

Environmental logistics performance indicators affecting per capita income and sectoral growth: evidence from a panel of selected global ranked logistics countries

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Abstract The objective of the study is to examine the long-run and causal relationship between environmental logistics performance indicators (ELPI) and growth-specific factors in a panel of 15 selected global ranked logistics countries over a period of 2007–2015. This study is exclusive as we utilized a number of LPI factors including logistics performance, logistics competence, and logistics infrastructure with mediation of sustainable factors, i.e., carbon dioxide (CO₂), fossil fuel, and greenhouse gas (GHG) emissions in a region. The results show that the per capita income, industry, manufacturing, and service share to GDP is affected by CO₂ emissions and GHG emissions. Logistics competence and infrastructure promote economic growth and sectoral value added, while energy demand and FDI inflows both are prerequisite for sustainable agriculture in a region. The causal relationships confirm that more energy demand results in an increase in economic growth, industry value added, and the service sector (i.e., feedback hypothesis), while the sustainable supply chain system

improves energy demand, FDI inflows, economic growth, and sectoral growth (i.e., conservation hypothesis) in a panel of countries.

Keywords Environmental logistics performance indicators · Carbon dioxide emissions · Fossil fuel energy consumption · GHG emissions · Per capita income · Sectoral growth · FDI inflows · Energy demand · Panel GMM estimator

Introduction

The notion of “green supply chain management (GSCM)” is traced from the early 1990s, i.e., Stevens (1990), Taylor (1992), Gupta (1995), Lamming and Hampson (1996), Min and Galle (1997), Walton et al. (1998), Green et al. (1998), Beamon (1999), etc. These studies mainly described the importance of GSCM for sustainable profit seeking through internal, external, and functional integration of the supply chain process. The logistics indicators are considered as a carrier to transport different air pollutants that greatly affected countries’ economic growth. The main contribution of the study is to assess the performance of logistics indicators under the presence of different air pollutants and their resulting impact on economic and sectoral growth contribution in a panel of 15 global ranked logistics countries over a period of 2007–2015. We believe that this study provides a good policy proposal for global health and wealth.

There are a number of studies that emphasize the need of environment-friendly logistics activities to promote public goods in order to achieve corporate sustainable profit, which is ultimately transformed into advancement of the sectoral growth of the countries. Vachon and Mao (2008) confirmed the positive linkage between environmental sustainability and the supply chain system and argued that the supply chain

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system significantly increases the intensity of environmental indicators, corporate pro-active environmental policies, and social development, which are pivotal for green supply chain management. Hutchins and Sutherland (2008) highlighted the need for corporate social sustainability under the premises of the supply chain system for competitive gains. Tsoulfas and Pappis (2008) emphasized the importance of logistics regulations that need to be addressed with sustainable instruments. The policies to mitigate environmental issues required strong corporate vision and wisdom to adjust the environmental concern in the production and consumption of goods that traveled through logistics activities across the countries. Neto et al. (2008) identified the possible linkage between corporate profitability and environmental considerations under an integrated logistics model and argued that government legislation for consumer protection considerably required sustainable logistics activities to promote eco-labeling goods across Europe. Pourmohammadi et al. (2008) developed an integrated environmental model to reduce environmental costs and increase economic growth. This model has its own merit that considerably minimizes industrial waste by sustainable logistics activities.

Kim and Lee (2012) investigated the relationship between stakeholder pressure and proactive environmental logistics practices under the premises of eco-oriented culture and found that proactive environmental practices are affected by stakeholder pressure, which is mediated by eco-oriental culture in the context of Korean manufacturing and logistics countries. Song et al. (2012) argued that the logistics industry largely consumes energy by gearing their logistics activities from road to train and found that traveling by road significantly decreases logistics energy usage while traveling by train consumes greater logistics energy which has a considerable impact on China's logistics activities. The policies for energy conservation are a vital component for the country's sound growth. Large et al. (2013) conducted a field survey of 750 logistics managers about procurement of logistics services and found that logistics service purchasers give high weightage to the social and ecological aspects of sustainable element that is prerequisite for integrating economic decisions toward healthy and wealthy logistics across the countries. Wei and Hehua (2015) examined the relationship between energy demand and economic growth of Shanghai, China, and found that logistics energy demand first decreases in the initial level of economic development; however, it substantially increases in the later development phase of the country. The policies should be reserved for reducing high logistics energy demand for balancing the energy flow in a country. Kim et al. (2016) discussed the importance of green supply initiatives in the construction industry to reduce environmental risks by balancing the contractor and supplier orders and further promote sustainability agenda in an industry's corporate vision. Yang and Zhao (2016) argued that logistics

outsourcing partners, i.e., clients and vendors, both are closely monitored in a highly volatile environment, as operational performance considerably enhances the integration of outsourcing partners in terms of financial incentives and overall firm strategic performance that contribute into the financial performance of inter-firm relationship management toward a sustainable environment. Mota et al. (2015, p. 14) argued that, “*Costumers and governments are pressuring companies to become more sustainable. However, the lack of research on how to incorporate these issues makes this a challenging task.*”

Research gap(s) and contribution of the study

The above cited literature confirmed that logistics performance indicators are significantly associated with the country's economic growth, while environmental risks delimit the growth of the industries, which required sustainable logistics activities to promote green supply chain management. The previous studies mostly focused on firm level analysis to assess green supply chain management practices, while the scope of the present study is far greater than the micro level analysis, as it is mediated by a unique intersection of logistics performance indices (i.e., logistics performance, logistics infrastructure, and logistics competence) with the nationwide environmental factors including CO₂ emissions, GHG emissions, and fossil fuel energy consumption, which are helpful in assessing the economic performance in a panel of 15 top ranked global logistics countries for the period of 2007–2015.

Objectives of the study

The prime objective of the study is to develop an interactive environmental model where growth factors are modeled with logistics performance indices that are mediated by air pollution and climate change. Economic growth and sectoral growth factors serve as a ‘response variables’, while they are affected by logistics indices and environmental factors in a panel of countries. The study examined the long-run and causal relationship between environmental logistics performance indicators (ELPI) and economic factors under four alternative and plausible hypotheses: (i) ELPI and economic factors confirmed the bidirectional causality (i.e., feedback hypothesis); (ii) ELPI Granger causes economic factors (i.e., conservation hypothesis); (iii) economic factors cause ELPI Granger (i.e., growth hypothesis); and (iv) no causality between ELPI and economic factors (i.e., neutrality hypothesis).

