country *j*, and the geographical distance between the two countries. Theoretically, the *GDPs* of countries *i* and *j* both have a positive impact on export volume. In contrast, the distance has a negative impact on export.

Equation (1) is not linear in parameters. The gravity model is estimated using a linear equation in most cases. The linear version of the gravity model is as follows:

$$lnExp_{ij} = \alpha_0 + \alpha_1 lnGDP_i + \alpha_2 lnGDP_j + \alpha_3 lnD_{ij} + \varepsilon_{ij} \tag{2}$$

where *ln* denotes natural logarithms, and ε_{ij} is the random error term.

Besides the economic factors, there are many semi-economic and political factors playing important roles in determining trade flow. Many researchers augmented the simple gravity model with these factors as control variables or dummy variables, such as sharing the same border and having the same language or colonial heritage [4–6]. In this study, the standard gravity model is augmented with these semi-economic and political variables. In addition, the *LPI* and green logistics variables are included in the gravity model to assess their impact on international trade.

There are two proxy indicators of green logistics performance, namely, logistics CO_2 intensity (*LCI*) and the environmental logistics performance index (*ELPI*). Logistics CO_2 intensity reflects the logistics CO_2 emission levels adjusted for the *GDP* of a country or region. It is the ratio of the logistics CO_2 consumption and the *GDP*. Logistics CO_2 consumption (*LCC*) refers to the physical quantity of CO_2 emissions from logistics operation. McKinnon found that transportation accounts for 80–90% of the carbon emissions of logistics operations [8]. We use the CO_2 emissions from transportation as a proxy for logistics CO_2 consumption. The *ELPI* reflects the green logistics performance level of a country or region. It is the ratio of the logistics performance index and the logistics CO_2 intensity. The lower the value of *LCI*, conversely, the higher the value of *ELPI*, indicating the higher level of green logistics and a more sustainable economic output. The equations for *LCI* and *ELPI* are as follows:

$$LCI_{it} = \frac{LCC_{it}}{GDP_{it}} \tag{3}$$

where LCI_{it} denotes the logistics CO_2 intensity of country i in year t; LCC_{it} denotes the logistics CO_2 consumption of country i in year t; and GDP_{it} denotes the gross domestic production of country i in year t.

$$ELPI_{it} = \frac{LPI_{it}}{LCI_{it}} \tag{4}$$

where $ELPI_{it}$ denotes the green logistics performance of county i in year t; LPI_{it} denotes the logistics performance of country i in year t; and LCI_{it} denotes the logistics CO_2 intensity of country i in year t.

The basic equations of this research are as follows: Equations (5) and (6) aim to assess the impact of LPI and green logistics on international trade, respectively.

$$\begin{aligned} lnEXP_{ijt} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnGDP_{jt} + \beta_3 lnLPI_{it} + \beta_4 lnLPI_{jt} + \beta_5 lnD_{ij} + \beta_6 ADJ_{ij} \\ +\beta_7 LANG_{ij} + \beta_8 COL_{ij} + \beta_9 RQ_j + \beta_{10} PS_j + \beta_{11} LLD_i + \beta_{12} LLD_j + \varepsilon_{ij} \end{aligned} \quad (5)$$

$$\begin{aligned} lnEXP_{ijt} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnGDP_{jt} + \beta_3 lnGL_{it} + \beta_4 lnGL_{jt} + \beta_5 lnD_{ij} + \beta_6 ADJ_{ij} \\ +\beta_7 LANG_{ij} + \beta_8 COL_{ij} + \beta_9 RQ_j + \beta_{10} PS_j + \beta_{11} LLD_i + \beta_{12} LLD_j + \varepsilon_{ij} \end{aligned} \quad (6)$$

where i denotes the exporting country, j denotes the importing country, t denotes the year (t = 2007–2014), and the other variables are defined as follows:

- EXP_{ijt} is the export volume from country i to country j at year t in constant 2010 US dollars;
- GDP_{it} and GDP_{jt} are the GDP values of country i and country j at year t in constant 2010 US dollars;
- GL_{it} and GL_{jt} are the green logistics performance of country i and country j at year t, while *LCI* and *ELPI* are used as proxies of green logistics performance;
- LPI_{it} and LPI_{jt} are the logistics performances of country i and country j at year t;
- D_{ij} is the weighted distance between the capitals of country i and country j;
- RQ_j denotes the regulatory quality of country j;
- PS_j denotes the political stability of country j;
- ADJ_{ij}, $LANG_{ij}$, and COL_{ij} are dummy variables, which denote whether country i and j share the common border, have the same language, and have the same colony heritage. The dummy variables' value is 1 if the exporting and importing countries have a common border, the same language, or colony heritage; otherwise, it is 0;
- LLD_i and LLD_j are dummy variables, if a country is landlocked, the value of this variable is 1; otherwise, it is 0;
- ε_{ij} is the random error term.

