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A Correlative Study of Modern Logistics Industry in Developing Economy and Carbon Emission Using ARDL: A Case of Pakistan

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Abstract: The modern logistics industry in relation to economic growth and carbon emission has opened new strategic perspectives. Recent research work have analyzed such complex interference from a broad perspective. However, analyzing this overlap needs comprehensive insight into the logistics industry while simultaneously estimating its short-run and long-run effects from regional aspects due to continue-evolving factors and their impact on it. This paper competently analyzes logistics industry components in connection with economic prosperity, energy consumption, trade development, and carbon emission from a more specific regional perspective of a developing country. Methodologically, an autoregressive distributive lag model (ARDL) is employed using correlative evaluation of the dynamic factors and their interactive impact in short and long run on this relation, based on time-series data of Pakistan from 1990 to 2019. The study results endorse the previous studies' outcomes by recognizing that an increase in carbon emission depends on trade development, energy usage, economic development, and the logistics industry's various components except for air logistics. However, study results show a unidirectional long-run causality directing from economic development, logistics industry, energy utilization, and trade development to carbon emission. Moreover, these results reveal that this emission is the leading factor to introduce stringent emission standards that further overlap with regional demographics trends, i.e., carbon emission implications. These findings imply that economic development applies a substantial demand-pull impact on national logistics, i.e., regional economic development directs to the growth of the logistics industry in the corresponding region. Consequently, high-income geographical regions have higher long-run risk concerning contemporary developmental activities of the logistics industry when adhering to carbon emission standards. Particularly, the influence of upcoming emission standards must be prioritized when planning the future returns of contemporary research and development activities of the logistics industry in a given geographic area, such as CPEC. Given Pakistan's perspective, the proposed empirical analysis can be exampled to other developing countries. This analysis may facilitate the design and development of strategies for upcoming financial funding in the modern logistics industry to seek its sustainable development-goals in developing economies.

Keywords: modern logistics industry; carbon emission; logistics energy consumption; economic prosperity; ARDL; sustainable development

MSC: 91Bxx; 62P20

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1. Introduction

Sustainable development performance examines three areas: people (social), planet (environment), and profits (economic). In this aspect, the logistics industry has continued to evolve as a complex entity involving dynamic systems and their inter-related influence under social preferences and environment policy implications—a modern logistics industry [1]. Despite many advantages, it is also a leading source of carbon emissions that contribute around half of the world's total volume [2]. In reference to the "carbon emissions from fuel combustion" statement published by the International Energy Agency (IEA) in 2019, the world's transportation industry has contributed a two-thirds share of global carbon emissions [3]. Such environmental consequences gradually led to the progressive introduction of increasingly strict environmental regulations mainly dominated by social preference [4]. Consequently, in upcoming years, the implications of this carbon emission may overlap with prospects of current developmental activities in a logistics industry that could open new strategic risks for this industry. This scenario demands a comprehensive view of the logistics industry and its linkage to economic developemt and carbon emission [5] when seeking sustainable development performance of the modern logistics industry.

Existing studies have analyzed the complex interface of logistics industry, economic growth, and carbon emission from various perspectives, such as (1) investment in transport as a threat to the environment [6], (2) carbon emission leading to boost economic growth [7], and (3) geographical features in exploring such a relationship [7–9]. Only a few studies capture the comprehensive view of logistics infrastructure and its relationship with economic development and carbon emission [10,11].

In a concise statement, there are numerous shortcomings in these studies concerning relationships between logistics industry, economic growth, and CO_2 emissions. First, current literature mostly emphasizes transport and logistics infrastructure. Notably, most logistics industry components—the modern logistics industry [1], reference [12]—are ignored when simultaneously estimating their short- and long-run effects besides testing the given propositions on the projected coefficients in the long-run. This interpretation and implementation of most logistics industry components need to apply in an appealing, straightforward way [13] and require a single-form equation [14], while existing studies applied procedures in a system of equations. It makes these studies less robust and affects the performance of a given data sample. Second, such studies have mainly focused on developed economies, and/or environmental protection remains a core issue in these studies [15–17]. Thirdly, the geographic characteristics of developing countries are thoroughly underexplored when investigating such relations. A country's geostrategic position directs the demographic preference to carbon emissions; it leads to carbon implications to influence a national economic policy to determine the scope of the modern logistics industry [9,18].

In this context, the overlapping of carbon emission creates further complexities to the already dynamic association, i.e., the logistics industry's development come after economic growth. This complex interface evolves differently across various parts of the world under a given set of demographic preferences [19,20]. Subsequently, the implications of those CO_2 emissions overlap with national and geographical social preferences, which are increasingly involved in introducing increasingly stringent environmental standards; it constantly mounts long-run risks to current developmental activities of the logistics industry [21]. This scenario demands an understanding of a comprehensive view of most logistics industry components from a much closer geographic perspective through simultaneous estimates of short- and long-run influence that could examine given propositions on the projected coefficients in the long-run, i.e., the regional aspects of modern logistics industry concerning economic development and carbon emission. Moreover, the scarce resources of developing economies also justify a need for strategic adjustments to the prospects of current developmental activities in the logistics industry, given its overlap with the forthcoming implications of these carbon emissions.

Given this background, the current research study emphasizes the arguments stated-above and analyzes the modern logistics industry's association with the economic growth and carbon emission. Hence, we used econometric modelling to examine short- and long-run association between the modern logistics industry and economic development and carbon emission. Besides, this association is analyzed from an empirical context to attain a visible and persuasive effect. Methodologically, a comprehensive analysis of the logistics industry is presented under carbon emission in connection with economic growth, energy utilization, and trade development from a more specific geographic perspective in a developing country. Methodologically, an autoregressive distributive lag model (ARDL) is applied using a correlative examination of the dynamic factors and their inter-related influence in both the short- and long-run on this relation using time-series data of Pakistan from 1990–2019. The use of the ARDL model [22] facilitates the analyses of the variables involved to study the complex relationship better than other methods [23,24] owing to its interpretation and straightforward implementation [13]. Moreover, it needs a single-form equation [14], though other methods necessitate an arrangement of equations. Furthermore, it is very reliable considering sample size over some other cointegration approaches [25] in simultaneously estimating the short- and long-run effects for a comprehensive view of the logistics industry.

The rest of the paper is organized in the five sections. Section 2 describes the review of existing literature and accordingly explains the reason for using Pakistan as a case study. Section 3 illustrates the components of the methodology step-wise. Section 4 shows the case study bordered by the findings and analysis of our research methodology. Section 5 includes the discussion according to the findings of the immediate result. The final section describes the concluding findings.

