



RETRACTED: Dynamic Linkages Between Developing Economy and Environmental Pollution: An Autoregressive Distributed Lag Statistical Approach

Hong Wang¹, Nada Alfryyan², M. S. Al-Buriah³, Yousaf Ali Khan⁴, Majid Alhomrani⁵, Abdulhakeem S. Alamri⁵, Muhammad Azhar⁶ and Syed Zaheer Abbas^{4*}

¹School of Tourism, Hainan University, Haikou, China, ²Department of Physics, College of Science, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia, ³Department of Physics, Sakarya University, Sakarya, Turkey, ⁴Department of Mathematics and Statistics, Hazara University Mansehra, Mansehra, Pakistan, ⁵Department of Clinical Laboratories Sciences, The Faculty of Applied Medical Sciences, Taif University, Taif, Saudi Arabia, ⁶Department of Mathematics, Abbottabad University of Science and Technology, Abbottabad, Pakistan

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*Correspondence:

Syed Zaheer Abbas
zaheer@hu.edu.pk

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The goal of the study is to examine the dynamic linkages between developing economy and environmental pollution. FDI, the tourism industry, electricity use, and GDP growth have all been studied in relation to CO₂ emissions over the period from 1980 to 2019. The study applied the ARDL model for statistical data analysis and to ensure the results reliability, the FMOLS and DOLS models have been used in conjunction. The results disclose a significant negative correlation between GDP squared and the observed data. FDI and GDP growth, in contrast, have significant long-term positive effects on CO₂ emissions. Due to Pakistan's lack of infrastructure and transportation facilities, the tourism industry has a long-term negative impact on Pakistan's CO₂ emissions, which are expected to rise over the next several decades. CO₂ emissions and GDP growth are linked in a U-shape. The results also showed that GDP growth and electricity use have no significant short-term impacts on CO₂ emissions; only FDI coefficients have a negative significance. The Granger causality test found connections between electricity use, FDI, GDP, and CO₂ emissions shows a one-way causation.

Keywords: granger causality test, GDP growth, tourism industry, electricity use, ARDL test, developing economy

1 INTRODUCTION

The international pattern shows that certain nations have withstood economic expansion without also seeing an increase in CO₂ emissions. However, there has been an increase in concerns about the "low carbon and green growth" strategy (Elahi et al., 2022a). An important question is whether it is possible to maintain economic growth without increasing energy use or

Abbreviations: ARDL, Autoregressive Distributed Lag Model; CO₂, Carbon dioxide; EKC, Environmental Kuntz Curve; FDI, Foreign Direct Investment; FMOLS, Fully Modified Ordinary Least Square; GDP, Gross Domestic Product; LM, Lagrangian Multipolar.

emissions of greenhouse gases. Several activities, such as transportation, use more energy and produce more emissions in urban areas (Tu et al., 2019; Zhao et al., 2020) (Sun et al., 2021). Some of the environmental and climate change measures developed by global organizations have already had a positive impact. Environmental and climatic change are being threatened by the increasing consumption of natural resources as a result of economic growth (Elahi et al., 2021). To gain economic benefits at the price of the environment's depletion (Elahi et al., 2022b), the world's economies have traditionally expanded their energy use (Peng et al., 2021a) (Destek and Aslan 2017). Energy consumption continues to rise with transportation sector expansion, although this tendency is reversed in other sections of the economy. According to Rafindadi, economic growth leads to an increase in CO₂ emissions despite a decrease in energy consumption (2016). Manufacturing now has a higher energy intensity (Odhiambo et al., 2020; Peng et al., 2020a). Understanding the factors that influence climate change, energy intensity, renewables and electricity consumption and CO₂ emissions in this context need more research (Elahi et al., 2022a). International trade's CO₂ emissions may be curbed by countries with rigorous environmental regulations to avoid human health damages (Gu et al., 2019; Gu et al., 2020a; Gu et al., 2020b) (Nathaniel et al., 2021). The world's economies have generally increased their energy consumption as a trade-off for larger economic advantages. CO₂ and other harmful greenhouse gases have been released into the atmosphere as a result of fossil fuels being burned to fulfil global energy demands (Peng et al., 2021b; Zhong et al., 2021) (Baloch et al., 2021). Since international trade and FDI inflows are part of economic globalization, it's more relevant to look at how these emissions affect globalization for wealthy countries, the benefits of free trade outweigh the costs (Wang et al., 2021b) (Copeland and Taylor, 1997). A no-brainer involves using energy as a fuel and technology in the home, office, and other areas. Energy and resources are used more intensively by businesses in order to improve output (Shen et al., 2019; Peng et al., 2020b; Peng et al., 2021c). Economic growth and CO₂ emissions have an inverted U-shape connection (Koondhar et al., 2021). Foreign direct investment (FDI) and environmental harm may be connected to global climate change. According to Grimes and Kentor, investment in developing countries is connected to an increase in greenhouse gas emissions (2003a). Tourism and rising coal and oil use both contribute to short-term and long-term increases in CO₂ emissions. As the tourist and transportation industries grow as a consequence of more visitors, there will be an increase in energy consumption. The total CO₂ emissions from the Chinese tourism business increased on an annual average by 12.6%, with transportation contributing to the majority of those increases (more than 80%). The influence of FDI, tourism, economic development, and energy consumption on Pakistan's CO₂ emissions has been studied annually since 1980 using CO₂ emissions data. When it comes to CO₂ emissions, energy needs, foreign

investment (FDI), and tourism there have been many questions in Pakistan. Based on the findings, what are Pakistan and other developing countries advised to do? A number of things are on our mind, including adding new material to what has already been published. The electricity is used in every area of activity, including FDI and tourism, this study focuses on the influence of electricity consumption rather than energy consumption. A technique known as autoregressive distributed lag (ARDL) limits analysis is used for long-term relationships; the error-correcting model (ECM) and the Granger causation technique are used for short-term consequences, while VECM and the Granger causation approach are used for causal links.

