



# Driving factors of CO<sub>2</sub> emission reduction in the logistics industry: an assessment of the RCEP and SAARC economies

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## Abstract

As a strategic pillar of the Asian economic trade partnership, the logistics industry is a source of significant industrial relevance and specifically targeted CO<sub>2</sub> emission initiatives. Therefore, in order to address the potential environmental risks that are associated with existing Asian free trade agreements and achieve global mitigation targets, it is imperative that one evaluates both the performance of the logistic sector and the factors that drive carbon emissions. As such, our research analyses 16 countries both the Regional Comprehensive Economic Partnership, from one of the largest emerging global trade partnerships in Asia, and the South Asian Association for Regional Cooperation. The results of which act as an important guide in how the green logistic service sector can be driven in emerging economies. In order to conduct this analysis, a balanced panel dataset from 2007 to 2018 is employed and estimated using Generalized Least Square and the Generalized Method of Moments regression approaches, with the issues of cross-sectional dependence, unit-root, stationarity, and cointegration also checked. The results revealed that economic growth, foreign direct investment inflows, and international trade positively affect logistics performance. In addition, improved logistics services, a hassle-free customs clearance process, and the frequency of shipments reduce transport CO<sub>2</sub> emissions by 0.177%, 0.026%, and 0.014%, respectively. These findings suggest that renewable energy sources may alleviate the detrimental impact of logistics services on low-carbon transportation and spur economic action with substantial international trade opportunities available. This study hypothetically proposes and verifies a new dimension for two variables: international trade (export–import goods) and transport CO<sub>2</sub> emissions. The lessons drawn from the study assist policymakers and stakeholders in rethinking the roles of green logistics infrastructure in the future.

**Keywords** Logistics performance · Transport CO<sub>2</sub> emissions · International trade · Renewable energy · Economic growth

## Abbreviations

APEC Asia–Pacific Economic Cooperation  
ASEAN Association of Southeast Asian Nations

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EGLS	Estimated generalized least square
FTA	Free trade agreement
FDI	Foreign direct investment
GMM	Generalized method of moments
LPI	Logistics performance index
OECD	Organization for Economic Cooperation and Development
RCEP	Regional Comprehensive Economic Partnership
R&D	Research and development
SAARC	South Asian Association for Regional Cooperation
SEM	Structural equation model

## 1 Introduction

The Paris Agreement of 2015 (UNFCCC-2015) provides a global framework that serves to combat severe global warming by intensifying efforts to keep temperature rises below 1.5 °C over the medium to long-term (Magazzino et al., 2021; Sikder et al., 2022; Wang et al., 2020c). Since carbon dioxide makes up around half of all greenhouse gases, cutting back on these emissions has become a global priority (Karaduman et al., 2020; Khan et al., 2017; Wang et al., 2020b). The logistics industry is a significant contributor to the national economy since it connects production, manufacturing, and consumption (Rashidi & Cullinane, 2019; Zaman et al., 2022). In other words, it has been critical in encouraging economic development, changing economic structure, increasing domestic demand, and boosting social welfare (Li et al., 2021a; Venus Lun et al., 2015). However, the transportation, warehousing, and distribution aspects of the logistics industry drive energy usage and in doing so continue to exacerbate CO<sub>2</sub> emissions levels (Liu et al., 2018; Wang et al., 2020a). For instance, CO<sub>2</sub> emissions from the aviation and shipping sectors have increased dramatically, accounting for more than 75% of all transportation demand and emissions (IEA, 2021). According to the Organization for Economic Co-operation and Development (OECD, 2017), CO<sub>2</sub> emissions from transportation and international freight could increase by 60% and 160%, respectively, by 2050, and might impede ongoing carbon mitigation actions (Khan et al., 2017; Wang et al., 2020b).

Already, the carbon emissions from the transportation, warehousing, and postal services in major Asian economies such as China has increased more than 20% and are expected to rise with the development and intensification of existing free trade partnerships such as Asia–Pacific Economic Cooperation (APEC), Trans-Pacific Partnership (TPP), the Association of Southeast Asian Nations (ASEAN) and the South Asian Association for Regional Cooperation (SAARC) (Khan et al., 2018a; Ratna & Sharma, 2016; Wang et al., 2020a). Currently, the Regional Comprehensive Economic Partnership (RCEP) involving Asia–Pacific nations has become one of the world’s largest free trade deal, valued at US\$26 trillion and covering nearly 30% of global GDP growth (Kang et al., 2020; Korwatanasakul, 2020; Ratna & Sharma, 2016). Apart from the social and economic impact on member countries, this partnership is expected to remove existing trade barriers, increase supply chain efficiency and logistic sector performance that boost firms’ resilience in Asia and beyond (Khan et al., 2019a). Nevertheless, in the absence of effective regulations, the potential environmental pressure associated with trade expansion and logistic services development is issue of great concern (Magazzino et al., 2021; Wang et al., 2020b; Zaman et al., 2022). Therefore, given this context, it is important to understand the current logistic

infrastructure and the possible economic drivers of environmental pollution. Officially, the World Bank evaluates how well countries are linked to global supply chains using the Logistics Performance Index (LPI) so as to best assist nations figure out where they should boost their trade logistics operations (Dare et al., 2019; Karaduman et al., 2020; Zaman & Shamsuddin, 2017).

Based on these indicators, many studies (Karaduman et al., 2020; Khan et al., 2018a; Magazzino et al., 2021; Saidi et al., 2020; Wang et al., 2020a, 2021; Wood et al., 2019) have traced the rate of carbon emissions in developed and developing regions to technological innovation, international trade (goods and services), green supply chains, logistics performance, Human Development Index (HDI), GDP growth, and CO<sub>2</sub> emissions. However, the literature on the trends and patterns of transport CO<sub>2</sub> emissions from the international logistics expansions in the RCEP and SAARC economic regions is scant, despite the consistent economic progress that has occurred in these regions over the past decade, and the considerable differences that exist between member countries regarding the logistics performance level, economic growth and trading prospects. Again, the group represents emerging Asian economies that have high levels of global trade and investment.

Given this context, the study makes several significant contributions to the field. Primarily, this study investigates the performance of the logistics sector, from the perspective of regional economic integration and the level of international trade and transport CO<sub>2</sub> emissions in RCEP and SAARC countries. Moreover, using panel data from 2007 to 2018, this study unravels the correlation between trade volume, transport CO<sub>2</sub> emissions, and a series of macro-level economic indicators. The best way to minimize transport CO<sub>2</sub> emissions without compromising the logistics industry and economic performance are identified in this regard. Finally, the study captures a robust set of findings using a sound empirical model that utilizes the Estimated Generalized Least Square (EGLS) and Generalized Method of Moments (GMM) regressions.

The remainder of the study is structured as follows, Section 2 details the relevant literature proposes relevant hypotheses based on earlier key empirical works; Section 3 documents the Methodological and data collection procedures, while the results, key findings and discussion sections are represented in Sect. 4. Finally, Sect. 5 reveals our concluding remarks and policy suggestions.

## 2 Literature review and hypothesis development

### 2.1 The relationship between logistics performance and CO<sub>2</sub> emissions

Over the past decade, numerous scholars have explored the relationship between CO<sub>2</sub> emissions and logistics performance indicators, including: transportation infrastructure, supply chain management, GDP growth, trade openness, renewable energy, and foreign direct investment (Khan & Dong, 2017; Liu et al., 2018; Magazzino et al., 2021; Wang et al., 2020a). In particular, Khan et al. (2018a) investigated in-depth global economies and the link between logistical operations, economic growth, energy demand, and environmental sustainability. Their results illustrate that inefficient logistical operations, longer custom clearance operations, and poor transportation infrastructure are important contributors to CO<sub>2</sub> emissions. Zaman and Shamsuddin (2017) found that logistics performance (i.e., international shipments, and services of quality-competence) increases fossil fuel energy use and CO<sub>2</sub> emissions in European countries. Similarly, Liu et al. (2018)

also found that the timeliness of logistics and tracking and tracing consignments positively intensifies environmental pressure in Asia, while competitively price shipments reduced CO<sub>2</sub> emissions. Again, Khan et al. (2020a) and Khan et al. (2019b) asserted that logistics performance is positively and negatively associated with environmental degradation in Asia. Larson (2021) also confirmed that logistics performance is key driver of CO<sub>2</sub> emissions, in particular, greenhouse gas emissions. Santosa et al. (2022) revealed that, of the six LPI indicators measured, logistics performance (global shipments) is only correlated with CO<sub>2</sub> emissions, which emphasized that logistics performance has a negative influence on CO<sub>2</sub> emissions. Using multiple econometric techniques, Magazzino et al. (2021) and Karaduman et al. (2020) concluded that improving logistic performance impedes the positive effects that can be had on CO<sub>2</sub> emissions in high performed logistics and Balkan economies. In contrast, Khan et al. (2020b) found that green logistics performance is negatively associated with CO<sub>2</sub> emissions in the international ranked logistics nations, hence this study utilizes the above findings in formulating the following hypothesis:

**H1** Logistics performance and CO<sub>2</sub> emissions are highly interrelated.

## 2.2 The relationship between logistics infrastructure and international trade

Previous studies (Khan et al., 2019a) are being conducted worldwide to explore the CO<sub>2</sub> emission effects of international trade that is associated with individual (air, sea, rail, and road) transportation modes. Research has shown that emissions from air transportation were much more significant than those from marine and ground transportation. Wang et al. (2020a) examined the effect of logistics infrastructure on Sino-Korea Trade, and found that logistics infrastructure (inland ports) positively contributes to bilateral trade. Martí et al. (2014) confirmed that the influence of the LPI indicators (i.e., customs processes, the quality of land and marine transportation infrastructure logistical expenses) on global trade. Their results revealed that increases in any LPI indicator could lead to massive boosts in a nation's trade volumes and a spillover effect on global trade. Bugarčić et al. (2020) also found that logistics services and LPI components are positively correlated with the bilateral trade flows that exist between the Western Balkans, Central and Eastern European economies. Buvik and Takele (2019) also examined the significance of trade-logistics for African country exports' and concluded that Africa has the lowest LPI score due to the region's weak logistics infrastructure (transport-related, and customs and border processes), which in turn prevents strong export growth from occurring. A global study by Jayathilaka et al. (2022) investigated the effect of global trade, GDP growth, and logistics infrastructure. Their findings show that logistics infrastructure is positively interrelated with international trade (net exports). Furthermore, Ma et al. (2021) found that the logistics development in Chinese provinces significantly influences bilateral trade more than that of partner countries. Wu (2020) confirmed a strong correlation between trade and logistics infrastructure (i.e., container and port cargo services). Çelebi (2019) examined the contribution of logistics performance in promoting bilateral trade and found that low- and lower-middle-income countries benefited from improved logistics performance through increased exports relative to imports. On the other hand, Larson (2021) asserted that logistics infrastructure (freight transport by truck) is a key factor of carbon emissions compared to that of rail. Similarly, Gao et al. (2021) and Santosa et al. (2022) found that the impact of trade and transport-related logistics infrastructure and international trade on CO<sub>2</sub> emissions is parallel to that of other economies and local regions. They also emphasized that measuring logistic

performance in businesses is intended to evaluate the combined effects of the logistics chain on regional trade. The above findings have demonstrated the possible nexus between logistic infrastructure and trade; therefore, the study proposed the following hypothesis:

**H2** Logistics infrastructure and international trade is positively correlate with CO<sub>2</sub> emissions.

### 2.3 The relationship between economic and logistics performance indicators

Regarding the logistics performance effects of global economic growth, the emphasis has primarily surrounded the need for accountability and understanding of the environmental degradation caused by growing FDI inflows and trading levels. Using GMM estimation with LPI as the dependent variable, Khan et al. (2018a) found that logistics performance (quality of logistics services and shipments reached on time) positively spurs economic growth. Similarly, Khan et al. (2019a) illustrated that the quality of logistics services significantly improves per capita GDP growth using GMM techniques in SAARC economies. Li et al. (2021b) found that green logistics operations improved economic growth in Europe and across the Belt and Road economies. With LPI as a depend variable, Khan et al. (2019b) also found that LPI (quality of services, transport-based infrastructure, and efficient customs processes) have a significant positive impact on economic growth in emerging Asia. Suki et al. (2021) examined the relationship between logistics performance, sustainable growth, and CO<sub>2</sub> emissions in Asian countries and confirmed that six LPI indicators have a positive correlation with economic growth. Again, Zaman and Shamsuddin (2017) found that a positive relationship between LPI and national income, particularly (timely shipment reached, efficiency of tracking and tracing, and effective customs clearance) leads to GDP growth in European countries. Using quarterly data from 2010 to 2018, Suki et al. (2021) confirmed the logistic performance harmonized economic expansion in top Asian economies. Moreover, using the system GMM technique, Chakamera and Pisa (2021) highlighted that the LPI indicator (competence and quality of logistics) is a key contributor of economic performance in African countries. These prior studies have highlighted how the LPI indicator actively promotes economic transition through the implementation of efficient logistics operations; hence, this study developed the hypothesis as follows:

**H3** Logistics performance activities positively contribute to maintaining economic growth.

In order to better grasp the current study trends in this research area, the study has summarized the most recent and relevant studies in Table 1. Although most of the previous literature has had a very strong Asian regional focus, there are still a few works which have focused on SAARC and RCEP countries from a micro-level perspective within the logistics industry. Also, Khan et al. (2019a) recommended intense comparative studies between ASEAN, SAARC, and other economies' focusing on economic growth, the logistics industry, and CO<sub>2</sub> emissions. The evaluation of the LPI is one of the critical indicators examined in research at the macro level. As a result, this study is essential in bridging the gap that exists between a lack of knowledge on the changes in CO<sub>2</sub> emissions that have occurred from the transportation sector and international trade volume (goods) within the RCEP and SAARC regions.

**Table 1** Summary of previous studies overview

Author	Period	Study area	Model/design	Key findings
Zaman and Shamsuddin (2017)	2007–2014	27 European countries	First difference GMM	Logistics are inextricably tied to the economic variables that drive demand for green supply chains
Khan et al. (2018a)	2007–2016	43 countries	Panel FGLS and GMM	Poor logistics operations and transport-related infrastructure are the leading causes of CO <sub>2</sub> emissions
Georgatzi et al. (2020)	1994–2014	12 European countries	FMOLS and DOLS	The transport sector causes CO <sub>2</sub> emissions
Khan et al. (2019a)	2001–2016	SAARC	FGLS, GMM	Green practices may help reduce CO <sub>2</sub> emissions by improving logistical activities, resulting in increased GDP, trade openness, and export prospects
Karaduman et al. (2020)	2007–2016	11 Balkan countries	Fixed-effects panel regression	The association between logistics performance and CO <sub>2</sub> is both favorable and statistically significant
Venus Lun et al. (2015)	Total of 107 questionnaires survey in 2012	Hong Kong	Correlation and regression analysis	Customers are involved in developing greening tendencies by executing logistical operations to obtain social and economic advantages
Li et al. (2021b)	2007–2019	BRI economies	Panel 2SLS, and GMM	Green logistics operations improve economic growth and CO <sub>2</sub> emissions in BRI economies
Liu et al. (2018)	2007–2016	42 Asian countries	System GMM	Logistics performance is related to environmental pressure, while trade openness reduces CO <sub>2</sub> emissions
Lu et al. (2019)	2007–2014	112 countries	RAM-DEA	The logistics and environmental logistics performance index is closely related to income
Khan et al. (2019b)	2001–2007	Asian countries	FMOLS, DOLS	Logistics operations is positively correlated with GDP per capita and trade openness, however, greater logistics activities were negatively associated with environmental issues
Khan et al. (2020a)	2007–2018	ASEAN	SEM	Using renewable energy in logistics operations helps with economic growth and reduces emissions

### 3 Methodology and data sources

This study examines the nexus between per capita GDP growth, logistics performance, transport CO<sub>2</sub> emissions, FDI inflows, international trade, and renewable energy consumption using panel data from 16 selected countries. Logistics performance plays a pivotal role in regional economic growth. Nevertheless in the absence of logistics innovation and green policies, the impact on CO<sub>2</sub> emission levels can be detrimental (Khan et al., 2018a). As a result, our study analyses the relationship between logistics performance and transport CO<sub>2</sub> emissions with international trade in the presence of economic variables that support green logistics and practices across the selected regions from 2007 to 2018. Based on hypotheses, this study has given the regression equation as follows:

$$LGP_i = \alpha_o + \beta_1 REC_i + \beta_2 TCO_{2i} + \beta_3 EG_i + \beta_4 contr_i + \varepsilon_i \quad (1)$$

For input variables, LGP indicates the logistics performance index with six parameters, which include: competence and quality of logistics services (LP), quality of trade and transport-related infrastructure (LQT), ease of arranging competitively priced shipments (LPS), ability to track and trace consignments (LTC), the frequency with which shipments reach the consignee within the expected time (LFS), and the efficiency of the customs clearance process (LCC). The global index values of 1 (inferior) and 5 (higher) refer to logistics performance. Furthermore, REC represents renewable energy consumption (% of total final energy consumption), TCO<sub>2</sub> signifies the level of CO<sub>2</sub> emissions from transportation (Mt), and EG indicates the rate of GDP per capita (current US\$). Finally, CONTR indicates the control variables that relate to international trade (ITR), such as; export and import of goods (BoP, current US dollars), foreign direct investment (FDI) net inflows (% of GDP), while  $\alpha$  and  $\varepsilon$  denote the constant and error terms respectively.

$$LGP_{it} = \alpha_o + \beta_{1t} REC_{it} + \beta_{2t} TCO_{2it} + \beta_{3t} EG_{it} + \beta_{4t} contr_{it} + v_t + \varepsilon_{it} \quad (2)$$

Based on the purpose of the study, the study estimated regression models are based on the panel data obtained from 16 countries situated within the RCEP and SAARC regions. These countries are captured as  $i$ , while  $t$  shows the timeframe in Eq. 2. The flowchart of this study is presented in Fig. 1.

