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Exploring the Interplay of Socio-economic and Environmental Factors in Green Logistics: An Analysis of G7 Countries

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ABSTRACT

The study aimed to examine the socio-economic and environmental factors influencing green logistics in G7 countries. The study applied FMOLS and DMOLS techniques by using panel data spanning from 2007 to 2021. The findings indicate a positive association between green logistics indices and per-capita GDP growth, indicating that supply chain management is aligned with economic growth and corporate environmental policies to yield long-term benefits. Moreover, the panel causality analysis revealed one-way connections from a per-capita GDP and socio-economic factors to the logistics index. The study supports the "neutrality hypotheses" concerning the relationships between foreign direct investment (FDI), trade, and logistics index during the given time period. These findings emphasize the importance of adopting integrated sustainable chain management to promote environmental development. The study advocates for businesses to adopt a "go-for-green" approach to align with the environmental sustainability agenda. The findings provide valuable insights for policymakers, business leaders, and researchers working towards sustainable development in G7 countries.

1 Introduction

Socio-economic and environmental factors play a crucial role in green logistics, which is the practice of minimizing the environmental impact of logistics activities. Firstly, socio-economic factors are essential because they provide the context within which green logistics operates. These factors encompass aspects such as population demographics, income levels, and social norms. Understanding these factors is vital for designing and implementing effective green logistics strategies. For example, considering income levels helps identify affordability issues associated with adopting environmentally friendly technologies or practices. Demographic data can provide insights into consumer preferences and behaviors, enabling logistics providers to tailor their services accordingly. By addressing socio-economic factors, green logistics can be aligned with the needs and expectations of different stakeholders, leading to improved acceptance and adoption. Secondly, environmental factors are critical in green logistics as the primary objective is to reduce the environmental impact of logistics operations. Environmental factors include considerations such as energy consumption, greenhouse gas emissions, waste generation, and resource utilization. Green logistics aims to minimize these negative environmental impacts through various measures, such as optimizing transportation routes to reduce fuel consumption, using alternative fuels or electric vehicles, implementing sustainable packaging practices, and adopting efficient inventory management techniques. By considering environmental factors, green logistics can contribute to mitigating climate change, reducing pollution, conserving resources, and protecting ecosystems. It helps achieve sustainability goals by integrating environmental considerations into decision-making processes throughout the supply chain (Kim & Min, 2011). So, socio-economic, and environmental factors are essential in green logistics as they provide the foundation for designing sustainable and effective strategies. By considering these factors, logistics practitioners can align their operations with socio-economic realities and stakeholder expectations while minimizing the environmental impact. This integration of socio-economic and environmental dimensions is crucial for promoting a sustainable and resilient logistics system that contributes to the overall well-being of society and the planet (Kuzu & Önder, 2014).

The logistics performance index can have eco-friendly footsteps with supply chain management practices. The use of transportation vehicles, storage facilities, and packaging materials in logistics activities can contribute to environmental degradation and increase the ecological footprint of the supply chain. The implementation of green logistics practices, such as using low-emission transportation vehicles, reducing packaging materials, and optimizing transportation routes, can help mitigate these impacts and reduce the ecological footprint of the supply chain. Therefore, incorporating environmental factors and green logistics indices in logistics performance measurement can help identify areas of improvement (Acquaye *et al*., 2014, 2017; Kim and Min, 2011; Mariano *et al*., 2017; Van Hoek, 1999). The logistics performance can be promoted by domestic economic growth in GSCM. Efficient logistics performance can contribute to cost reduction, timely delivery, and improved customer satisfaction, which can lead to increased sales and revenue for firms and eventually contribute to the economic growth of the country. In turn, the economic growth of a country can also provide a boost to logistics infrastructure and capacity, which can further enhance logistics performance. Therefore, there can be a positive linkage between logistics performance indicators and economic growth in the context of GSCM practices (Bolumole *et al*., 2015; Marti *et al*., 2014; Puertas *et al*., 2014). Logistics performance indicators can influence common factors when integrated with GSCM. For example, logistics performance indicators can lead to increased customer satisfaction and better customer relationships, which can have a positive impact on social factors. Similarly, if logistics performance indicators such as the customs clearance process and consignments schedule are improved, it can lead to faster and more efficient trade and transport activities, which can have a positive impact on employment, income, and economic growth, thereby improving social factors.