The remaining of the paper is as structured follows; **section 2** describes the supporting literature of the study. The third section consists of the methodology, data collection process and econometrical descriptions. The **section 4** explains the results and discussions. **Section 5** describes the conclusions of the study and future suggestions for the researchers.

2 LITERATURE REVIEW

According to Grimes and Kentor (2003), FDI inflows to less developed nations considerably increase the growth of carbon emissions. Inflows of foreign direct investment (FDI) can help the host country's economy by introducing more energy-efficient and environmentally friendly technology (Wang et al., 2021a). There is a negative correlation between FDI inflows and emissions, according to Zhu et al. (2016). Climate change has been linked to increased carbon emissions by FDI inflows, according to Shahbaz et al. (2019). A developed country like the United States would be anticipated to have lower carbon dioxide emissions as a result of foreign direct investment (FDI). In addition, Kaya et al. (2017) found that FDI inflows have a short-term negative impact on carbon emissions, but they will have a long-term positive impact on Turkey's carbon emissions. As FDI inflows increase, so do carbon emissions, implying that the G20 economies are producing more carbon dioxide as a result of the increased inflows (Huang et al., 2022). Trade variable has a statistically negligible link to environmental deterioration, and decreases in FDI contribute to worsening environmental quality. In the long term, it is expected that the drop in renewable energy use would lead to a decrease in CO₂ emissions (Abdul Rehman, 2021).

The world's economies have generally increased their levels of energy employment in exchange for greater economic rewards at the expense of environmental pollution (Peng et al., 2019) (Destek and Aslan 2017). Aside from that, environmentalists have long recognized that nations with strict environmental regulations are better able to rein in global CO₂ emissions *via* trade (Nathaniel et al., 2021). As a result of international commerce, CO₂ emission performance may be impacted by both quick technological advancements and the expansion of high-polluting sectors (Du and Li 2019). Because of international commerce and openness, sophisticated environmentally-friendly

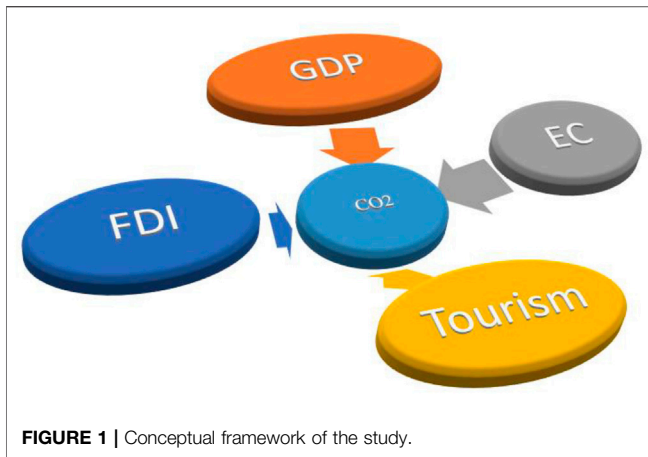


FIGURE 1 | Conceptual framework of the study.

industrial technology and knowledge may be transferred, resulting in a reduction in CO₂ emissions (Ahmed et al., 2015).

According to Li and Wang (2019), International trade is helpful in increasing carbon productivity. Some research suggests, however, that global commerce really has a detrimental effect on CO₂ emission performance. There is a correlation between increased agricultural CO₂ emissions and increasing wealth throughout the world, but economic integration appears to minimize emissions in the sector, according to Nguyen et al. (2020). Businesses who offer tours, festivals, and other services to attract visitors must be aware of the negative environmental impacts of tourism (Lee and Brahmaasrene, 2013). Even environmental activists who are well-aware of the environmental harm that tourism does do not (Juvan and Dolnicar, 2014), alter their travel habits in order to safeguard the environment.

According to Tang et al. (2014), China's tourism-related CO₂ emissions increased at an annual average rate of 12.6% between 1990 and 2012, with transportation contributing to more than 80% of the total. Tourist arrivals have a beneficial influence on CO₂ emissions, but tourism revenues reduce CO₂ emissions, according to Koçak and Ulucak (2019). There is an inverse U-shape relationship between economic expansion and emissions of CO₂ (Koonthar et al., 2021). Salahuddin et al. (2018) used the ARDL to suggest that Kuwait's economic growth is a role in both the short and long term increase in CO₂ emissions. According to Rafindadi (2016), even if energy demand is declining, economic expansion leads to an increase in CO₂ emissions. The study included analytical methods employed the ARDL and DOLS, FMOLS, and classical Co-integration regression approaches.

