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RESEARCH ARTICLE

The impact of foreign direct investment, tourism, electricity consumption, and economic development on CO_2 emissions in Bangladesh

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Abstract
The study's goal is to investigate the impact of foreign direct investment (FDI), tourism, electricity consumption, and economic development on CO_2 emissions in Bangladesh between 1990 and 2019. Empirical results reveal that FDI, electricity consumption, and economic development variables have significant and positive long-term effects on CO_2 emissions. Tourism, on the other hand, has a long-term negative effect. The square of the GDP variable has a substantial negative coefficient. This indicates that in Bangladesh, the nexus between CO_2 emissions and economic development is *U*-shaped inverted. As a result, the EKC postulate is proven to be correct. In the short term, electricity consumption, economic development, GDP^2, and tourism have no substantial effect on CO_2 emissions. Only the coefficients of FDI are negative and significant. The expected ECM coefficients are also negative and statistically significant. According to these data, the system as a whole adjusts at a rate of 60%. The Granger causality study reveals one direction of causation between electricity consumption and CO_2 emissions, CO_2 emissions and economic development, electricity consumption and economic development, FDI, and CO_2 emissions.

Keywords CO_2 emissions · FDI · Tourism · Economic growth · Electricity consumption · Bangladesh

Introduction

Climate change has emerged as a serious concern for worldwide society. The presence of greenhouse gases (GHG), especially the increasing amount of CO_2, is widely acknowledged as the primary driver of global warming. In the 5th IPCC Review Article, the international community decided that global temperatures should not rise beyond 2 °C by the twenty-first century's end (IPCC 2014). CO_2 emissions will be allotted in a restricted number of locations throughout the world to accomplish this goal.

Global CO_2 emissions from fossil fuel burning were 321.3 billion tons in 2013 (IEA 2018), whereas overall CO_2 emissions in the electricity industry emitted 136.6 billion tons, this industry accounts for 42.5% of aggregate emissions. It implies that throughout the generation and use of energy, the electricity industry is a major source of GHG emissions around the world. The electricity-generating industry acts as an important function in decreasing CO_2 emissions and meeting the demand for economic development across the world. According to the IPCC (2014), electricity generation is both the largest CO_2 emitter and the sector with the greatest potential for decarbonization.

CO_2 emissions from the electricity industry showed various features in different nations and regions due to disparities in economic growth, resource endowments, and emission control methods. An important target of the SDGs is climate action, which focuses on limiting global warming to 1.5 °C, between 2010 and 2030, global net CO_2 emissions will be reduced by 45% as well as by 2050 achieving net-zero (UNDP 2009).

Sea levels will continue to rise if this is not addressed, placing Bangladesh at risk owing to its location on the Bay

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of Bengal. The key policy question is whether a country should follow a strategy of reducing CO_2 emissions immediately, regardless of economic growth, to maintain higher environmental quality, or whether it should avoid rapid and aggressive reductions of CO_2 emissions, which could harm economic development and growth prospects. The use of various forms of energy is critical for a country's diverse economic operations. With Bangladesh's rapid development, both power generation and consumption are growing gradually, resulting in increased CO_2 emissions.

Bangladesh's development economy benchmark is largely impacted by assistances of peripheral variables like foreign direct investment (FDI) and tourism, which raises GHG emissions and therefore affects environmental value. Bangladesh's development plan is comparable to worldwide practice, in which governments are adamant about maintaining the current rate and ambition of economic growth. As a result, various economies' environmental policies are dictated by their economic policies (Shrinkhal 20019a, b; Khan et al. 2020; Hossain et al. 2021a; Hossain and Chen 2021a; Chishti et al. 2021; Zhang et al. 2021).

FDI, which helps recipient nations trade more quickly (Shahbaz et al. 2017; Acheampong et al. 2019; Shrinkhal 2019a, b) and trade-related activities, transnational and multinational corporations' diverse activities and investment operations become workable in external countries (Liu et al. 2020; Kim et al. 2019). Bangladesh's approach to trade openness strategy, which began in the 1980s, has created significant opportunities for both domestic and foreign businesses (Hossain et al. 2021b; Bashar and Khan 2007). The country has developed several economic zones, as part of its policy execution. Furthermore, because of lumbering investments in electricity production as well as labor-oriented businesses like readymade garments (RMG), it has seen a large increase in FDI inflows. As a result, Bangladesh received significant FDI inflows in 2018, putting it in first place in South Asia, and reaching the highest position of foreign direct investment receipt at \$3.612 billion (UNCTAD 2018). CO_2 emissions in Bangladesh are linked to the increase in inward FDI and its use in electricity and export-oriented businesses (Muhammad et al. 2021; Banerjee and Rahman 2012).

One of the most major sources of worldwide environmental degradation and CO_2 emissions has been identified as tourism (Al-Mulali et al. 2015; Jebli and Hadhri 2018). Between 2009 and 2013, tourism-associated CO_2 emissions increased from 3.90 to 4.50 billion metric tons per year, responsible for 8% of global GHG emissions (Lenzen et al. 2018). According to the UN World Tourism Organization (UNWTO), tourism-related emissions might contribute to 5.3% of global emissions of all anthropogenic emissions in the world by 2030, up from 5% in 2016. Bangladesh's tourism sector is booming. In 2019, it welcomed 323,000 international visitors, bringing in \$391 million in tourism earnings for Bangladesh. Bangladesh's tourism earnings grew at an average yearly rate of 15.99%, in 2019 it became \$391 million which was \$59 million in 2002 (WDI 2019).

As a result, the focus of this research is on the influence of FDI, tourism, economic development and, electricity consumption on CO_2 emissions in Bangladesh using annual data from 1990 to 2019. In Bangladesh, the intensity of CO_2 emissions, demand for energy, FDI, and tourism have prompted several issues, such as: (1) Is there any long- or short-term link between these variables in Bangladesh? (2) What are the strategy recommendations of the results for Bangladesh and different countries in the emerging world?

Our goal is to make a range of contributions to the present literature:(i) Contrary to previous research, this research emphasizes the influence of electricity consumption instead of energy consumption because electricity is used in every segment of action, comprising FDI and tourism and its consumption exceeds general fuel requirement; (ii) the autoregressive distributed lag (ARDL) limits analysis technique for cointegrating long-term relationships among factors; (iii) error-correcting model (ECM) for short-term consequences; (iv) vector error correction model (VECM) and Granger causation technique for causative relationships; and (v) dynamic least squares (DOLS) and fully modified least squares (FMOLS) techniques for assessing the robustness of the results. As a result, the consequences of this study will provide decision-makers with a better understanding of the long-term development of the causality relationship between the variables of this study in Bangladesh.

The rest of the part is formatted as part two comprises reviews of literature, part three describes the methodological approach, part four reveals the findings and in part five certain conclusions and policies are drawn.

Literature review

A brief literature review is divided into three parts in this section. The association between economic growth, CO_2 emissions, and electricity consumption is discussed in the first section. The nexus between CO_2 emissions and FDI is deliberated in the second section of the literature. Finally, in the third section, we investigate the nexus between CO_2 emissions and tourism literature.