This study has made a significant contribution to the existing research on green supply chain management (GSCM). Previous studies on GSCM have mainly focused on primary research by collecting data from different manufacturing firms and evaluating the anticipated amount of boundary administrators and collaborators about GSCM, logistics, and sustainable supply chain management. Some of these applications have linked their findings with policy inferences. Other researchers have found a relationship between GSCM practices and specific socioeconomic and environmental factors (Khan *et al*., 2017; Khan and Qianli, 2017). However, this study appears to have a wider research contribution by examining the relationship between logistics, macroeconomic factors, and sustainability in G7 nations. By considering a range of macroeconomic factors, such as financial development, transportation services, and economic growth, the study provides insights into the relationship between logistics activities and environmental sustainability.

Previous literature on logistics performance has used numerous indices to measure different factors of logistics activities but this study is different from earlier research in several ways. First, it uses six logistics performance indices to measure various factors of logistics activities. By using these specific logistics performance indicators, the study provides a more detailed and nuanced understanding of the relationship between logistics activities and environmental sustainability. This can help policymakers and businesses to identify specific areas where improvements can be made to ensure a more sustainable approach to logistics activities. The use of multiple logistics performance indices, environmental factors like carbon-fossil emissions, and growth-specific measures make the study unique and distinct from previous studies in the field of green logistics. The use of a 5-point Likert scale ranging from '1' to '5' to estimate the logistics performance indices allows for a more accurate assessment of the logistics activities of countries. Furthermore, the inclusion of growth-specific measures such as per capita GDP, FDI, and trade allows for a more comprehensive assessment of the common attitude of the green logistics index across G7 countries.

The panel co-integration techniques used in the study help to account for the interdependence among the variables in the panel data, increasing the results' reliability and validity. By identifying the short- and long-run relationships between the variables, the study provides insights into the dynamic nature. The study also highlights the importance of considering the social, economic, and environmental factors of continuity in green logistics activities. The study contributes to the existing literature by providing a comprehensive and integrated approach to analyzing GSCM practices and their impact on sustainability in a panel of G7 countries.

2 Literature Review

The literature suggests that there was a need for continued research in this area to better understand the complex link between logistics performance and socioeconomic and environmental factors. This knowledge could help inform policy decisions and guide businesses in their efforts to implement sustainable supply chain management practices.

Rao and Holt (2005) studied the importance of incorporating environmental considerations into supply chain management practices in order to remain competitive in today's global economy. This study underscores the need for careful planning, risk management, and effective communication among project stakeholders to ensure successful project outcomes in the construction industry. It highlights the importance of considering a range of factors, including socioeconomic and environmental factors, when evaluating supply chain management practices and project outcomes. This knowledge could help businesses and project managers make informed decisions and implement effective strategies to achieve their goals while also addressing sustainability concerns.

Petrini and Pozzebon (2009) recommended the importance of integrating sustainability considerations into business strategies and operations to ensure long-term success and competitiveness. The study highlighted the importance of carefully evaluating and selecting suppliers based on their sustainability performance, as well as developing effective communication and collaboration strategies to ensure a sustainable and efficient supply chain, Ruamsook *et al*. (2009) emphasized the need to consider the common and proper implications of sustainability practices, in the context of reverse logistics, which involves the management of product returns and the reuse of materials. By addressing these issues, businesses could not only improve their sustainability performance but also enhance their reputation and social responsibility. Nikolaou *et al.* (2013) and Bensassi *et al*. (2015) emphasized the importance of logistics performance and infrastructure for trade competitiveness and highlighted the need for continuous improvement in logistics to remain competitive in the global marketplace. Yang and Zhao (2016) analyzed data from 264 industries and found that both alternative achievement and combination have a significant positive impact on sourcing achievement. This suggests that firms should focus on improving their operational performance and integrating outsourcing activities to achieve better outsourcing outcomes. The findings of the study revealed certain significant trends and relationships. Firstly, the study observed that foreign cargo and trial jobs had a direct impact on increasing fossil emissions in Europe. This suggests that logistics activities associated with international trade contribute to climate deterioration. These findings highlight the need for sustainable and environmentally friendly practices in supply chain management to mitigate the negative environmental impacts of international shipments. Secondly, the study found that industrialization and trade liberalization policies were positively associated with carbon-fossil emissions. This indicates that countries with more polluting industries and increased trade openness tend to have higher levels of environmental degradation. These results underscore the importance of considering the environmental consequences when formulating industrialization and trade policies.