The researchers found economic expansion monotonically increases emissions of carbon dioxide. According to Zhang (2018), non-fossil energy consumption is damaging to environmental well-being since it increases CO₂ emissions into the atmosphere when this form of energy is consumed at a higher rate. As Usama et al. (2020) showed, the ARDL model may be used in Ethiopia to show that both renewable and non-renewable energy generation can reduce CO₂ emissions, and that renewable electricity can have a positive influence on energy-related CO₂. In the long term, renewable energy usage

lowers energy-related CO₂ emissions, according to an ARDL analysis by Zambran, (2017). Several activities, such as transportation, use more energy and produce more pollution for urban residents (Sun et al., 2021).

A linear linkage between economic development and CO₂ emissions has been hypothesized by the Environmental Kuznet Curve (EKC) hypothesis, despite this theory's inverted U form (Khalid and Muhammad, 2013). As Tang and Tan (2015) explain, they investigate the relationship between energy consumption, income, and foreign direct investment (FDI) on carbon emissions in Vietnam. Long-term and short-term CO₂ emissions are both attributed to energy use as a Granger-cause. The North-South trade model was established by Copeland and Taylor (1997) to investigate links between pollution and international commerce, and it demonstrated that free trade benefits industrialized nations' environments while aggravating those of developing countries'. Increases in CO₂ emissions are one of the more common side effects of global trade's growing influence on the environment (Shahbaz et al., 2017). The connection between FDI, GDP, Tourism and Electricity consumption on CO₂ emission are hypothesized in Figure 1 below.

3 MATERIALS AND METHODS

3.1 Data Collection

Yearly, numbers from 1980 through 2019 are included in this study. CO₂ emissions are replaced by environmental damage, whereas GDP is peroxided by GDP. Table 1 highlights the description of the study's variable.

3.2 Research Design

The econometric model used in the study is as follows: On the other hand, the development of eco-friendly FDI and tourism may easily contribute to the preservation of natural resources. Tourist flows have a direct impact on CO₂ emissions since the EKC model incorporates both foreign direct investment (FDI) and tourism factors.

$$CO_2 = f(FDI, EC, TOUR, GDP, IT) \quad (1)$$

CO₂; Carbon dioxide, FDI; Foreign direct investment, EC; Energy utilized for electricity generation, TOUR; International tourism, GDP; Gross domestic products, IT; International trade are all included in the CO₂ category. Logarithms (ln) were used to help shift the stationarity of all variables. Using a log-quadratic regression model, we may see the following:

$$\ln CO_{2t} = \alpha_0 + \beta_1 \ln FDI + \beta_2 \ln EC + \beta_3 \ln TOUR + \beta_4 \ln GDP + \beta_5 \ln IT + \epsilon \quad (2)$$

Eq. 2's predicted signs include positive values for β_1 , β_2 , β_3 , and β_4 . Whereas, if the EKC theory is correct, then β_5 should have a negative sign. The expansion of environmentally friendly forms of foreign direct investment (FDI) and tourism might easily

TABLE 1 | Provides the brief information of variables and database.

Variable	Measurement	Data provider
FDI	Foreign direct investment	World Bank Database
GDP	Gross domestic product (Calculated in \$)	World Bank Database
IT	International trade volume of the country	World Bank Database
EC	Energy used (in shape of Oil and Coal) for electricity production	World Bank Database
CO ₂	Carbon dioxide emissions in tones	World Bank Database
TOUR	Tourism industry	World Bank Database

contribute to the conservation of natural resources. Tourist flows have a direct impact on CO₂ emissions since the EKC model incorporates both foreign direct investment (FDI) and tourism factors. A pre-assessment of the unit root is not required for the ARDL co-integration strategy, because it is possible to test for co-integration using a set of variables of orders I(0) and I(1).

The stationarity of each variable should be checked before moving on to the next stage of study and its implications. Unit root testing techniques Phillips–Perron (PP) and Augmented Dickey–Fuller (ADF) were used to verify the unit roots of the variables.

3.3 Tests for Co-Integration

Using the limits analysis approach and the traditional Johansen co-integration procedure, this study examines the long-term linkage between the variables under consideration. Equation-2 may be used to do co-integration using the ARDL method as follows:

$$\begin{aligned}
 \ln CO_{2t} = & \alpha_0 + \sum_{i=1}^{p_1} \beta_i \Delta \ln CO_{2t-i} + \sum_{i=0}^{p_2} \gamma_i \Delta \ln FDI_{t-i} \\
 & + \sum_{i=0}^{p_3} \rho_i \Delta \ln GDP_{t-i} + \sum_{i=0}^{p_4} \vartheta_i \Delta \ln IT_{t-i}^2 \\
 & + \sum_{i=0}^{p_5} \mu_i \Delta \ln FDI_{t-i} + \sum_{i=0}^{p_6} \pi_i \Delta \ln TOUR_{t-i} \\
 & + \Phi_{11} \ln CO_{2t-1} + \Phi_{12} \ln EC_{t-1} + \Phi_{13} \ln GDP_{t-1} \\
 & + \theta_{14} \ln IT_{t-1} + \Phi_{15} \ln FDI_{t-1} + \Phi_{16} \ln TOUR_{t-1} + \varepsilon_t
 \end{aligned} \tag{3}$$