The relation between economic development, CO_2 emissions, and electricity consumption

Several empirical studies in energy economics have studied the nexus between CO_2 emissions, economic development, and electricity consumption in current periods (Al-Mulali et al. 2019; Salahuddin et al. 2018; Bah and Azam 2017) explored the causative connection between electricity consumption, economic development, and CO_2 emissions by exercising the ARDL and Toda Yamamoto approaches in South Africa. The primary results of this analysis point out that in South Africa, no direct relationship exists between economic development and electricity consumption. However, CO_2 emissions and electricity consumption have a one-way causal connection. Balsalobre-Lorente et al. (2018) evaluated how economic development, electricity consumption, and natural resources affected CO_2 emissions in five EU member states. Energy innovation, natural resources, and electricity consumption all enhance environmental value, whereas trade liberation and the interaction between electricity consumption and economic development reduce CO_2 emissions. Njoke et al. (2019) scrutinize the connection between economic development, CO_2 emissions, and electricity consumption in Cameroon between the years 1971 and 2014. The results of the ARDL limits test specify that CO_2 emissions and economic growth have a positive and substantial long-term and short-term connection.

Numerous research on energy consumption and other factors have been done in Bangladesh, but only a handful have examined electricity consumption as a significant contributing factor to CO_2 emissions. Sarker and Alam (2010) investigated the causal link between the variables using data from Bangladesh's economic development and electricity consumption from 1973 to 2006. Only undirected causation was established between energy generation and economic growth. Their research advised that Bangladesh's electricity consumption be increased to boost the country's economic growth. Mozumder and Marathe (2007) experimented with determining the link between economic growth and electricity consumption. They discovered that energy conservation had no impact on the economy's growth and development, and so recommended energy conservation as a policy instrument for Bangladesh. Bangladesh's growth is heavily reliant on electricity. Increased electricity consumption has a straight influence on Bangladesh's economic activity. Bangladesh is currently going through a phase of transition in which nearly every sector of the economy is being affected by development. Bangladesh's electricity consumption is increasing as a result of economic progress, resulting in CO_2 emissions (Khan et al. 2021a, b; Hossain and Chen 2021b; Hossain et al. 2020; Jahangir Alam et al. 2012; Shahbaz et al., 2014). There has been a significant advancement in the realm of electricity. Nuclear power, coal power, hydropower, oil and gas power plants, and other sectors are also being developed.

The nexus between FDI and CO_2 emission

To investigate the nexus between CO_2 emission and FDI, data attributes from a single nation's time series (Shahbaz et al. 2019; Bakhsh et al. 2017; Abbasi and Riaz 2016; Seker et al. 2015; Sbia et al. 2014; Lau et al. 2014) were used. Khan et al. (2021a, b) tried to explore how CO_2 emissions and FDI are connected in the perspective of MENA countries between the years 1990 and 2021 to incorporate biomass energy usage as an additional indicator of CO_2 emissions. The findings of the research supported the positive and *N*-shaped the relationship between CO_2 emissions and FDI. To et al. (2019) investigated the extent to which FDI has degraded the environment in Asian developing economies from 1980 to 2016 for testing the EKC assumption. The study discovered that FDI has a substantial effect on CO_2 emissions implying the "pollution heaven theory" and EKC curve are valid for these nations.

In Bangladesh, Sarker et al. (2016) assessed the effect of energy consumption, economic growth, natural gas usage FDI, and CO_2 emissions between the years 1978 and 2010. The findings of the research revealed that FDI had a beneficial influence on CO_2 emissions. Islam et al. (2021) applied the ARDL simulations method for analyzing the impact of globalization, FDI, and energy consumption on CO_2 emissions from 1972 to 2016 in Bangladesh. The effect of globalization, FDI, and innovation on CO_2 emissions are negative.

The nexus between tourism and CO_2 emission

The construction of hotels, tourism facilities, infrastructure, the transportation of visitors, increased energy use, and the decrease of natural and agricultural regions can all contribute to environmental deterioration. Environmental deterioration, on the other hand, may result in a decrease in tourism growth. Danish and Wang (2019) investigated the connection between economic development, CO_2 emissions, and tourism in the setting of the BRICS nations between 1995 and 2014. They used econometric investigations for heterogeneity and cross-sectional dependence. The findings of the study demonstrate that the tourist industry promotes economic expansion while degrading environmental quality. For the period 1995–2014, in the topmost ten tourist destination nations, Koçak et al. (2020) studied the association between CO_2 emissions and tourism development. The findings demonstrate that the effect of tourist entrances on CO_2 emissions is greater, but the influence of tourism earnings is less. Gao et al. (2019) used panel data to conduct cointegration tests from eighteen Mediterranean nations from 1995 to 2010 to inspect the connection between economic development, tourist receipts, energy consumption, and CO_2 emissions. According to the study, in the southern Mediterranean, tourism impact on CO_2 emissions was negative and substantial. The dynamic connection between economic development, tourism, and CO_2 emissions is also contentious from an empirical standpoint. Sharif et al. (2017), for example, used cointegration techniques to examine the influence of tourist arrivals and economic development on CO_2 emissions between the years 1972 and 2013 in Pakistan. The results of the analysis support the long-run relation between tourism and CO_2 emissions., Shakouri et al. (2017) discovered the influence of economic development and tourism on CO_2 emissions in several Asia–Pacific nations from the years 1995 to 2013. The finding revealed that tourist entrances influence CO_2 emissions positively.

This study examines the influence of FDI, tourism, economic development, and electricity consumption on CO_2 emissions in Bangladesh. Unlike other kinds of energy, electricity is employed in almost every aspect of life (Rahman 2020; Shaari et al. 2017; Ferguson et al. 2000). The addition of electricity consumption in the research of the consequence of economic development, FDI, and tourism on CO_2 emissions adds to the existing studies. Perhaps no studies have investigated the connections between electricity consumption, economic development, FDI, and tourism on CO_2 emissions simultaneously. As a result, the causal connections among the variables are investigated in this study.

Data sources, variable definition, and methodology

Data

Yearly, figures from 1990 through 2019 are included in this analysis. CO_2 emissions are substituted by environmental deterioration, while economic development is proxied by GDP.

Table 1 summarizes the study's variable definition.

Empirical strategy

In terms of methodology, we use Balcilar et al. (2019) and Magazzino's (2016) empirical framework to investigate the relation between FDI, tourism, economic development, and electricity consumption on CO_2 emissions in Bangladesh. Consequently, the study's econometric model is as follows.:

$$CO_2 = f(EC, \mathrm{FDI}, TA, \mathrm{GDP}, \mathrm{GDP}^2) \quad (1)$$

where CO_2,FDI, EC, TA, GDP, and GDP^2 represent CO_2 emissions, foreign direct investment, electricity consumption, overseas tourist arrivals, gross domestic products, and the square of gross domestic products per capita respectively. Natural logarithms (ln) have been applied to all variables to aid in the mobilization of stationarity.