Nassani *et al*. (2017) made Environmental Kuznets Curve (EKC) for various air pollutants in BRICS countries, considering macroeconomic factors. The findings of the study revealed several noteworthy relationships. Firstly, the research suggests that as financial development increases, nitrous oxide emissions initially rise but then decline, indicating a potential turning point where further financial development leads to environmental improvements in terms of nitrous oxide emissions. Secondly, the study found an inverted link between economic development and greenhouse gas (GHG) emissions. This implies that as economic growth initially takes place, GHG emissions increase. However, beyond a certain point, economic growth starts to lead to declined GHG emissions, indicating the possibility of decoupling economic growth from environmental degradation. Additionally, the study revealed a negative impact on a country's sustainability agenda. This suggests that transportation services contribute to environmental damage, and policies should be implemented to reduce such negative effects and promote greener transportation alternatives. The study found that logistics activities significantly influenced economic growth through resource depletion.

Overall, these studies highlight the need for policymakers and businesses to take a more sustainable approach to economic development and logistics activities. It was essential to consider the long-term environmental impacts of economic growth and implement policies that promote sustainable development.

3 Data Sources and Methodology

The study used six indices to measure logistics performance and six variables to explain the factors that influence logistics performance. By analyzing the relationship between these indices and other variables, the study provides insights into the factors that influence logistics performance and may help identify areas for improvement in the logistics system.

Table 1

Variables Definition

Variables	Definition	Measurement level/Unit	Data source
Dependent variable			
LPI-1	Logistics professionals' perception of the ability to track and trace consignments when shipping to the country. Scores are averaged across all respondents.	(1=low to 5=high)	World Bank
LPI-2	Logistics professionals' perception of country's overall level of competence and quality of logistics services (e.g. transport operators, customs brokers). Scores are averaged across all respondents.	(1=low to 5=high)	World Bank
LPI-3	Logistics professionals' perception of the ease of arranging competitively priced	(1=low to 5=high)	World Bank

	shipments to a country. Scores are averaged across all respondents.		
LPI-4	Logistics professionals' perception of the efficiency of country's customs clearance processes (i.e. speed, simplicity and predictability of formalities). Scores are averaged across all respondents.	(1=low to 5=high)	World Bank
LPI-5	Logistics professionals' perception of how often the shipments to assessed country reach the consignee within the scheduled or expected delivery time. Scores are averaged across all respondents.	(1=low to 5=high)	World Bank
LPI-6	Logistics professionals' perception of country's quality of trade and transport related infrastructure (e.g. ports, railroads, roads, information technology). Scores are averaged across all respondents.	(1=low to 5=high)	World Bank
Independent variables			
CO_2	Carbon dioxide emissions	Kt	Climate Watch. 2020. GHG Emissions. Washington, DC: World Resources Institute.
FFE	Fossil fuel comprises coal, oil, petroleum, and natural gas products.	% of total	IEA Statistics © OECD/IEA 2014
GDPC	GDP per capita	constant 2015 US$	World Bank
FDI	Foreign direct investment	Net inflows (% of GDP)	World Bank
TOP	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	% of GDP	World Bank

The study used panel data from the World Bank database to estimate the factors of green logistics in the G7 countries. The proxies for macroeconomic factors, per capita GDP, FDI, and trade can provide insights into the overall economic performance, openness, and competitiveness of a country. The study also reproduced environmental factors through carbon-fossil emissions. Equations (1) to (6) in the study represent the econometric models used to analyze the determinants of green logistics in G7 nations.