The ARDL procedure consists of two phases. The main period of the ARDL model’s blunder repair process incorporates F-statistics to dissect the variables. Both assumptions accept that all variables in the autoregressive distributed slack approach are I(0) and I(1). It is a long term association if the F- statistics is over a certain significance level’s maximum cutoff. If there is no long-term relationship with the dependent variable, F-statistics is less than basic edge. Uncertain outcomes occur when the value is between two limitations. The null and alternative hypotheses for the F-statistic test are phrased as follows:

$$\begin{aligned}
 H_0 : (\varphi_1 = \varphi_2 = \dots = \varphi_k = 0); H_1 : (\varphi_1 = 0, \varphi_2 = 0) \\
 \Delta \ln CO_{2t} = & \alpha_0 + \sum_{i=1}^{p_1} \beta_i \Delta \ln CO_{2t-i} + \sum_{i=0}^{p_2} \gamma_i \Delta \ln EC_{t-i} \\
 & + \sum_{i=0}^{p_3} \delta_i \Delta \ln GDP_{t-i} + \sum_{i=0}^{p_4} \vartheta_i \Delta \ln GDP_{t-i}^2 \\
 & + \sum_{i=0}^{p_5} \mu_i \Delta \ln FDI_{t-i} + \sum_{i=0}^{p_6} \pi_i \Delta \ln TA_{t-i} + \lambda ECT + + \varepsilon_t
 \end{aligned} \tag{4}$$

As a result, the long-term coefficient and the second-stage estimates may be established. Based on model selection criteria, the long-term coefficients estimate may change. The correction restraint has an effect on changes in the drawn-out harmony gauge of the dependent variable’s coefficient of error repair. Following the selection of the ARDL model, the connection between variables may be evaluated using the AIC or SBC metric.

3.4 Granger Causality

No of whether or not we find co-integration in this study, we may still utilize Granger causation with error correction to assess causatives (Engle and Granger 1987). A larger Granger causation assessment with error correction arises as a consequence of the following equation:

$$\begin{pmatrix} \ln CO_{2t} \\ \ln GDP_t \\ \ln IT_t \\ \ln EC_t \\ \ln FDI_t \\ \ln TOUR_t \end{pmatrix} = \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \end{pmatrix} + \begin{pmatrix} \sigma_{11,1} & \sigma_{12,1} & \sigma_{13,1} & \sigma_{14,1} & \sigma_{15,1} & \sigma_{16,1} \\ \sigma_{21,1} & \sigma_{22,1} & \sigma_{23,1} & \sigma_{24,1} & \sigma_{25,1} & \sigma_{26,1} \\ \sigma_{31,1} & \sigma_{32,1} & \sigma_{33,1} & \sigma_{34,1} & \sigma_{35,1} & \sigma_{36,1} \\ \sigma_{41,1} & \sigma_{42,1} & \sigma_{43,1} & \sigma_{44,1} & \sigma_{45,1} & \sigma_{46,1} \\ \sigma_{51,1} & \sigma_{52,1} & \sigma_{53,1} & \sigma_{54,1} & \sigma_{55,1} & \sigma_{56,1} \\ \sigma_{61,1} & \sigma_{62,1} & \sigma_{63,1} & \sigma_{64,1} & \sigma_{65,1} & \sigma_{66,1} \end{pmatrix} \begin{pmatrix} \ln CO_{2t} \\ \ln GDP_t \\ \ln IT_t \\ \ln EC_t \\ \ln FDI_t \\ \ln TOUR_t \end{pmatrix} + \dots + \begin{pmatrix} \Phi_1 \\ \Phi_2 \\ \Phi_3 \\ \Phi_4 \\ \Phi_5 \\ \Phi_6 \end{pmatrix} ECT_{t-1} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \\ \varepsilon_{5,t} \\ \varepsilon_{6,t} \end{pmatrix}$$

ECT_{t-1} is the long-run equilibrium model’s trailing error correction equation. It is critical that the ECT_{t-1} causation evaluation be statistically significant for both long and short-term causation. The stochastic standard error equation is ε_{1,t} to ε_{6,t}. Corrective action is shown by the number, which indicates the amount of disequilibrium that will be corrected in a given length of time.

3.5 The Model’s Diagnostic Tests

Errors in Eq. 3 are assumed to be normally distributed and serially independent, which is the underlying concept of the ARDL limits analysis approach. As a consequence, the Breusch-Godfrey serial correlation LM evaluation, the Ramsey reset test, and the “Breusch-Pagan-Godfrey” test will be used to evaluate the model’s working formula and check for heteroscedasticity.

3.6 Robustness Test

The FMOLS and DOLS procedures are used to evaluate the results’ validity.

TABLE 2 | Descriptive Statistics of all variables.