Significance of the study

The importance of the study is to analyze different patterns of logistics activities (during the process of production to distribution) that act as a driver to increase air pollutants and

climate change to delimit economic performance and sectoral contribution to the country's GDP. This study provides a better understanding of green supply chain management at the macro level where the country's economic growth is modeled by logistics performance indices and air quality indicators to provoke sustainable environmental agenda across the countries. This study would be helpful for environmentalists, logisticians, and governmental officials to devise a strong policy framework to support global green logistics agenda for a broad-based sustainable growth.

Data source and methodological framework

The study used a number of logistics indices and environmental factors including logistics performance index (1 = low to 5 = high), logistics competence index (1 = low to 5 = high), logistics infrastructure index (1 = low to 5 = high), CO₂ emissions (metric tons per capita), fossil fuel energy consumption (% of total), and total greenhouse gas emissions (kt of CO₂ equivalent). Moreover, the study used some specific growth measures including per capita GDP growth (annual %), sectoral growth including agriculture value added (annual % growth), industry value added (annual % growth), manufacturing value added (annual % growth), and service value added (annual % growth). The miscellaneous factors include foreign direct investment net inflows (% of GDP) and energy use (kg of oil equivalent per capita) as both variables that intervene in the model to advance the environmental logistics performance indicators (ELPI) on per capita income and sectoral growth. The consistent time series data is used for the period of 2007–2015 in a panel of 15 global ranked logistics countries, namely, Germany, Netherlands, Belgium, UK, Singapore, Sweden, Norway, Luxembourg, USA, Japan, Ireland, Canada, France, Switzerland, and Hong Kong, China. The data values filled by interpolation technique were required. The data is taken from World Development Indicators published by the World Bank (2015).

Logistics performance index—definition, methodology, and scale

The logistics performance index (LPI) is used to assess the performance of trade logistics which served as a catalyst to promote the country's performance in terms of six logistics indicators including efficiency of the custom process, quality of trade and transport-related activities, international price shipments, competence of logistics services, ability to track and trace consignments, and expected timeliness for delivery of the products. It is the weight average score of all six LPI indices for measuring the country's logistics performance (World Bank 2016).

The World Bank extensively surveyed the LPI in collaboration with academia, industry, institutions, and individuals engaged in the process of supply chain distribution. This survey covered around more than 5000 country assessments and approximately 1000 international freight forwarders. The sample for the assessment of logistics performance is merely based on randomly selected markets in specific countries that have a diversified portfolio of the import and export market. The five-point Likert scale is used ranging from 1 (low) to 5 (high), in which respondents were asked to rate the country's supply chain process on six core dimensions of logistics in a country. By using principal component analysis, the scores are averaged and constructed into a single aggregated component, which measures the performance of the logistics supply chain in a country (World Bank/Turku School of Economics 2010).

Figure 1 shows the trend of the study variables for a ready reference.

These countries were selected because of two main reasons: first, these countries are categorized as top ranked global logistics countries which maintain a considerable portion of their growth share in terms of GDP since the last decade by the aid of travel and transport logistics infrastructure, and second, these countries spend their considerable earnings to reduce environmental issues that may hinder their economic growth. ELPI is one of the viable estimation techniques to assess global logistics environmental sustainability for a sustainable green supply chain process in a region. The ELPI served as a carrier of environmental factors affected by logistics activities; therefore, it is prerequisite to manage environmental issues with the green supply chain process across the countries.

Theoretical and empirical framework

The study utilized the Solow growth model to examine the relationship between environmental logistics performance indicators and per capita income (and sectoral growth) in a panel of 15 global ranked logistics countries. The general specification of the Solow growth model is as follows:

$$Y = f(K, AL) \quad (i)$$

where Y denotes output, K is capital, A is technology, and L denotes labor.

Equation (i) shows that output depends upon the amount of capital stock and augmented labor; the higher

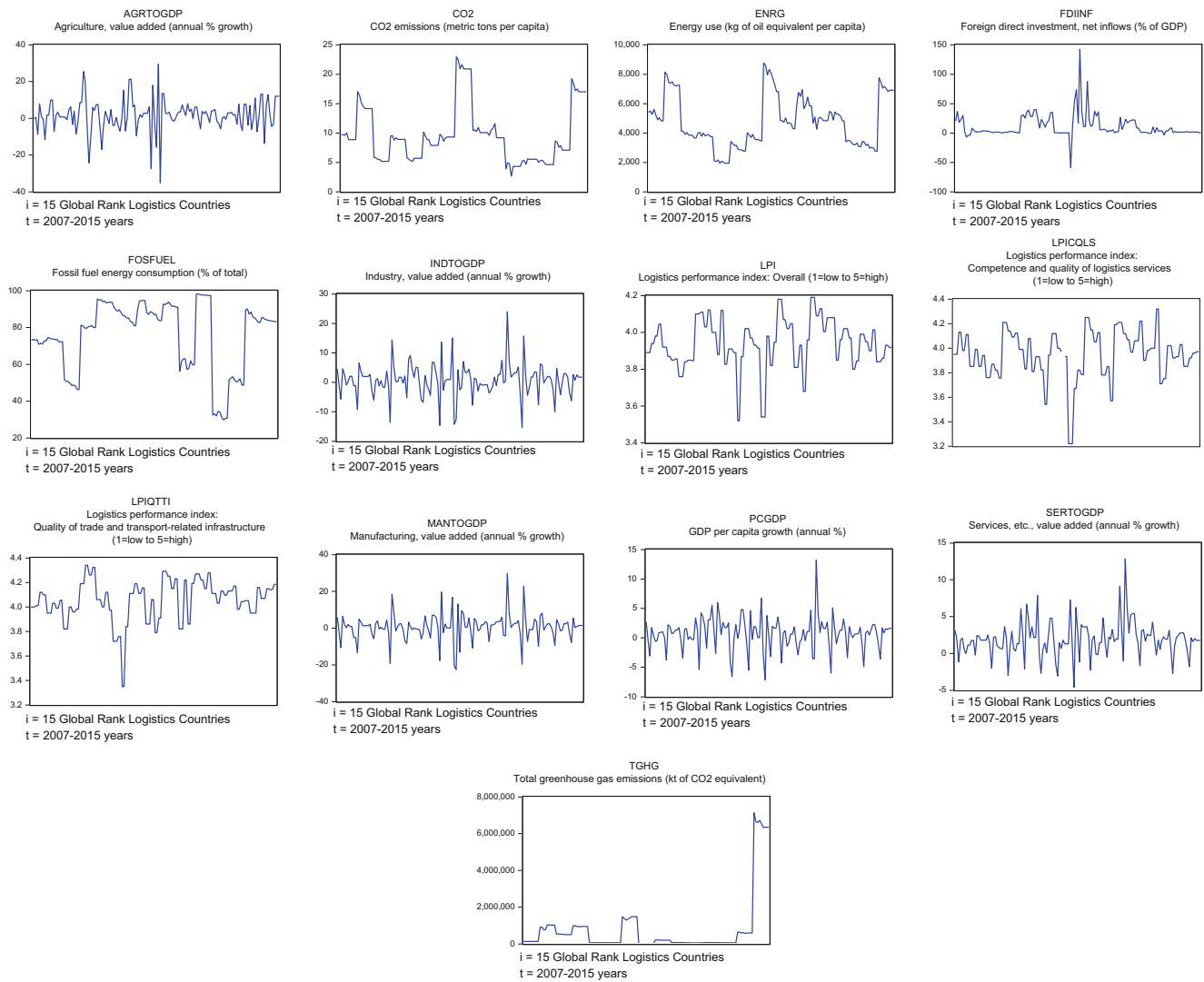


Fig. 1 Plots of level data. Source: World Bank (2015)

the capital stock and labor-augmenting technology, the higher the output will be over a period of time.