2. Review of Existing Literature

Existing studies have investigated the relationship between the logistics industry, economic development, and carbon emission from various standpoints. However, these studies have some limitations, which are discussed distinctively and highlight some overlapping points between those limitations and the Pakistan case.

The complex interference of the logistics industry, economic growth, and carbon emission has been studied from various perspectives. First, these studies have mainly observed such relations with the main focus on carbon emission as a threat to the environment [6]. Accordingly, the primary motivation remains financial support to transport as the key to economic development, and simultaneously, it is triggering environmental mortification. These study insights are crucial for various stakeholders of the logistics industry [26,27]. Second, the other empiricists investigated these relations, given carbon emission as a positive indicator to boost economic growth and its positive relationship with infrastructure [7,28]. Third, besides the widespread studies accessible on the association between economic development, fuel usage, and carbon emissions, only a few scholars have taken the comprehensive view of logistics infrastructure and its relationship with economic development and carbon emission [10,11]. Specifically, geostrategic characteristics in analyzing the association between the logistics industry, economic development, and carbon emission have captured few collective investigations of scholars [7–9].

In a concise statement, these studies have numerous shortcomings concerning relationships between the logistics-industry, economic development, and CO_2 emissions. First, current research works mostly emphasize transport and logistics infrastructure while overlooking most components of logistics industry, i.e., the modern logistics industry [1,12], when simultaneously estimating their short- and long-run influence, besides testing the given suppositions on the projected coefficients in the long-run. Moreover, existing studies applied procedures in a system of equations, while this interpretation and implementation of most logistics industry components need to apply in an attractive, straightforward way [13] and require a single-form equation [14]. It makes these studies less robust and affects the performance of a given data sample. Second, current research has mostly concentrated on developed countries, and/or environmental protection remains an issue in these studies [15–17]. Developing economies have considerably different implication perspectives than developed economies, where the economic boost remains the main preference at the end of logistics industry development. Third, especially, the geographic characteristics of developing economies are thoroughly underexplored when exploring such relations. A geostrategic position of a given country is unique in the sense of guiding the demographic preference to carbon emissions, which govern the national economic policy that decides the scope of modern logistics industry [9,18]. Finally, the association between logistics industry and economic development is continued to evolve as the logistics industry's development is trailed by economic growth, while the carbon emission overlaps in this association. Subsequently, carbon emission creates further complexity to the association between transport infrastructure and economic growth, which evolve differently across the various parts of the world and create hindrance in seeking sustainable development goals of the logistics industry, particularly in developing economies [19,20].

Given the limitations mentioned above, understanding a comprehensive view of the logistics industry from regional aspects becomes necessary concerning the relationships of the logistics industry with economic growth and CO_2 emissions. Undoubtedly, implications of CO_2 emission are increasingly involved by introducing increasingly stringent environmental standards that constantly mount long-run risks to current developmental activities of the logistics industry. Since implications of those carbon emissions overlap with geosocial preference, this scenario demands a quantitative analysis that can simultaneously estimate their short- and long-run effects of a comprehensive view of the logistics industry. Moreover, these interpretations and implementations of most logistics industry components need to be straightforward [13] and require a single-form equation [14] considering the geostrategic features of developing countries such as Pakistan. Accordingly, the analysis takes data from Pakistan to examine the relationship between the modern logistics industry, economic growth, and carbon emission for the following reasons.

First, Pakistan's logistics industry compressively involves most logistics industry components, with a net worth of about USD 35 billion and its growth rate is in double-digit. This logistics contributes to around 6% of the overall national employment opportunities with around 23% of the service sector. In 2019, the growth of this industry was around 3.34% with a 12.9% contribution to the national GDP [29], according to the Pakistan Bureau of Statistics [30]. These figures take Pakistan to rank 122 among 163 countries in the ranking of World Bank's logistics performance index [31]. In short, the overall less spending on logistics infrastructure in this sector takes Pakistan after many Asian countries.

Being a developing country, Pakistan seeks to improve development of the logistics industry by depending on its national economy while ignoring constraints associated with environmental protection to compete the increasing demands of logistics with the concurrently eradicating its colonial infrastructure [1]. The economic development and mobility ease lead to population concentration in a few geographical areas, which rises but concurrently creates congestion to the transport network. This average presence of logistics industry can be characterized by overall incomplete services facilities in custom departments, tracking, locating, and completing the time-lines in the country [31]. Besides, the transport infrastructure has also been provided by the inconsistent investment among its many subsectors. Hence, the influence of transport infrastructure is anticipated to be different on economic growth. Notwithstanding the damaging implications of non-renewable fuel-driven growth, developing countries such as Pakistan have restricted choices, whose funding in the logistics industry besides other industries are critical bases of economic development.

Geographically, Pakistan has a crucial strategic position due to its position in the world map acts as a bridge between Asia, the Arabian Sea, the Middle East, and Africa. The area of 881,913 square kilometers makes Pakistan with a geographical coverage around, or equal, to the joint areas of the UK and France. The spread of a large population over the huge land indicates the prominence of logistics industry and infrastructure to certify the accessibility of goods and services to all across the national boundaries [29].

Besides the relevance of the logistics industry to economic growth, its contribution to energy usage is the source of a large percentage of CO_2 emission [10]. Pakistan's transport-related CO_2 emission was three metric tons in 1971. However, it reached 50 metric tons in 2020, growing at an average annual rate of 5.97% [32]. These emissions evidently lead to a substantial part in climate variation, which contribute to environmental degradation. Subsequently, a close association lies between logistics industry investments, economic development and growth, transport fuel usage rate, and transport CO_2 emissions.

In summary, the Pakistan case offers a unique scenario to analyze the association between the modern logistics industry, economic development, and carbon emission. Pakistan Vision 2025 envisages "Modernizing Transportation Infrastructure and Greater Regional Connectivity" as the main priority among its strategic goals [29]. Therefore, understanding a comprehensive view of the Pakistan logistics industry from regional aspects offers the opportunity to understand logistics industry components and their relevance to economic development and carbon emission. Since social preferences overlap with carbon emission implications, such overall statistical analysis under the influence of a population of 212 million, the 5th-most populated geographical area on the world map, can be generalized to other developing economies; it can facilitate the understanding of upcoming risks associated with current logistics industry investment in developing economies, which may guide policymakers in seeking sustainable development goals of this industry. Given the points mentioned above, a comprehensive research gap exists in examining the association between logistics industry growth, economic growth, and carbon emissions for a large-structured developing country like Pakistan.

3. Materials and Methods

This study analyzes the association between the logistics industry, logistics carbon emission, logistics energy consumption, trade, and economic prosperity to fulfill the literature gap. The most recent and updated data of these variables is used from the Pakistan Bureau of Statistics, the World Bank, different issues of Pakistan economic survey, and the Pakistan railways yearbook from 1990 to 2019. An econometric model, autoregressive distributed lag model (ARDL), introduced by Pesaran [33], is employed to evaluate and assess the short- and long run association and causalities between the ever-evolving factors.