#### 3.1 Cross-sectional dependence (CD) tests

It is imperative that any cross-sectional dependency is assessed in the panel data, predominantly if the panel consists of nations with similar economic interests and characteristics, such as the rate of industrialization, trade association, and regional blocks. Furthermore, economic integration, globalization, and global trade in one economy may have a ripple effect on other countries (Sikder et al., 2022). Given this importance, four tests were conducted for cross-sectional dependence (i.e., Breusch-Pagan LM, Pesaran scaled LM, Bias-corrected scaled LM, and Pesaran CD). Therefore, the Lagrange multiplier (LM) test, proposed by Breusch and Pagan (1980), which is valid in cross-Sects. (1.0.2.0.3..N), is smaller than  $T$ . As a result, according to Eq. (1), the study computed the statistics of the LM test:

$$y_{it} = \alpha_o + \delta_1 x_{it} + v_{it} \quad i = 1, \dots, N \text{ and } t = 1, \dots, T \quad (3)$$

where  $y_{it}$  and  $x_{it}$  denotes endogenous variable and exogenous variables, respectively. The subscripts  $i$  and  $t$  indicate cross-sections and timeframe, respectively. Therefore, the LM test is accounted for as follows;

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \rightarrow_d \chi^2_{N(N-1)/2} \tag{4}$$

where  $\hat{\rho}_{ij}$  indicates a sample estimate of the pair-wise correlation of the residuals. However, the LM statistic is inappropriate when  $N$  is large. In this context, Pesaran et al. (2008) suggested the scaled edition of the following LM test ( $CD_{lm}$ ) statistic:

$$CD_{lm} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N (T\hat{\rho}_{ij}^2 - 1) \tag{5}$$

where the  $CD_{lm}$  statistic follows an asymptotic standard normal distribution (Menyah et al., 2014) under the cross-sectional independence null hypothesis with the first  $T \rightarrow \infty$  then  $N \rightarrow \infty$ . In the case of a large  $N$  relative to  $T$ , the test  $CD_{lm}$  has considerable size distortions. As a result, the CD test suggested by Pesaran (2004) is captured in the equation due to its suitability.

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left( \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \right) \tag{6}$$

Nonetheless, the CD test has the following flaw: when the population average pair-wise correlations are zero, even if the underlying individual population pair-wise correlations are not zero, the CD test loses its superiority (Ozcan & Ozturk, 2019). Therefore, a bias-corrected edition of the LM test, initially proposed by Pesaran et al. (2008), developed the precise mean and variance of the LM statistic when it comes to large panels first  $T \rightarrow \infty$  then  $N \rightarrow \infty$ . The bias-corrected scaled LM test is defined as:

$$LM_{cor} = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \frac{(T-K)\hat{\rho}_{ij}^2 - \mu_{Tij}}{v_{Tij}^2} \rightarrow_d N(0, 1) \tag{7}$$

where  $K$  refers to the number of regressors,  $\mu_{Tij}$  and  $v_{Tij}^2$  represent the exact mean and variance of  $(T-K)\hat{\rho}_{ij}^2$ , respectively.

### 3.2 Specification of the empirical models

Autocorrelation and heteroskedasticity issues in the panel data can be misleading or distort the model’s proper estimation (Khan et al., 2018a, 2019a). Based on these assumptions and the nature of the data, the study used the panel EGLS and panel GMM models estimation techniques to test the above hypotheses, owing to their merits over the traditional OLS technique. Although both techniques can potentially address heteroskedasticity issues, the GMM model can resolve the specific occurrences of heterogeneity, autocorrelation, and heteroscedasticity (Farooq et al., 2022; Khan et al., 2018a).

Additionally, to solve the heterogeneity and serial correlation problem, the individual equations are transformed by first difference estimators (Arellano & Bond, 1991). Moreover, all variables are converted to logarithmic form to ensure normal data distribution,



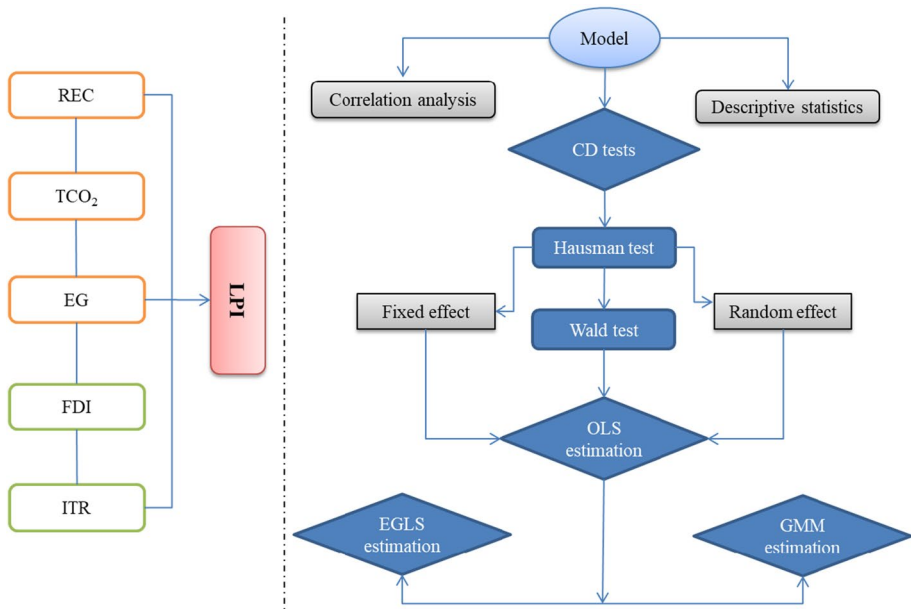


Fig. 1 Conceptual model and estimation procedure of this study

linearity between variables, robust estimation, and the validity of our statistical models. Equations 8–13 account for these endogenous and exogenous variables as follows:

$$\begin{aligned}
 \text{LNLP}_{it} &= \text{LNEG}_{it}\phi_1 + \text{LNTCO}_{2it}\psi_1 + \text{LNFDI}_{it}\psi_2 + \text{LNITR}_{it}\psi_3 + \text{LNREC}_{it}\psi_4 + \varepsilon_i + v_{it} \\
 &= Z_{it}\varphi + \varepsilon_i + v_{it}
 \end{aligned}
 \tag{8}$$

$$\begin{aligned}
 \text{LNLTC}_{it} &= \text{LNREC}_{it}\phi_1 + \text{LNEG}_{it}\phi_2 + \text{LNTCO}_{2it}\psi_1 + \text{LNFDI}_{it}\psi_2 + \text{LNITR}_{it}\psi_3 + \varepsilon_i + v_{it} \\
 &= Z_{it}\varphi + \varepsilon_i + v_{it}
 \end{aligned}
 \tag{9}$$

$$\begin{aligned}
 \text{LNLPS}_{it} &= \text{LNREC}_{it}\phi_1 + \text{LNITR}_{it}\phi_2 + \text{LNTCO}_{2it}\psi_1 + \text{LNFDI}_{it}\psi_2 + \text{LNEG}_{it}\psi_3 + \varepsilon_i + v_{it} \\
 &= Z_{it}\varphi + \varepsilon_i + v_{it}
 \end{aligned}
 \tag{10}$$

$$\begin{aligned}
 \text{LNLQT}_{it} &= \text{LNTCO}_{2it}\phi_1 + \text{LNEG}_{it}\psi_1 + \text{LNFDI}_{it}\psi_2 + \text{LNREC}_{it}\psi_3 + \text{LNITR}_{it}\psi_4 + \varepsilon_i + v_{it} \\
 &= Z_{it}\varphi + \varepsilon_i + v_{it}
 \end{aligned}
 \tag{11}$$

$$\begin{aligned}
 \text{LNLFS}_{it} &= \text{LNEG}_{it}\phi_1 + \text{LNTCO}_{2it}\psi_1 + \text{LNREC}_{it}\psi_2 + \text{LNFDI}_{it}\psi_3 + \text{LNITR}_{it}\psi_4 + \varepsilon_i + v_{it} \\
 &= Z_{it}\varphi + \varepsilon_i + v_{it}
 \end{aligned}
 \tag{12}$$

$$\begin{aligned}
 \text{LNLCC}_{it} &= \text{LNEG}_{it}\phi_1 + \text{LNTCO}_{2it}\phi_2 + \text{LNITR}_{it}\psi_1 + \text{LNFDI}_{it}\psi_2 + \text{LNFDI}_{it}\psi_3 + \varepsilon_i + v_{it} \\
 &= Z_{it}\varphi + \varepsilon_i + v_{it}
 \end{aligned}
 \tag{13}$$

In Eqs. 8–13, the dependent variables are indicated as  $\text{LNLP}_{it}$ ,  $\text{LNLTC}_{it}$ ,  $\text{LNLPS}_{it}$ ,  $\text{LNLQT}_{it}$ ,  $\text{LNLFS}_{it}$ , and  $\text{LNLCC}_{it}$  respectively, with the coefficient shown as  $\phi$ . The set of observations on  $g_2$  and the endogenous variables are incorporated as covariates with

coefficients, and these variables are allowed to be connected with  $v_{it}$  (Khan et al., 2019a). On the other hand, the variables with coefficients  $\psi$  are observations on the exogenous variables included as covariates. In addition,  $Z_{it}$  denotes the instruments which can be endogenous or exogenous with lags of dependent and independent variables (Arellano & Bond, 1991). Furthermore,  $\varphi$  is a  $K \times 1$  vector of coefficients, where  $K = g_2 + k_1$  (Khan et al., 2018a). The GMM estimator is also superior in a condition where the cross-section identifiers are large when compared to the small numbers used for a specific time (Alonso-Borrego & Arellano, 1999). Based on the nature of the current data (panel) and the merits of the GMM model over other estimators, the study adopts the GMM techniques as the vigorous estimator for the cross-section identifiers of 16 counties within the RCEP and SAARC region.