The study further modified Eq. (i) into different environmental factors, substituting it with capital K and quantity of labor L during the production, i.e.,

$$Y_t = ELPI^{\alpha_t} \times A \times LPI_t^{\beta} \times F_t^{\gamma} \times E_t^{\varphi} \tag{ii}$$

where ELPI denotes environmental logistics performance indicators, A is assumed as constant, LPI is the logistics performance index, F denotes FDI inflows, E denotes energy use, t denotes time period, and $\alpha, \beta, \gamma,$ and φ denote the parameter coefficients of ELPI, LPI, F, and E, respectively.

The natural logarithmic form for Eq. (ii) is as follows:

$$\ln(Y)_t = \alpha \ln(ELPI) + \beta [\ln(A)_t + \ln(LPI)_t] + \gamma \ln(F)_t + \varphi \ln(E)_t \tag{iii}$$

where ln denotes natural logarithm.

The study is composed of the relationships between ELPI and growth factors in a panel of 15 countries over a period of 2007–2015, as we examined the impact of ELPI on per capita growth and sectoral growth; therefore, we used modeling of simultaneous equations by a panel of GMM estimators where the same regressors affect the sectoral growth and per capita growth by including a lagged dependent regressor and appropriate instrumental lists of the exogenous variables, i.e.,

Model 1: ELPI and per capita GDP

$$\begin{aligned} PCGDP_{it} = & \alpha_0 + \alpha_{1i}(CO2 \times LPI)_{it} \\ & + \alpha_{2i}(FOSFUEL \times LPI)_{it} + \alpha_{3i}(TGHG \times LPI)_{it} \\ & + \alpha_{4i}(LPIQTTI)_{it} + \alpha_{5i}(LPICOLS)_{it} + \alpha_{6i}(FDIINF)_{it} \\ & + \alpha_{7i}(ENRG)_{it} + \varepsilon_{it} \end{aligned} \tag{1}$$

Model 11: ELPI and sectoral growth

$$\begin{aligned} \text{AGRTOGDP}_{it} = & \alpha_0 + \alpha_{1i}(\text{CO}_2 \times \text{LPI})_{it} \\ & + \alpha_{2i}(\text{FOSFUEL} \times \text{LPI})_{it} + \alpha_{3i}(\text{TGHG} \times \text{LPI})_{it} \\ & + \alpha_{4i}(\text{LPIQTTI})_{it} + \alpha_{5i}(\text{LPICQLS})_{it} + \alpha_{6i}(\text{FDIINF})_{it} \\ & + \alpha_{7i}(\text{ENRG})_{it} + \varepsilon_{it} \end{aligned} \quad (2)$$

$$\begin{aligned} \text{INDTOGDP}_{it} = & \alpha_0 + \alpha_{1i}(\text{CO}_2 \times \text{LPI})_{it} \\ & + \alpha_{2i}(\text{FOSFUEL} \times \text{LPI})_{it} + \alpha_{3i}(\text{TGHG} \times \text{LPI})_{it} \\ & + \alpha_{4i}(\text{LPIQTTI})_{it} + \alpha_{5i}(\text{LPICQLS})_{it} + \alpha_{6i}(\text{FDIINF})_{it} \\ & + \alpha_{7i}(\text{ENRG})_{it} + \varepsilon_{it} \end{aligned} \quad (3)$$

$$\begin{aligned} \text{MANTOGDP}_{it} = & \alpha_0 + \alpha_{1i}(\text{CO}_2 \times \text{LPI})_{it} \\ & + \alpha_{2i}(\text{FOSFUEL} \times \text{LPI})_{it} + \alpha_{3i}(\text{TGHG} \times \text{LPI})_{it} \\ & + \alpha_{4i}(\text{LPIQTTI})_{it} + \alpha_{5i}(\text{LPICQLS})_{it} + \alpha_{6i}(\text{FDIINF})_{it} \\ & + \alpha_{7i}(\text{ENRG})_{it} + \varepsilon_{it} \end{aligned} \quad (4)$$

$$\begin{aligned} \text{SERTO GDP}_{it} = & \alpha_0 + \alpha_{1i}(\text{CO}_2 \times \text{LPI})_{it} \\ & + \alpha_{2i}(\text{FOSFUEL} \times \text{LPI})_{it} + \alpha_{3i}(\text{TGHG} \times \text{LPI})_{it} \\ & + \alpha_{4i}(\text{LPIQTTI})_{it} + \alpha_{5i}(\text{LPICQLS})_{it} + \alpha_{6i}(\text{FDIINF})_{it} \\ & + \alpha_{7i}(\text{ENRG})_{it} + \varepsilon_{it} \end{aligned} \quad (5)$$

where PCGDP denotes per capita GDP, AGRTOGDP denotes agriculture share to GDP, INDTOGDP denotes industry share to GDP, MANTOGDP denotes manufacturing share to GDP, SERTO GDP denotes services share to GDP, CO₂ denotes carbon dioxide emissions, FOSFUEL denotes fossil fuel energy consumption, TGHG denotes total greenhouse gas emissions, LPI denotes logistics performance index, LPIQTTI denotes LPI infrastructure, LPICQLS denotes LPI logistics competence, FDIINF denotes foreign direct investment inflows, ENRG denotes energy use, i denotes sample countries, i.e., $i = 1, \dots, 15$, t denotes study time period, i.e., $t = 2007\text{--}2015$, and ε denotes error term.