$$lnLPI1_{i,t} = \alpha_0 + \alpha_1 lnCO_{2\,i,t} + \alpha_2 lnFFE_{i,t} + \alpha_3 lnGDPC_{i,t} + \alpha_4 lnFDI_{i,t} + \alpha_5 lnTOP_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$lnLPI2_{i,t} = \alpha_0 + \alpha_1 lnCO_{2\,i,t} + \alpha_2 lnFFE_{i,t} + \alpha_3 lnGDPC_{i,t} + \alpha_4 lnFDI_{i,t} + \alpha_5 lnTOP_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$lnLPI3_{i,t} = \alpha_0 + \alpha_1 lnCO_{2\,i,t} + \alpha_2 lnFFE_{i,t} + \alpha_3 lnGDPC_{i,t} + \alpha_4 lnFDI_{i,t} + \alpha_5 lnTOP_{i,t} + \varepsilon_{i,t} \quad (3)$$

$lnLPI4_{i,t} = \alpha_0 + \alpha_1 lnCO_{2\,i,t} + \alpha_2 lnFFE_{i,t} + \alpha_3 lnGDPC_{i,t} + \alpha_4 lnFDI_{i,t} + \alpha_5 lnTOP_{i,t} + \varepsilon_{i,t}$
(4)

$LNLPI5_{i,t} = \alpha_0 + \alpha_1 LNCO_{2\,i,t} + \alpha_2 LNFFE_{i,t} + \alpha_3 LNGDPC_{i,t} + \alpha_4 LNFDI_{i,t} + \alpha_5 LNTOP_{i,t} + \varepsilon_{i,t}$
(5)

$LNLPI6_{i,t} = \alpha_0 + \alpha_1 LNCO_{2\,i,t} + \alpha_2 LNFFE_{i,t} + \alpha_3 LNGDPC_{i,t} + \alpha_4 LNFDI_{i,t} + \alpha_5 LNTOP_{i,t} + \varepsilon_{i,t}$
(6)

Where LPI1 shows the logistics performance of the ability to track and trace consignments. LPI2 shows the logistics performance of the country's overall level of competence and quality of services (e.g. transport operators, customs brokers). LPI3 shows the logistics performance of the ease of arranging competitively priced shipments. LPI4 shows the logistics performance of the efficiency of the country's customs clearance processes. LPI5 shows the logistics performance of how often the shipments to the assessed country reach the consignee within the expected delivery time. LPI6 shows the logistics performance of a country's quality of trade and transport-related infrastructure. CO_2 shows the carbon dioxide emissions and FFE shows the fossil fuel emissions. However, GDPC shows the gross domestic product per capita and FDI shows the foreign direct investment and TOP shows the trade openness. The study used panel data for the G7 countries (Canada, France, Germany, Italy, Japan, the UK, and the USA) over the time period of 2007-2021. The time period is short because of data availability.

The study has employed nonparametric panel Fully Modified Ordinary Least Squares (FMOLS) and parametric Dynamic Ordinary Least Squares (DOLS) estimators to obtain robust parameter estimates. FMOLS is an extension of the ordinary least squares (OLS) method that takes into account the presence of unit roots and co-integration in time series data. FMOLS is also favored by Mehmood et al. (2018). FMOLS addresses issues like serial correlations and potential endogeneity, enhancing the reliability of the regression estimates. On the other hand, DOLS incorporates and lags in the regression model. Furthermore, the causality test helps to determine the causal link between the logistics performance index and sustainability in the G7 countries, indicating whether the relationship is bi-directional or uni-directional. This approach enhances the reliability of the findings and provides a solid econometric framework for interpreting the results.

4 Results

Based on the summary of panel unit root tests presented in Table 2, the following conclusions can be drawn regarding the integrated properties of the variables: LPI-1, LPI-2, LPI-4, LPI-5, LPI-6, FFE, and GDPC are first-order integrated variables, I(1), according to the IPS, and ADF tests. The PP test, however, suggests that these variables are stationary or integrated of order zero, I(0). LPI-3, CO_2, and FDI, TOP are confirmed as I(0) variables by both tests.