### 3.3 Data source

Using 2007–2018 data, the study selected a panel of 16 countries, namely Australia, Bangladesh, Cambodia, China, India, Indonesia, Japan, Malaysia, New Zealand, Pakistan, the Philippines, Singapore, Sri Lanka, South Korea, Thailand, and Vietnam. As depicted in Table 2 and Fig. 2, the selected nations were grouped based on their respective RCEP and SAARC economic groups, as identified in earlier studies (Khan et al., 2018a, 2019a, 2020a; Li et al., 2021b; Liu et al., 2018; Snovia & Tong, 2021).

Table 3 illustrates the data sources for competence and quality of logistics services (LP), quality of trade and transport-related infrastructure (LQT), ease of arranging competitively priced shipments (LPS), ability to track and trace consignments (LTC), the frequency with which shipments reach a consignee within an expected time (LFS), the efficiency of the customs clearance process (LCC), GDP per capita (current US\$), Foreign direct investment, net inflows (% of GDP), and renewable energy consumption (% of total final energy consumption) were sourced from the World Development Indicator (WDI, 2022) database. Additionally, data for transportation CO<sub>2</sub> emissions (Mt) was gleaned from the International Energy Agency (IEA, 2022), while of the data associated with exports and imports (BoP, current US\$) was obtained from the World Integrated Trade Solution (WITS, 2022) database. The plots of level data are shown for convenient reference in “Appendix 3”.

## 4 Results and discussion

Table 4 presents the results of descriptive statistics and correlation analyses from 96 observations. The mean, maximum and minimum values indicate the performance and the variations in the selected economic and logistic sector indicators of RCEP and SAARC economies between 2007 and 2018. Additionally, the correlation between the variables is displayed through a correlation matrix where the values  $\leq 0.50$  and  $\geq 0.60$  show low and high-level relationships, respectively.

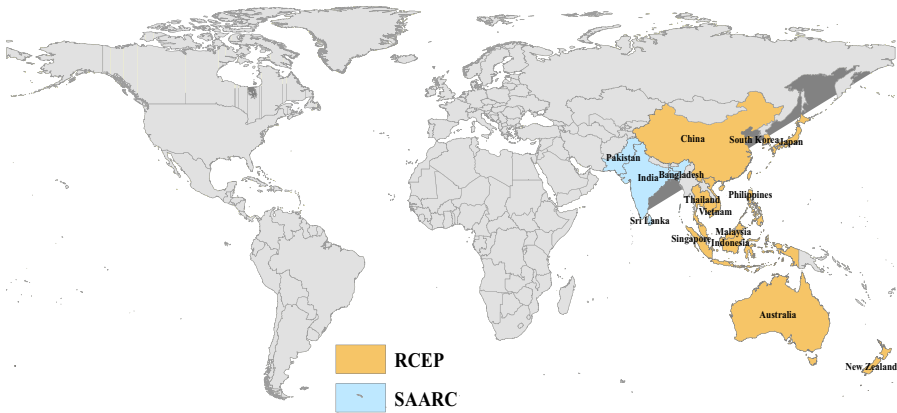
### 4.1 Results of cross-sectional dependence test

Panel-data models are prone to cross-sectional dependence errors due to common shocks and unobserved components in selected panels (RCEP and SAARC). Table 5 shows the

**Table 2** Grouping of countries

Name of groups	Selected countries
RCEP	Australia, China, Cambodia, Indonesia, Japan, Malaysia, New Zealand, Philippines, Singapore, South Korea, Thailand, and Vietnam
SAARC	Bangladesh, India, Pakistan, and Sri Lanka

RCEP represents the (Regional Comprehensive Economic Partnership) and SAARC represents the (South Asian Association for Regional Cooperation)



**Fig. 2** Groupings of RCEP and SAARC regions

cross-sectional dependence (CD) test used to account for such occurrences. The results showed 54% cross-sectional dependence. Furthermore, the Hausman test was conducted considering the fixed and random effects in the OLS (ordinary least square) regression for different dependent variables. *R*-square and *F*-statistics supported the model’s fit and stability (Table 6). The Wald test failed to reject the alternative hypothesis, which states that the variables are stationary. The 1% Wald test results verify the model’s fitness. These diagnostic tests are acceptable; hence, the OLS models with random and fixed effects are valid for estimating coefficients.

The findings of the OLS, fixed and random effect estimations are presented in Table 6. Economic growth (LNEG) and international commerce (LNITR) are substantially connected with logistical operations at the 1%, 5%, and 10% significance levels, respectively. Briefly, well-organized logistics operations will considerably increase GDP growth and international trade (goods export–import). Moreover, at the 5% and 10% significant levels, the efficiency of the customs clearance procedure (LNLCC), the organization of competitively priced shipments (LNLPS), and the effectiveness of the tracking and tracing consignments (LNLTC) had a positive association with FDI inflow. It must be noted that the selected groups share a common interest in enhancing the ease of doing business; consequently, the majority of FDI is likely to be channeled towards quality logistics services, as efficient logistics operations and transportation infrastructure facilitate cross-border trade

and boost the confidence of foreign investors. Therefore, the high positive link between economic growth, international trade, and FDI and logistics operations within the selected panel data is not surprising. However, the ordinary least squares (OLS) estimation is susceptible to problems such as noise in independent variables and Unequal Training Point Variances, which may result in a biased interpretation. Consequently, the study employs the EGLS and GMM approaches, which deliver more effective outcomes.

#### 4.2 Estimated generalized least square (EGLS) and generalized method of moments (GMM) estimations outcomes

To eliminate possible biased results associated with OLS estimations, Table 7 shows the EGLS and GMM estimations. The result shows a positive relationship between LNLTP, LNLCC, LNLTC, and LNEG at a 1% significance level. Specifically, an increase in the quality of logistics services (LNLTP) will increase GDP growth by 0.068%. These results amplify the role of quality logistic services in enhancing national income and trade performance. Moreover, a 1% efficiency improvement in the customs clearance process (LNLCC) and the capacity of tracking and tracing consignments (LNLTC) will lead to a 0.096% and 0.070% improvement in national income, respectively. These results are consistent with prior studies of key economies such as; Vietnam (Pham et al., 2019), Asian countries (Khan et al., 2019b), the USA (Cooper et al., 2017), European countries (Zaman & Shamsuddin, 2017), Hong Kong (To, 2015), Germany (Dijkman, 2008), and 150 countries around the world (Marti et al., 2014). Similarly, the above studies also unravel a positive connection between the logistics industries and national income, trade openness, and logistics mechanisms. Following prior studies (Farooq et al., 2022; Khan et al., 2018a), the GMM model confirms an adverse effect of LNLQT, LNLFS, and LNLPS on LNEG at a 10% level of significance. As highlighted in Table 7, a decline in trade and transport-related infrastructure quality, shipment speed, and inefficiently arranged competitively priced shipments will reduce per capita GDP growth by 0.271%, 0.202%, and 0.490%. Poor logistic infrastructure is economically unfavorable and unattractive for businesses, individuals, and trade partners, with ripple effects on the value of income generated from goods and services. However, as trade improves through quality logistic services, there is a spillover effect on the

**Table 3** Source of data and description

Indicator	Variable	Definition/measurement of Unit
Environment	TCO <sub>2</sub>	CO <sub>2</sub> emission from transportation (Mt)
	REC	Renewable energy consumption (% of total final energy consumption)
	LP	Competence and quality of logistics services
	LQT	Quality of trade and transport-related infrastructure
Logistics	LPS	Ease of arranging competitively priced shipments
	LTC	Ability to track and trace consignments
	LFS	Frequency with which shipments reach consignee within expected time
	LCC	Efficiency of customs clearance process
	EG	GDP per capita (current US\$)
Economic	FDI	Foreign direct investment, net inflows (% of GDP)
	ITR	Export and Import of goods (BoP, current US\$)

**Table 4** Descriptive statistics and correlation matrix

	LNLP	LNLCC	LNLFS	LNLPS	LNLQT	LNLTC	LNEG	LNFDI	LNITR	LNTCO <sub>2</sub>	LNREC
<i>Descriptive statistics</i>											
Mean	1.150	1.090	1.278	1.157	1.116	1.176	8.700	0.736	26.168	3.725	2.734
Median	1.167	1.090	1.293	1.181	1.137	1.193	8.277	0.659	26.514	3.784	3.334
Maximum	1.437	1.430	1.510	1.396	1.453	1.446	11.127	3.264	29.030	6.805	4.239
Minimum	0.737	0.672	0.978	0.783	0.631	0.802	6.324	-4.742	22.772	0.693	-0.748
Std. Dev	0.172	0.189	0.133	0.130	0.219	0.161	1.478	1.229	1.471	1.434	1.338
Observation	96	96	96	96	96	96	96	96	96	96	96
<i>Correlation matrix</i>											
LNLP	1										
LNLCC	0.949	1									
LNLFS	0.884	0.849	1								
LNLPS	0.888	0.873	0.843	1							
LNLQT	0.962	0.957	0.898	0.882	1						
LNLTC	0.953	0.934	0.907	0.876	0.957	1					
LNEG	0.856	0.889	0.797	0.751	0.875	0.857	1				
LNFDI	-0.002	0.045	-0.001	0.062	-0.013	0.014	-0.053	1			
LNITR	0.758	0.671	0.728	0.746	0.765	0.751	0.537	-0.097	1		
LNTCO <sub>2</sub>	0.450	0.346	0.405	0.439	0.448	0.443	0.217	-0.367	0.809	1	
LNREC	-0.761	-0.735	-0.725	-0.738	-0.769	-0.749	-0.745	-0.157	-0.636	-0.171	1