Equations (1), (2) (3), (4), and (5) examine the dynamic relationships between environmental logistics performance index and growth factors in a panel of countries. The study employed the system panel generalized method of moments (GMM) estimator developed by Arellano and Bond (1991) to address the possible heterogeneity and serial correlation problems by a lagged dependent variable as a regressor and a set of instrumental variables with first-difference transformation processes. The following models 1 and 2 are used to estimate the system panel GMM estimator, i.e.,

$$\begin{aligned} \text{PCGDP}_{it} = & \alpha_0 + \alpha_{1i}\text{PCGDP}_{i,t-1} + \alpha_{2i}(\text{CO}_2 \times \text{LPI})_{it} \\ & + \alpha_{3i}(\text{FOSFUEL} \times \text{LPI})_{it} + \alpha_{4i}(\text{TGHG} \times \text{LPI})_{it} \\ & + \alpha_{5i}(\text{LPIQTTI})_{it} + \alpha_{6i}(\text{LPICQLS})_{it} \\ & + \alpha_{7i}(\text{FDIINF})_{it} + \alpha_{8i}(\text{ENRG})_{it} + z_{it} + \varepsilon_{it} \end{aligned} \quad (1a)$$

$$\begin{aligned} \text{AGRTOGDP}_{it} = & \alpha_0 + \alpha_{1i}\text{AGRTOGDP}_{i,t-1} \\ & + \alpha_{2i}(\text{CO}_2 \times \text{LPI})_{it} + \alpha_{3i}(\text{FOSFUEL} \times \text{LPI})_{it} \\ & + \alpha_{4i}(\text{TGHG} \times \text{LPI})_{it} + \alpha_{5i}(\text{LPIQTTI})_{it} \\ & + \alpha_{6i}(\text{LPICQLS})_{it} + \alpha_{7i}(\text{FDIINF})_{it} + \alpha_{8i}(\text{ENRG})_{it} \\ & + z_{it} + \varepsilon_{it} \end{aligned} \quad (2a)$$

$$\begin{aligned} \text{INDTOGDP}_{it} = & \alpha_0 + \alpha_{1i}\text{INDTOGDP}_{i,t-1} \\ & + \alpha_{2i}(\text{CO}_2 \times \text{LPI})_{it} + \alpha_{3i}(\text{FOSFUEL} \times \text{LPI})_{it} \\ & + \alpha_{4i}(\text{TGHG} \times \text{LPI})_{it} + \alpha_{5i}(\text{LPIQTTI})_{it} \\ & + \alpha_{6i}(\text{LPICQLS})_{it} + \alpha_{7i}(\text{FDIINF})_{it} + \alpha_{8i}(\text{ENRG})_{it} \\ & + z_{it} + \varepsilon_{it} \end{aligned} \quad (3a)$$

$$\begin{aligned} \text{MANTOGDP}_{it} = & \alpha_0 + \alpha_{1i}\text{MANTOGDP}_{i,t-1} \\ & + \alpha_{2i}(\text{CO}_2 \times \text{LPI})_{it} + \alpha_{3i}(\text{FOSFUEL} \times \text{LPI})_{it} \\ & + \alpha_{4i}(\text{TGHG} \times \text{LPI})_{it} + \alpha_{5i}(\text{LPIQTTI})_{it} \\ & + \alpha_{6i}(\text{LPICQLS})_{it} + \alpha_{7i}(\text{FDIINF})_{it} + \alpha_{8i}(\text{ENRG})_{it} \\ & + z_{it} + \varepsilon_{it} \end{aligned} \quad (4a)$$

$$\begin{aligned} \text{SERTO GDP}_{it} = & \alpha_0 + \alpha_{1i}\text{SERTO GDP}_{i,t-1} \\ & + \alpha_{2i}(\text{CO}_2 \times \text{LPI})_{it} + \alpha_{3i}(\text{FOSFUEL} \times \text{LPI})_{it} \\ & + \alpha_{4i}(\text{TGHG} \times \text{LPI})_{it} + \alpha_{5i}(\text{LPIQTTI})_{it} \\ & + \alpha_{6i}(\text{LPICQLS})_{it} + \alpha_{7i}(\text{FDIINF})_{it} + \alpha_{8i}(\text{ENRG})_{it} \\ & + z_{it} + \varepsilon_{it} \end{aligned} \quad (5a)$$

where, $t - 1$ shows the lagged dependent variable and z denotes the instrumental list.

Equations (1a) (2a), (3a), (4a), and (5a) show the lagged dependent variable as a regressor along with the instrumental list including the first lagged ELPI variables, FDI inflows, and energy use. The cross section fixed effects are traced out by the Sargan-Hansen J statistic and instrumental ranks, while the Arellano-Bond serial correlation test is used to detect the possible autocorrelation problem in the given models. The lagged dependent variable is assumed to have a negative sign with the nominal dependent variable that would show the ‘long-run convergence’ between the variables over a period of time, while ELPI is expected to have a positive sign in case of

Table 1 Descriptive statistics and correlation matrix

	AGRTOGDP	CO2	ENRG	FDIINF	FOSFUEL	INDTOGDP	LPI	LPIQCLS	LPIQTTI	MANTOGDP	PCGDP	SERTOGDP	TGHG
Panel A:													
Mean	1.730	9.533	4761.355	11.194	75.559	0.775	3.939	3.948	4.053	0.604	0.709	1.918	774,961.900
Maximum	29.335	22.965	8773.897	142.257	98.247	23.910	4.190	4.320	4.340	29.675	13.216	12.819	7,128,952
Minimum	-35.262	2.655	1938.361	-58.978	29.811	-15.369	3.520	3.220	3.350	-22.588	-7.113	-4.605	12,343.320
Std. Dev.	8.815	4.818	1728.820	19.783	18.834	5.523	0.136	0.197	0.171	7.250	2.757	2.359	1,613,129.000
Skewness	-0.505	1.150	0.452	2.753	-0.916	0.169	-0.712	-1.079	-1.153	0.011	0.104	0.814	3.104
Kurtosis	6.333	3.501	2.274	18.708	2.770	6.212	4.244	5.572	5.725	6.564	6.039	6.591	11.429
Panel B: correlation matrix													
AGRTOGDP	1												
CO2	0.025	1											
ENRG	0.005	0.785	1										
FDIINF	0.087	0.096	-0.029	1									
FOSFUEL	-0.018	0.280	-0.078	0.337	1								
INDTOGDP	0.066	-0.108	-0.050	0.017	0.087	1							
LPI	0.023	-0.324	-0.241	0.061	0.183	0.168	1						
LPIQCLS	0.061	-0.392	-0.292	0.002	0.073	0.197	0.876	1					
LPIQTTI	0.023	-0.151	-0.006	-0.123	0.094	0.188	0.758	0.671	1				
MANTOGDP	0.116	-0.091	-0.014	0.036	0.007	0.907	0.139	0.208	0.142	1			
PCGDP	0.097	-0.104	-0.086	0.006	0.105	0.873	0.121	0.118	0.146	0.788	1		
SERTOGDP	0.035	-0.107	0.009	0.091	0.143	0.694	0.104	0.018	0.072	0.599	0.849	1	
TGHG	0.077	0.457	0.347	-0.210	0.150	-0.033	-0.086	0.003	0.170	-0.010	-0.024	-0.139	1