	CO ₂	GDP	FDI	TOUR	EC	IT
Mean	-0.654224	-0.241940	8.448022	6.191954	2.207308	-0.194073
Median	-0.665442	-0.240248	8.665907	6.273082	2.242777	-0.273476
Maximum	-0.244827	-0.054220	7.542764	6.667419	2.80748	-0.070447
Minimum	-0.742448	-0.195919	6.244194	4.727427	2.678064	-0.641942
Std. dev	0.219087	0.067347	2.04888	0.192782	0.424762	0.220088
Skewness	0.241974	-0.619748	-0.877619	0.062274	0.064044	-0.619748
Kurtosis	2.878259	2.808278	2.447474	2.82442	2.806407	2.808278
Jarque-Bera	2.619819	2.444708	4.854196	0.222002	2.87627	2.444708
Probability	0.454444	0.474667	0.194827	0.740824	0.407447	0.474667
Sum	-19.07444	-4.694708	273.2204	259.8744	66.27322	-8.871919
Sum sq. dev	2.48742	0.088847	42.87819	0.748742	2.74847	0.542476
Observations	40	40	40	40	40	40

FDI, has the highest standard deviation, followed by EC, emissions, TOUR, IT, and GDP. In terms of skewness, CO₂, EC, GDP, IT, and TA are all in the negative half of the normal distribution range (-0.5 to 0.5), while FDI, is in the negative half of the normal distribution (one to one), indicating that it is far out of the normal distribution. To make matters more complicated, because of the low level of kurtosis (less than 3), all of the above variables were found to be platykurtic in this distribution. Both the Jarque-Bera numbers and the p-values support the standard distribution null hypothesis.

4 RESULTS AND DISCUSSIONS

4.1 Descriptive Statistics

It has been described in Table 2 for us as a means of reaching our objective.

4.2 Correlation Matrices

The correlation matrix is shown in Table 3. There appears to be a link between CO₂ emissions and all other factors. EC, FDI, GDP, IT, and TOUR exhibit and a positive link with CO₂ emissions. For Pakistan FDI inflows, GDP growth, and TOUR all have a favorable impact on each other. FDI and TOUR have a positive correlation, respectively.

4.3 Unit Root Analysis Test

Research factors are studied using the ARDL bound estimation approach to examine the long-term influence. With regard to series integration orderliness, the bound estimate is flexible. The variables need to be transformed into a value of I(0) or I(1). ARDL co-integration can be employed in this experiment as a result. The PP and ADF estimates of CO₂ emissions continue stationary at the current levels, whereas energy consumption, GDP growth, FDI, and tourism remain stationary at the 1st differences, as shown in Table 4.

4.4 Selection of Lag Order by VAR

The ARDL limitations check should be completed before the F-bound assessment is finalized. If the elements are co-integrated, the proper slack sequencing of the factors should be used to conduct a survey. According to the estimations in this computation, the results are shown in Table 5.

For lag length order selection, the estimation of F-statistics presents a key issue. Endogenous variables such as CO₂ emissions, electricity consumption (EC), foreign direct investment (FDI), GDP, GDP squared, and tourism (TA)

TABLE 3 | Shows the correlations matrix of all variables.

	CO ₂	EC	FDI	GDP	IT	TOUR
CO ₂	1					
EC	0.86278	1				
FDI	0.761157	0.70583	1			
GDP	0.85232	0.79098	0.643422	1		
IT	0.70635	0.83920	0.621134	0.628221	1	
TOUR	0.64304	0.57575	0.427537	0.276347	0.276347	1

were taken into account. Based on lag length split-up computations and cooperative lag choice algorithms, statistics show that a lag length of one is the best possible.

4.5 The Coexistence: The Autoregressive Distributed Lag Bound Test

Once stationarity has been proven for the variables, the F-statistic may be computed using the bound testing approach. It's revealed in Table 6 that F-statistic exceeds the top limit of critical values.

4.6 Johansen Co-Integration Test

Johansen co-integration has been used to examine CO₂ emissions, energy consumption, foreign direct investment (FDI), gross domestic product (GDP), and tourism output (TOUR). The proper lag length must be determined before to executing the Johansen co-integration test. We may deduce that the lag duration is one based on the unconstrained VAR model's least SC and AIC values for the issue's five initial transformations. Tables 7, 8 illustrate the findings of the Johansen co-integration assessment, which is employed since all components are integrated in the same order.

Table 8 reveals that the IT variable has a negative and significant coefficient. This suggests that the relationship

TABLE 4 | Shows the results of Unit Root Test at different levels.