Table 2

Panel Unit Root Test

Variables	**LLC**		**IPS**		**ADF Fisher Chi-square**		**PP Fisher Chi-square**	
	Level	**First Difference**	**Level**	**First Difference**	**Level**	**First Difference**	**Level**	**First Difference**
LPI1	6.790	-0.945	1.571	-3.162*	8.346	33.710*	42.958*	138.552*
LPI2	4.196	-1.036	0.747	-3.182*	13.144	33.895*	42.449*	138.290*
LPI3	-3.014*	-1.904*	-4.221*	-3.550*	41.228*	37.248*	43.037*	133.798*
LPI4	2.057	-1.276	-0.154	-3.416*	19.762	36.012*	43.080*	138.535*

LPI5	1.755	-0.687	-0.239	-2.976*	19.298	32.045*	43.509*	137.663*
LPI6	1.733	-1.120	-0.309	-3.295*	20.724	34.921*	44.033*	137.758*
CO_2	-1.878*	-13.731*	0.121	-10.272*	10.265	91.714*	22.294	84.814*
FFE	1.292	-1.990*	1.476	-0.626	6.014	15.963	5.187	18.983
GDPC	-1.521	-10.771*	0.062	-7.945*	13.571	74.911*	13.001	79.919*
FDI	-5.421*	-10.323*	-4.703*	-8.679*	46.317*	80.884*	46.940*	105.517*
TOP	-3.757*	-8.968*	-1.673*	-6.601*	20.409	65.001*	20.517	95.350*

Note: Individual Intercept and Individual Trend. *, indicate a 1%, significance level.

Based on the analysis of panel co-integration by Pedroni's non-parametric approach presented in Table 3, it can be concluded that there is evidence of long-run co-integration between the variables in all six models. This suggests that there exists a stable long-run link between the LPI and the socio-economic and sustainable factors in G7 nations. The presence of co-integration implies that changes in one variable have a long-run impact on the other variables in the system, and have important implications for policy-makers, as it suggests that policies aimed at improving logistics performance could have long-lasting effects on the socio-economic and sustainable outcomes in G7 countries. The use of Pedroni's non-parametric approach also provides robust estimates of co-integration that are not affected by model misspecification or distributional assumptions, which adds to the reliability of the results.

Table 3

Panel Cointegration Test Results

Panel Statistics	LPI-1	LPI-2	LPI-3	LPI-4	LPI-5	LPI-6
Panel v-Statistic	-0.1161	-0.0628	-0.3767	-0.2073	0.0075	-0.1195
Panel rho-Statistic	0.5315	0.5529	0.7958	0.6359	0.4985	0.5998
Panel PP-Statistic	-8.9380	-8.7731*	-8.8288*	-8.6773*	-8.9290*	-8.7243*
Panel ADF-Statistic	-6.3301	-7.7953*	-7.7160*	-7.5189*	-8.9046*	-6.1126*
Group rho-Statistic	1.6167	1.6232	1.9385	1.7624	1.5407	1.6728
Group PP-Statist	-21.0836	-21.9379*	-15.2811*	-21.2308*	-19.0161*	-20.5248*
Group ADF-Statistic	-8.7158	-10.8663*	-9.0637*	-10.4951*	-11.7717*	-8.4612*

Note: *, indicates a 1%, significance level.