AGRTOGDP agriculture share to GDP, CO₂ carbon dioxide emissions, ENRG energy use, FDIINF FDI inflows, FOSFUEL fossil fuel energy consumption, INDTOGDP industry share to GDP, LPI logistics performance index, LPIQCLS LPI of international competence, LPIQTTI LPI of infrastructure, MANTOGDP manufacturing share to GDP, PCGDP per capita GDP, SERTOGDP services share to GDP, TGHG total greenhouse gas emissions

environmental destruction and a negative sign in favor of environmental protection. The other two LPI indices including LPI infrastructure and LPI international competence both are expected to have a positive sign in order to support economic activities and sectoral contribution to GDP. The miscellaneous variables, i.e., FDI inflows and energy demand, both are expected to have a positive sign with per capita income and sectoral contribution to GDP in a panel of countries.

Results and discussions

Descriptive statistics and correlation matrices are presented in Table 1. In panel A, the mean values of agriculture share to GDP, industry share to GDP, manufacturing share to GDP, and services share to GDP are about 0.730, 0.775, 0.604, and 1.918 %, respectively, while the maximum share of agriculture, industry, manufacturing, and services to GDP is about 29.335, 23.910, 29.675, and 12.819 %, respectively. The mean values of CO₂ emissions, energy use, FDI inflows, fossil fuel energy consumption, total greenhouse gas emissions, and per capita income is about 9.533 metric tons per capita, 4761.353 kg of oil equivalent per capita, 11.194 % of GDP, 75.559 % of total energy consumption, 774,961.900 kt of CO₂ equivalent, and 0.709 %, respectively. The average value of LPI of international competence is about 3.948, for LPI of infrastructure about 4.053, and for overall LPI about 3.939.

These statistics indicate the following conclusive remarks:

1. The service sector has a greater mean value as compared to the agriculture, industry, and manufacturing sectors, while the manufacturing sector has a maximum value as compared to other sectoral growth to GDP. These statistics show that sectoral growth in terms of the service sector consistently improves, which facilitates an increase in energy demand in a region.
2. Air quality indicators including CO₂ emissions, fossil fuel, and GHG emissions considerably increase over a period of time, which deteriorate the natural environment of the region.
3. The minimum value of logistics indicators, i.e., logistics overall performance, logistics competence, and logistics infrastructure, fall in the index value of 3 to 3.5, which considered as the average performance of the supply chain across the countries.
4. Finally, the average growth rate of FDI inflows and per capita income is around 11.194 and 0.709 %, respectively, which shows the relative importance of FDI inflows and per capita income in environmental sustainability agenda in a region.

Table 1 panel B presented the results of the correlation matrix and found that there is a positive correlation with

CO₂ emission, energy use, FDI inflows, logistics indicators, and GHG emissions with the agriculture value added, while it has a negative correlation with the fossil fuel. Industry value added has a negative correlation with the CO₂ emission, energy use, and GHG emissions, while it has a positive correlation with the FDI inflows, fossil fuel energy consumption, and logistics performance index in a region. The manufacturing sector considerably decreases CO₂ emission and fossil fuel energy consumption while it increases FDI inflows and logistics performance indices. Moreover, there is a positive correlation with fossil fuel energy, energy demand, FDI inflows, and LPI indicators in the service sector, while there is a negative correlation with CO₂ emissions and GHG emissions in the service sector. Finally, per capita income significantly reduces CO₂ emissions, energy use, and GHG emissions, while it increases FDI inflows, fossil fuel energy consumption, and logistics performance indices across the countries. Followed by the estimation of the correlation matrix, the study estimates panel GMM for model 1 and presents the results in Table 2.

The results show that the lagged dependent variable has a positive relationship with the nominal term of its dependent variable, which shows the long-run convergence between the variables. The results of environmental logistics indicators including interaction term of LPI and carbon emissions have a negative and significant correlation with the per capita income, which implies that along with the one unit increase in carbon emissions as metric tons per capita, per capita income

Table 2 Estimates of panel generalized method of moments for per capita GDP

Variables	PGMM(1)	PGMM(2)	PGMM(3)
PCGDP _{t-1}	-0.289*	-0.281*	-0.267**
CO ₂ × LPI	0.224	0.194	-0.770**
FOSFUEL × LPI	-0.020	-0.063	-0.079
TGHG × LPI	4.64E-06**	4.81E-06**	1.08E-06
LPIQTTI	–	4.886	8.590
LPICQLS	–	2.792	11.369**
FDIINF	–	–	-0.050
ENRG	–	–	0.017*
Cross section-fixed (first differences)			
<i>J</i> statistic	1.58E-30	7.88E-30	1.04E-29
Instrumental rank	4	6	8
Arellano-Bond serial correlation test			
AR(1)	-4.879*	-4.712*	-1.600
AR(2)	-3.164*	-2.937*	-1.485

Note: Dependent variable: PCGDP

PGMM panel generalized method of moments, CO₂ carbon dioxide emissions, ENRG energy use, FDIINF FDI inflows, FOSFUEL fossil fuel energy consumption, LPI logistics performance index, LPICQLS LPI of international competence, LPIQTTI LPI of infrastructure, PCGDP per capita GDP, TGHG total greenhouse gas emissions