PP unit root test table							
At level							
		CO₂	EC	FDI	GDP	IT	TOUR
With constant	t-Statistic	2.5753	-0.1816	-2.0275	-2.6524	-2.6524	-2.0526
	Prob	0.6987	0.7353	0.2756	0.3482	0.3482	0.2834
		NO	NO	NO	NO	NO	NO
With constant and trend	t-Statistic	-4.6426	-2.8642	-2.0160	-6.5746	-6.5746	-2.2652
	Prob	0.0524	0.2752	0.7376	0	0	0.5304
		**	NO	NO	***	***	NO
Without constant and trend	t-Statistic	-4.5273	7.6742	2.4346	-0.6853	-0.6853	0.7536
	Prob	0.0002	2	0.6948	0.5267	0.5267	0.7048
		***	NO	NO	NO	NO	NO
1st difference							
		d(CO ₂)	d (EC)	d (FDI)	d (GDP)	d (IT)	d (TOUR)
With constant	t-Statistic	-8.2646	-7.2734	-6.8034	-34.7568	-34.7568	-6.0653
	Prob	0.00002	0.0002	0	0.0002	0.0002	0.0004
			***	***	***	***	***
With constant and trend	t-Statistic	-20.8536	-6.5253	-20.1648	-34.6967	-34.6967	-4.7846
	Prob	0	0.0007	0	0	0	0.0034
		***	***	***	***	***	***
Without constant and trend	t-Statistic	-2.7826	-2.3468	-4.8648	-34.0752	-34.0752	-4.7758
	Prob	0.0052	0.0526	0	0	0	0
		***	**	***	***	***	***
ADF unit root test table							
At Level							
With constant	t-Statistic	2.8687	-0.2867	-4.0264	-2.5368	-2.5368	-2.0526
	Prob	0.6974	0.7268	0.0073	0.3468	0.3468	0.2834
		NO	NO	***	NO	NO	NO
With constant and trend	t-Statistic	-4.7570	-6.3416	-4.2873	-4.7384	-4.7384	-2.2074
	Prob	0.0427	0.0028	0.2084	0.006	0.006	0.5694
		**	***	NO	***	***	NO
Without constant and trend	t-Statistic	-4.5698	8.464	2.1812	-2.3481	-2.3481	0.7602
	Prob	0.0002	2	0.7526	0.181	0.181	0.7048
		***	NO	NO	NO	NO	NO
1st difference							
At level							
With constant	t-Statistic	-4.0524	-6.4272	-6.0706	-6.3487	-6.3487	-6.0653
	Prob	0.006	0.0002	0.0004	0.0004	0.0004	0.0004
		***	***	***	***	***	***
With constant and trend	t-Statistic	-4.6468	-6.5234	-6.7382	-6.0275	-6.0275	-4.7846
	Prob	0.0067	0.002	0.0006	0.0016	0.0016	0.0034
		***	***	***	***	***	***
Without constant and trend	t-Statistic	-4.0282	-8.7756	-4.7572	-7.8282	-7.8282	-4.7754
	Prob	0.0048	0	0	0	0	0
		***	***	***	***	***	***

***, **, * present significance at 1,5, and 10 percent respectively.

between Pakistan's GDP and CO₂ emissions is an inverted U-shape. Because of this, the EKC theory is correct.

Whether energy consumption, FDI, tourism, and GDP have a co-integration relationship with CO₂ emissions. Co-integration

between variables was found to exist. EKC hypothesis's energy literature is extensively addressed in this study. The long-term effects of energy consumption, FDI, and GDP on CO₂ emissions are positive and large, but tourism is significant and negative. A

TABLE 5 | Shows the results of Lag Order used by VAR.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	167.3532	NA	2.87E-10	-8.174024	-7.931820	-8.096287
2	108.9192	194.2919*	6.87e-16*	-16.85185*	-18.41678*	-16.42479*
2	163.3532	29.87938	2.53E-12	-16.16872	-20.62198	-18.43872

*Indicates lag order selected by the criterion. LR, sequential modified LR, test statistic (each test at 5% level); FPE, final prediction error; AIC, Akaike information criterion; SC, Schwarz information criterion; HQ, Hannan-Quinn information criterion.

TABLE 6 | Shows results of the co-integration: ARDL bound test.

F-bounds test		H0: No relationship			
Test Statistic	Value	Signif (%)	I (0)	I (2)	
Asymptotic $n = 1230$					
F-statistic	8.08272	22	2.9	3.09	
k	7	8	2.97	3.49	
		2	2.87	4.37	
		3.20	2.91	3.65	

In this case, the F-statistic is 9.24, which is over the threshold. As a consequence, the connected variables alternative hypothesis is accepted. CO₂ emissions, energy consumption, FDI, GDP, IT, and TOUR, all have a long-term relationship.

TABLE 7 | Shows johansen co-integration assessment results.

Lags interval (in first differences): ONE to ONE				
Hypothesized	Trace			
No. of CE(s)	Eigenvalue	Statistic	0.05 Critical value	Prob.**
None *	0.753449	65.27073	67.73165	0.0073
At most 1	0.619351	48.76824	48.75624	0.1919
At most 2	0.460348	41.62427	27.65808	0.6202
At most 3	0.19463	6.52524	9.47482	0.682
At most 4	0.047546	2.083524	4.732449	0.1937

TABLE 8 | Shows the results of johansen co-integration assessment

Hypothesized	Max-eigen 0.05			
No. of CE(s)	Eigenvalue	Statistic	Critical value	Prob.** none *
None	0.792266	40.2255	51.65275	0.0075
At most 1	0.626428	20.51296	28.68514	0.4289
At most 2	0.550223	22.60226	22.24262	0.481
At most 3	0.26481	7.127528	24.2655	0.8558
At most 4	0.047955	2.085124	4.842556	0.2819

At the 0.05 threshold, the max-eigenvalue test reveals 1-Cointegration equations

negative and statistically significant coefficient can be found for IT. This demonstrates that Pakistan's GDP and CO₂ emissions are linked in an inverted U-shape, as seen by this graph. Because of this, the EKC theory is correct. EC, GDP, IT, and TOUR do not have a significant short-term effect on CO₂ emissions. Both short- and long-term CO₂ emissions in Pakistan are reduced by foreign direct investment (FDI), which has significant and negative coefficients at 5% confidence level. There is a 95% assurance that the evaluated ECM coefficients are negative and really large in magnitudes. The statistic shows a 60% rate of adaptation.

TABLE 9 | Shows the results of long-term estimation.