The following is a representation of the log quadratic regression model:

$$ln\mathrm{ICO}_{2t} = \alpha_0 + \beta_1 lnEC_t + \beta_2 ln\mathrm{FDI}_t + \beta_3 lnTA_t + \beta_4 ln\mathrm{GDP}_t + \beta_5 ln\mathrm{GDP}_t^2 + \epsilon_t \quad (2)$$

where ϵ_t is the error term, β's are the slope parameters, and α is the constant term. $CO_{2t}, lnEC_t, ln\mathrm{FDI}_t, lnTA_t, ln\mathrm{GDP}_t, ln\mathrm{GDP}_t^2$, are the natural log of CO_2 emissions, electricity consumption, FDI, overseas tourist arrivals, gross domestic products, and the square of gross domestic products per capita respectively. When it comes to the expected signs in Equation (2) $\beta_1, \beta_2, \beta_3, \text{and} \beta_4$ should have a positive sign, whereas β_5 should have a negative sign if the EKC hypothesis is valid. Because increasing electricity consumption might raise an economy's scale and stimulate CO_2 emissions (e.g., Farhani and Shahbaz 2014; Farhani et al. 2014). Nevertheless, different signs might exist; hence, the connection between economic development and CO_2 emissions in this situation the form of the inverted "U" does not exist (Rahman 2020; Shaari et al. 2017). Furthermore, FDI and tourism have the potential to degrade the ecosystem (Bella 2018). The growth of ecologically acceptable types of FDI and tourism, on the other hand, may readily help to natural resources conservation. In this context, the EKC model's integration of FDI and tourism variables allows for the measurement of the influence of tourist flows on CO_2 emissions.

The unit root test

The ARDL cointegration approach does not need unit root pre-assessment since cointegration may be tested within a collection of variables of order I (0), I (1); otherwise, a mixture of them together. Pesaran et al. (2001) utilized the ARDL bounds analysis approach, which necessitates that

Table 1 Variable explanation

Variable	Measurement	Data provider
CO_2	CO_2 dioxide emissions: kilo tonne (per capita)	World Development Indicators (WDI)
FDI	Foreign direct investment (constant US dollar, balance of payments)	WDI
TA	International tourist arrivals (number of arrivals)	WDI
GDP	Gross domestic product: (2010 constant US $ per capita)	WDI
EC	Electricity consumption: KWh(kilowatt-per capita)	International Energy Agency

no variables must be included in I (2) because this would invalidate the procedure. It is appropriate to examine each variable's stationarity before going on to the next level of research and consequences. The variables were unit-root checked unit root testing methods Phillips–Perron (PP) and Augmented Dickey-Fuller (ADF).

Cointegration tests

Exercising the bounds analysis technique and the conventional Johansen cointegration strategy for cointegration, this study investigates the long-term nexus among the variables of interest. The following is the ARDL technique for cointegration by using equation 2:

$$\begin{aligned} \ln \mathrm{CO}_{2t} = \alpha_0 + \sum_{i=1}^{k_1} \beta_i \Delta \ln Ico_{2t-i} + \sum_{i=0}^{k_2} \gamma_i \Delta \ln EC_{t-i} + \sum_{i=0}^{k_3} \delta_i \Delta \ln \mathrm{GDP}_{t-i} + \\ \sum_{i=0}^{k_4} \vartheta_i \Delta ln\mathrm{GDP}^2{}_{t-i} + \sum_{i=0}^{k_5} \mu_i \Delta ln\mathrm{FDI}_{t-i} + \sum_{i=0}^{k_6} \pi_i \Delta lnTA_{t-i} + \theta_{11} lnIco_{2t-1} + \theta_{12} lnEC_{t-1} + \\ \theta_{13} ln\mathrm{GDP}_{t-1} + \theta_{14} ln\mathrm{GDP}^2_{t-1} + \theta_{15} ln\mathrm{FDI}_{t-1} + \theta_{16} lnTA_{t-1} + \epsilon_t \end{aligned} \tag{3}$$

where $\beta_i, \gamma_i, \delta_i, \vartheta_i, \mu_i, \pi_i, \theta_{11}, \theta_{12}, \theta_{13}, \theta_{14}, \theta_{15}$, and θ_{16} are the estimated parameters, and Δ signifies the first difference between the variables. Akaike's information criterion (AIC) determines the appropriate lag lengths of k_1, k_2, k_3, k_4, and k_5. ϵ_t is the term for an error. There are two steps to the ARDL method. F-statistics are used in the first phase of the ARDL model's error correction approach to investigate the influence of the lagged levels of the variables for perceiving if a long-term nexus between them. Pesaran et al. (1996) developed 2 sets of acceptable critical values for diverse numbers of repressors depending on whether an intercept trend or both were used in the approach. In one set of assumptions, all variables in the autoregressive distributed lag technique are meant to be I (0), whereas, in the other set of assumptions, all variables are expected to be I (1). For a particular significance level, if the upper bound critical value of the F-statistic is exceeded, the dependent variable has a non-spurious long-term level connection. If the F-statistic for the lower limit is less than the critical threshold, there is no long-term association with the dependent variable. If the result falls between the lowest and highest limits, the result is indecisive. For the F-statistic test, the null and alternative hypotheses are written as follows:

$$H_0 : (\omega_1 = \omega_2 = \cdots = \omega_k = 0); H_1 : (\omega_1 \neq 0, = \omega_2 \neq 0)$$

$$\begin{aligned} \Delta \ln \mathrm{CO}_{2t} = + \sum_{i=1}^{k_1} \beta_i \Delta \ln Ico_{2t-i} + \sum_{i=0}^{k_2} \gamma_i \Delta \ln EC_{t-i} + \sum_{i=0}^{k_3} \delta_i \Delta \ln \mathrm{GDP}_{t-i} + \\ \sum_{i=0}^{k_4} \vartheta_i \Delta \ln \mathrm{GDP}^2{}_{t-i} + \sum_{i=0}^{k_5} \mu_i \Delta \ln \mathrm{FDI}_{t-i} + \sum_{i=0}^{k_6} \pi_i \Delta \ln TA_{t-i} + \beth \mathrm{ECT}_{t-i} + \epsilon_t \end{aligned} \tag{4}$$

The long-term coefficient, as well as the estimations generated in the second stage of the research, may be determined. The long-run coefficients estimate may change depending on the model selection criteria used. The error-correcting version of the ARDL model may now be approximated. The modification constraint controls how much the dependent variable changes as a result of departures from its long-term equilibrium estimate, as indicated in the coefficient of error correction expression. After selecting the ARDL model using the AIC or SBC criterion, the long-term relationship between variables may be calculated.