*Significance at the 1 % level; **significance at the 5 % level

Table 3 Estimates of panel generalized method of moments for sectoral growth

Variables	Dependent variable: AGRTGDP			Dependent variable: INDTOGDP			Dependent variable: MANTOGDP			Dependent variable: SERTOGDP		
Lagged dependent variable	-0.489*	-0.493*	-0.368*	-0.393*	-0.401*	-0.363*	-0.425*	-0.424*	-0.323***	-0.261*	-0.255*	-0.176
CO ₂ × LPI	-0.783	-0.767	-0.440	0.391	0.288	-1.215	0.450	0.289	-1.811***	0.059	-0.001	-0.520***
FOSFUEL × LPI	0.376	0.363	0.157	-0.073	-0.036	-0.190	-0.137	-0.087	-0.266	-0.045	-0.020	-0.046
TGHG × LPI	1.36E-05	1.37E-05	7.42E-06	9.58E-06***	9.75E-06***	2.72E-06	1.40E-05***	1.44E-05**	1.75E-06	2.94E-06	2.94E-06	-1.46E-07
LPIQTTI	-	-5.200	40.332**	-	3.344	10.306	-	1.244	15.803	-	5.467	7.693***
LPICQLS	-	5.810	-18.237	-	9.860	28.701*	-	21.076***	43.704*	-	0.070	5.984***
FDIINF	-	-	0.664*	-	-0.109	-0.109	-	-	-0.061	-	-	-0.029
ENRG	-	-	0.001	-	-	0.031*	-	-	0.048*	-	-	0.012*
Cross section fixed (first differences)												
J statistic	2.39E-30	7.15E-30	8.71E-30	1.38E-30	3.14E-31	4.80E-29	6.16E-31	1.70E-30	4.04E-29	5.27E-31	6.38E-30	6.60E-30
Instrumental rank	4	6	8	4	6	8	4	6	8	4	6	8
Arellano-Bond serial correlation test												
AR(1)	-2.374**	-2.308**	0.276	-3.975*	-4.105*	-1.890***	-4.140*	-4.238*	-1.536	-5.726*	-5.936*	-2.258**
AR(2)	-2.285**	-2.437**	-1.462	-3.784*	-3.574*	-1.615	-3.253*	-3.255*	-1.156	-3.170*	-2.873*	-1.592

AGRTGDP agriculture share to GDP, CO₂ carbon dioxide emissions, ENRG energy use, FDIINF FDI inflows, FOSFUEL fossil fuel energy consumption, INDTOGDP industry share to GDP, LPI logistics performance index, LPICQLS LPI of international competence, LPIQTTI LPI of infrastructure, MANTOGDP manufacturing share to GDP, SERTOGDP services share to GDP, TGHG total greenhouse gas emissions

*1 % level of significance; **5 % level of significance; and ***10 % level of significance

decreases by -0.770% , $p < 0.050$. The interaction term of LPI and GHG emissions exhibits a positive relationship with the per capita income, which implies that per capita income increases on the cost of LPI activities that exacerbate the climatic conditions and increase the GHG emissions in a region. The policies to formulate a sustainable green supply process to mitigate GHG emissions required sound government interventions in order to monitor LPI activities that deteriorate the environment and intensify air pollutants in the atmosphere. The LPI of international competence and energy demand both considerably increase the per capita income of the region. The policies to strengthen the different components of LPI and macroeconomic factors would help to reduce the burden of air pollutants and climatic variations across the countries.

The other statistical tests including cross section fixed estimates confirm that the Sargan-Hansen J statistics and the instrumental rank both provoke the validity of the prescribed instruments of the models, while the problem of serial correlation is detected in PGMM (1) and PGMM(2) by AR(1) and AR(2), as the significant values of AR(1) and AR(2) clearly show the presence of serial correlation in the per capita income model. However, autocorrelation is expected to occur due to exclusion of some other potential explanatory variables that are incorporated in PGMM(3) and we found that the values of AR(2) tend to become insignificant, which confirms that such autocorrelation problem does not exist in the per capita income model. Followed by the results of panel GMM estimates for the per capita income model, the study further estimates panel GMM for sectoral growth and presents the results in Table 3.

The results further show that the environmental logistics indicator of CO₂ emission significantly decreases the manufacturing and service share to GDP; however, the intensity to decrease the manufacturing share is far greater than that of the service share to GDP across the countries. The impact of the environmental logistics indicator of fossil fuel energy consumption does not significantly explain its impact on sectoral growth during the study time period. The industrial and manufacturing share to GDP significantly increases on the cost of the increase in the share of the environmental logistics indicator of GHG emission. The LPI of infrastructure significantly increases the agriculture and service share to GDP, while the LPI of international competence supports agriculture value added across the countries. FDI inflows have a significant and positive relationship with the agriculture share to GDP while energy demand significantly increases the industry, manufacturing, and service share to GDP. The results emphasized the need for sustainable long-term policy planning in order to strengthen the growth-specific factors and logistics performance indices to reduce air pollutants and greenhouse gas emissions in a region.

The validity of the prescribed instruments for the sectoral growth factors is detected by the Sargan-Hansen J statistics

and their instrument ranks, where a serial correlation problem is detected by AR(1) and AR(2). The estimated equations where we did not include all the regressors were expected to show a serial correlation problem, while it overcomes the inclusion of all variables, and found no autocorrelation problem in the sectoral growth factors. Table 4 shows the summary and comparison of the results for ready reference.

Table 4 presented the results in support of previous literature. Chapman et al. (2003) argued that innovation in logistics services expedites the process of resource mobilization that would facilitate growth of new business models for competitiveness. Hesse and Rodrigue (2004) emphasized the need for advancement of logistics infrastructure and quality of goods that are linked with the transportation and freight distribution in order to improve the life cycle of the transported goods. Rao and Holt (2005) confirmed the positivity of ‘green supply chain management practices’ that are helpful to enhance the economic performance for the greening of the different components of the supply chain process. Facanha and Horvath (2005) concluded that logistics outsourcing has a profound impact on the process of supply chain management, as logistics outsourcing considerably reduces climatic concerns and fatalities and utilizes energy efficiently. Hausman et al. (2005) argued that logistics indicators are helpful for the increase in bilateral trade and the advancement of operational performance of the economic and financial variables in order to reap maximum gains from trade. Meyer et al. (2007) supported that climate change is affected by logistics transport activities, as an increase in the number of car vehicles considerably increases global CO₂ emissions. Brooks (2008) linked logistics, trade, and infrastructure in Asian perspectives and found that logistics activities aid to facilitate export-driven growth, which further helps to reap economic profit by expanding linkages of the global supply chain for producers. Saatçioğlu et al. (2009) favored electronic logistics and transport (e-logistics and transport) services for maintaining the high standard of the supply chain process in a country. Shukla et al. (2009) emphasized the early adoption of green supply chain management for addressing environmental issues to meet sustainable growth agenda nationwide. Arora et al. (2011) projected future oil demand, motor vehicles demand, and CO₂ emissions and showed that oil demand by 2040 would be 8.5 to 15.1 million barrels per day, while motor vehicles would be 206 to 309 million and corresponding CO₂ emissions would be 1.2 to 2.2 billion metric tons. Tang and Zhou (2012) stressed the need for sustainable operations in business competitive profit, conservation of natural resources, and healthy development activities by green operations research. Ross et al. (2012) confirmed that environmental sustainability is affected by the development of supply chain infrastructure that not only deteriorates a country’s natural environment but also affects social equity. Dekker et al. (2012) concluded that environmental concern especially air