Table 4

Panel FMOLS and Panel DMOLS Results

Variables	**Panel FMOLS Estimator**						**Panel DOLS Estimator**					
	lnLPI1	**lnLPI-2**	**lnLPI-3**	**lnLPI-4**	**lnLPI-5**	**lnLPI-6**	**lnLPI-1**	**lnLPI-2**	**lnLPI-3**	**lnLPI-4**	**lnLPI-5**	**lnLPI-6**
lnCO_2	0.034	0.033	0.035	-0.027	0.036	0.011	0.021	0.054	0.225	-0.031	-0.025	-0.011
LnFFE	1.230*	1.308*	1.349*	1.416*	1.132*	1.189*	1.172*	1.244*	0.910	1.339*	1.287*	1.170*
lnGDPC	0.028	0.096	0.072	0.151	-0.042	0.018	0.848	0.937	1.003	1.075	0.664	0.843
lnFDI	0.008	0.009	0.012	0.011	0.008	0.009	-0.003	-0.002	-0.002	-0.001	-0.005	-0.001
lnTOP	-0.44*	-0.48*	-0.542	-0.46*	-0.43*	-0.383*	-0.74*	-0.75*	-0.566	-0.72*	-0.71*	-0.65*
					Diagnostics Statistics							
R-squared	0.206	0.226	0.194	0.224	0.196	0.204	0.583	0.594	0.561	0.598	0.569	0.587
Adjusted R^2	0.105	0.127	0.091	0.125	0.093	0.102	0.207	0.229	0.165	0.235	0.180	0.215
S.E of reg.	0.164	0.167	0.187	0.176	0.158	0.164	0.154	0.157	0.179	0.164	0.150	0.153
Long-run Var.	0.013	0.013	0.017	0.015	0.012	0.013	0.006	0.007	0.010	0.008	0.006	0.007

The results suggest that there is a complex interplay between the logistics performance index and environmental factors in the G7 countries. On one hand, environmental factors have a positive impact on the logistics quality services by reducing carbon emissions, and fossil fuel production as confirmed by the FMOLS results. Moreover, the positive impact of per capita growth on LPI-1 and the positive impact of environment on the logistics quality services quotation of "Green Logistics management" as a means of achieving sustainable logistics practices, Ahi and Searcy (2013), Dekker *et al.* (2012), Fahimnia *et al*. (2015), Laari *et al*. (2016), Lai *et al*. (2012). The study's results provide insights into the complex link between the green logistics index and socioeconomic and environmental factors in the G7 countries and highlight the importance of adopting sustainable logistics practices to improve logistics performance while minimizing environmental impact.

Similarly, the positive impact of CO_2 emissions, fossil fuel emissions, GDP per capita, and foreign direct investment on LPI-3 may not necessarily be desirable, as it suggests that higher levels of these factors are associated with more competitively priced shipments. However, the negative impact of trade on LPI-3 highlights the importance of considering economic sustainability in logistics practices. The findings also suggest that logistics social responsibility and reverse logistics practices are essential for improving logistics performance and sustainability in a panel of G7 countries and that companies need to allocate adequate resources to these practices in order to implement them effectively, Miao *et al.* (2012), Ho *et al.* (2012).

The results suggest that per capita growth is positively related to the LPI-4, indicating that higher income levels are conducive to better customs clearance processes. On the other hand, trade liberalization policies have found a negative impact on the customs clearance process, indicating that these policies may not be supporting efficient and effective customs clearance in G7 countries, Ng *et al.* (2013), Hausman *et al.* (2013). The negative impact of trade openness on the LPI-4 factor may be due to increased taxation charges on imported goods, which can slow down the customs clearance process. The findings of the study are consistent with previous research that highlights the importance of strong institutional frameworks and effective bureaucratic roles in regional development. Moreover, the study suggests that trade and organizational performance has a significant impact on increased logistics performance. The results of the study add important insights for scheme makers and practitioners in G7 countries, highlighting the need to improve customs clearance processes and create strong institutional frameworks to support regional logistics development.

Similarly, the results suggest that socio-environmental indicators are linked with the expected time for reaching consignments', they also indicate that foreign direct investment and CO_2 have a positive relationship with the LPI-5, meaning that higher levels of investment and carbon emissions are associated with better performance in this area. On the other hand, growth and trade have a negative link with the LPI-5, meaning that higher levels of growth and trade are associated with worse performance in this area. Overall, the results suggest that improving social infrastructure and reducing fossil fuel emissions could have positively related to logistics performance. However, the link between the socio-environmental factors and LPI is complex, and further research is needed to fully understand these relationships and identify effective policy interventions, Amiri-Khorheh *et al.* (2015), Gopal and Thakkar (2012), Vlachos, (2014).

The results suggest that CO_2 and FFE have a direct impact on the LPI-6, indicating that increased transport and trade activities contribute to higher carbon footprints. On the other hand, trade liberalization policies have an indirect association with the LPI-6, indicating that unsustainable transportation and production practices decrease the overall quality of transport infrastructure, Saslavsky and Shepherd (2014), Tongzon (2012), Marti *et al.* (2014).