3.1. Data Sources

We used secondary data to analyze the relationship between the selected factors. The logistics industry is represented by its four major components: road, rail, air, and port logistics. Road logistics (RoadL) are represented by the length of roads in this study due to the data constraints [12–36]. It involves national roads, provincial roads, highways, regional roads, and various other roads within in national boundary. Railway logistics (RailL) is represented by the total cargo transported by the railways [37]. Air logistics (AirL) are represented by the total goods shipped by airplanes [37]. Port logistics (PortL) are analyzed by the total cargo operated at the port-side [12]. Economic prosperity is measured in gross domestic product and represented by EP [38]. Trade is represented by exports, which are measured by the value of exports in the current local currency [12,34,35]. The CO_2 emission from logistics represents the total carbon emission expelled from transport CO_2 [6]. Transport energy consumption (TEC) represents the fuel consumption by the transport sector. The factors are taken to analysis using an extensive examination of exiting literature, e.g., [6,12,31–35], and availability of data. The data of EP, air logistics, and trade are taken from the database of World Bank development indicators. The road logistics data are taken from the Ministry of Finance. The data of railway logistics are taken from the Pakistan railways yearbook. The port logistics data are obtained using multiple issues of the Pakistan Economic Survey (Ministry of Maritime Affairs) and transport energy consumption data are taken from the International Energy Agency. The details and descriptions of all variables selected are presented in Table 1. The sample period of time-series data is from 1990 to 2019. All the factors are used with their natural logarithms, given the heteroscedasticity problem with the time series data.

Table 1. The details and descriptions of all variables.

Descriptions of Selected Variables			
Variables	**Symbols**	**Descriptions**	**Data Source**
Logistics Carbon Emission	CO_2	CO_2 emissions resulted from the fuel combustion from all the transport activity.	Word Bank
Air Logistics	AirL	The domestic and international departures of the registered air carriers in the country.	World Bank
Rail Logistics	RailL	Goods transported by railways measured in metric tons times kilometers traveled.	Pakistan Railways Yearbook
Road Logistics	RoadL	Total road network (km) includes motorways, highways, and national roads, secondary or regional roads, and all other roads in a country.	Ministry of Finance
Port Logistics	PortL	Total cargo handled at ports measured in metric tons.	Pakistan Economic Survey
Logistics Energy Consumption	LEC	Transport fuel consumption	IEA
Trade	Trade	Trade is measured by the value of exports, the value of all the goods and other market services provided to the rest of the world.	Word Bank
Economic Prosperity	EP	GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. Data are in constant local currency.	Word Bank

3.2. Model Specification

This study investigates the relationship between the logistics industry, economic prosperity, logistics carbon emissions CO_2, logistics energy consumption (LEC), and trade. However, the extensive literature review discovered that no current study comprehensively investigates the linkage between these variables in Pakistan as a developing country. Moreover, our model uniquely incorporates the selected variables in the linear model. The functional form and econometric model specifications follow:

$$\mathrm{CO}_2 = f(AirL,\ RailL, RoadL,\ PortL,\ LEC, Trade,\ EP,) \tag{1}$$

The linear form of Equation (1) shows that the logistics carbon emission (CO_2) is a function of air logistics, railways logistics, road logistics, port logistics, logistics energy consumption, trade and economic prosperity, that is, $AirL,\ RailL, RoadL,\ PortL,\ LEC, Trade,\ EP$, respectively.

The linear form of Equation (1) can be rewritten after including error terms, as follows:

$$\mathrm{CO}_{2t} = a_0 + a_1 AirL_t + a_2 RailL_t + a_3 RoadL_t + a_4 PortL_t + a_5 LEC_t + a_6 Trade_t + a_7 EP_t + \varepsilon_t \tag{2}$$

The natural logarithm is taken for dependable and reliable findings. The log–linear form of Equation (2) can be rewritten as follows:

$$lnCO_{2t} = a_0 + a_1 lnAirL_t + a_2 lnRailL_t + a_3 lnRoadL_t + a_4 lnPortL_t + a_5 lnLEC_t + a_6 lnTrade_t + a_7 lnEP_t + \varepsilon_t \tag{3}$$

The logistics industry is represented by road logistics (*RoadL*), railways logistics (*RailL*), air logistics (*AirL*), and port logistics (*PortL*). *EP* represents the economic prosperity. *LEC* is the logistics energy consumption, Trade represents the exports while CO_2 is the logistics carbon emission. The parameters α_1, α_2, α_3, α_4, α_5, α_6, and α_7 are the long-term elasticity of respective variables. The expected sign of α_1, α_2, α_3, α_4, α_5, α_6, and α_7 is positive. It shows logistics industry development leads to higher exports, more significant economic activity, higher logistics energy consumption, economic prosperity, and a resulting higher logistics carbon emission. The t represents time. The parameter a_0 warrants for possible state fixed effect, and ε_t symbolizes the usually distributed error term.

3.3. Estimation Approach

Various econometric models are employed to analyze time-series data to assess long-run and short-run changes. The current analysis used the autoregressive distributed lag model (ARDL) to investigate the variables' relationship. It is developed by [22]. It has numerous advantages over other methods of cointegration [23,24]. One of the advantages of the ARDL model is that the ARDL approach's interpretation and implementation are reasonably straightforward [13]. The ARDL framework needs a single-form equation [14] when compared with other methods that need a complex system of equations. The ARDL method is much more dependable for small samples compared to Johansen and Juselius's cointegration approaches [25]. It simultaneously estimates short- and long-run effects and tests propositions on the estimated coefficients in the long run [12]. It is not completed in the Engle—Granger method.

The series of steps in the ARDL procedure is the investigation of (i) stationarity to calculate the extent of steadiness of the variables; (ii) cointegration, to calculate the long-run association between dynamic time-series variables; and last but not least (iii) causality, for showing a long- and short run causal association between the variables. There are various approaches to advance to causality examination that don't require the the first two phases; however, it happens in other methodologies. The proposed analysis used the statistical software Eviews 11 program package for this econometric investigation. It is provided by the IHS Eviews for econometric analysis, forecasting and simulation. This software can be downloaded from the Eviews official website (https://www.eviews.com, accessed on 10 December 2021).