Dependent variable: CO ₂ emissions				
Variable	Coefficient	Std. error	t-Statistic	p-Value
FDI	0.025082	0.006249	5.158252	0.0255
IT	-0.625597	0.05525	-15.20259	0.0001
EC	0.826335	0.015582	27.5205	0
GDP	1.278279	0.062582	15.20259	0.0009
TOUR	-0.062297	0.009046	-5.977279	0.0062

The Granger causality examination showed that GDP, CO₂ discharges, power use, and FDI are all linked together. Lastly, FMOLS and DOLS are two methods for analyzing the data. According to the most comprehensive Eigen-measurements and subsequent discoveries, there is a co-integration condition at 5%. The ARDL model was used with the Slack's highest request set to 1, and each determined coefficient was big at a 5 percent level in view of long distance connects for condition 4. The EC, FDI, and GDP factors have a favorable influence on CO₂ emissions, whereas the visit variable has a negative influence. To support the EKC hypothesis, it is usual for CO₂ emissions to be adversely affected. **Table 9** shows that CO₂ emissions have a long-term and strong connection to EC, FD, and GDP.

For every 1% increase in electricity use, there is increase in pollutants over the long run. However, a decrease in the TOUR variable suggests that this variable plays a role in Pakistan's CO₂ emission reduction.

4.7 Short-Run Co-Integration Test

EC, GDP, IT, and TOUR do not have a significant short-term influence on CO₂ emissions in the near run. There is just one variable that has both negative and significant coefficients (FDI) at the 5% level of confidence, indicating that this variable decreases CO₂ emissions in Pakistan in the near term as shown in **Table 10**. At a 95% confidence level, the projected ECM coefficients are also substantial and negative which is in line with the findings of Gu et al., 2020a. This means that the entire system is able to adjust by 55%. These findings imply that year-by-year recalculations are used to restore the results' long-term stability and resilience when they deviate from long-term stability.

The FMOLS and DOLS approaches yield results that are equivalent to those of the ARDL model. The following policy proposals are based on the conclusions of this study to reduce CO₂ emissions in FDI, tourism, and the Pakistan GDP sector. The EKC occurs in Pakistan, as evidenced by our research on the relationship between economic growth and carbon

TABLE 10 | Shows the results of estimation in the short-term.

Dependent variable: D (CO ₂)				
Variable	Coefficient	Standard error	t-Statistic	p-Value
D (EC)	0.145073	0.126191	1.345357	0.1643
D (FDI)	-0.030997	0.006449	-3.523784	0.0379
D (GDP)	-0.266430	0.073597	-1.745451	0.0784
D (IT)	-0.064003	0.075727	-1.005264	0.5264
D (TOUR)	-0.004784	0.034526	-0.173190	0.9731
Coint. Eq (-1)*	-0.703490	0.114545	-5.376475	0

emissions. Carbon dioxide emissions are exacerbated by consuming power. The government should look into a long-term energy strategy that increases the generation of renewable energy while reducing energy subsidies at a cost that minimizes CO₂ emissions in order to improve environmental conditions. Investment in clean energy should be a government priority, and environmental laws for polluting companies should be implemented. Improving and familiarizing oneself with new technology in the field of electricity generation, as well as improving the efficiency of energy transformation through the consolidation of heat and electricity generation and the integrated gasification combined cycle in order to reduce the consumption of fossil fuels such as gas, oil, and coal.

4.8 Analytical Test

The Ramsey RESET test for residual component normality, the LM test, and the Heteroskedasticity test for measurement are included in the Results Analytical **Table 11**. Analytical computations may be carried out using the short-term approach, as evidenced by the data. Heteroscedasticity, the operational formula for the approach, and serial correlation, which makes use of normally distributed residual expressions, have never been demonstrated in the literature.

The LM, heteroscedasticity, and Ramsey reset assessments all have *p*-values more than 0.1, hence the model's operational formula is unaffected. Economic growth may suffer as a result of measures to reduce carbon emissions because of the one-way nature of the relationship between CO₂ emissions and GDP

However, high CO₂ emissions as a result of GDP may have significant health consequences, as well as a gradual decrease in output. Progress in industrial technology can help reduce CO₂ emission regulations while simultaneously increasing production efficiency and reducing pollution. For the country to become a developed nation by 2040 without compromising environmental quality, the necessary efforts must be taken now. Sustainable growth in Pakistan requires that the country improve its reliance on renewable fuel supplies such as hydroelectricity and nuclear energy. Maintaining its present energy use while decreasing CO₂ emissions would be possible by doing so. In the future, the use of energy in low-carbon industrial processes and the improvement of power generating efficiency may be environmentally sound. FDI and CO₂ have a one-way relationship. Investment in FDI is critical to the growth of the economy and the creation of new jobs. Pakistan's government has the option of imposing a carbon tax in order to lower pollution levels, even if foreign direct investment (FDI) cannot be completely prevented. To decrease pollution in the future, we should rely increasingly on clean and renewable sources of energy. Consequently, tourism as a long-term development strategy and an energy efficiency approach should be aggressively promoted by the Pakistani government. These findings confirm the findings of Gu et al. (2020b) for china and Khalid and Muhammad (2013) for Saudi Arabia.

4.9 Granger Causation Valuation

With the ARDL approach, it is possible to investigate long-term and short-term co-integration between variables. **Table 12** displays the results of the Granger causation evaluation, which was performed to determine the causal relationship (direction) between the research's problem variables. The results of the Granger causation evaluation show that GDP and CO₂ emissions, EC and CO₂ emissions, and FDI, GDP, and EC all have a single direction of connection.