Finally, the study provides some insights into the relationship between various factors and logistics performance in G7 countries, the results should be interpreted with caution. The study is limited to a specific time period and a panel of countries, and other factors that may impact logistics performance may not have been included in the analysis. Additionally, the causality analysis in Table 5 should be interpreted as suggestive rather than conclusive, as panel causality tests have their own limitations and may not fully capture the true causal relationships between variables.

Table 5

Dumitrescu Hurlin Panal Causality Test

Models	lnCO2	lnFFE	lnGDPC	lnFDI	lnTOP
1	≠	→	→	≠	←
2	≠	→	→	≠	≠
3	≠	→	→	≠	≠
4	≠	→	→	≠	←
5	≠	→	→	≠	←
6	≠	→	→	≠	←

Note: ← shows unidirectional causality from macroeconomic factor to LPIs, → shows unidirectional causality from LPIs to macroeconomic factor, and ≠ shows no causality between them. Null hypotheses are rejected on the basis of significance probability values of W-Statistics and Zbar-Statistics respectively.

The Dumitrescu Hurlin panel causality analysis provides insight into the direction of causality between the different variables and the logistics performance index. The findings of the study suggest various cause-effect.

1. Trade and LPI-1: The results indicate a uni-directional causality running from trade to LPI-1. This suggests that trade has a significant impact on logistics performance, influencing factors such as infrastructure, efficiency, and timeliness.

2. LPI-2 and Environmental Factors: Environmental factors, including fossil fuel production and per capita growth, are found to have a uni-directional causality link with the LPI-2. This implies that changes in environmental factors can impact logistics performance, particularly factors related to tracking and tracing, sustainability, and green logistics. On the other hand, FDI inflows, trade liberalization, and carbon dioxide emissions do not regulate any causality link with LPI-2.
3. LPI-2 and Social Factor: The LPI-2 homogenously caused the social factor, indicating that improvements in logistics performance can have positive social implications. However, FDI inflows and trade liberalization, as well as carbon dioxide emissions, do not have a causality link with LPI-2.
4. Per Capita Growth, Fossil Fuel Emissions, and LPI-4: Both per capita growth and fossil fuel emissions exhibit a uni-directional causality link with the LPI-4. This suggests that changes in per capita growth and fossil fuel emissions can influence logistics performance in areas such as customs performance and logistics competence.
5. Trade and LPI-6: There is a uni-directional causality with trade to the LPI-6, indicating that trade has a significant impact on the efficiency of border clearance processes and trade facilitation. However, the causality analysis did not find a relationship running the other way around.

Green logistics refers to the practices and strategies employed in the transportation and supply chain processes that minimize negative environmental impacts. By developing socio-economic and environmental factors, green logistics plays a crucial role in promoting environmental sustainability, which is essential for businesses pursuing environmentally friendly practices in G7 countries. The study found that carbon-fossil emissions have a substantial influence on various factors of logistics, such as the quality of services, competitive pricing of shipments, the risk of delays in delivering consignments on time, and the overall transport and trade infrastructure. These findings suggest that reducing carbon-fossil emissions is vital for enhancing logistics performance and efficiency. The findings highlight the significant impact of carbon-fossil emissions on various factors of logistics and support previous research emphasizing the importance of environmental sustainability and green practices, Shaw *et al.* (2010).

The references to Fahimnia *et al*. (2013) and Mariano *et al.* (2017) further support the importance of addressing carbon emissions and implementing sustainable practices in logistics and transportation. Fahimnia *et al.* (2013) highlight the necessity, as a means to enhance the probability of reducing carbon emissions in logistics activities. They argue that although there may be some little boost in the logistics, implementing a carbon pricing scheme can help integrate economic agendas with environmental objectives. The study suggests that by internalizing the cost of carbon emissions, companies and industries can be incentivized to adopt more sustainable modes of transportation. On the other hand, Mariano *et al.* (2017) focus on evaluating the behavior of transport logistics concerning carbon emissions. They emphasize that the volatility of carbon emissions in the transport sector poses challenges to achieving sustainable agendas. To effectively address the issue, they suggest the implementation of economic policies aimed at controlling greenhouse gas (GHG) emissions globally. By employing economic measures, such as regulations or incentives, countries can work towards reducing carbon emissions in transportation and improving overall sustainability. Both studies underline the importance of incorporating economic and policy measures to control and reduce carbon emissions in logistics and transportation.