3.4. Stationarity Test

The stationarity test determines the sequence of variable's integration to avoid spurious regression results in the econometric analysis. Therefore, current research applies the augmented Dickey–Fuller (ADF) [39] and Phillips–Peron (PP) [40] standard time-series unit root tests to affirm the strength of the series for every variable. Given the alternative of stationarity, such methodologies evaluate the null hypothesis of a unit root. The process consists of a constant and time trend in the ADF equation while determining the unit root test at level and first difference. Before this, the lag length selection is determined by the Schwarz information criterion (SIC). The precondition of the expected outcome of this test is I(0) at levels and I(1) at first difference, as the same order of integration is required for the Johansen cointegrating test. The null hypothesis and alternative hypothesis of the ADF and PP unit root test is that the data are nonstationary at I(0) and contain no unit root, respectively. Applying the unit root test is necessary for the ARDL method to assure that none of the variables are integrated as I(2) or beyond, because the calculated F-statistics provided by [22] behave invalid in the existence of I(2) variables [6,41].

3.5. ARDL Bound Test of Cointegration

The autoregressive distributed lag (ARDL), introduced by Pesaran [22], is used in the current study that bounds test to evaluate the cointegration between the nominated variables. The ARDL framework offers few benefits while estimating cointegration. The ARDL model can be used to evaluate the association among the variables of a different order of integration, such as (0), I(1), or a mixed [6]. The ARDL model for this study follows:

$$\begin{aligned}\Delta lCO_{2t} &= \alpha_0 + \textstyle\sum_{i=1}^{n} \alpha_1\, \Delta lAirL_{t-1} + \sum_{i=0}^{n} \alpha_2\, \Delta lRailL_{t-1} + \sum_{i=0}^{n} \alpha_3\, \Delta lRoadL_{t-1} + \sum_{i=0}^{n} \alpha_4\, \Delta lPortL_{t-1} + \\ &\textstyle\sum_{i=0}^{n} \alpha_5\, \Delta lnLEC_{t-1} + \sum_{i=0}^{n} \alpha_6\, \Delta lnTrade_{t-1} + \sum_{i=0}^{n} \alpha_7\, \Delta lnEP_{t-1} + \beta_1\, lnLCO_{2\ t-1} + \beta_2\, lnRoadL\ _{t-1} + \\ &\beta_3\, lnRailL_{t-1} + \beta_4\, lnAirL_{t-1} + \beta_5\, lnPortL_{t-1} + \beta_6\, lnEP_{t-1} + \beta_7\, lnLEC_{t-1} + \beta_8\, lnTRD_{t-1} + \mu_t\ \ldots\end{aligned} \quad (4)$$

The ARDL bound assessment of cointegration consists of F-statistics to evaluate the null hypothesis ($H0 \neq \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq 0$) of no cointegration among the variables. There are three decision criteria to accept or reject $H0$ when the projected

F-statistics figure is matched against the two sets of critical-values having upper- and lower limits. First, the null hypothesis ($H0$) with no cointegration is not taken into account when the measured F-statistics figure is more than the upper-bound critical-values. Second, the null hypothesis of no cointegration ($H0$) is accepted if the F-statistics value is lower than the critical values. Third, if it lays between the upper- and lower-bounds critical values, the conclusion is indecisive. In the current scenario, the error correction term is valued for establishing cointegration [42,43]. There are two sets of critical-values for sample sizes ranging from 30–80 observations [44]. This study extracts suitable critical values from a small sample size of 29 observations. The estimation using the error correction model for short-run relationships is specified as:

$$\Delta lCO_{2t} = \alpha_0 + \textstyle\sum_{i=1}^{n} \alpha_1 \, \Delta lAirL_{t-1} + \sum_{i=0}^{n} \alpha_2 \, \Delta lRailL_{t-1} + \sum_{i=0}^{n} \alpha_3 \, \Delta lRoadL_{t-1} + \sum_{i=0}^{n} \alpha_4 \, \Delta lPortL_{t-1} + \sum_{i=0}^{n} \alpha_5 \, \Delta lnLEC_{t-1} + \sum_{i=0}^{n} \alpha_6 \, \Delta lnTrade_{t-1} + \sum_{i=0}^{n} \alpha_7 \, \Delta lnEP_{t-1} + \lambda ECT_{t-1} \quad (5)$$

where λ measures the adjustment in term of speed—it is a negative and significant coefficient (λ) of ECT_{t-1} .

It suggests that a given disequilibrium between the dependent and explanatory variables in the short-run would move back to join the long-run equilibrium association. After this, the stability and diagnostic tests are performed.

These tests are used to measure the sufficiency of the model's requirement. Diagnostic tests examine the issue of non-normality, heteroscedasticity, serial correlation, and functional form. The steadiness of short-run and long-run coefficients is tested by cumulative sum of squares (CUSUMSQ) tests and cumulative sum (CUSUM) [45,46]. The null hypothesis would be accepted when the coefficients of the proposed model are consistent and the plots of the CUSUM and CUSUMSQ figures are present between the critical limits of a 5% significance value.

3.6. Augmented Granger Causality Test

In 1969, Granger first used the term causality to evaluate for causality directed from X to Y, or from, Y to X in a transparent way [47]. Given the Granger causality test, when the previous figure of variable X directs to the present figure of variable Y, it offers quantitatively sufficient evidence concerning the future value of Y future, in this way, causality is leads from X to Y. The ARDL bounds test evaluate the existence or nonexistence of cointegration between the selected variables. However, such evaluation can not be used to examine the rout of causality. Similarly, the presence of cointegration between the selected variables shows the long-run association at least in unidirectional. This study uses the error correction model (ECM)-based Granger causality test to investigate the direction of causality between the variables. It consists of two processes. First, long-run causality is evaluated after estimating the error correction model (ECM). Second, the Wald statistic is estimated to test the short-run causality. The vector autoregressive of the first difference form is used to evaluate the Granger causality in case of cointegration between the variables. However, the Granger causality evaluation with single-period lagged error correction term (ECT_{t-1}) is used in the case of no cointegration between the variables. According to [23], the cointegration of VAR evaluation in first differences would be deceptive when the series are integrated of order one. The augmented Granger causality test with error correction term (ECT_{t-1}) is formulated as follows:

$$\begin{bmatrix} \Delta lnCO_{2t} \\ \Delta lnRoadL_t \\ \Delta lnRailL_t \\ \Delta lnAirL_t \\ \Delta lnPortL_t \\ \Delta lnEP_t \\ \Delta lnTrade_t \\ \Delta lnLEC_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \\ \alpha_8 \end{bmatrix} + \sum_{i=1}^{n} \begin{bmatrix} \alpha_{11i} & \alpha_{12i} & \alpha_{13i} & \alpha_{14i} & \alpha_{15i} & \alpha_{16i} & \alpha_{17i} & \alpha_{18i} \\ \alpha_{21i} & \alpha_{22i} & \alpha_{23i} & \alpha_{24i} & \alpha_{25i} & \alpha_{26i} & \alpha_{27i} & \alpha_{28i} \\ \alpha_{31i} & \alpha_{32i} & \alpha_{33i} & \alpha_{34i} & \alpha_{35i} & \alpha_{36i} & \alpha_{37i} & \alpha_{38i} \\ \alpha_{41i} & \alpha_{42i} & \alpha_{43i} & \alpha_{44i} & \alpha_{45i} & \alpha_{46i} & \alpha_{47i} & \alpha_{48i} \\ \alpha_{51i} & \alpha_{52i} & \alpha_{53i} & \alpha_{54i} & \alpha_{55i} & \alpha_{56i} & \alpha_{57i} & \alpha_{58i} \\ \alpha_{61i} & \alpha_{62i} & \alpha_{63i} & \alpha_{64i} & \alpha_{65i} & \alpha_{66i} & \alpha_{67i} & \alpha_{68i} \\ \alpha_{71i} & \alpha_{72i} & \alpha_{73i} & \alpha_{74i} & \alpha_{75i} & \alpha_{76i} & \alpha_{77i} & \alpha_{78i} \\ \alpha_{81i} & \alpha_{82i} & \alpha_{83i} & \alpha_{84i} & \alpha_{85i} & \alpha_{86i} & \alpha_{87i} & \alpha_{88i} \end{bmatrix} \begin{bmatrix} \Delta lnCO_{2t-1} \\ \Delta lnRoadL_{t-1} \\ \Delta lnRailL_{t-1} \\ \Delta lnAirL_{t-1} \\ \Delta lnPortL_{t-1} \\ \Delta lnEP_{t-1} \\ \Delta lnTrade_{t-1} \\ \Delta lnLEC_{t-1} \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \\ \delta_7 \\ \delta_8 \end{bmatrix} [ECT_{t-1}] + \begin{bmatrix} \lambda_{1t} \\ \lambda_{2t} \\ \lambda_{3t} \\ \lambda_{4t} \\ \lambda_{5t} \\ \lambda_{6t} \\ \lambda_{7t} \\ \lambda_{8t} \end{bmatrix} \ldots \quad (6)$$

Here, the ECT is error correction term, while the α and δ are the coefficients that are estimated. Moreover, the λ_t is the white noise error terms, and the first difference operator is represented by Δ. The ECM model is used to distinguish between the long-run and short-run Granger causality [12]. Furthermore, the t-statistics of the coefficients of the lagged error term are used to show the significance of the long-run causal effects. The statistically significant coefficient of ECT_{t-1} indicates long-run causality. However, the F-test of the lagged explanatory variables is used to show the short-run causal effects. The significance of the short-run relationship was examined by employing the lag of the individual coefficients.

4. Results and Discussion

4.1. Descriptive Statistics

Table 2 shows summary statistics of all the variables.

Table 2. Descriptive statistics.

Variables	Mean	Maximum	Minimum	Std. Dev.
lnCO_2	3.3072	3.43172	3.1471	0.0727
lnAirL	5.7824	6.0991	5.1674	0.2767
lnRailwayL	8.3158	8.9971	5.9976	0.7417
lnRoadL	12.3844	12.4950	11.9974	0.1442
lnPortL	10.3329	10.9093	9.8138	0.3314
lnLEC	9.0867	9.7795	8.4109	0.3486
lnTrade	27.5143	28.9771	25.5641	1.0211
lnEP	29.6331	30.2159	29.0416	0.3539

4.2. Stationarity (Unit Root) Test

Performing the unit root test is imperative to check the stationarity of each of the series selected for the analysis. It is also standard practice to perform this test before the cointegration test. The ADF and PP unit root test [39,40] findings of all the variables (CO_2, $RoadL$, $RailL$, $AirL$, $PortL$, EP, LEC, $Trade$) are summarized in Table 3. The results indicate that railway logistics (RailL) and road logistics (RoadL) are stationary at level 1(0) on 1% and 5% critical levels, respectively, while remaining variables—air logistics, port logistics, logistics carbon emission, logistics energy consumption, and trade (AirL, PortL, CO_2, LEC, Trade)—remains the same at first difference 1(1) with the critical level of 1% or 5%. It confirms that the ARDL bound testing could be used to evaluate the long-run relationship as the integration at the second difference 1(2) was not observed among the variables. Given the findings of the ADF and PP test, it was also observed that variables were stationary at the mix order of integration; we can proceed further with the ARDL bound cointegration test to evaluate the long-run equilibrium association between the variables.

Table 3. Unit root test result.

Variables	ADF Test Statistics		PP Test Statistics	
	At Level	At 1st Difference	At Level	At 1st Difference
	t-Statistics	t-Statistics	t-Statistics	t-Statistics
lnCO_2	−1.7004	−5.5702 ***	−1.7478	−5.5702 ***
lnAirL	−0.8689	−5.3454 ***	−0.7283	−5.6799 ***
lnRailwayL	−3.6194 **	−4.3892	−2.1381 **	−3.0383
lnRoadL	−4.3995 ***	−3.4787	−9.5499 ***	−4.6705
lnPortL	−0.1370	−5.9766 ***	0.0116	−5.9585 ***
lnLEC	−0.2590	−3.1256 **	−0.4625	−3.1256 **
lnTrade	−2.0791	−4.1857 ***	−2.2311	−4.1501 ***
lnEP	−0.3187	−3.4721 **	−0.2947	−3.3840 **

Note: *** significant at 1% level, ** significant at 5% level.

4.3. Cointegration and Bound Testing

In general, the cointegration technique, introduced by Pesaran [22], is used to evaluate the long-run association among the variables. It implies that the short-run disturbances that arise from the long-run trend; cause the variables to move together. The ARDL bounds testing framework is employed in this study to determine the long-run association among the logistics industry, logistics carbon emission, logistics energy consumption, trade, and economic prosperity. This method matches the values of F-statistics with the critical values of lower bounds and upper bounds. Moreover, the value of F-statistics is sensitive to the number of lags selected. Thus, using the AIC criteria, the optimal order of lags is determined [22]. Table 4 shows the critical values along with measured F-statistics. The F-statistics concerning the CO_2 equation measured at 10% level of significance shows that observed value is more than the upper bound 2.89 critical value. Consequently, it rejects the null hypothesis of no cointegration, which implies that the long-run association is present among the variables.

Table 4. Cointegration test.

Model	F-Statistics	Conclusion
$\ln CO_2$ = lnAirL, lnRailL, lnRoadL, lnPortL, lnLEC, lnTrade, lnEP	3.0799 *	Cointegrated
Critical Bound Value		
Significance	I(0)	I(1)
10%	1.92	2.89
5%	2.17	3.21
1%	2.73	3.9

* significant at 10% level.