Granger causality

If we discover cointegration in this research, we can use Granger causation with error correction, but if we do not, we can test causatives using Granger causation with vector autoregression (VAR) (Engle and Granger 1987). As a result, the formula for a bigger Granger causation assessment with error correction is as follows:

$$\begin{pmatrix} ln\mathrm{CO}_{2t} \\ ln\mathrm{GDP}_t \\ ln\mathrm{GDP}^2_t \\ lnEC_t \\ ln\mathrm{FDI}_t \\ lnTA_t \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \end{pmatrix} + \begin{pmatrix} \rho_{11,1} & \rho_{12,1} & \rho_{13,1} & \rho_{14,1} & \rho_{15,1} & \rho_{16,1} \\ \rho_{21,1} & \rho_{22,1} & \rho_{23,1} & \rho_{24,1} & \rho_{25,1} & \rho_{26,1} \\ \rho_{31,1} & \rho_{32,1} & \rho_{33,1} & \rho_{34,1} & \rho_{35,1} & \rho_{36,1} \\ \rho_{41,1} & \rho_{42,1} & \rho_{43,1} & \rho_{44,1} & \rho_{45,1} & \rho_{46,1} \\ \rho_{51,1} & \rho_{52,1} & \rho_{53,1} & \rho_{54,1} & \rho_{55,1} & \rho_{56,1} \\ \rho_{61,1} & \rho_{62,1} & \rho_{63,1} & \rho_{64,1} & \rho_{65,1} & \rho_{66,1} \\ \rho_{71,1} & \rho_{72,1} & \rho_{73,1} & \rho_{74,1} & \rho_{75,1} & \rho_{76,1} \\ \rho_{81,1} & \rho_{82,1} & \rho_{83,1} & \rho_{84,1} & \rho_{85,1} & \rho_{86,1} \end{pmatrix} \begin{pmatrix} ln\mathrm{CO}_{2t} \\ ln\mathrm{GDP}_t \\ ln\mathrm{GDP}^2_t \\ lnEC_t \\ ln\mathrm{FDI}_t \\ lnTA_t \end{pmatrix} + \cdots + \begin{pmatrix} \rho_{11,i} & \rho_{12,i} & \rho_{13,i} & \rho_{14,i} & \rho_{15,i} & \rho_{16,i} \\ \rho_{21,i} & \rho_{22,i} & \rho_{23,i} & \rho_{24,i} & \rho_{25,i} & \rho_{26,i} \\ \rho_{31,i} & \rho_{32,i} & \rho_{33,i} & \rho_{34,i} & \rho_{35,i} & \rho_{36,i} \\ \rho_{41,i} & \rho_{42,i} & \rho_{43,i} & \rho_{44,i} & \rho_{45,i} & \rho_{46,i} \\ \rho_{51,i} & \rho_{52,i} & \rho_{53,i} & \rho_{54,i} & \rho_{55,i} & \rho_{56,i} \\ \rho_{61,i} & \rho_{62,i} & \rho_{63,i} & \rho_{64,i} & \rho_{65,i} & \rho_{66,i} \\ \rho_{71,i} & \rho_{72,i} & \rho_{73,i} & \rho_{74,i} & \rho_{75,i} & \rho_{76,i} \\ \rho_{81,i} & \rho_{82,i} & \rho_{83,i} & \rho_{84,i} & \rho_{85,i} & \rho_{86,i} \end{pmatrix} \begin{pmatrix} ln\mathrm{CO}_{2t} \\ ln\mathrm{GDP}_t \\ ln\mathrm{GDP}^2_t \\ lnEC_t \\ ln\mathrm{FDI}_t \\ lnTA_t \end{pmatrix} + \begin{pmatrix} \varnothing_1 \\ \varnothing_2 \\ \varnothing_3 \\ \varnothing_4 \\ \varnothing_5 \\ \varnothing_6 \end{pmatrix} ECT_{t-1} + \begin{pmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \\ \epsilon_{3,t} \\ \epsilon_{4,t} \\ \epsilon_{5,t} \\ \epsilon_{6,t} \end{pmatrix} \tag{5}$$

The trailing error correction equation for the long-run equilibrium model is ECTt-1. For both long- and short-run causation, the ECTt-1 causation evaluation should be statistically significant. $\varepsilon_{1,t}$ to $\varepsilon_{6,t}$ represents the stochastic standard error equation. It shows the rate of corrections, with the number reflecting the amount of disequilibrium that will be rectified in a certain time.

The model's diagnostic tests

Equation (3) standard's error expression is normally distributed and serially independent, which is the most basic premise of the ARDL bounds analysis methodology. As a result, the serial correlation LM assessment of Breusch-Godfrey will be utilized for establishing serial independence, the Ramsey reset examination to determine the model's working formula, and the "Breusch-Pagan-Godfrey" examination to check for heteroscedasticity.

Stability test of the model

Any model with an autoregressive form must have its dynamic stability validated. The model's stability will be determined using recursive CUSUM and CUSUM of squares investigations (Brown et al. 1975). These studies are also provided by Pesaran and Pesaran (1997) to determine constraint consistency.

Robustness test

The validity of the results is assessed using the FMOLS and DOLS methods.

Discussion of the findings

The descriptive indicators figures

All of the variables' descriptive indicator statistics employed to attain our goal are summarized in Table 2. The largest standard deviation is FDI, which is followed by electricity consumption (*EC*), CO_2 emissions, tourism (*TA*), GDP-squared, and GDP. CO_2 emissions, electricity consumption (*EC*), GDP, square of GDP, and tourism (*TA*) all have skewness values between − 0.5 and 0.5, suggesting that they are symmetrically balanced; however, FDI has a skewness value between − 1 and 1, signifying that it is skewed significantly. Furthermore, because the kurtosis measurement was less than 3, the CO_2 emissions, electricity consumption (*EC*), FDI, GDP, square of GDP, and tourism (*TA*) variables were all platykurtic in this distribution. The standard distribution null hypothesis is supported by both the Jarque–Bera numbers and the *p*-values. As a result of this investigation, it is clear that statistics are normally distributed.

Correlation matrix results for model variables

Table 3 shows the correlation matrix. The correlation suggests that CO_2 emissions and all other variables have a positive relationship. Electricity consumption, FDI, GDP,

Table 2 The descriptive indicators figures

	CO_2	*EC*	FDI	GDP	GDP^2	*TA*
Mean	− 0.536214	2.205007	8.337012	− 0.131530	− 0.263060	5.262545
Median	− 0.553531	2.231999	8.655809	− 0.130248	− 0.260496	5.260071
Maximum	− 0.134719	2.707570	9.451963	− 0.045220	− 0.090439	5.669317
Minimum	− 0.862438	1.697063	6.143154	− 0.265816	− 0.531631	4.929419
Std. dev	0.218089	0.313951	1.048780	0.055039	0.110078	0.172982
Skewness	0.141594	0.053043	− 0.799618	− 0.528947	− 0.528947	0.062194
Kurtosis	1.898157	1.806309	2.337694	2.808198	2.808198	2.713420
Jarque–Bera	1.617817	1.795190	3.745256	1.444907	1.444907	0.122001
Probability	0.445344	0.407549	0.153719	0.485559	0.485559	0.940823
Sum	− 16.08643	66.15021	250.1104	− 3.945907	− 7.891815	157.8763
Sum sq. dev	1.379320	2.858390	31.89825	0.087849	0.351395	0.867761
Observations	30	30	30	30	30	30

Table 3 Correlation matrix results for model variables

	CO_2	*EC*	FDI	GDP	GDP2	*TA*
CO_2	1.000000	0.992850	0.891177	0.758340	0.758340	0.483054
EC	0.992850	1.000000	0.907769	0.780334	0.780334	0.487700
FDI	0.891177	0.907769	1.000000	0.704958	0.704958	0.557439
GDP	0.758340	0.780334	0.704958	1.000000	1.000000	0.334898
GDP2	0.758340	0.780334	0.704958	1.000000	1.000000	0.334898
TA	0.483054	0.487700	0.557439	0.334898	0.334898	1.000000

GDP^2, and tourism all show a substantial positive relationship with CO_2 emissions of 99%, 89%, 75%, 75%, and 48%, respectively. Electricity consumption (*EC*) and FDI, GDP, and tourism (*TA*) have a 90%, 78%, and 48% positive connection, respectively. FDI and tourism (*TA*) have a 70% and 55% positive connection, respectively.