Table 4 Summary and comparison of the results

Statement (S)	Results	Decisions	Supported with the previous literatures
S1: Logistics performance index (LPI) increases air pollutants that affected per capita income and sectoral value added	LPI in case of CO ₂ emissions decreases per capita income and manufacturing share to GDP and the service sector, while LPI in case of GHG emissions increases per capita income and industry share to GDP and the manufacturing sector.	Partially accepted	Rao and Holt (2005); Facanha and Horvath (2005); Meyer et al. (2007); Chandra Shukla et al. (2009); Arora et al. (2011); Tang and Zhou (2012); Ross et al. (2012); Dekker et al. (2012); Lai and Wong (2012); Liimatainen and Pöllänen (2013), etc.
S2: Quality of travel and transport infrastructure and logistics competence both have a positive impact on economic growth and sectoral share to GDP.	Logistics competence increases per capita income, industry, manufacturing, and service sectors, while logistics infrastructure supported agriculture and service share to GDP.	Accepted	Chapman et al. (2003); Hesse and Rodrigue (2004); Brooks (2008); Saatçioğlu et al. (2009)
S3: FDI inflows increase per capita income and sectoral value added.	FDI increases agriculture share to GDP.	Partially accepted	Hausman et al. (2005); Borensztein et al. (1998); De Mello (1999); Bengoa and Sanchez-Robles (2003); Hansen and Rand (2006); Lee (2013), etc.
S4: Energy demand increases per capita income and sectoral value added.	Energy demand increases per capita income, industry, manufacturing, and service value added.	Accepted	Lee and Chang (2008); Shahbaz et al. (2015); Bhattacharya et al. (2016); Ramakrishnan et al. (2016); Qureshi et al. (2016); Zaman et al. (2016), etc.

Source: Authors' estimation

pollutants and greenhouse gas emissions rapidly emerged due to four main economic activities including production of goods, transportation of goods, storage of goods, and consumption of goods, all of which have a deleterious impact on the natural environment but which could be sustained by green logistics operation across the globe. Lai and Wong (2012) confirmed that operational and environmental performance should be achieved through green logistics management and practices, while regulatory intervention in the operational and environmental performance is helpful for the enhancement of the performance of green logistics across the countries. Liimatainen and Pöllänen (2013) presented the overwhelming fact regarding road freight transport and carbon emissions, as carbon emissions gradually decline by the strong policy intervention regarding logistics freight, i.e., the low carbon accompanied by balancing between transporting parceled goods and transporting bulk goods that emit less carbon emissions, and it is further linked with trade and technology shift for energy utilization for sectoral development to sustain green growth agenda.

There are a number of studies that support the positive flow of FDI toward economic growth via technological advancement and knowledge spillovers, such as Borensztein et al. (1998), De Mello (1999), Bengoa and Sanchez-Robles (2003), Hansen and Rand (2006), Lee (2013), etc. Following FDI inflows, energy demand is another potential determinant that has a significant impact on economic growth, as Lee and Chang (2008) confirmed the cointegrated relationship between energy demand and economic growth in Asian

perspectives. Shahbaz et al. (2015) concluded that renewable energy boosts economic growth under the presence of capital and labor, while Bhattacharya et al. (2016) argued that renewable energy is the promising solution for sustainable development which may be enlarged with the government-regulated bodies to promote cleaner technologies across the countries. Ramakrishnan et al. (2016) concluded that global environmental sustainability agenda is affected by air pollutants, energy demand, population growth, trade policy, and per capita food production. Qureshi et al. (2016) confirmed the significant association between electricity production and growth-specific factors in the world's largest regions. Zaman et al. (2016) revealed that energy demand increases BRICS' economic growth while sustainability agenda is compromised by air quality indicators that affect the process of green growth agenda in a region.

Table 5 shows the causal relationship between ELPI and per capita income) by 'block exogeneity wald test'.

The multivariate causality relationship was obtained by wald chi-squared statistics, and it was found that per capita income has a bidirectional causal relationship with energy demand while energy demand has a unidirectional relationship with LPI of international competence across the countries. Environmental logistics performance indicators including CO₂ emission have a unidirectional causal relationship with per capita income and energy demand; ELPI of fossil fuel energy consumption and GHG emissions both have a unidirectional causal relationship with per capita income, FDI inflows, and energy demand; LPI of infrastructure has a unidirectional causality with energy demand; LPI of

Table 5 Estimates of block exogeneity wald test for per capita GDP

Variables	PCGDP	CO ₂ × LPI	FOSFUEL × LPI	TGHG × LPI	LPIQTTI	LPICQLS	FDIINF	ENRG
PCGDP	–	≠	≠	≠	≠	≠	≠	↔
CO ₂ × LPI	→	–	≠	≠	≠	≠	≠	→
FOSFUEL × LPI	→	≠	–	≠	≠	≠	→	→
TGHG × LPI	→	≠	≠	–	≠	≠	→	≠
LPIQTTI	≠	≠	≠	≠	–	≠	≠	→
LPICQLS	≠	≠	→	≠	≠	–	→	≠
FDIINF	≠	→	≠	≠	≠	≠	–	≠
ENRG	↔	≠	≠	≠	≠	→	≠	–

CO₂ carbon dioxide emissions, ENRG energy use, FDIINF FDI inflows, FOSFUEL fossil fuel energy consumption, LPI logistics performance index, LPICQLS LPI of international competence, LPIQTTI LPI of infrastructure, PCGDP per capita GDP, TGHG total greenhouse gas emissions, → unidirectional causality, ↔ bidirectional causality, ≠ no causality between the variables

international competence Granger causes FDI inflows; FDI inflows induces ELPI of CO₂ emission; and energy demand Granger causes LPI of international competence. The remaining causal relationships are neutral, although they are highly correlated in regression apparatus. Table 6 shows the causality relationships between ELPI and sectoral growth.

The results of multivariate Granger causality confirm the feedback relationship between agriculture share to GDP and FDI inflows, while there is unidirectional causality running from ELPI of fossil fuel energy consumption to agriculture share to GDP and FDI inflows, from LPI of infrastructure to energy demand, from LPI of international competence to agriculture and FDI inflows, and from FDI inflows to ELPI of carbon emissions. There is a bidirectional causality relationship between industry value added to energy demand and between LPI of infrastructure and energy demand, while there is a unidirectional causality relationship running from industry to LPI of international competence, from ELPI of CO₂ emission to industry and energy demand, from ELPI of fossil fuel energy to FDI inflows and energy demand, from GHG emissions to FDI inflows, from LPI of international competence to FDI inflows, and from FDI inflows to ELPI of carbon emissions. The results confirm the feedback relationship between manufacturing and energy demand, while there is a unidirectional causality relationship running from manufacturing to LPI of international competence and FDI inflows, from ELPI of carbon emissions to manufacturing, and from energy demand to LPI of international competence. There is a bidirectional causality relationship between ELPI of carbon emissions and FDI inflows, between LPI of infrastructure and energy demand, between FDI inflows and services and ELPI of carbon emissions, and between energy demand and LPI of infrastructure. The results confirm the unidirectional causality running from services to LPI of international competence and FDI inflows, from ELPI of CO₂ emission to the service sector,

from ELPI of CO₂ emission to energy demand, from fossil fuel energy consumption to the service sector, from ELPI of GHG emissions to the service sector, and from energy demand to the service sector. The causality analysis is helpful for devising global sustainable supply chain strategy for long-term growth.