4.4. Short- and Long-Run Result

The ARDL bounds cointegration technique confirms the existence of cointegration among the variables. It indicates a long-run association among the variables [12]. The coefficients of the variables are contracted by applying the optimal lag selection, AIC criteria. Table 5 shows the long-run results of all the variables. It expresses all the estimated coefficients, association signs, and statistical significance in the stated model.

Table 5. Long-run and short-run results.

Variables	Coefficient	
Long-run estimates		
lnAirL	−0.0856	−0.0211
lnRailL	0.0249 ***	−0.0187
lnRoadL	0.4336 **	−0.0749
lnPortL	0.2129	−0.0638
lnLEC	0.5428 ***	−0.0201
lnTrade	0.1953 ***	−0.043
lnEP	0.6454 ***	−0.1064
C	20.0188 **	−2.3034
Short-run estimates		
lnAirL(−1)	0.2487	−0.0421
lnRailL(−1)	0.0041 *	−0.0085
lnRoadL(−1)	0.4932 ***	−0.1072
lnPort(−1)	−0.2902	−0.0543
lnLEC(−1)	0.6560 ***	−0.0513
lnTrade(−1)	0.2030 **	−0.0279
lnEP(−1)	1.9968 ***	−0.1759
ECT(−1)	−0.5108 ***	−0.3858

Table 5. *Cont.*

Variables	Coefficient
Diagnostic tests	
Serial Correlation	0.3948
Heteroscedasticity	0.8341
Normality	0.2150
Multicollinearity test	
lnAirL	7.2602
lnRailL	3.8307
lnRoadL	9.3526
lnPortL	8.5959
lnLEC	6.7249
lnTrade	2.0270
lnEP	5.5274

Note: values in the parenthesis are standard errors; *** significant at 1% level, ** significant at 5% level, * significant at 10% level.

The findings show that the logistics industry is contributing to carbon emissions, which leads to degradation of the environment. However, one component of the logistics industry out of four, air logistics, is insignificant with carbon emission in the long run. This result follows previous studies [12].

The coefficient of rail logistics is positive and significant, indicating a positive long-run effect of rail logistics on the dependent variable logistics carbon emission. It is interpreted as a 1% increase in railways logistics will create a 0.024% impact on logistics carbon emission. The possible explanation for this result is that since Pakistan's economy is still developing, the railway system is a century old. There is no improvement in the technology and the railway's engines, which are inefficient and less effective in fuel consumption and maintenance [48,49]. The road logistics coefficient is positive and significant. It suggests a 1% increase in road logistics would impact 0.433% logistics carbon emissions. The possible causes of this situation are that the road logistics use fossil fuel, and old technology vehicles are on the roads that are less efficient and effective in fuel consumption [50]. Besides this, the outdated engines (below Euro-II), rapid increase in the number of vehicles on roads due to ease in car financing, and the inclusion of new entrants into the ride-a-car market are also reasons. These all make an alarming situation as it increases the carbon emission daily and impacts the environment and produces greenhouse gasses, and the ultimate effect on the health and the lifestyle of the public [10,51].

The coefficient of port logistics is positive; however, it is not significant when calculated for the long run. The possible explanation of this can be the focus of the respective authorities. The port logistics in Pakistan are not yet explored up to the mark. It needs more in-depth studies to analyze and understand the possible causes of this result [12]. Logistics energy consumption is a major source of CO_2 emission in Pakistan. The studies show that carbon emission is projected to rise to 72% from the transport sector in 2050 [6]. It is alarming for policymakers and departments to make the carbon emission reduction policies and implement them urgently. These policies include the latest technology in the automobile sector, fuel-efficient vehicles, rebates on electric cars (industrial level), and subsidiaries to the supporting industries [10,51–53].

The coefficient of trade is positive and significant. It implies that a 1% increase in trade would impact 0.20% carbon emissions. This result supports the previous studies [54]. This study also analyzes that trade is interrelated to the logistics industry. The logistics industry is a major source of carbon emissions, so if trade increases, it will ultimately impact carbon emissions. However, there is more focus on increasing trade, even at the cost of mitigation of the environment in the case of Pakistan as a developing country. It is a scenario of a developing nation that focuses on increasing exports. Thus, there is a clear need to make and implement strict policies to control carbon emissions [55].

The coefficient of economic prosperity is also positive and significant. It implies that a 1% increase in economic prosperity (GDP) would affect the CO_2 emission rise at 0.64%. A pervasive cause of developing countries' focus is on increasing per capita GDP. Thus, sometimes developing countries do it at the cost of environmental degradation. The global scenario has changed, and the new strict carbon emission control policies have been implemented. Every country has to make a short- and long-term plan according to the global standards to be competitive [56,57].

Moreover, the short-run dynamic is also mentioned in Table 5. The short-run dynamics show a slightly different result as air logistics is positive but not significant. At the same time, port logistics is negative but also not significant. However, other variables are positive and significant. It implies a need to make short- and long-run plans to control CO_2 emission.

The coefficient of error correction term is significant at the 1% level of significance, and it is negative. It provides evidence of a steady long-run association among the variables. The value −0.5108 of the error correction term indicates a deviate for the long-run equilibrium and is corrected by about 51% in one year.

4.5. Causality Relationship

After confirming the long-run association between the variables by applying the ARDL bounds cointegration test, the direction of causality among the variables was evaluated by employing the Granger causality [58] test. Table 6 shows the findings of the Granger causality test. The short run causality (Wald test) findings are described first.

Table 6. Causality test.

Variables	Short-Run Causality (Wald Statistic)								Long-Run Causality (t-Statistic)
	lnCO_2	**lnAirL**	**lnRailL**	**lnRoadL**	**lnPortL**	**lnLEC**	**lnTrade**	**lnEP**	**ECT$t-1$**
lnCO_2		2.2997	1.7855	5.9470 *	2.0708	1.6930 ***	3.4265 **	2.6331 ***	−0.3419 ***
lnAirL	0.7418		0.2592	1.8357	2.0565	0.5203	0.1218	1.1698	−0.4170
lnRailL	1.6328	2.3787		1.5710	0.2902	1.2814	0.1171	1.1582	−0.7493
lnRoadL	1.0455	0.0872	0.0690		0.0005	2.9586 **	1.3424 **	2.2045 *	−0.3808 ***
lnPortL	2.8801	4.6461	1.9482	1.2306		1.7433	0.7339	2.9993	−0.7175 ***
lnLEC	4.1107 ***	0.0026	2.0238	3.8204	2.5216		1.7904	1.4739	−0.5689
lnTrade	1.9651 **	2.5754	0.5276	2.3720 **	0.2435	1.2323		1.9357	−0.6127 **
lnEP	0.4185	3.0908	1.3830	1.9289	2.9735 ***	1.6824	2.6954		−0.4955 ***

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

In the CO_2 equation, road logistics, logistics energy consumption, trade, and economic prosperity are statistically significant at 10, 1, 5, and 1%, respectively, while rail logistics, air logistics, and port logistics are not significant. It means that no causal association was observed among CO_2, rail logistics, air logistics, and port logistics in the short run.