The unit root assessment's final result

Using the ARDL bound estimate technique, we investigate the long-term impact between the study variables. The bound estimate has the benefit of being changeable in terms of the series' integration orderliness. This necessitates converting the variables to *I* (0) or *I* (1). For establishing the subsistence of the unit roots test and the order for all variables, the PP estimation (Phillips and Perron 1988) and the ADF estimate (Dickey and Fuller 1981) were used. In both the PP and ADF estimates, CO_2 emissions are stationary at present levels, but electricity consumption, economic growth, FDI, and tourism are stationary at their first differences, as shown in Table 4. As a consequence, the ARDL cointegration approach may be used in this experiment.

VAR selection criteria of lag order

The ARDL bounds check must be completed before the ARDL F bound assessment can be calculated. To determine whether or not the variables are co-integrated, the proper lag sequence of the variables must be chosen. The estimate of *F*-statistics offers a significant problem when it comes to lag length order selection. The researchers used a VAR technique to determine the best potential lag length, taking into account endogenous variables like CO_2 emissions, electricity consumption (*EC*), foreign direct investment (FDI), GDP, square of GDP, and tourism (*TA*), as well as a randomly generated lag length period and a diagnosis assessment of that time. Table 5 shows the outcomes of this calculation's measurements. Statistics suggest that a lag length of order one is the best achievable, based on cooperation lag decision procedures and lag length split-up computations.

The cointegration: ARDL bound test

The *F*-statistic is obtained using the bound testing technique once the variables have been established for stationarity. The allowable critical value upper bound is exceeded by the *F*-statistic (Table 6). The *F*-statistic calculated is 9. 24, which is higher than the cutoff values. As a result, the alternative hypothesis of linked variables is accepted. These figures show a long-term nexus between CO_2 emissions, electricity consumption, FDI, GDP, GDP square, and tourism (*TA*).

Johansen cointegration assessment results

CO_2 emissions, electricity consumption, FDI, GDP, and tourism (*TA*) have all been tested using the Johansen cointegration method. Before performing the Johansen cointegration test, the appropriate lag length must be established. Based on the least *SC* and AIC obtained by evaluating the unconstrained VAR model for the initial transformations of the five variables in the issue, we infer that the lag length is one. The Johansen cointegration evaluation is used since all components are integrated in the same order, and the results are shown in Tables 7 and 8. Based on maximum Eigen statistics and trace statistics, the results indicated that at least one cointegration equation(s) exists at the 5% level.

Long-term estimates of ARDL

If a long-term relationship exists, the ARDL model was used to estimate equation-iv, with the lag's maximum order set to 1 and each of the estimated coefficients significant at the 5% level. Electricity consumption, FDI, and GDP variables have a long-term positive and substantial impact on CO_2 emissions, conversely, the tourism (*TA*) variable is negative and significant. To prove the EKC hypothesis, GDP^2 is predicted to be negative as well as have a substantial effect on CO_2 emissions. Table 7 shows that A negative and significant coefficient exists for the GDP^2 variable. This indicates the association between CO_2 emissions and GDP in Bangladesh is inverted *U*-shaped. As a result, the EKC hypothesis is valid. CO_2 emissions have a long-term and significant nexus with electricity consumption, *FD*, and GDP as seen in Table 9. In the long term, a 1% rise in power use and FDI increases pollution by 0.78% and 0.025%, respectively. Conversely, a 1% decrease in tourism (*TA*) variable decrease pollution by 0.047% which indicates that this variable play CO_2 emission reduction in Bangladesh.

Short-run estimation results

The short-term outcomes are summarized in Table 10. Electricity consumption (*EC*), GDP, GDP^2, and tourism (*TA*) have no substantial short-term impact on CO_2 emissions. Only the coefficients of the FDI variable, at the 5% confidence level, results are both negative and significant, signifying that this variable reduces CO_2 emissions in Bangladesh in the short run. The expected ECM coefficients are likewise negative and at the 5% confidence level, statistically significant. Based on these figures, the entire system adapts at a rate of 60% (The entire system may return to long-run equilibrium at a 60% pace). To put it another way, these data suggest that deviations from long-term stability between variables are recalculated on a year-by-year basis to revert to long-term stability.

Table 4 The outcome of the unit root assessment

PP unit root test table							
At level							
		CO_2	*EC*	FDI	GDP	GDP^2	*TA*
With constant	*t*-Statistic	1.5149	−0.2425	−2.0187	−2.5344	−2.5344	−2.0346
	Prob	0.9989	0.9219	0.2776	0.1181	0.1181	0.2712
		n0	n0	n0	n0	n0	n0
With constant and trend	*t*-Statistic	−3.6425	−2.8632	−2.0140	−6.6146	−6.6146	−2.1644
	Prob	0.0434	0.1881	0.5696	0.0000	0.0000	0.4904
		**	n0	n0	***	***	n0
Without constant and trend	*t*-Statistic	−4.4365	9.6941	2.3225	−0.9265	−0.9265	0.9496
	Prob	0.0001	1.0000	0.9937	0.3069	0.3069	0.9047
		***	n0	n0	n0	n0	n0
At first difference							
		d (CO_2)	*d* (*EC*)	*d* (FDI)	*d* (GDP)	*d* (GDP^2)	*d* (*TA*)
With constant	*t*-Statistic	−8.1535	−5.5921	−5.8011	−22.8858	−22.8858	−5.0639
	Prob	0.0000	0.0001	0.0000	0.0001	0.0001	0.0003
		***	***	***	***	***	***
With constant and trend	*t*-Statistic	−10.7496	−5.3449	−10.1337	−21.9959	−21.9959	−4.9746
	Prob	0.0000	0.0009	0.0000	0.0000	0.0000	0.0022
		***	***	***	***	***	***
Without constant and trend	*t*-Statistic	−2.9816	−2.1237	−4.7637	−12.0881	−12.0881	−4.9877
	Prob	0.0043	0.0345	0.0000	0.0000	0.0000	0.0000
		***	**	***	***	***	***
ADF unit root test table							
At level							
		CO_2	*EC*	FDI	GDP	GDP^2	*TA*
With constant	*t*-Statistic	1.7579	−0.2769	−4.0164	−2.4957	−2.4957	−2.0346
	Prob	0.9994	0.9168	0.0055	0.1268	0.1268	0.2712
		n0	n0	***	n0	n0	n0
With constant and trend	*t*-Statistic	−3.7890	−5.2214	−3.1865	−4.6683	−4.6683	−2.1094
	Prob	0.0319	0.0018	0.1074	0.0050	0.0050	0.5193
		**	***	n0	***	***	n0
Without constant and trend	*t*-Statistic	−4.5298	7.4640	1.1422	−1.1241	−1.1241	0.9502
	Prob	0.0001	1.0000	0.9305	0.2310	0.2310	0.9047
		***	n0	n0	n0	n0	n0
At first difference							
		d (CO_2)	*d* (*EC*)	*d* (FDI)	*d* (GDP)	*d* (GDP^2)	*d* (*TA*)
With constant	*t*-Statistic	−4.0403	−5.4192	−5.0906	−5.1189	−5.1189	−5.0639
	Prob	0.0050	0.0001	0.0003	0.0004	0.0004	0.0003
		***	***	***	***	***	***
With constant and trend	*t*-Statistic	−4.6358	−5.3022	−5.6572	−5.0187	−5.0187	−4.9746
	Prob	0.0059	0.0010	0.0006	0.0024	0.0024	0.0022
		***	***	***	***	***	***
Without constant and trend	*t*-Statistic	−3.0271	−8.9775	−4.7792	−9.7182	−9.7182	−4.9884
	Prob	0.0038	0.0000	0.0000	0.0000	0.0000	0.0000
		***	***	***	***	***	***