**Table 5** Cross-sectional dependency test

Variables	Breusch-Pagan LM CD-test	Pesaran scaled LM CD-test	Bias-corrected scaled LM CD-test	Pesaran CD CD-test
LNLFP	150.98**	0.96	-0.63	0.94
LNLCC	143.00*	0.45	-1.14	4.77***
LNLFS	152.29**	1.05	-0.54	-0.24
LNLPS	138.36	0.15	-1.44	0.35
LNLQT	146.24**	0.66	-0.93	3.48***
LNLTC	144.57*	0.55	-1.04	-0.61
LNEG	490.23***	22.86***	21.26***	20.87***
LNFDI	149.66**	0.88	-0.71	1.89**
LNITR	461.25***	20.99***	19.39***	20.56***
LNTCO <sub>2</sub>	512.94***	24.33***	22.73***	16.37***
LNREC	378.92***	15.68***	14.08053***	-1.05

An examination of cross-dependency (CD) test of Breusch-Pagan LM, Pesaran scaled LM, Bias-corrected scaled LM, and Pesaran CD of observed variables of 16 countries

\*\*\*, \*\*, and \*denotes significance at the 1%, 5%, and 10% levels statistically

levels of GDP growth achieved through the creation of additional revenue sources, such as import and export taxes on goods and services. Even though the quality of logistics infrastructure is directly linked to income in previous studies, more meaningful impacts can be attained through specialized logistics operations (i.e., adopting green policies in logistics and transport-related infrastructures), which not only assists in mitigating CO<sub>2</sub> emissions but also contributes to improving overall logistics performance in individual firms (Khan & Dong, 2017; Zhu et al., 2005). Moreover, using the GMM estimation, previous studies (Bose & Pal, 2012; Khan et al., 2018b) highlighted the fact that green logistics initiatives improve firms' income and national income (GDP). Similarly, (Li et al., 2021b) depicted that green logistics practices and FDI are positively correlated with economic growth in the Middle East and North Africa, East and Southeast Asia, and Belt and Road countries. In the case of China, Wang et al. (2021) found that the relationship between logistics infrastructure and economic development has a long-term equilibrium.

Similarly, the OLS estimation revealed a positive association between LNLFP, LNLCC, LNLTC, and FDI inflows with varying significance levels (1%, 5%), implying that FDI inflows propelled by the quality of logistics services and the efficiency of the customs clearance process, while a 1% improvement in the efficiency of tracking and tracing consignments will bring a valuable change in FDI of 0.008%. In comparison, these findings support that of (An et al., 2021) where FDI significantly improved the quality of logistic operations and customs clearance processes in the Belt and Road countries using the GMM approach. Again using GMM estimators, Saidi et al. (2020) concluded that logistics infrastructure positively affects FDI and long-term economic expansion in South Asia, East Asia and the Pacific, the Middle East, Europe, Central Asia, and North and Sub-Saharan African countries due to the efficiency of the logistics infrastructure, a smooth customs process, size of trade volume, and the implementation and execution of attractive national policies. Similarly, Siddiqui and Vita (2021) concluded that the logistics infrastructure,

**Table 6** The results of OLS, fixed and random effect estimation

	LNLP		LNLTQT		LNLC		LNLF		LNLS		LNLP		LNLT	
	OLS	Random	OLS	Random	OLS	Random	OLS	Random	OLS	Fixed	OLS	Random	OLS	Fixed
LNREG	0.072*** (0.007)	0.067*** (0.009)	0.095*** (0.007)	0.086*** (0.012)	0.098*** (0.007)	0.092*** (0.012)	0.048*** (0.007)	0.048*** (0.007)	0.037*** (0.007)	-0.021 (0.057)	0.037*** (0.007)	0.035*** (0.010)	0.070*** (0.006)	0.018 (0.057)
LNTRCO <sub>2</sub>	-0.001 (0.013)	0.007 (0.017)	-0.011 (0.015)	-0.003 (0.021)	-0.012 (0.015)	-0.008 (0.020)	-0.022 (0.013)	-0.022 (0.013)	-0.000 (0.013)	0.014 (0.052)	-0.000 (0.013)	0.002 (0.018)	-0.004 (0.012)	0.046 (0.052)
LNFDI	0.009 (0.006)	0.008 (0.007)	0.007 (0.007)	0.005 (0.009)	0.016** (0.007)	0.012 (0.009)	0.001 (0.006)	0.001 (0.006)	0.011* (0.006)	-0.013 (0.010)	0.011* (0.006)	0.009 (0.008)	0.011** (0.006)	-0.003 (0.010)
LNTR	0.050*** (0.016)	0.037* (0.020)	0.074*** (0.018)	0.058** (0.024)	0.052*** (0.018)	0.044* (0.024)	0.061*** (0.016)	0.061*** (0.016)	0.040** (0.016)	0.002 (0.050)	0.040** (0.016)	0.036* (0.021)	0.051*** (0.015)	-0.002 (0.049)
LNREC	-0.002 (0.011)	-0.014 (0.014)	0.003 (0.012)	-0.012 (0.017)	0.014 (0.012)	0.003 (0.017)	0.006 (0.011)	0.006 (0.011)	-0.010 (0.011)	-0.029 (0.032)	-0.010 (0.011)	-0.015 (0.015)	0.004 (0.010)	-0.039 (0.032)
Constant	-0.789** (0.400)	-0.412 (0.504)	-1.630*** (0.451)	-1.132* (0.603)	-1.156** (0.450)	-0.867 (0.591)	-0.678* (0.402)	-0.678* (0.402)	-0.222 (0.409)	1.430 (0.973)	-0.222 (0.409)	-0.083 (0.531)	-0.786** (0.378)	1.020 (0.968)
R-squared	0.864	0.746	0.893	0.728	0.858	0.706	0.771	0.771	0.751	0.868	0.751	0.580	0.862	0.911
F-statistic	114.969	53.024	151.30	48.263	108.90	43.254	60.825	60.825	54.554	24.841	54.554	24.868	112.636	38.641
Hausman test	5.722	5.906	5.906	5.906	3.943	43.254	18.439***	18.439***	1.908	24.841	1.908	24.868	11.782**	38.641
Wald Test	574.847***	574.847***	756.508***	756.508***	544.516***	43.254	304.127***	304.127***	272.770***	24.841	272.770***	24.868	563.183***	38.641

Robust standard errors are in brackets. The individual Wald and Hausman test indicates chi-squared statistics values, and weighted statistics follow random effect models' R-square values

\*p < 0.1; \*\*p < 0.05; \*\*\*p < 0.01

**Table 7** The results of panel EGLS and GMM estimation

	LNLTP		LNLQT		LNLCC		LNLFS		LNLPS		LNLTC	
	EGLS	GMM	EGLS	GMM	EGLS	GMM	EGLS	GMM	EGLS	GMM	EGLS	GMM
LNEG	0.068*** (0.005)	0.288** (0.112)	0.091*** (0.005)	-0.271* (0.144)	0.096*** (0.006)	0.064 (0.116)	0.045*** (0.004)	-0.202* (0.117)	0.032*** (0.006)	-0.490** (0.219)	0.070*** (0.005)	0.057 (0.187)
LNTCO <sub>2</sub>	0.000 (0.007)	-0.177** (0.073)	-0.015 (0.010)	0.143** (0.056)	-0.026** (0.011)	-0.057 (0.053)	-0.014* (0.008)	0.021 (0.092)	0.001 (0.009)	0.289** (0.157)	-0.001 (0.009)	0.061 (0.091)
LNFDI	0.008** (0.004)	0.026*** (0.008)	0.002 (0.004)	0.000 (0.019)	0.010** (0.005)	0.016 (0.016)	0.002 (0.003)	-0.014 (0.009)	0.010** (0.004)	-0.047** (0.023)	0.008** (0.004)	-0.003 (0.018)
LNITR	0.044*** (0.009)	-0.098 (0.107)	0.076*** (0.011)	0.260** (0.104)	0.060*** (0.013)	0.053 (0.080)	0.049*** (0.010)	0.095 (0.091)	0.032*** (0.010)	0.271 (0.164)	0.043*** (0.011)	-0.079 (0.121)
LNREC	-0.010* (0.006)	0.022 (0.102)	0.003 (0.009)	0.038 (0.134)	0.017* (0.009)	0.108 (0.092)	0.001 (0.007)	0.064 (0.058)	-0.015** (0.007)	0.293** (0.137)	0.001 (0.008)	-0.148** (0.072)
Constant	-0.589** (0.225)		-1.623*** (0.307)		-1.283*** (0.339)		-0.355 (0.263)		0.060 (0.260)		-0.577** (0.300)	