Conclusions

The long-term and sustained logistics policy is required to promote environmental goods in order to minimize the effects of CO₂ emission and GHG emissions by sustainable supply chain management practices. The main contribution of the study is to develop a unique environmental sustainable model, which is aligned with logistics performance indices, air quality indicator, and growth-specific factors in a panel of 15 global ranked logistics countries. This study used three diversified environmental logistics performance indicators (ELPI) including CO₂ emission, fossil fuel energy consumption, and GHG emissions with the interaction of the logistics performance index (LPI) which serves as a carrier to transport air pollutants during the supply chain process in a region. In addition, the study used LPI of infrastructure and LPI of international competence; both of the LPIs simultaneously have an impact on per capita income and sectoral growth across the countries. The study used FDI inflows and energy demand as intervening variables which enhance the strength of ELPI and LPI factors to affect income and sectoral growth of the region. The study employed the system panel GMM estimator to address the problem of possible heterogeneity and serial correlation in the given models. The results show that ELPI factors, LPIs, FDI inflows, and

Table 6 Estimates of block exogeneity wald test for sectoral growth

Variables	AGRTOGDP	CO ₂ × LPI	FOSFUEL × LPI	TGHG × LPI	LPIQTTI	LPICQLS	FDIINF	ENRG
Agriculture share to GDP								
AGRTOGDP	–	≠	≠	≠	≠	≠	↔	≠
CO ₂ × LPI	≠	–	≠	≠	≠	≠	≠	≠
FOSFUEL × LPI	→	≠	–	≠	≠	≠	→	≠
TGHG × LPI	≠	→	≠	–	≠	≠	≠	≠
LPIQTTI	≠	≠	≠	≠	–	≠	≠	→
LPICQLS	→	≠	→	≠	≠	–	→	≠
FDIINF	↔	→	≠	≠	≠	≠	–	≠
ENRG	≠	≠	≠	≠	≠	≠	≠	–
Variables	INDTOGDP	CO ₂ × LPI	FOSFUEL × LPI	TGHG × LPI	LPIQTTI	LPICQLS	FDIINF	ENRG
Industry share to GDP								
INDTOGDP	–	≠	≠	≠	≠	→	≠	↔
CO ₂ × LPI	→	–	≠	≠	→	≠	≠	→
FOSFUEL × LPI	≠	≠	–	≠	≠	≠	→	→
TGHG × LPI	≠	≠	≠	–	≠	≠	→	≠
LPIQTTI	≠	≠	≠	≠	–	≠	≠	↔
LPICQLS	≠	≠	→	≠	≠	–	→	≠
FDIINF	≠	→	≠	≠	≠	≠	–	≠
ENRG	↔	≠	≠	≠	↔	≠	≠	–
variables	MANTOGDP	CO ₂ × LPI	FOSFUEL × LPI	TGHG × LPI	LPIQTTI	LPICQLS	FDIINF	ENRG
Manufacturing share to GDP								
MANTOGDP	–	≠	≠	≠	≠	→	→	↔
CO ₂ × LPI	→	–	≠	≠	≠	≠	≠	→
FOSFUEL × LPI	≠	≠	–	≠	≠	≠	→	→
TGHG × LPI	≠	→	≠	–	≠	≠	→	≠
LPIQTTI	≠	≠	≠	≠	–	≠	≠	→
LPICQLS	≠	≠	→	≠	≠	–	→	≠
FDIINF	≠	→	≠	≠	≠	≠	–	≠
ENRG	↔	≠	≠	≠	≠	→	≠	–
Variables	SERTOOGDP	CO ₂ × LPI	FOSFUEL × LPI	TGHG × LPI	LPIQTTI	LPICQLS	FDIINF	ENRG
Services Share to GDP								
SERTOOGDP	–	≠	≠	≠	≠	→	→	≠
CO ₂ × LPI	→	–	≠	≠	→	≠	↔	→
FOSFUEL × LPI	→	≠	–	≠	≠	≠	≠	→
TGHG × LPI	→	→	≠	–	≠	≠	→	≠
LPIQTTI	≠	≠	≠	≠	–	≠	≠	↔
LPICQLS	≠	≠	→	≠	≠	–	→	≠
FDIINF	↔	↔	≠	≠	≠	≠	–	≠
ENRG	→	≠	≠	≠	↔	→	≠	–

AGRTOGDP agriculture share to GDP, *CO₂* carbon dioxide emissions, *ENRG* energy use, *FDIINF* FDI inflows, *FOSFUEL* fossil fuel energy consumption, *INDTOGDP* industry share to GDP, *LPI* logistics performance index, *LPICQLS* LPI of international competence, *LPIQTTI* LPI of infrastructure, *MANTOGDP* manufacturing share to GDP, *SERTOOGDP* services share to GDP, TGHG total greenhouse gas emissions, → unidirectional causality, ↔ bidirectional causality, ≠ no causality between the variables

energy demand all have a differential impact on per capita income and sectoral growth in a region. LPIs’ factors, FDI inflows, and energy demand considerably increase per capita income and sectoral growth, while

ELPI factors have a positive and/or negative impact on income and sectoral growth across the countries. The causal relationships confirm the bidirectional causality between the service sector and (i) energy demand, (ii)

per capita income, and (iii) industry value added, while there is a unidirectional causality running from ELPI to (i) energy demand, (ii) FDI inflows, (iii) economic growth, and (iv) sectoral growth in a panel of countries.

These results are helpful in devising long-term green supply chain management policies that are helpful for the conservation of natural resources and the resolution of environmental issues for a healthy and clean environment. The logistics performance index is considered as a viable instrument to assess the efficiency of the supply chain management process, which is further linked with the countries' external environment which influences energy demand and economic growth, as well as the country's natural environment in order to indulge with the global competitive war of better health and wealth. The logistics support provides a carrier to transport pollutants in the environment and climate change which damage the global natural flora. The policies to preserve our natural resources and mitigate GHG emissions are possible by strengthening the logistics sector, while sound sustainable policies are required to promote supply chain management that would be helpful in achieving the green growth agenda across the countries.

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