Table 5 The selection measure for the lag order used by VAR

Lag	LogL	*LR*	FPE	AIC	*SC*	HQ
0	119.3662	NA	1.95e-10	− 8.169014	− 7.931120	− 8.096287
1	223.9161	164.2926*	6.87e-13*	− 13.85115*	− 12.42378*	− 13.41479*
2	240.3532	19.95938	1.53e-12	− 13.23951	− 10.62268	− 12.43952

*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

The results analytical test

Table 11 includes the Ramsey RESET test for residual component normalcy, the LM test, and the Heteroskedasticity test for measurement. According to the data, the short-term method authorizes all analytical computations. There are no examples of heteroscedasticity, the method's operational formula, or serial correlation, which utilizes normally distributed residual expressions, in the literature. Serial correlation, heteroscedasticity, and the model's operational formula are unaffected by the *p*-values of the LM, heteroscedasticity, and Ramsey reset evaluations, which are all more than 0.1. The CUSUM and CUSUMSQ evaluations were exercised for checking that long and short-term limitations were consistent (Pesaran et al. 2001). The outlines for the CUSUM and CUSUMSQ assessments are presented in graphs 1 and 2, respectively. The cumulative total and cumulative sum of squares plots are balanced since they lie between the diagnostic boundaries at the 5% level. Graph 3 depicts the scatterplot matrix of variables.

Outcomes of Granger causality assessments

Long-term as well as short-term cointegration of variables may be assessed using the ARDL method. The Granger causation evaluation was used to define the causation link (direction) between the issue variables in this research, and the outcomes are presented in Table 12. The outcomes of the Granger causation assessment indicate that there is one direction of causality between GDP and CO_2 emissions, electricity consumption and CO_2 emissions, CO_2 emissions, and FDI, GDP, and electricity consumption.

Robustness check

FMOLS and DOLS are two alternative assessment procedures used to analyze the robustness of the outcomes. The experimental outcomes, which include the influences of electricity consumption, GDP, FDI, and tourism on CO_2 emissions are shown in Table 13. Both GDP and electricity consumption have statistical significance. The conclusions produced by the FMOLS and DOLS methods are comparable to those obtained by the ARDL model since the logic of adding both lags and leads, as well as altering autocorrelations and heteroscedasticity, is thought to be beyond consistent.

Conclusion and policy implications

Applying time-series figures between the years 1990 and 2019, the current research studies the effect of electricity consumption, FDI, tourism, and GDP on CO_2 emissions in Bangladesh. To confirm the existence of the unit-roots assessment and the order for all variables, the PP estimation, and ADF estimate were utilized. In both the *PP* and ADF estimates, CO_2 emissions are stationary at present levels, but electricity consumption, economic growth, FDI, and tourism are stationary at their first differences. The Johansen multivariate cointegration assessment was employed to see

Table 6 The cointegration: ARDL bound test

F-bounds test		H_0: No relationship		
Test statistic	Value	Signif	*I* (0)	*I* (1)
			Asymptotic: $n = 1000$	
F-statistic	9.242269	10%	2.2	3.09
k	5	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

Table 8 Johansen cointegration assessment results

Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical value	Prob.**
None *	0.762255	40.22360	33.87687	0.0077
At most 1	0.516418	20.34295	27.58434	0.3179
At most 2	0.360117	12.50115	21.13162	0.4990
At most 3	0.164990	5.048727	14.26460	0.7357
At most 4	0.037645	1.074413	3.841466	0.2999

At the 0.05 threshold, the max-eigenvalue test reveals 1 cointegrating eqn(s)

Table 7 Johansen cointegration assessment results

Lags interval (in first differences): 1 to 1				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical value	Prob.**
None *	0.762255	79.19083	69.81889	0.0074
At most 1	0.516418	38.96724	47.85613	0.2616
At most 2	0.360117	18.62429	29.79707	0.5201
At most 3	0.164990	6.123140	15.49471	0.6810
At most 4	0.037645	1.074413	3.841466	0.2999

At the 0.05 level, the trace test reveals one cointegrating eqn(s)

whether there was a cointegrating relation in electricity consumption, FDI, tourism, and GDP on CO_2 emissions. We observed the subsistence of cointegration between variables. This manuscript further addresses a gap in the EKC hypothesis's existing energy literature.

Empirical results reveal that electricity consumption, FDI, and GDP are a positive and substantial effect on CO_2 emissions in the long term; in contrast, the tourism variable is significant and negative. The GDP^2 variable has a negative and significant coefficient. This shows the link between GDP and CO_2 emissions in Bangladesh is inverted *U*-shaped. As a result, the EKC hypothesis is valid. Electricity consumption, GDP, GDP^2, and tourism have no substantial short-term impact on CO_2 emissions. Only the coefficients of the foreign direct investment (FDI) variable are significant and negative at the 5% confidence level, demonstrating that this variable reduces CO_2 emissions in Bangladesh both in the short run. The expected ECM coefficients at the 5% confidence level are likewise negative and statistically significant. Based on the figure, the entire system adapts at a rate of 60%. The outcomes of the Granger causality assessment indicate that there is one direction of causation between GDP and CO_2 emissions, electricity consumption and CO_2 emissions, electricity consumption and GDP, FDI, and CO_2 emissions. At last FMOLS and DOLS are two alternative assessment procedures used to analyze the

Table 9 Long-term estimation results

Dependent Variable:CO_2				
Variable	Coefficient	Std. error	*t*-Statistic	Prob
EC	0.785715	0.021568	36.43040	0.0000
FDI	0.025069	0.004899	5.116953	0.0144
GDP	1.176993	0.088479	13.30248	0.0009
GDP2	−0.588497	0.044240	−13.30248	0.0000
TA	−0.047296	0.008049	−5.876393	0.0098
C	−2.345959	0.060649	−38.68086	0.0000

Table 10 Estimation results in the short term

Dependent variable: *D* (CO_2)				
Variable	Coefficient	Std. error	*t*-Statistic	Prob
D (*EC*)	0.153063	0.113191	1.352256	0.1922
D (FDI)	−0.020887	0.009354	−2.232977	0.0378
D (GDP)	−0.128220	0.073587	−1.742421	0.0976
D (GDP2)	−0.066002	0.065846	−1.002366	0.3266
D (*TA*)	−0.005583	0.034213	−0.163180	0.8721
CointEq (−1)*	−0.602440	0.114353	−5.268265	0.0000