Robust standard errors are in brackets

\* $p < 0.1$ ; \*\* $p < 0.05$ ; \*\*\* $p < 0.01$



such as E-clearance (an online service that streamlines the foreign trade process, reduces transport costs, and ensures the development of clear and transparent regulatory standards for the delivery of goods) leads to a significant effect on FDI inflows in Southeast Asian economies. Accordingly, Wood et al. (2019) found that logistics services enhance RCEP regions (i.e., China, Japan, Korea) and Taiwan's trading partnership. On the other hand, a 1% decline in the quality of competitively priced shipments will decrease FDI inflows by 0.047%. The main reason is that logistics operations costs are rising due to poor logistics infrastructure and inefficient transportation legislation (Werikhe & Jin, 2016). However, Lai et al. (2012) and Zawaydeh (2017) argued that green logistics and environmental-friendly government policies not only encourage FDI inflows but can also improve economic growth and create a positive image of firms. Therefore, the quality of logistics operations, sustainable logistics infrastructure, efficacious tracking, and tracing systems, uncompetitive price shipments, and simplicity of customs clearance could help deliver high returns for foreign investors.

International trade (export–import goods) enhances regional economic growth and FDI inflows. Specifically, all six logistics performance indexes enhance the volume of international trade in RCEP and SAARC as follows; LNLN (0.044%), LNLQT (0.260%), LNLCC (0.060%), LNLFS (0.049%), LNLPS (0.032%), and LNLTC (0.043%), respectively. The study contributes to the debate on the role of international logistics services and the performance of global trade volumes. Also, it supports the results of Marti et al. (2014) and Wang et al. (2018), who found that LPI had a significant and positive effect on international trade flows in the global developing economies and developed economies. Furthermore, Jayathilaka et al. (2022) and Katrakylidis and Madas (2019) also confirmed that the LPI has a positive relationship with net exports from the Middle East, Asia, Europe, and Oceania regions. In particular, international trade (exports and imports) and logistics performance are the driving engines of global economic growth while enhancing trade volume (Arvis et al., 2018; Gani, 2017). In this context, Host et al. (2019) argued that trade can be enhanced with international trade facilitation, and exporter logistics performance is more vital than importer logistics performance. Again, Stojanović and Ivetić (2020) concluded that the performance of logistics operations acts as a catalyst for international trade and supply chain activities.

On the other hand, Shepherd (2013) asserted that trade between countries is a keystone of a well-established relationship between the logistics and transportation sectors. Likewise, the significant level of logistics infrastructure (local transportation) that exists in the region positively affects both international trade and FDI in Asian economies (Halaszovich & Kinra, 2020). Siddiqui and Vita (2021) also concluded that LPI measured by online customs clearance process significantly impacts the international trade of the garment industry in Bangladesh, Cambodia, and India. Although, environmentally unfriendly logistics infrastructure reduces trade opportunities and creates a negative image in the international market due to the exacerbation of non-greener practices. Khan et al. (2020a) argued that using renewable energy in logistics operations can enhance both the quality of environmental sustainability and the rate of economic development while simultaneously declining emissions. Recently, Lu et al. (2022) asserted that international trade is correlated with the use of renewable energy. Finally, an increase in the use of renewable energy sources in conjunction with effective government policies and international trade is ecologically favorable.

As a contribution to the global environmental agenda of CO<sub>2</sub> emission reduction, the next stage of the study analyses logistic performance and the CO<sub>2</sub> nexus under two

environmental factors (CO<sub>2</sub> emissions from transportation and renewable energy consumption). From the analysis, the study found a significant but negative association between TCO<sub>2</sub> (CO<sub>2</sub> emissions from transportation) with LNLQ (competence and quality of logistics services), LNLCC (efficiency of customs clearance process), and LNLFS (frequency with which shipments arrive at consignee within expected time) as depicted in Table 7, respectively. The results indicate that a 0.177%, 0.026%, and 0.014% reduction in transportation CO<sub>2</sub> emissions can be brought about due to a 1% improvement in superior logistics services, a hassle-free customs clearance process, and the frequency of shipments that arrive within an expected time. That means, more extended customs clearance processing and shipment delays are the leading causes of CO<sub>2</sub> emissions from the transportation sector, which can be minimized through quality and efficient logistics services. These findings are consistent with recent studies (Khan et al., 2018a), which use the GMM model and confirm increased CO<sub>2</sub> emissions due to inefficient customs clearance processes and shipment delays. On the contrary, Dekker et al. (2012) traced environmental pressure, climate change, CO<sub>2</sub> emissions, air pollution, flora and fauna disease, and greenhouse gas emission to logistics activities. Logistics operations highly depend on transport infrastructure, and transportation is the primary source of CO<sub>2</sub> emissions globally (Wang et al., 2020a, 2020b). In this regard, Shepherd and Hamanaka (2015) emphasized that the customs services and shipment processes represent the cross-cutting nature of logistics, which creates logistics operations of critical significance, but also substantial inefficiencies that can lead to reductions in the overall performance of the logistics sector. On the other hand, Simão et al. (2016) argued that green logistics can help operations run more efficiently while lowering transportation-related CO<sub>2</sub> emissions.

Furthermore, Wang et al. (2020d) argued that transportation-intensity and energy-intensity effects significantly minimize transportation CO<sub>2</sub> emissions in the Eurasian (developed and developing economies) logistics corridor. In particular, Wang et al. (2020c) concluded that the Southeast and West Asian economies are experiencing increases in their transport CO<sub>2</sub> emissions because of rapid industrial developments and international trade growth. However, this is essential to promoting green investment and adopting cutting-edge technologies across the renewable energy platforms and transport industry (Sikder et al., 2022; Wang et al., 2020c). As a result, recent logistics emphasize biofuels and renewable energy sources that help to reduce CO<sub>2</sub> emissions within the transportation sector while continuing a sustainable economy (Gold & Seuring, 2011). However, this would not be possible without effective regulatory support from the relevant governmental authorities.

Table 7 demonstrates that TCO<sub>2</sub> (CO<sub>2</sub> emissions from transportation) has a positive relationship with LNLQT (quality of trade and transport-related infrastructure) and LNLPS (ease of arranging competitively priced shipments). In particular, a 1% increase in LNLQT and LNLPS will increase TCO<sub>2</sub> by 0.143% and 0.289%, respectively. Existing literature highlights some key reasons, including: increased transport-related infrastructure associated with GDP growth, energy use, and industrialization. In addition, a well-developed transport infrastructure promotes population mobility due to the clustering of jobs in urban centers, which is one of the significant drivers of urbanization-related CO<sub>2</sub> emissions (Awaworyi Churchill et al., 2021). Further, the Transport CO<sub>2</sub> emissions are positively linked to LNLPS (ease of arranging competitively priced shipments), which raises questions about potential causes. Because, most of the shipment transactions are processed manually in SAARC countries (Khan et al.,

2019a), there are always delays in the end-to-end clearance process which can in turn be a critical cause of transport CO<sub>2</sub> emissions due to the nature of certain goods (An et al., 2021). Moreover, in most of the SAARC and Asian countries, particularly India, Pakistan, and Bangladesh, the culture of bribery, the triviality of regulatory bodies, and corruption may worsen delays in shipments (Khan et al., 2019b; Quazi, 2014). Similarly, Nguyen et al. (2021) added that in Vietnam, logistics activities (RCEP member) are disrupted by customs clearance and processing while customs inspectors create difficulties in processing and resolving administrative papers (import–export procedures). In the case of the Asia–Pacific region, Shepherd and Hamanaka (2015) argued that shipment delays due to prohibited actions (making speed money) are a vital impediment to trade-logistics performance, and delays affect not only timeliness but also the direct and indirect costs borne by the logistics operators. Because there is an aspect of negotiation concerned with individual payment services, logistics performance can be affected in three key manners (i.e., reliability, time, and cost). On the other hand, trade and transportation-related infrastructure, inefficient customs and border clearance influence LPI lower scoring of the SAARC (i.e., Pakistan, Sri Lanka, and Bangladesh) and RCEP (i.e., Cambodia, Indonesia, Philippines, and Vietnam) countries positions from a bottom-line perspective (see “Appendix 1”). Similarly, Buvik and Takele (2019) relate the low LPI score of African economies due to poor transport-related infrastructure and custom clearance processes. Again, there are fossil fuel-based transport sectors and international shipping in RCEP economies (i.e., Malaysia, Singapore, Indonesia, Cambodia, Vietnam, Philippines, and Thailand) that generate high CO<sub>2</sub> emissions compared to the quality of their logistics infrastructure (Mariano et al., 2017; Santosa et al., 2022). Although developed regions have proper green infrastructures to mitigate transport-related emissions, high CO<sub>2</sub> emission rates due to transportation growth and increased road vehicles persist (Mariano et al., 2017). Recently, Wen and Song (2022) found that China is facing challenges in minimizing CO<sub>2</sub> emissions due to its inefficient logistics infrastructure (poor freight transportation systems).