In the road logistics equation, logistics energy consumption, trade, and economic prosperity are statistically significant and show a causal relationship, while CO_2, AirL, RailL, and PortL are not statistically significant in the short-run causal relationship. The port logistics equation shows that the economic prosperity is significant statistically, which suggests a causal association between PortL and EP.

The trade equation shows that, CO_2, and RoadL is significant in statistical terms and displays a causal relationship. Moreover, the EP equation shows that PortL is also significant in statistical terms and shows a causal relationship. In the LEC equation, CO_2 is significant in statistical terms. In the AirL and RailL equations, none of the variables are observed to be significant in statistical terms; it indicates no causal relationship between the variables. In summary, a unidirectional causality is observed that run from CO_2 to airL, roadL, rail, portL, trade, and EP, while bidirectional causality is present between trade—road and trade—CO_2.

The long-run causality findings show that logistics industry Granger directs the logistics carbon emission and economic prosperity. Moreover, the CO_2 equation shows that the coefficient of error correction term is significant and negative. It indicates that the long-run causality exists from air logistics, rail logistics, road logistics, port logistics, logistics energy consumption, trade, and economic prosperity to CO_2; it imply that these variables have a causal long-run influence on CO_2. Similarly, the roadL equations show a long-run causal relation run from AirL, RailL, PortL, LEC, trade, and EP to RoadL. Similarly, the PortL and EP equations also show a long-run causal relationship among the variables having a significant and negative error correction term.

Therefore, as observed from the proposed analysis, the study findings show that these variables followed a steady trend in the model during the sample period. Deep insights from such a continuing trend could facilitate the concerned government authorities to make relevant policies and their implementation for concerned experts involved with the logistics industry and carbon emission regulations.

4.6. Diagnostic Test

Diagnostic tests are executed to check the econometric properties of the model. The Ramsey test, heteroscedasticity test, serial correlation LM test, and Jarque–Bera test, are performed to check the existence of autocorrelation, heteroscedasticity, normality, and multicollinearity in the time-series data [59,60]. The end of Table 5 shows the diagnostic test results. The results indicate that air logistics, rail logistics, road logistics, port logistics, logistics energy consumption, trade, and economic prosperity explain the variation in logistics carbon emission in autocorrelation' absence, heteroscedasticity, and multicollinearity. Therefore, the diagnostic test results are dependable and indicate that this model has desired econometric features. The CUSUM and CUSUM of the squares test are also performed to check the model's structural invariance, endogeneity, and stability [45]. Figures 1 and 2 show the results. The stability of the model is indicated in the figures as the blue lines lie between the red lines. It suggests the significance level and the stability of all the coefficients in the error correction model. The study findings could be applied concerning when framing the relevant policies about economic prosperity, logistics energy consumption, logistics carbon emission, port logistics, road logistics, rail logistics, air logistics, and trade all perform a crucial part for CO_2 emission because a stable pattern was observed among the parameters follow throughout the sample period when applying the model.

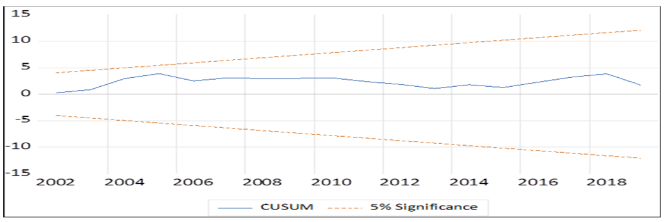

Figure 1. The CUSUM test result shows the model's structural invariance, endogeneity, and stability (x-axis, data points; y-axis, cumulative sum).

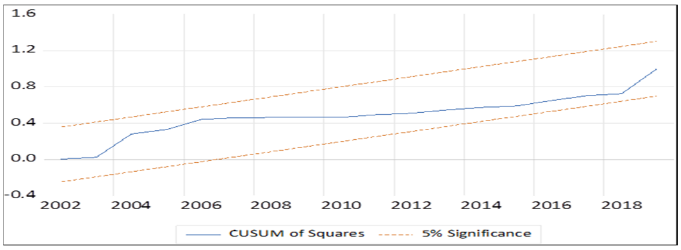

Figure 2. The CUSUM of squares test result shows the model's structural invariance, endogeneity, and stability (x-axis, data points; y-axis, cumulative sum of squares).

4.7. Robust Analysis

The impulse response is an alternate when analyzing the variance decomposition. It estimates the reaction of one variable based on the shocks arising from various other variables [12,61]. Figure 3 shows the finding of the impulse response function. The impulse response function can be observed as the blue line; however, the red lines show a confidence interval with a value the 95%. Still, the impulse response function is observed to be within the range of red-line. It indicates the positive response in logistics CO_2 emissions due to standard shocks arising from road logistics. This implies that road logistics contribute the CO_2—the positive reaction in CO_2 due to standard shocks stemming in EP, LEC, and trade. The response of air logistics, rail logistics, and port logistics is positive due to standard shocks stemming in trade and economic prosperity. The response in road logistics is positive and significant due to standard shocks stemming from logistics carbon emission, trade, logistics energy consumption, and economic prosperity. The trade shows a positive response due to standard shock stemming in road logistics, logistics energy consumption, railways logistics, and economic prosperity. The response in economic prosperity is positive due to shock stemming from air logistics, trade, rail logistics, and logistics energy consumption.