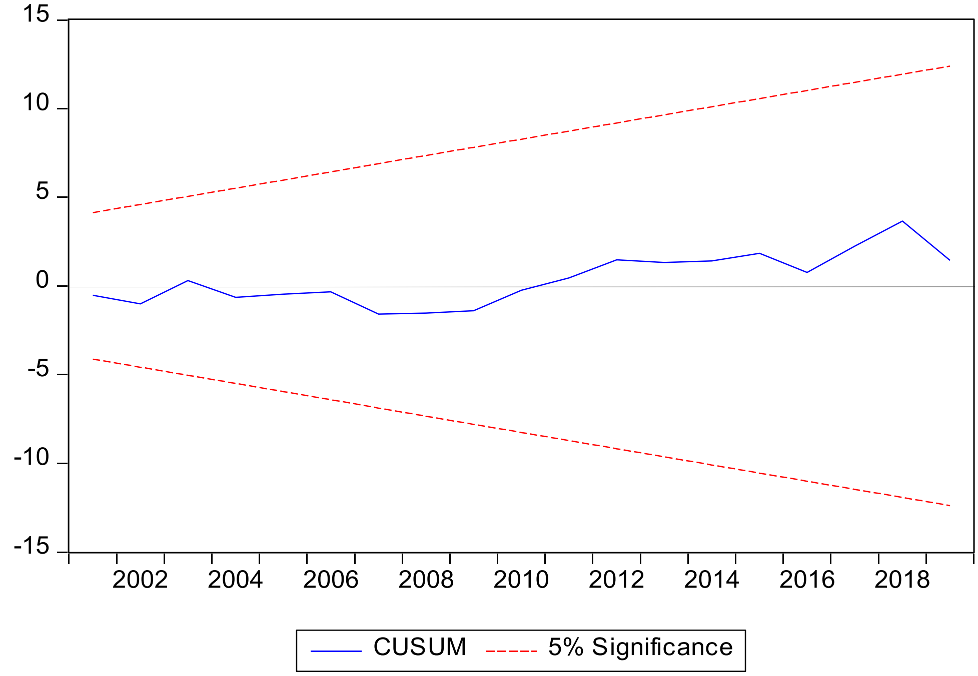
robustness of the outcomes. The conclusions produced by the FMOLS and DOLS methods are comparable to those obtained by the ARDL model.

This study proposes the following policy recommendations based on the research findings to minimize CO_2 emissions in FDI, tourism, and electricity the sector of Bangladesh's economic development.

1. Our findings show that in Bangladesh, between economic development and carbon emissions, the EKC exists. Carbon emissions are increased by using electricity consumption. To enhance the environmental condition, the government should look at a long-term energy plan that boosts renewable energy production, while lowering energy subsidies at a cost that reduces CO_2 emissions. Clean energy investment should be prioritized by the government, while also enacting environmental regulations for polluting businesses.
2. On the electricity production side, improving and familiarizing new technology, improving energy transformation efficiency through consolidated heat and electricity production and the integrated gasification combined cycle for reducing gas, oil, and coal consumption, and then realizing graded energy use in more comprehensive and effective ways.

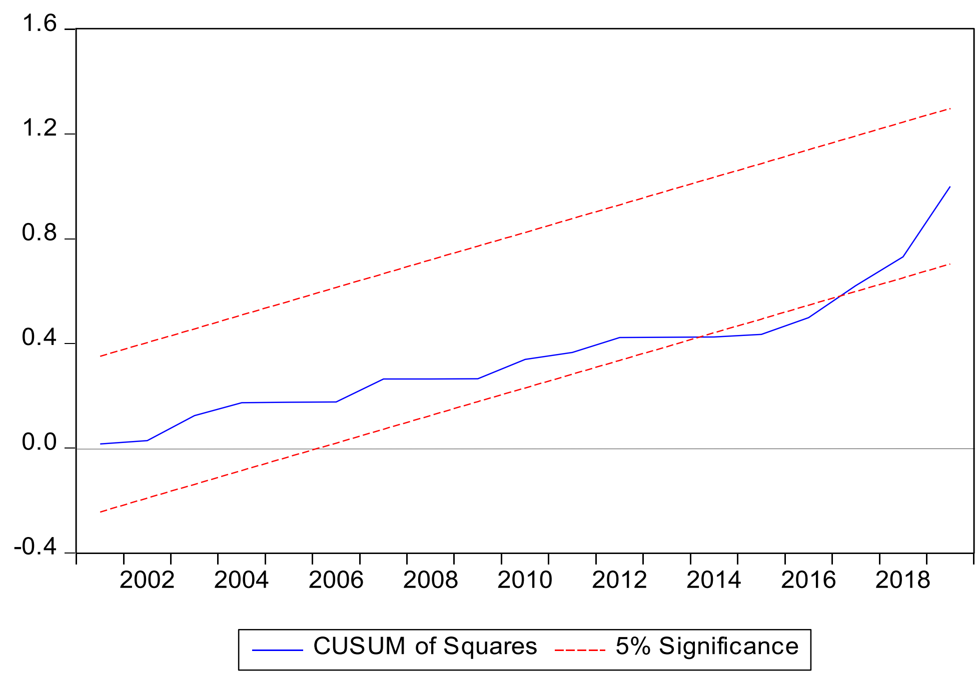
Table 11 The analytical test outcomes

LM Test: Breusch-Godfrey			
F-statistic	2.486620	Prob. *F*(2,17)	0.1129
Obs**R*-squared	6.563618	Prob. Chi-square(2)	0.0376
Heteroskedasticity test: Breusch-Pagan-Godfrey			
	1.143897	Prob. *F*(9,19)	0.3817
Obs**R*-squared	10.19138	Prob. Chi-square(9)	0.3352
Scaled explained SS	5.353040	Prob. Chi-square(9)	0.8025
Ramsey RESET test			
	Value	df	Probability
t-statistic	0.474854	18	0.6406
F-statistic	0.225486	(1, 18)	0.6406