For international trade flow data, there are many zeros between many countries. A zero value, which is not missing information, may reflect the real trade volume between these countries. How to deal with these zeros is a key issue in estimating the proposed gravity model. If zeros are dropped, it may lead to estimation bias when the gravity model is estimated by ordinary least squares (OLS), because the appearances of the zero values are not random. To deal with this problem, Heckman (1979) proposed a two-stage procedure, which has two equations. The first stage (selection equation) is to calculate the probability of whether trade is carried out with a probit model. The second stage (outcome equation) is to estimate the trade volume between the mentioned countries with the OLS model. The equations for the two stages are as follows:

$$Pr(EXP = 1) = \Phi(\textstyle\sum_n \alpha^n Z^n_{j(t-1)}) \quad (7)$$

$$EXP_{ijt} = \textstyle\sum_n \alpha^n Z^n_{j(t-1)} + \beta\gamma_{ijt} + \varepsilon_{ijt} \quad (8)$$

Equation (7) is the first stage of Heckman's two-stage procedure, where $Pr(EXP = 1)$ means that the trade volume is more than zero; otherwise, it is 0. $\Phi(\sum_n \alpha^n Z^n_{j(t-1)})$ is the probability distribution function of standard normal distribution, and Z is the factor that affects trade flow between the pair of countries.

Equation (8) is the second stage of Heckman's two-stage procedure, where EXP_{ijt} is the actual export volume, and γ_{ijt} denotes the inverse Mills ratio, the function of which is to deal with the sample selection bias problem. γ_{ijt} can be calculated from the estimated outcome of the first stage:

$$\gamma_{ijt} = \varphi(\textstyle\sum_n \alpha^n Z^n_{j(t-1)} / \displaystyle\sum_n \alpha^n Z^n_{j(t-1)}) \quad (9)$$

where $\varphi(\cdot), \Phi(\cdot)$ are the probability density function and probability distribution function of standard normal distribution, respectively. If γ_{ijt} is not significant and equals zero, it means that there is a sample selection bias problem and the use of Heckman's two-stage procedure is valid.

Moreover, when we use Heckman's two-stage procedure, we need at least an identification variable for the probit model (as an exclusion restriction), which influences export probability but does not affect export volume. As in previous studies, this study uses entry costs, which have two indicators, namely, cost and the number of days and procedures to start a business in the importing country, as the identification variables [4,45]. Entry cost variables are dummy variables with a value of 1 if the relative cost or number of days and procedures to start a business is greater than the median value; otherwise, it is 0.

3.2. Data Sample and Data Source

There are 112 countries and one administrative region of Hong Kong in the sample. It includes 25 developed countries plus Hong Kong, and 87 developing countries, which are used in this paper to discuss the relationship between green logistics and international trade. The standard to divide the developed and developing countries is the Human Development Index (HDI), proposed by the United Nations Development Programme (UNDP, New York, NY, USA) in 1990. The countries that had incomplete or absent logistics and environmental data for the period 2007–2014 were left out of the sample.

Data for this research come from different sources. Table 1 presents a description of the variables and data sources that were used in this study. All of the explanatory variables are divided into seven categories: economic variables, environmental variables, trade facilitation variables, geographical variables, political variables, cultural variables, and entry costs.

Table 1. Definition of variables and data sources. UN: United Nations.

Variable	Description and Abbreviation	Data Source
Export (Exp_{ijt})	Export volume	UN Comtrade Database [46]
Economic variables		
Regional economic volume (LnGDP)	Natural logarithm of real GDP of exporting ($lnGDP_i$) and importing country ($lnGDP_j$)	The World Development Indicators (World Bank) [47]
Geographical variables		
Distance (LnD_{ij})	Natural logarithm of weighted distance between capital of exporting and importing country	GeoDist database (Mayer and Zignago, 2011) [48]
Common Border (ADJ_{ij})	Dummy variables: value of 1 if exporting and importing country share a common land border, 0 otherwise	GeoDist database (Mayer and Zignago, 2011) [48]
Landlocked (LLD)	Dummy variables: value of 1 if exporting (LLD_i) or importing country (LLD_j) is landlocked, 0 otherwise	GeoDist database (Mayer and Zignago, 2011) [48]
Environmental variables		
Logistics CO_2 intensity (LCI)	Natural logarithm of the ratio of CO_2 emission of transport and GDP of exporting (LCI_i) and importing (LCI_j) country	The World Development Indicators (World Bank) [47]
Environmental Logistics Performance Index (ELPI)	Natural logarithm of the ratio of LPI and LCI of exporting ($ELPI_i$) and importing ($ELPI_j$) country	The World Development Indicators (World Bank) [47]
Trade facilitation variables		
Logistics performance index (LPI)	Logistics performance index of importing (LPI_i) and exporting (LPI_j) country	Logistics performance index (World Band) [49]
Political variables		
Regulatory quality (RQ_j)	Regulatory quality level of importing country	World Governance Indicators (World Bank) [47]
Political stability (PS_j)	Political stability level of importing country	World Governance Indicators (World Bank) [47]