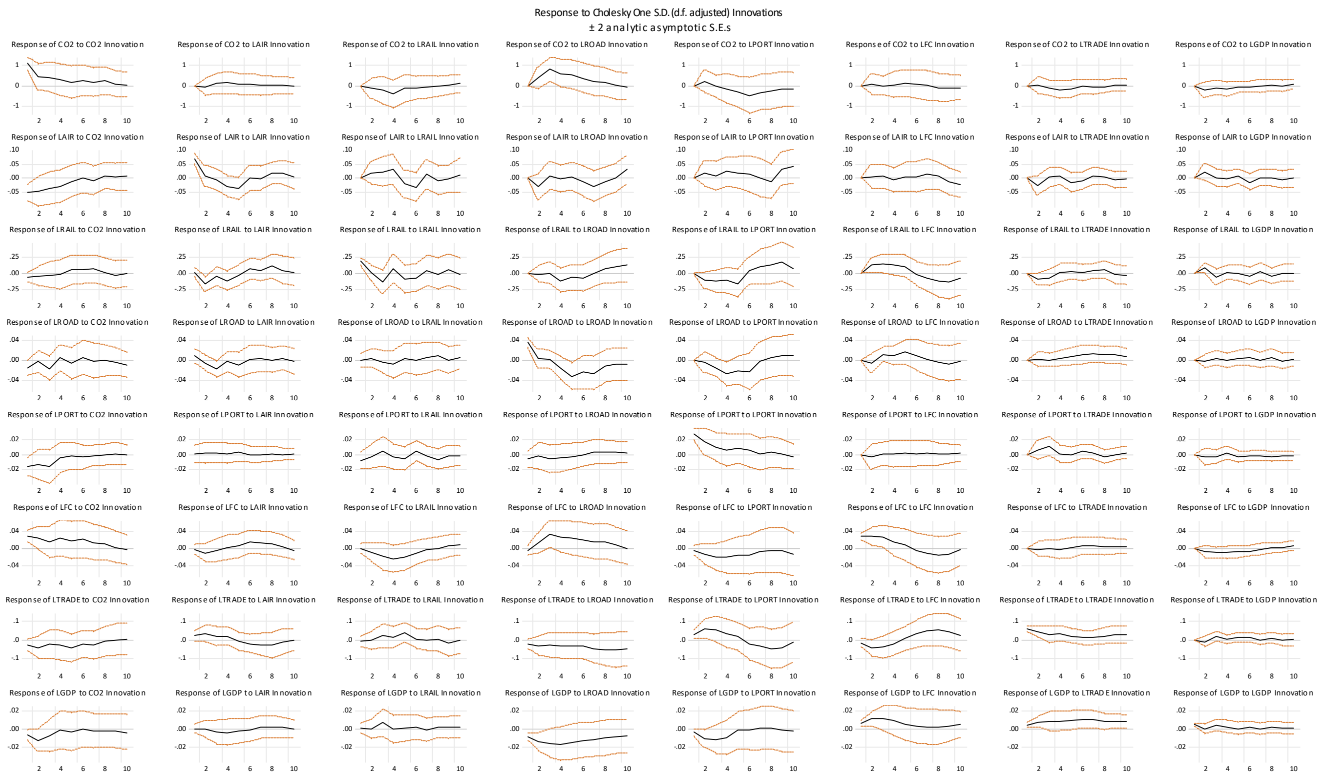

Figure 3. Impulse Response Function.

5. Concluding Remarks

This research study examines the logistics industry concerning economic growth, energy utilization, trade, and CO_2 emissions. Various statistical approaches are applied using time-series data; it covered over 29 years. The stationarity of the variables was measured based on PP and the ADF [39,40] unit root tests; later, the optimal lag length was applied in addition to ARDL-bound testing [22]. The vector error correction model and Wald's test statistic and [46] was applied for measuring the short- and long-run causalities for most logistics industry components, respectively.

The scientific novelty of this research is concurrent evaluation of short- and long-run influence for most logistics industry components, the modern logistics industry [1,12], besides testing the given propositions on the projected coefficients in the long-run, which are mainly ignored by existing studies. The implementation of most logistics industry components is applied straightforwardly [13] using a single-form equation [14]; it contrasts with existing studies that involved procedures in a system of equations. Thus, the interpretation of these studies becomes robust and affects the performance of a given logistics industry considering sustainable development goals when comparing it over other cointegration methods [23,24]. Moreover, another issue is reliability for samples when comparing it with Johansen and Juselius's cointegration methodologies [25].

The results show a short-term causality that runs from logistics industry, economic growth, and logistics energy usage to CO_2 emissions; it implies an increase in emissions resulting from economic development and growth in logistics. Moreover, the finding also exhibits the existence of a "long-run" bidirectional association between economic development and the logistics industry. Furthermore, a unidirectional causality exists from economic growth, logistics industry, and logistics energy usage to emissions. Such findings suggest that the economic growth and investments in logistics industry infrastructure would continue to develop this industry and higher emissions. Accordingly, the Pakistan case offers interesting insights for developing countries, considering that the country is aggressively investing in logistics industry development. The country shows causality between logistics industry and economic development in both the short and long run suggesting the contribution of logistics industry investment to economic development. Concurrently, Such significant investment in logistics industry would direct to more CO_2 emissions in both the short and long run. Being a developing country, Pakistan still needs to accelerate its economic growth to development and prosperity regardless of its linkage with emission future after-effects. Given these outcomes, the study provides crucial implications and policy insights for Pakistan due to rigorous upcoming investment, estimated to be in billions of dollars' worth, in its transport sector, especially for the improvement of road infrastructure, as part of the CPEC (China–Pakistan Economic Corridor) OBOR (One Belt One Road) initiative. However, these improvements will come at a price, mainly in terms of environmental deprivation; it might become alarming in future as Pakistan is among is those countries that ranked at the top ten nations expected to be most susceptible to climate variation. Moreover, more importantly, the implications of those environmental degradations are increasingly involved by introducing increasingly stringent environmental standards that constantly mount long-run risks to these current developmental investments of the logistics industry because the implications of those environmental degradations overlap with geosocial preference. Accordingly, the findings also indicate that, in general, the government makes policies to achieve higher economic development based on investment in the logistics industry. Accordingly, when the policies are designed to encourage economic growth and logistics industry development, however, at the same time, geospecific policies, specifically the overlap of geosocial preferences to carbon implications, also need to be considered. Consequently, a long-term view of current logistics investment in developing countries must focus on the protection of the environment and regulation of emissions, considering scarce resources and sustainable logistics industry development. Policymakers should to locate a tradeoff between developing the logistics industry and regulating the emissions. It could suggest a necessity to emphasize green, or renewable, energy in Pakistan, while concurrently developing the technological capacity by directing fuel-efficient, or renewable energy-led, motor vehicles.

6. Limitations of the Study

This study also has a few limitations concerning the theoretical implications. First, the proposed analysis of this type may find difficulties in successfully recognizing the "right" connections between the selected variable, including a unit root, as problems of spurious association may appear. Therefore, the step-by-step unit root test needs to be performed to confound this problem.

Furthermore, concerning our analysis, some studies have noted that Granger causality is not necessarily a true condition [62]. Given this view, future research prospects for all microlevel and macrolevel elements related to the logistics industry, such as fuel-related European standard, sustainable energy policies, fuel-efficient vehicles, and subsidies for green technology, regardless of their direct and indirect impact on freight and economic prosperity, should be incorporated for overall strategic implications in the logistics industry for sustainable perspective and development.

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