4.10 Robustness Check

Analysis of robustness is done using FMOLS and DOLS, two different methods. **Table 13** shows the experimental findings, which include the effects of energy consumption, GDP, FDI, and tourism on CO₂ emissions.

TABLE 11 | Shows the results of analytical test.

LM test: Breusch-godfrey

F-statistic	2.407862	Prob. F (2,17)	0.1249
Obs*R-squared	6.089977	Prob. Chi-square (2)	0.0376

Heteroskedasticity test: Breusch-Pagan-Godfrey

Obs*R-squared	10.20456	1.208743	Prob. F (9,19)	0.3817
Scaled explained SS	5.08966		Prob. Chi-square (9)	0.3087
			Prob. Chi-square (9)	0.8025

Ramsey RESET test

	Value	df	Probability
t-statistic	0.534477	20	0.5709
F-statistic	0.156654	(1,20)	0.6347

TABLE 12 | Shows the results of the Granger causation evaluation.

VAR granger causality			
Dependent variable: CO ₂			
Excluded	Chi-square	df	p-Value
EC	16.45619	2	0.0003
FDI	1.139682	2	0.5799
GDP	6.90765	2	0.0378
TOUR	0.9105	3	0.7413
All	41.37472	9	0.003
Dependent variable: EC			
Excluded	Chi-square	df	p-Value
CO ₂	0.303182	2	0.6199
FDI	3.17413	3	0.429
GDP	7.657482	2	0.0349
TOUR	3.482472	2	0.1661
All	13.39619	9	0.1907
Dependent variable: FDI			
Excluded	Chi-square	df	p-Value
CO ₂	5.737857	2	0.057
EC	1.579157	3	0.495
GDP	0.961575	2	0.7391
TOUR	5.154237	2	0.1349
All	13.82519	9	0.0787
Dependent variable: GDP			
Excluded	Chi-square	df	p-Value
CO ₂	1.178257	2	0.4823
EC	3.565737	2	0.3982
FDI	0.136479	3	0.6137
TOUR	0.647299	2	0.6949
All	10.78279	9	0.3161
Dependent variable: TOUR			
Excluded	Chi-square	df	p-value
CO ₂	0.907319	2	0.7413
EC	0.790739	3	0.6915
FDI	1.051249	2	0.5913
GDP	0.542759	2	0.9061
All	3.349579	9	0.9109

Statistically, the discrepancy between GDP and EC is substantial. When it comes to adding lags and leads, as well as altering autocorrelation and heteroscedasticity in the FMOLS or DOLS models, the findings are equivalent to those of the ARDL model.

5 CONCLUSION AND DISCUSSIONS

The study examines the connection between Pakistan's GDP growth and environmental pollution. FDI, the tourist industry, electricity consumption, and GDP growth have all been considered in relative to CO₂ emissions throughout the period from 1980 to 2019. The study applied ARDL model for the statistical analysis and to ensure that the results are reliable, FMOLS and DOLS models have been used in aggregation. The

TABLE 13 | Shows the result of FMOLS and DOLS models.

Variable	Coefficient	Standard error	t-Statistic	p-Value
Dependent Variable: CO ₂				
FMOLS				
EC	0.652917	0.094243	7.649643	0.00001
FDI	0.00421	0.021523	0.364975	0.79101
GDP	0.427057	0.149153	1.659793	0.05010
TOUR	0.000427	0.052143	0.006573	0.65420
C	-3.645219	0.365217	-9.520527	0.00001
Dependent Variable: CO ₂				
DOLS				
EC	0.90037	0.063643	17.53217	0.00001
FDI	-0.010641	0.015165	-0.709579	0.5807
GDP	-1.321552	0.439757	-5.197149	0.0019
TOUR	-0.021564	0.036431	-0.523151	0.7321
C	-3.642573	0.305757	-14.65975	0.0000

results reveal a significant negative correlation between GDP squared and the observed data, FDI, GDP growth, in contrast, have considerable long-term beneficial effects on CO₂ emissions.

Due to Pakistan's lack of infrastructure and transportation capabilities, the tourist sector has a long-term negative influence on Pakistan's CO₂ emissions, which are expected to rise over the next several decades. CO₂ emissions and GDP growth are linked in a U-shape. The results also showed that GDP growth and power usage have no significant short-term impacts on CO₂ emissions; only FDI coefficients had a negative significance. The Granger causality test shows a one-way connection between electricity usage, FDI, GDP, and CO₂ emissions. The growth of the tourism sector has led to a rise in the use of coal and oil, which has a long-term impact on CO₂ emissions with an increase in economic activity comes an increase in demand for transportation services that requires an increase in energy consumption. FDI has insignificant influence on CO₂ emissions in the short and long run. The great majority of FDI in Pakistan's construction and farming industries don't contribute considerably to CO₂ emissions. Biodiesel, hydroelectricity, and solar power should be used more frequently in Pakistan since non-renewable energy is not sustainable.

5.1 Future Research Suggestions

Pakistan's use of renewable energy is still quite low and environmental pollution must be halted by enacting legislation to increase the use of renewable energy sources. It is hoped that by adopting this law, Pakistan would not only be able to attract more visitors but also reduce its CO₂ emissions in the progression.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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