Table 1. *Cont.*

Variable	Description and Abbreviation	Data Source
Cultural variables		
Language ($Lang_{ij}$)	Dummy variables: value of 1 if exporting and importing country share a common language, 0 otherwise	GeoDist database (Mayer and Zignago, 2011) [48]
Colony (Col_{ij})	Dummy variables: value of 1 if exporting and importing country have common colony heritage, 0 otherwise	GeoDist database (Mayer and Zignago, 2011) [48]

Table 2 presents the descriptive statistic results and correlation coefficients of the main variables used in this research. The correlation coefficients of the core variables are below 0.6, and the variance inflation factors (VIF) of all of the variables are below 3.63, which means that there is no multicollinearity problem among variables used in this research. In order to solve the heteroskedasticity problem, we take the natural logarithm of the core variables' value with a larger standard deviation, which can control the heteroskedasticity in the original data.

Table 2. Correlation coefficients and descriptive statistics of core variables.

Variable	LnExp	$lnGDP_i$	$lnGDP_j$	lnD_{ij}	$lnLCI_i$	$lnLCI_j$	LLD_i	LLD_j	ADJ_{ij}	$Lang_{ij}$	Col_{ij}	PS_j	RQ_j
lnExp	1.000												
$lnGDP_i$	0.581 ***	1.000											
$lnGDP_j$	0.405 ***	−0.008 **	1.000										
lnD_{ij}	−0.266 ***	0.013 ***	0.013 ***	1.000									
$lnLCI_i$	−0.356 ***	−0.543 ***	0.005	0.067 ***	1.000								
$lnLCI_j$	−0.226 ***	0.005	−0.545 ***	0.067 ***	−0.009 **	1.000							
LLD_i	−0.147 ***	−0.287 ***	0.003	−0.061 ***	0.035 ***	0.000	1.000						
LLD_j	−0.140 ***	0.003	−0.286 ***	−0.062 ***	0.000	0.039 ***	−0.009 ***	1.000					
ADJ_{ij}	0.197 ***	0.033 ***	0.032 ***	−0.379 ***	−0.004	−0.003	0.023 ***	0.023 ***	1.000				
$Lang_{ij}$	0.087 ***	−0.005	−0.005	−0.141 ***	−0.007 **	−0.007 **	−0.044 ***	−0.045 ***	0.155 ***	1.000			
Col_{ij}	0.140 ***	0.081 ***	0.081 ***	−0.078 ***	−0.050 ***	−0.051 ***	−0.025 ***	−0.025 ***	0.151 ***	0.191 ***	1.000		
PS_j	0.117 ***	−0.001	0.203 ***	−0.057 ***	0.004	−0.503 ***	0.000	0.018 ***	0.005	−0.047 ***	0.010 ***	1.000	
RQ_j	0.223 ***	−0.004	0.446 ***	−0.076 ***	0.007 **	−0.680 ***	0.001	−0.133 ***	−0.001	−0.017 ***	0.050 ***	0.722 ***	1.000
Mean	16.797	25.434	25.436	8.663	−2.120	−2.119	0.175	0.174	0.026	0.098	0.017	−0.096	0.248
Std. Dev.	3.802	1.839	1.839	0.819	0.618	0.618	0.380	0.379	0.158	0.297	0.129	0.907	0.917
Min	0.693	21.782	21.782	4.742	−4.201	−4.201	0.000	0.000	0.000	0.000	0.000	−2.806	−2.139
Max	26.707	30.415	30.415	9.886	−0.199	−0.199	1.000	1.000	1.000	1.000	1.000	1.490	2.231
Obs	75,927	92,195	92,195	92,195	92,195	92,195	92,195	92,195	92,195	92,195	92,195	92,195	92,195

Note: p values are in parentheses. ** $p < 0.05$; *** $p < 0.01$.