Finally, in analyzing renewable energy and logistic performance, the findings revealed a significant negative impact of logistic performance (LNLPI and LNLTC) on LNREC (renewable energy consumption); improving the quality of logistics services would decrease renewable energy consumption by 0.010%. Again, improving the tracking and tracing of consignments minimizes renewable energy use by 0.148%, which is explained by the cost of doing business and the willingness to pay for cleaner logistic services. The high cost and adoption of renewable energy sources linked with a lack of government interest and support further discourage the adoption of quality environmentally friendly logistic infrastructures. In particular, developing regions heavily rely on non-renewable energy sources (i.e., fossil fuel-based) due to their poor logistics infrastructure and high demand for imported goods (Ozcan & Ozturk, 2019). In this regard, it will be tough for those logistics industries that are currently adopting green practices to thrive in this environment. As a result, Fig. 3 shows renewable energy policy strategies that call for government assistance to encourage firms to switch to renewable energy sources to provide better logistical and operational services.

The current findings revealed that renewable energy consumption (LNREC) is positively interrelated with LNLCC (efficiency of customs clearance process) at a 10% confidence level. From Table 7, the GMM estimation shows that LNLPS has a positive

relationship with LNREC, implying that a 1% increase in the efficiency of arranging competitively priced shipments will increase renewable energy consumption by 0.293%. The prior study by Iakovou et al. (2010) confirmed that renewable energy sources are one of the practical policy agendas that connect logistics operations with greener practices that can minimize emissions and decrease reliance on fossil fuel energy use. Farooq et al. (2022) found that renewable energy significantly contributes to promoting industrial investment and other forms of development.

Figure 4 summarizes the findings, revealing that the LPI (quality of logistics services, track and tracing competence, and efficiency of customs clearance process) contributes to GDP growth, FDI inflows, and international trade (export–import goods). In addition, transport CO<sub>2</sub> emissions are exacerbated by the driving factors of improving logistics services, a hassle-free customs process, and the shipments reached on time among the selected countries.

The above findings reveal a strong relationship between logistics performance and economic indicators like GDP growth, international trade, and FDI inflows across the RCEP and SAARC countries. However, in developing countries, CO<sub>2</sub> and greenhouse gas emissions positively impact per capita GDP, while logistics sustainability and infrastructure benefit economic development (Khan et al., 2017; Sikder et al., 2022). This study empirically investigated the role of logistics performance and economic factors, with its results and relevant discussion consistent and comparative to other current and prior studies. Based on these assertions and previous studies, the study can conclude that the panel EGLS and GMM approaches are valid means of testing hypotheses.

### 5 Conclusions and policy implications

In recent attempts to address green sustainability challenges from harmful economic and trade activities, a series of mixed findings have emerged around the relationship that exists between logistics performance operations and transportation CO<sub>2</sub> emissions. While some suggest that profit-driven logistics are always destructive, others concluded

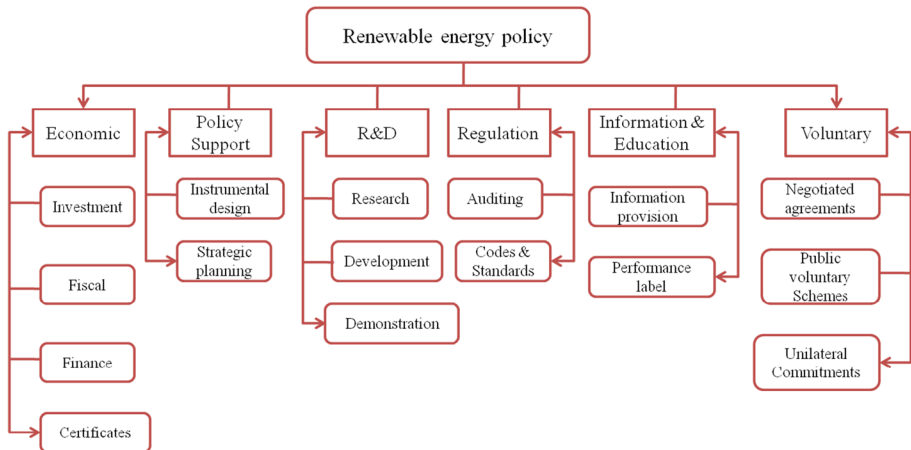


Fig. 3 Instrumental framework for renewable energy policies. Source: Asian Development Bank Institute

that the significance of innovation at each level of the global logistics process had been largely disconnected from trade-economic factors and transport CO<sub>2</sub> emissions. This study extensively investigated the issue of logistics performance using a range of economic factors (i.e., international trade, renewable energy consumption, foreign direct investment) and transport CO<sub>2</sub> emissions levels for a panel of 16 RCEP and SAARC countries from 2007 to 2018. This study used EGLS and GMM models to examine the regional autocorrelations and heterogeneity by taking the first difference operator and exploring the interrelation between logistics performance, transport CO<sub>2</sub> emissions, FDI inflows, and trade-economic factors. Our findings complement the existing literature well and provide compelling policy implications for green logistics performance in light of the economic expansion across the countries.

The results illustrate that three key logistics performance parameters (competence and quality of logistics services; efficiency of customs clearance process; and ability to track and trace consignments) positively impact FDI inflows, GDP growth, and international trade. It confirms that the quality of logistics services, the efficiency of customs clearance, and effective tracking and tracing of consignments are critical contributors to a country's FDI inflows, international trade, and economic growth. Furthermore, improving logistics services, a hassle-free customs clearance process, and the frequency and timing of shipments mitigates transport CO<sub>2</sub> emissions by 0.177%, 0.026%, and 0.014%, respectively. Although transport CO<sub>2</sub> emissions are propelled by the poor quality of logistics services, inefficient customs processes, and the frequency of shipments, the price tag on overall logistics operations is also affected in the long run.

Furthermore, the study examined economic and environmental factors to verify their nexus with LPI. With these insights, policymakers and legislators can formulate green transportation and logistics policies that would assist in the drawing up of environmentally friendly trade-logistics operations. In particular, renewable energy consumption transitions in logistics and the quality of trade and transport-related infrastructure will help reduce global warming, mitigate CO<sub>2</sub> emissions, and build a sustainable national economy. In other words, green logistics and practices play a prominent role in solving several logistical, environmental, and economic challenges. In particular,

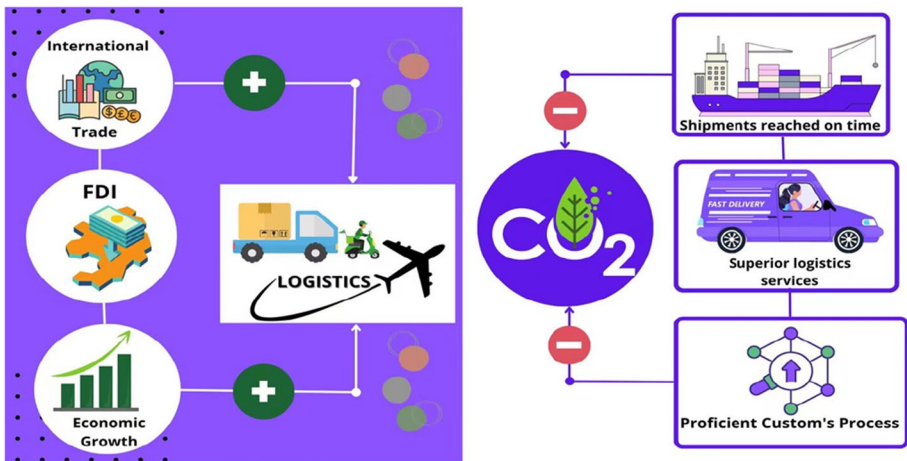


Fig. 4 The logistic performance indicators and transport CO<sub>2</sub> emission

the development and implementation of renewable energy policies might reduce environmental pressures across the system, while also driving GDP growth, attract foreign investors and enhance international trade opportunities. Therefore, a country's economic and environmental performance must be balanced by promoting green practices in international logistics operations via renewable energy consumption and eco-friendly policies.

## 5.1 Policy relevance

The study findings reveal valuable policy implications as follows:

- (1) The RCEP and SAARC regions should attract more low-carbon FDI and energy-efficient projects by introducing new tax incentives, many of which can be sourced from developed economies such as those embraced by the European Union. Additionally, successful policy formulations for logistics infrastructure (i.e., smooth connectivity with domestic and international ports and modernization of warehouse systems) would favor the national economy. Furthermore, policy makers from respective countries should reconsider implementing intermodal transport infrastructure and road networks. For example, an artificial intelligence-based transport management system that automatically charges vehicles would aid with the development of road projects. Also, the selected countries should improve tracing consignments systems (i.e., GPS navigation and transportation management), software tracking systems (i.e., provide shipment updates and road mapping), and incorporate cutting-edge technologies (i.e., block chains, digital connectivity, data analytics, and the psychology of the Fourth Industrial Revolution) to create a more attractive and efficient logistics industry. Similarly, governments should improve their human capital such as ICT specialists and international logistics stakeholders and policymakers should keep an eye on the punctuality of shipments and a smooth custom clearing procedure when considering the integration of green practices and declining trade-offs. The attitude to accomplish green logistics operations while growing globalization means the capacity to handle logistics activities in an eco-friendly manner is essential.
- (2) Individual countries (trading partners) should deliberately adhere to the following green policies through modern technology and the deployment of green practices in logistics operations (e.g., green packaging, subsidies taxation, green transportation) in order to promote their competitiveness in the international market. Furthermore, global exporters should set up a structure for reverse logistics to enhance green logistics practices that comply with domestic and international laws. On the other hand, the government should encourage green logistics services through "best performance certifications" to sustain the reciprocal connection between regulatory authorities and the logistics industry. Although, the logistics industry is a significant source of CO<sub>2</sub> emissions, green measures in logistics operations have a substantial and positive impact on the regional economy. The logistics industry should adopt green energy-based transportation modes that promote electric forklift trucks, expand vehicle charging systems and stations to support electric transportation (forklift trucks), and use mobile applications to reserve and obtain charging stations.