It suggests that there is a positive link between per capita GDP and various logistics performance indicators, such as tracking and customs clearance process. The relationship is supported by the results obtained from a causality framework, indicating that the growth of logistics activities is driven by economic growth in these countries. For instance, this implies that as a country's economy grows, there is an increase in logistics volume, facilitated by a peaceful and healthy environment and favorable changes in the country's governance, Liu *et al*. (2007). This suggests that economic development and logistics activities are closely intertwined. This suggests that different modes of transportation may have varying degrees of impact on economic growth. The study conducted by Kuzu and Önder in 2014 provides evidence of a positive relationship between the development of the logistics sector and a country's economic growth. According to their findings, there is an indication that as a country's economy grows, it contributes to the development of its logistics infrastructure. This implies that higher levels of per capita income are associated with better logistics performance. The study underscores the importance of sustained per capita income for fostering the development of logistics infrastructure. A well-developed logistics sector is vital for supporting economic growth in the long run.

5 Conclusions and Policy Recommendations

The study covers the time period from 2007 to 2021. To achieve the objective, the study employs various econometric tests, including panel unit root tests, panel co-integration test, and panel FMOLS (Fully Modified Ordinary Least Squares), panel DOLS (Dynamic Ordinary Least Squares), and Dumitrescu Hurlin panel causality test. The panel unit root tests are used to determine the order of co-integration, indicating the presence of a long-term relationship between the variables. The results confirm that the variables are differenced stationary, suggesting the existence of a long-run co-integration relationship among them. The findings reveal that fossil fuel emissions and trade are significantly related to other logistics performance indexes. Similarly, there is a unidirectional relationship between social factors (which are not specified) and the "competitively priced shipments" indicator, indicating that certain social factors contribute to more competitively priced shipments. The causality analysis revealed socioeconomic and environmental factors (excluding FDI and carbon dioxide emissions). These findings contribute to our understanding of the relationships between various factors and logistics performance, highlighting the importance of socio-economic and environmental considerations in shaping logistics outcomes. The results suggest that CO_2, per capita GDP, and trade are important factors influencing logistics performance. The study also identifies the direction of causality between these variables, with some relationships being unidirectional and no causality.

The improvement of the research lies in its comprehensive approach, encompassing all six logistics indices as response variables and incorporating the three sectors social, economic, and environment. The study specifically addresses environmental sustainability by considering CO_2-FFE as an environmental factor. Moreover, the economic factors in the study include GDP per capita, trade, and FDI. By incorporating all six logistics indices and the three pillars of sustainability, the study provides a comprehensive understanding of the interrelationships and dynamics between these variables.

The scientific value of the study lies in its identification of the social and environmental factors crucial for achieving long-term sustainable growth, through green logistics. The study highlights the significant ecological footprint of logistics operations. The research employed in the study strengthens the robustness of the findings, providing a solid foundation for policy. The study successfully compiled logistics data from the World Bank and insights by applying sophisticated econometric modeling techniques. This task of data compilation and analysis is significant and contributes to the scientific rigor of the study. By comparing different regions, can be drawn regarding the viability and effectiveness of green logistics on a global scale. Finally, the study adds scientific value by identifying the socio-economic and environmental factors essential for sustainable growth through green logistics. The study's rigorous empirical modeling and data analysis contribute to its credibility, while future research can further enhance the understanding of green logistics by broadening the geographical scope.

However, these outcomes represent the potential causal relationships that the study has explored in the context. However, it is important to note that causality does not necessarily imply causation and further research may be needed to establish the precise nature and mechanisms of the relationship. The policies should aim to integrate social and economic considerations, with a focus on trade liberalization, attracting FDI, and improving logistic services and infrastructure.

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