4. Empirical Results

4.1. Main Results

Equations (5) and (6) are estimated for the export volumes for the whole sample of 113 countries and regions, with data over the period of 2007–2014. First, we test whether there is a sample selection bias problem for Equations (5) and (6). In an estimation of Equation (5), which aims to examine the relationship between the LPI and international trade, the lambda value is significantly not equal to zero. It indicates that there is a sample selection bias problem, so Heckman's two-stage procedure was used to estimate Equation (5). Meanwhile, in Equation (6), which aims to examine the relationship between the green logistics performance and international trade, the lambda value is not statistically significant, indicating that there is no sample selection bias problem. Therefore, a random-effects generalized least squares (GLS) regression model is used to estimate Equation (6), and robust standard errors are computed. Table 3 presents the estimation results for Equations (5) and (6).

Table 3. Impact of the Logistics Performance Index (LPI) and green logistics on trade flow for the entire sample of 113 countries and regions.

Variables	Logistics Performance Index		Logistics CO_2 Intensity (LCI)	Environmental Logistics Performance Index (ELPI)
	First Stage	Second Stage		
$LnGDP_i$	0.474 *** (0.019)	1.233 *** (0.013)	1.366 *** (0.013)	1.315 *** (0.013)
$LnGDP_j$	0.327 *** (0.017)	0.927 *** (0.013)	1.005 *** (0.013)	1.003 *** (0.013)
LnD_{ij}	−0.665 *** (0.035)	−1.364 *** (0.026)	−1.423 *** (0.025)	−1.408 *** (0.025)
LPI_i	1.471 *** (0.051)	0.625 *** (0.031)		
LPI_j	−0.079 (0.059)	0.160 *** (0.030)		
LCI_i			−0.269 *** (0.035)	
LCI_j			0.171 *** (0.034)	
$ELPI_i$				0.395 *** (0.031)
$ELPI_j$				−0.098 *** (0.031)
ADJ_{ij}	−0.503 *** (0.186)	1.403 *** (0.128)	1.281 *** (0.129)	1.318 *** (0.130)
LLD_i	−0.188 *** (0.057)	−0.415 *** (0.054)	−0.530 *** (0.062)	−0.528 *** (0.061)
LLD_j	−0.429 *** (0.060)	−0.796 *** (0.054)	−0.788 *** (0.061)	−0.799 *** (0.060)
RQ_j	0.312 *** (0.039)	0.114 *** (0.025)	0.187 *** (0.028)	0.179 *** (0.029)
PS_j	−0.078 *** (0.029)	0.026 (0.018)	0.041 * (0.022)	0.035 (0.022)
$Lang_{ij}$	1.053 *** (0.089)	1.032 *** (0.064)	1.068 *** (0.061)	1.073 *** (0.060)
Col_{ij}	−0.192 (0.255)	0.345 ** (0.150)	0.283 ** (0.122)	0.272 ** (0.123)
constant	−16.227 *** (0.625)	−29.423 *** (0.481)	−32.213 *** (0.482)	−36.244 *** (0.478)
lambda	−0.393 *** (0.075)		/	/

Note: Standard errors or robust standard errors are in brackets. "*", "**", "***" stand for significance level of 0.1, 0.05, and 0.01. "/" means there is no sample selection bias problem.

The results show that our target variable, the LPI coefficient of exporting countries, is positive and statistically significant in the first stage. The LPI coefficients of exporting and importing countries are positive and statistically significant in the second stage of the Equation (5) regression estimation results. This means that the LPI of an exporting country has a positive and significant impact on the export probability and volume. The LPI of importing countries has a positive significant impact on the export volume of foreign exporters. These results are consistent with previous studies [4,5,33–35]. In addition, the LPI coefficient of exporting countries is higher than that of importing countries, indicating that the impact of LPI on the international trade of exporting countries is bigger than that for importing countries. H1 is supported.

Equation (6) aims to study the relationship between green logistics and international trade. Regression results indicate that H2 is strongly supported. Our results show that the coefficient of LCI_i of exporting countries is negative, while the coefficient of the $ELPI_i$ of exporting countries is positive, and these coefficients are statistically significant, indicating that the green logistics performance of exporting countries is positively correlated with export volume. The higher the value of the green logistics level of exporting countries, the larger the export volume. The possible reason for these results is that exporters do some innovations into green logistics or implement green practices to decrease the negative externality of logistics with the pressure from government environmental regulations or other factors [15,22,36]. These innovations can promote their economic, environmental, operational, and social performance [12]. Hence, their competitiveness is strengthened, or new competitive advantages are fostered, which leads to a larger export volume. Meanwhile, by implementing green logistics practices, exporters can better comply with the environmental regulations of the importing country, which also can increase the export volume [50].