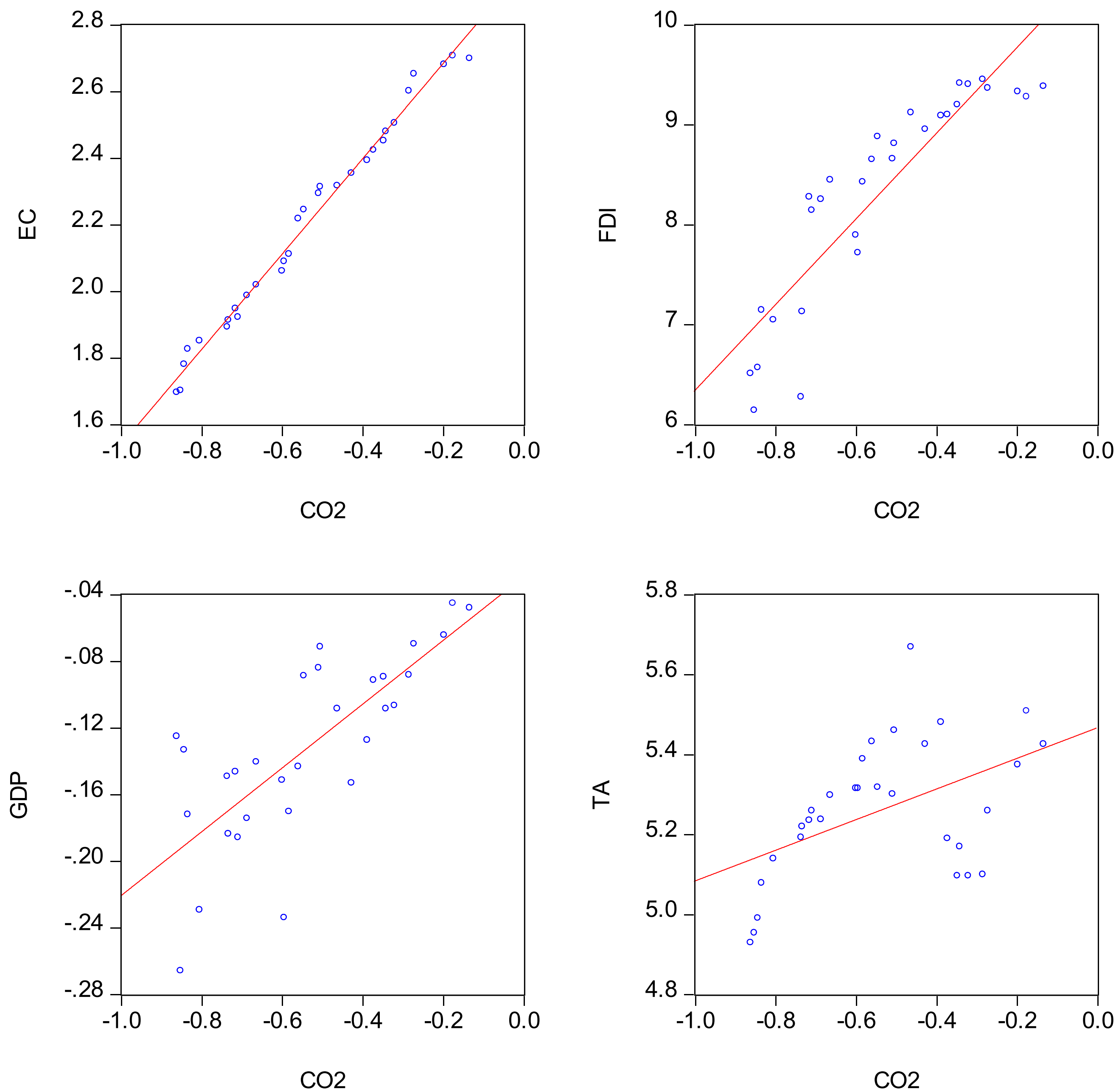


Graph 1 Plots of the cumulative sum

3. Because the association between CO_2 emissions and GDP is unidirectional, efforts to cut carbon emissions may have a detrimental influence on economic growth. However, excessive CO_2 emissions because of economic development may have negative health implications, as well as a progressive reduction in productivity. CO_2 emission restrictions can be decreased with advancements in manufacturing technology; these advancements will assist boost production efficiency while lowering pollution rates. The required actions must be done to achieve the goal of being a developed country by 2041 without compromising environmental quality. Bangladesh has to increase its reliance on renewable fuel resources,



Graph 2 Plots of the squares cumulative sum



Graph 3 Charts of scatter matrix of variables

for instance, solar, wind, hydro, and nuclear energy to meet its 2030 sustainable development objective. This would allow it to maintain energy consumption while lowering CO_2 emissions. Furthermore, increased efficiency in electricity generation and use of electricity in low-carbon-emitting manufacturing processes may be environmentally sustainable as the world progresses.

4. Between FDI and CO_2, there is one-way causation. In terms of economic growth and development, as well as job generation, FDI is critical for the country. Although FDI cannot be prevented, the Bangladesh government may surely establish a carbon price as an effective method for reducing pollution levels. Furthermore, embracing clean and renewable energy sources will reduce pollution and help to a more sustainable economy in the future.

Table 12 The Granger causation evaluation

VAR Granger causality			
Dependent variable: CO_2			
Excluded	Chi-sq	*df*	Prob
EC	17.41948	2	0.0002
FDI	1.128617	2	0.5688
GDP	6.530073	2	0.0382
TA	0.910500	2	0.6343
All	24.37597	8	0.0020
Dependent variable: *EC*			
Excluded	Chi-sq	*df*	Prob
CO_2	0.302197	2	0.8598
FDI	2.163410	2	0.3390
GDP	6.676447	2	0.0355
TA	3.457496	2	0.1775
All	11.38959	8	0.1806
Dependent variable: FDI			
Excluded	Chi-sq	*df*	Prob
CO_2	5.728256	2	0.0570
EC	1.579157	2	0.4540
GDP	0.895464	2	0.6391
TA	4.152336	2	0.1254
All	13.96418	8	0.0827
Dependent variable: GDP			
Excluded	Chi-sq	*df*	Prob
CO_2	1.169756	2	0.5572
EC	2.477727	2	0.2897
FDI	0.117928	2	0.9427
TA	0.669798	2	0.7154
All	10.69769	8	0.2194
Dependent variable: *TA*			
Excluded	Chi-sq	*df*	Prob
CO_2	0.907219	2	0.6353
EC	0.680729	2	0.7115
FDI	1.051344	2	0.5912
GDP	0.422649	2	0.8095
All	3.345478	8	0.9108

5. Furthermore, because tourism improves environmental quality in the long run, authorities in Bangladesh should promote tourism as a tool for long-term development and a method of increasing energy efficacy. As a result, policymakers should enforce adherence to existing environmental rules, promote low-carbon activities, and improve sensitive regions.
6. Finally, create an awareness of energy conservation. Everyone must contribute to energy saving and CO_2 emissions reduction. By either increasing public knowledge or teaching people's environmental concepts and energy-saving consciousness, energy management, and emission cutback may be executed.

Table 13 The result of FMOLS and the DOL

Variable	Coefficient	Std. error	*t*-Statistic	Prob
Dependent variable: CO_2				
FMOLS				
EC	0.555817	0.083338	6.669458	0.0000
FDI	0.003310	0.012353	0.267964	0.7910
GDP	0.237057	0.119143	1.989682	0.0501
TA	0.000336	0.034112	0.009863	0.9922
C	−2.458519	0.263217	−9.340256	0.0000
Dependent variable: CO_2				
DOLS				
EC	0.900270	0.054459	16.53126	0.0000
FDI	−0.010761	0.015189	−0.708468	0.4948
GDP	−1.212535	0.289656	−4.186119	0.0019
TA	−0.012566	0.035581	−0.353151	0.7313
C	−2.453463	0.204647	−11.98875	0.0000

This research's primary drawback is that it is a single-country study, if additional aggregated level studies for the Asia region are done, it may give more insights in terms of policy implications. To address this issue, one of the study's future research goals is to use aggregated data in future investigations.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no competing interests.

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