- (3) Without a proper initiative, it is impossible to improve the quality and services of the logistics industry on a global scale. In this regard, governments should address issues like low compensation, poor transport modes, lack of skillful workers, and inequitable and unfair green adoption practices that could discredit international trade, curtail logistics performance, and hinder economic growth. Additionally, revitalize financial institutions' to provide low-interest loan schemes and subsidies on eco-friendly transportation to support logistics firms in adopting renewable energy sources. In particular, the SAARC nations should coordinate policies to increase renewable energy production while minimizing regional emissions. Finally, as part of contributing to the sustainable development and CO<sub>2</sub> emission goals (below 2 degrees policy), all countries should embrace local and international environmental strategies.
- (4) To encourage more environmentally friendly initiatives, the government should promote risk-free green investment strategies (see "Appendix 2"), such as fixed revenue flows. Finally, because the success of policies is contingent on the degree to which obstacles are removed, extensive consultations are recommended before implementing the aforementioned policies.

## 6 Research limitations and future research

There are some limitations to the current study that should be addressed in further research. First, this study selected only 16 countries from 2 economic groups, which may have led to some slight biases among the results. Additionally, the work focused on CO<sub>2</sub> emissions, regional economic factors, and logistics performance without considering human and social aspects at a micro-level. Finally, since the selected panel is primarily made up of Asian economies, which have established diverse FTAs with African countries, the study recommended a comparative study between Asia and Africa in terms of logistic performance and environmental pollution to help formulate efficient green-logistics policies and agreements.

## Appendix 1

See Table 8

**Table 8** Ranging scores of LPI from 2007 to 2018

Country	2007		2010		2012		2014		2016		2018	
	LPI score	Country	LPI score	Country	LPI score	Country	LPI score	Country	LPI score	Country	LPI score	Country
Singapore	4.19	Singapore	4.09	Singapore	4.13	Singapore	4.00	Singapore	4.14	Singapore	4.03	Japan
Japan	4.02	Japan	3.97	Japan	3.93	Japan	3.91	Japan	3.97	Japan	4.00	Singapore
Australia	3.79	Australia	3.84	Australia	3.73	Australia	3.81	Australia	3.79	Australia	3.88	New Zealand
New Zealand	3.75	New Zealand	3.65	South Korea	3.70	South Korea	3.67	South Korea	3.72	South Korea	3.75	Australia
South Korea	3.52	South Korea	3.64	China	3.52	New Zealand	3.64	China	3.66	China	3.61	China
Cambodia	2.50	China	3.49	Malaysia	3.49	Malaysia	3.59	Malaysia	3.43	Malaysia	3.61	South Korea
Malaysia	3.48	Malaysia	3.44	New Zealand	3.42	China	3.53	India	3.42	India	3.41	Thailand
China	3.32	Thailand	3.29	Thailand	3.18	Thailand	3.43	New Zealand	3.39	New Zealand	3.27	Vietnam
Thailand	3.31	Philippines	3.14	India	3.08	Vietnam	3.15	Thailand	3.26	Thailand	3.22	Malaysia
India	3.07	India	3.12	Philippines	3.02	India	3.08	Vietnam	2.98	Vietnam	3.18	India
Indonesia	3.01	Vietnam	2.96	Vietnam	3.00	Indonesia	3.08	Indonesia	2.98	Indonesia	3.15	Indonesia
Vietnam	2.89	Indonesia	2.76	Indonesia	2.94	Philippines	3.00	Pakistan	2.92	Pakistan	2.90	Philippines
Philippines	2.69	Bangladesh	2.74	Pakistan	2.83	Pakistan	2.83	Philippines	2.86	Philippines	2.60	Sri Lanka
Pakistan	2.62	Pakistan	2.53	Sri Lanka	2.75	Cambodia	2.74	Cambodia	2.80	Cambodia	2.58	Bangladesh
Sri Lanka	2.40	Cambodia	2.37	Bangladesh	2.61	Sri Lanka	2.70	Bangladesh	2.66	Bangladesh	2.58	Cambodia
Bangladesh	2.47	Sri Lanka	2.29	Cambodia	2.56	Bangladesh	2.56	Bangladesh	2.53	Sri Lanka	2.42	Pakistan



## Appendix 2

See Fig. 5

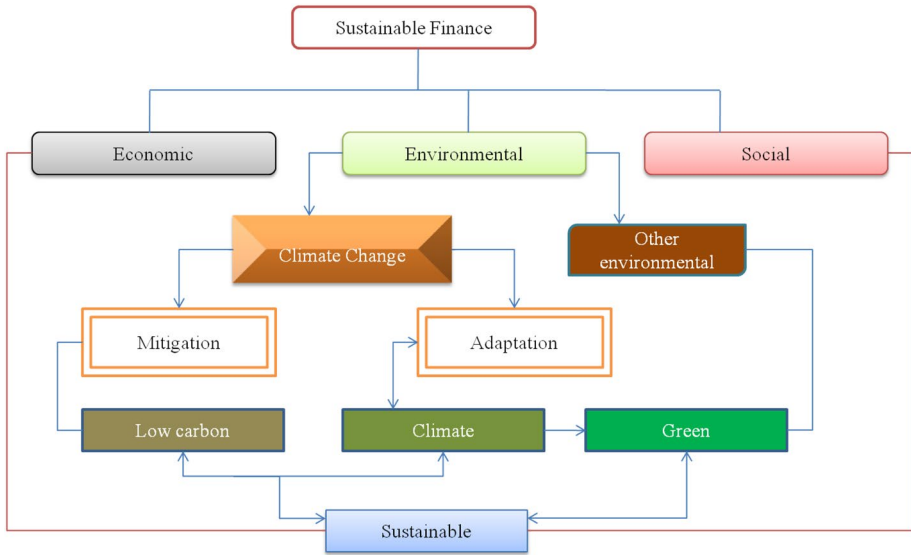
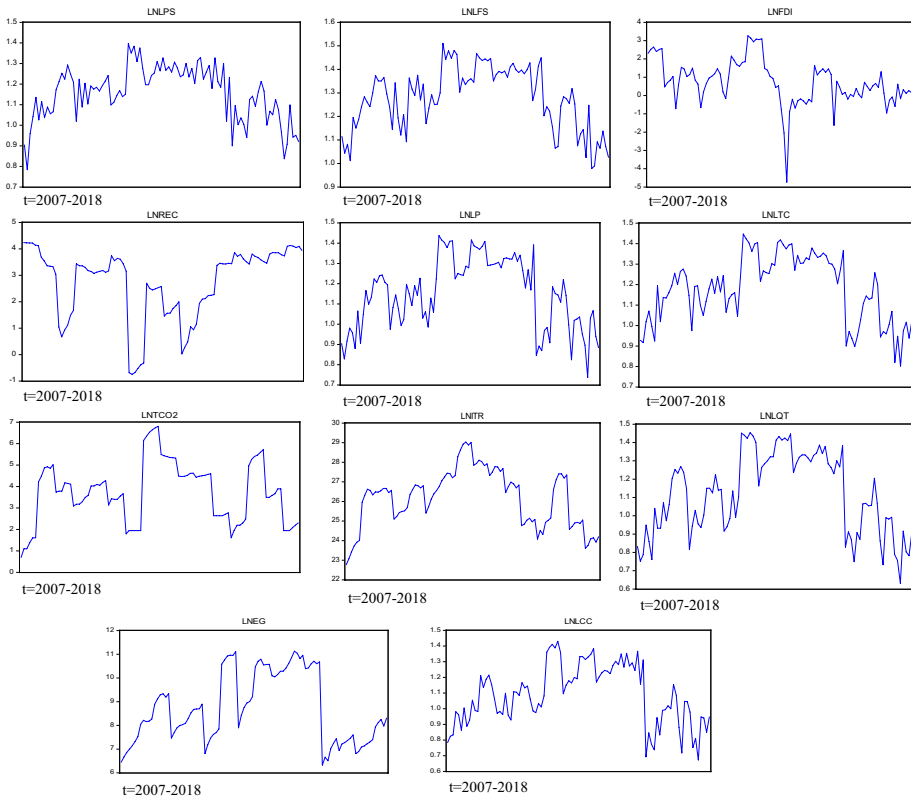


Fig. 5 Green investment roadmap

## Appendix 3

See Fig. 6



**Fig. 6** Plots of selected variables on level data (2007–2018)

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