In contrast, the LCI coefficient of the importing countries is positive and statistically significant, while the ELPI coefficient of the importing countries is negative and statistically significant. Therefore, these variables have a negative relationship with export volume, indicating that the higher the green logistics performance, the lower the CO_2 intensity of an importing country and the smaller the export volume of the exporting countries. The possible reason for this result is that the environmental regulations of the importing country efficiently decrease CO_2 emissions and increase the carbon productivity of the importing country [17,25], but these regulations may become new green trade barriers for foreign exporters. Subsequently, the export volume decreases. This result supports the results of former studies [29,51,52]. H3 is strongly supported.

Values and the significance of the other control variables are as expected. The economic variables that impact the extent of supply and demand, namely the GDP of the exporting and importing countries, have a positive and statistically significant impact on trade flow. The GDP coefficient of the exporting countries is higher than that of the importing countries in all of the equations, which means that the impact level of the GDP of the exporting countries on trade probability and volume is higher than that of the importing countries. One geographical variable sharing the common border (ADJ_{ij}) decreases the transportation costs and has a positive impact on the trade volume. The other geographical variables—the distance between countries and being landlocked, which directly increase logistics cost—negatively correlate with the trade flow, as expected.

For political variables, the coefficients of regulatory quality are positive and significant in all of the equations, indicating that there is a positive significant relationship between the regulatory quality of importing countries and the export volume of exporting countries. This result means that the higher regulatory quality of importing countries corresponds to the higher probability and larger export volume of exporting countries. In contrast, the relationship between the political stability of importing countries and export probability is negative in the first stage in Equation (5). This result is consistent with the findings of Berden et al. [53] and Mattee et al. [4].

Cultural variables between the exporting and importing countries, such as sharing a common language ($Lang_{ij}$) and having common colony heritage (Col_{ij}), can facilitate trade and decrease trade costs as expected, and are thus positively correlated with trade flow and are statistically significant.

In order to further study the relationship between the green logistics and trade flow of economies with different levels of development, the countries in the sample are divided into two groups: 25 developed countries plus Hong Kong (these countries and region are collectively referred to developed countries in the next sections), and 87 developing countries. The criterion for this stratification is the HDI. We estimate Equation (6) with four samples: developing–developing countries (sample 1), developing–developed countries (sample 2), developed–developing countries (sample 3), and developed–developed countries (sample 4). First, we test if there is a sample selection bias problem for these four samples, and find that sample 1 and 2 indeed have the sample selection bias. Heckman's two-stage procedure is used to estimate these two samples. The results are presented in Table 4. For samples 3 and 4, there is no sample selection bias problem; these samples are estimated with GLS and robust standard errors are computed. Regression estimation results are presented in Table 5.

Table 4. Estimation results of sample 1 and sample 2 with Heckman's two-stage procedure. ELPI: environmental logistics performance index; LCI: logistics CO_2 intensity.

Variables	Developing–Developing Countries (Sample 1), LCI		Developing–Developing Countries (Sample 1), ELPI		Developing–Developed Countries (Sample 2), LCI	Developing–Developed Countries (Sample 2), ELPI	
	First Stage	Second Stage	First Stage	Second Stage		First Stage	Second Stage
LnGDPi	0.545 *** (0.020)	1.454 *** (0.024)	0.498 *** (0.020)	1.432 *** (0.023)	1.276 *** (0.029)	0.234 *** (0.040)	1.252 *** (0.030)
LnGDPj	0.342 *** (0.019)	1.016 *** (0.022)	0.336 *** (0.020)	1.021 *** (0.022)	1.250 *** (0.038)	0.185 *** (0.054)	1.246 *** (0.041)
LnDij	−0.645 *** (0.041)	−1.665 *** (0.047)	−0.646 *** (0.041)	−1.696 *** (0.046)	−1.201 *** (0.058)	−0.536 *** (0.083)	−1.227 *** (0.064)
LCIi	−0.386 *** (0.045)	−0.161 *** (0.046)			−0.348 *** (0.083)		
LCIj	−0.015 (0.048)	0.183 *** (0.043)			−0.389 *** (0.120)		
ELPIi			0.529 *** (0.043)	0.387 *** (0.043)		0.477 *** (0.091)	0.470 *** (0.059)
ELPIj			0.036 (0.046)	−0.088 ** (0.040)		−0.352 ** (0.137)	0.339 *** (0.087)
ADJij	−0.377 * (0.205)	1.447 *** (0.185)	−0.370 * (0.203)	1.439 *** (0.184)	1.668 *** (0.377)	0.072 (0.850)	1.679 *** (0.515)
LLDi	−0.834 *** (0.073)	−1.276 *** (0.101)	−0.807 *** (0.072)	−1.309 *** (0.099)	−0.655 *** (0.143)	−0.538 *** (0.150)	−0.718 *** (0.133)
LLDj	−0.628 *** (0.077)	-0.957 *** (0.093)	−0.624 *** (0.076)	−1.009 *** (0.092)	−0.639 *** (0.147)	−0.395 ** (0.157)	−0.658 *** (0.128)
RQj	0.184 *** (0.044)	0.303 *** (0.040)	0.176 *** (0.044)	0.297 *** (0.041)	−0.043 (0.091)	0.378 *** (0.141)	−0.020 (0.074)
PSj	−0.080 ** (0.031)	0.023 (0.027)	−0.080 *** (0.031)	0.178 (0.027)	−0.084 (0.084)	−0.195 (0.149)	−0.119 * (0.071)
Langij	1.168 *** (0.101)	1.312 *** (0.096)	1.139 * (0.100)	1.299 *** (0.095)	0.681 *** (0.159)	0.633 ** (0.247)	0.678 *** (0.183)
Colij	0.037 (0.417)	0.452 (0.369)	0.047 (0.412)	0.460 (0.367)	0.764 *** (0.229)	−0.126 (0.391)	0.757 *** (0.287)
constant	−15.44 *** (0.732)	−32.459 *** (0.855)	−15.019 ** (0.724)	−32.699 *** (0.839)	−39.913 *** (1.316)	−3.298 * (1.772)	−39.996 *** (1.344)
lambda	0.570 *** (0.140)		0.709 *** (0.134)		/	2.253 * (1.198)	

Note: Standard errors or robust standard errors are in brackets. "*", "**", "***" stand for significance level of 0.1, 0.05 and 0.01. "/" means there is no sample selection bias problem.

Table 5. Estimation results of sample 3 and sample 4 with generalized least squares (GLS).

Variables	Developed–Developing Countries (Sample 3)		Developed–Developed Countries (Sample 4)	
LnGDPi	1.005 *** (0.023)	0.983 *** (0.023)	0.802 *** (0.034)	0.787 *** (0.034)
LnGDPj	1.039 *** (0.017)	1.040 *** (0.017)	1.059 *** (0.034)	1.070 *** (0.034)
LnDij	−1.063 *** (0.033)	−1.063 *** (0.033)	−1.032 *** (0.037)	−1.029 *** (0.037)
LCIi	−0.541 *** (0.056)		−0.285 *** (0.056)	
LCIj	0.164 *** (0.041)		0.354 *** (0.070)	
ELPIi		0.567 *** (0.051)		0.287 *** (0.050)
ELPIj		−0.113 *** (0.036)		−0.323 *** (0.064)
ADJij	1.043 *** (0.265)	1.092 *** (0.273)	0.474 *** (0.123)	0.477 *** (0.124)
LLDi	0.063 (0.061)	0.082 (0.062)	0.010 (0.084)	0.016 (0.085)
LLDj	−0.500 ** (0.077)	−0.508 *** (0.077)	−0.113 (0.104)	−0.126 (0.105)
RQj	0.287 *** (0.034)	0.289 *** (0.035)	0.131 *** (0.050)	0.135 *** (0.049)
PSj	0.069 *** (0.022)	0.066 *** (0.022)	0.254 *** (0.044)	0.268 *** (0.044)
Langij	0.722 *** (0.097)	0.710 *** (0.097)	0.260 ** (0.117)	0.259 ** (0.118)
Colij	0.404 *** (0.130)	0.411 *** (0.131)	0.120 (0.161)	0.127 (0.161)
constant	−26.896 *** (0.729)	−27.149 *** (0.733)	−21.371 *** (1.187)	−21.339 *** (1.192)
Wald chi2	9555.32 ***	9151.25 ***	3112.07 ***	3087.35 ***

Note: Standard errors or robust standard errors are in brackets. "**", "***" stand for significance levels of 0.05, and 0.01.

Columns 2–5 and columns 6–8 of Table 4 are the estimation results of Equation (6) with the sample of developing–developing countries and developing–developed countries, respectively. Columns 2–3 and columns 4–5 of Table 5 are the estimation results of Equation (6) with the sample of developed–developing countries and developed–developed countries.

For exporting countries, the regression coefficients of LCI in sample 1 to sample 4 are negative and statistically significant; conversely, the coefficients of ELPI are positive and statistically significant, meaning that the green logistics performance of exporting countries is positively correlated to export. The higher the green logistics performance of the exporting countries, the greater the export probability and export volume, which aligns with the estimation results for the whole sample of 113 countries and regions.

For importing countries, the LCI coefficients of the second stage regression results of sample 1, sample 3, and sample 4 are positive and statistically significant, while the coefficients of the ELPI are negative and statistically significant. These results are similar to the estimation results for the whole sample of 113 countries and regions, indicating that the green logistics performance of importing countries is negatively correlated with the export volume among the countries in the sample. The higher the green logistics performance of the importing countries, the lower the export volume of foreign exporters. For sample 2, the coefficient of the green logistics variables of importing countries is different from the other samples. The coefficient of ELPI is negative in the first stage and positive in the second stage, while the coefficient of LCI is negative. All of the coefficients are statistically significant, indicating that a higher level of green logistics of importing countries corresponds to the lower export probability and larger export volume for foreign exporters. This result is consistent with the findings of Gao and Zhang [54], who analyzed the EU environmental regulations on the exports of Chinese small and medium enterprises, and found that these regulations increase the market access threshold; hence, in a short period, export volume decreased, but in the long run, export volume increased. The probable reason for the negative coefficient in the first stage is that developed countries issue more and stricter environmental regulations on the ground of protecting environment. In the short term, most companies in developing countries could not meet the standards of these regulations; subsequently, the trade probability decreased. The probable reason for the increased export volume is that the industries of developing and developed countries have their own comparative advantages. Generally, developed countries produce products with high technology and high added value, and products produced by developing countries have low added value. Meanwhile, developed countries relocate their manufacturing bases to new emerging countries, aggravating the global industry distribution. Developing countries play the role of material providers and manufacturing factories for most of the products consumed in developed countries [15]. However, demand for low added value products in developed countries does not decrease. Therefore, in the long term, companies from developing countries progressively comply with the requirements of these environmental regulations and enhance their competitiveness in the international competition. Hence, environmental regulations from developed countries can increase the export volume from developing countries to developed countries in the long run.

For other control variables, coefficient values and significance are in accordance with the estimation results of the whole sample of 113 countries and regions.

4.2. Sensitivity Analysis based on Time Period Difference

The results of a robustness check are presented in this section. The time period for the samples used in this paper is 2007–2014, including 2008 and 2009, when the global financial crisis broke out. This serious financial crisis had a significant impact on the global economy. For instance, global trade volume decreased by 17.5% from September 2008 to January 2009, compared with the same time period from 2007 to 2008. Many countries that were used in this research were influenced less than others by the financial crisis. The negative impact of this financial crisis presents a hysteresis quality. To deal with it, we set 2009 as a cut-off time for this financial crisis, divided the time period into two samples, 2007–2008 and 2010–2014, and divided the sample countries into eight samples. The estimation results of these samples are presented in Tables 6 and 7; however, only the coefficients of green logistics variables are reported because of space limitations. The results of Tables 6 and 7 show that the values of coefficients and significance of green logistics variables are unchanged.

Table 6. Estimation results with divided time periods for developing–developed countries and developing country to developing countries.

Variables	Developing–Developed Countries (2007–2008)	Developing–Developed Countries (2010–2014)		Developing–Developing Countries (2004–2008)		Developing–Developing Countries (2010–2014)	
		First Stage	Second Stage	First Stage	Second Stage	First Stage	Second Stage
LCIi	−0.526 *** (0.097)	−0.665 *** (0.128)	−0.430 *** (0.077)	−1.193 *** (0.086)	−0.372 *** (0.071)	−0.646 *** (0.062)	−0.238 *** (0.056)
LCIj	−0.516 *** (0.140)	0.682 *** (0.197)	−0.272 ** (0.118)	−0.034 (0.085)	0.213 *** (0.070)	0.033 (0.068)	0.128 ** (0.055)
ELPIi	0.655 *** (0.083)	1.129 *** (0.133)	0.497 *** (0.069)	1.298 *** (0.083)	0.594 *** (0.063)	0.870 *** (0.058)	0.451 *** (0.052)
ELPIj	0.515 *** (0.127)	−0.518 *** (0.181)	0.280 *** (0.107)	0.090 (0.082)	−0.069 (0.068)	0.017 (0.064)	−0.079 (0.051)

Note: Standard errors or robust standard errors are in brackets. "**", "***" stand for significance level of 0.05 and 0.01.

Table 7. Estimation results with a divided time period of developed–developing countries and developed–developed countries.

Variables	Developed–Developing Countries (2004–2008)	Developed–Developing Countries (2010–2014)	Developed–Developed Countries (2004–2008)	Developed–Developed Countries (2010–2014)
LCIi	−0.261 *** (0.066)	−0.299 *** (0.062)	0.035 (0.084)	−0.272 *** (0.062)
LCIj	0.229 *** (0.051)	0.179 *** (0.042)	0.196 ** (0.088)	0.244 *** (0.071)
ELPIi	0.319 *** (0.056)	0.375 *** (0.057)	0.057 (0.072)	0.270 *** (0.055)
ELPIj	−0.092 * (0.048)	−0.126 *** (0.040)	−0.133 * (0.079)	−0.227 *** (0.064)

Note: Standard errors or robust standard errors are in brackets. "*", "**", "***" stand for significance level of 0.1, 0.05, and 0.01.

5. Conclusions and Discussion

The rapid industrial modernization and globalization have led to numerous environmental problems, especially greenhouse gas emissions and waste [55]. The implementation of green logistics, through optimizing operations and reducing environmental externalities, can achieve a sustainable balance among environmental, economic, and social objectives for a company. This paper analyzes the effect of green logistics on international trade with the data of 113 countries and regions for the period between 2007–2014. The main contribution of this study is that it is the first literature that systematically studies the influence of green logistics on international trade. A better understanding of this effect could provide guidance for countries with different levels of development on creating better regulations for green logistics. It can also help enterprises implement green practices.

For this purpose, this paper proposes an augmented gravity model with green logistics variables to study the relationship between green logistics and international trade. Two proxy variables of green logistics, named logistics CO_2 intensity (LCI) and environmental logistics performance index (ELPI) were used in this study. The main findings of this research confirmed that the LPI of exporting and importing countries are positively correlated with trade volume. The LPI of exporting countries is positively correlated with trade probability. Moreover, the impact of LPI on the international trade of exporting countries is higher than that of importing countries. The green logistics performance of exporting countries has a positive impact on exports over the whole sample of 113 countries and regions, indicating that decreasing CO_2 emissions and increasing the CO_2 productivity of the logistics industry can increase the export volume. For trade flow between developing–developing countries, developed–developed countries, and developed–developing countries, importing countries' green logistics performance has a negative impact on the export volume of foreign exporters. In terms of trade flow between developing–developed countries, green logistics performance has a negative impact on export probability and a positive impact on export volume. Overall, the green logistics performance of an importing country decreases the probability or volume of export for foreign exporters, which is consistent with previous studies. The results of the robustness test show that the relationship between core variables of green logistics and international trade are unchanged.

This research has important policy and management implications. Based on the empirical findings, the following policy advice should be considered. The governments and exporters should pay more attention to improving the logistics performance and enhancing international competitiveness, such as improving infrastructure, promoting a higher quality of logistics services, and strengthening the application of modern information technology to improve the efficiency of customs and logistics tracing capabilities.

For governments, they can formulate and issue efficient and effective environmental regulations to create a good environment for the development of green logistics, especially green logistics policy on standards and licensing systems, which can significantly decrease carbon emissions [25] and promote the implementation of green logistics practices in different sectors [22,23]. It will help achieve a sustainable and balanced development among the economy, society, and the environment. At the same time, in order to ensure the effectiveness of these policies, other supportive policies, such as subsidies or decreased taxation, could be issued to guide enterprises to implement green logistics practices during the early stages of environmental policy implementation.

For exporters, they should proactively comply with environmental policies through the innovation of technology or optimization of operations and implementation of green practices in logistics operations, such as green transportation, green packaging, and green supply chain design, in order to maintain or promote their competitiveness in the global market. Moreover, exporters could build a reverse logistics system to cater to consumer needs and orient themselves toward sustainable development. With these activities, exporters can better improve their green logistics performance, and meet the requirements of domestic and international green logistics regulations, which can enhance their competitiveness and increase export volume.

Although some interesting results are confirmed in this study, some issues still remain for future research. Future studies could explore the effects of green logistics on different export sectors to examine the extent of influence for different products. Meanwhile, research could be carried out to study the relationship between different green logistics practices, including transportation, warehousing, other operations, and international trade.

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