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RESEARCH ARTICLE

Exploring Environmental Kuznets Curve and Pollution Haven Hypothesis in Bangladesh: The Impact of Foreign Direct Investment

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Abstract
Bangladesh receives the second-most foreign direct investment in South Asia. Over the past 30 years, Bangladesh's economy has expanded tremendously because of increased investment from several foreign countries. Although it can be beneficial in certain ways including the generation of new jobs, the improvement of infrastructure, and the equalization of economic rewards across the population; foreign direct investment has unintended consequences, such as ecological damage. In light of this, it is worth exploring the effects of foreign direct investment on sustainable development in Bangladesh. Using the most up-to-date annual data between 1990 and 2019, this study investigated the evidence of the Environmental Kuznets Curve and the Pollution Haven Hypothesis in Bangladesh. To assess the effects of economic growth, foreign direct investment, energy use, and trade on carbon dioxide emissions, this research employed the autoregressive distributed lag method. The empirical results indicated that the country has an inverted U-shaped Environmental Kuznets Curve and the adverse impact of foreign direct investment on the environment confirmed the validity of the Pollution Haven Hypothesis in Bangladesh. The results paint a bleak picture, sounding an alarm for policymakers to pay closer attention to the ways in which development leads to increased carbon emissions and how multinational companies operating within the country worsen the situation. That's why it's important to subject foreign investors to stringent environmental regulations. In addition, the nation's economic expansion should be guided by sustainable development goals.

Keywords: Environmental Kuznets Curve; Economic growth; Foreign direct investment; Carbon emission; Pollution Haven Hypothesis; Energy use; Sustainable development

Introduction

Climate change causes many different types of difficulties, including global warming, ecosystem imbalance, macroeconomic problems, technical problems, and social and economic concerns (Raihan et al., 2018; Begum et al., 2020; Raihan et al., 2021a; Raihan and Tuspekova, 2022a). Greenhouse gas (GHG) increases are widely recognized as the primary driver of climate change on a global scale (Raihan et al., 2019; Jaafar et al., 2020; Raihan et al., 2021b; Raihan and Tuspekova, 2022b). Lessening GHG emissions has risen to the top of the global community's agenda in light of the gravity of the climate change problem and the persistent warming of the Earth's surface (Ali et al., 2022; Raihan and Tuspekova, 2022c; Raihan et al., 2022a). While numerous different GHGs exist, the vast majority of emissions are due to carbon dioxide (Raihan and Said, 2022; Isfat and Raihan, 2022). With 37.12 billion metric tons of carbon dioxide (CO_2) emitted into the atmosphere through combusting fossil fuels and producing industrial goods worldwide in 2021 set a new record. Since this is becoming an increasingly urgent problem, it is generally agreed that governments around the world need to take effective actions to mitigate climate change's negative impacts quickly (Raihan et al., 2022b; Raihan and Tuspekova, 2022d). Hence, reducing CO_2 emissions has proven to be an effective tactic in the fight against global warming (Raihan et al., 2022c; Raihan and Tuspekova, 2022e). To increase the worldwide response to climate change concerns within the context of sustainable development and alleviate poverty initiatives, the United Nations Framework Convention on Climate Change (UNFCCC) created the Paris Agreement as a multilateral environmental pact.

Bangladesh is a developing nation in South Asia that has made remarkable economic strides during the past three decades (Raihan et al., 2023a). Beginning in 1999, the country's Gross Domestic Product and carbon dioxide emissions both steadily increased (World Bank, 2023). When it comes to climate change, Bangladesh is among the most at-risk nations (Raihan et al., 2022d). According to the Global Climate Risk Index 2022, Bangladesh is the sixth worst country in the world when it comes to the frequency

and severity of extreme weather events during the past 20 years. By ratifying the Paris Agreement in 2016, Bangladesh became part of the international effort to keep global warming far below 2 degrees Celsius, with the ultimate goal of reducing it to 1.5 degrees Celsius. This demonstrates the country's dedication to cutting emissions and preparing for the effects of climate change. Bangladesh plans to take part in global collective action to reduce future emissions as part of a broad and ambitious international agreement. The Paris Agreement has a target for Bangladesh to reduce greenhouse gas emissions by 15% below 2005 levels by the year 2030. The developed nations' contributions to climate finance, technology transfer, and capability building make up 10% of the unconditional basis and 5% of the conditional basis, respectively. An understanding of Bangladesh's vulnerability to climate change is necessary for policymakers seeking to strike a balance between anti-climate change policies and those promoting sustainable development, or between measures that do both. Balancing pollution and development is the most challenging aspect of achieving this dual goal simultaneously. There has been some discussion about whether or not increased environmental quality (emission reduction) and sustained economic expansion are incompatible objectives.

Research on the Environmental Kuznets Curve (EKC), which depicts the connection between economic growth and environmental degradation, continues to this day because of its importance in addressing the environmental and developmental difficulties that countries face. It has been hypothesized that after economic growth surpasses a certain threshold value, CO_2 emissions will begin to fall. Previous research in Bangladesh found support for the EKC, highlighting the trade-off between fostering economic growth and environmental quality (Chen et al., 2022; Rahaman et al., 2022). Yet, there is also evidence to suggest that the so-called inverted U-shaped curve between GDP growth and CO_2 emissions is not always the case (Islam et al., 2023). Since pollution levels can be affected by a variety of factors, it is imperative that more recent empirical evidence be gathered (Raihan et al., 2022e).

However, as economic globalization has accelerated, foreign direct investment (FDI) has increased on a regular basis. The United States, China, Canada, Singapore, Brazil, India, Russia, South Africa, and Mexico are just some of the countries that have boosted their investment in Bangladesh's economy recently. Because of this, Bangladesh receives the second-most foreign direct investment in all of South Asia. This expenditure has multiple positive effects on the economy, including the generation of new jobs, the improvement of infrastructure, and the equalization of economic rewards across the population. FDI is one of the world's largest investment activities and has played a crucial role in advancing the field of sustainable development (Esquivias et al., 2022). Although FDI can be beneficial in certain ways, they can also have unintended consequences, such as ecological damage. Rising FDI inflows may have an impact on global warming. Foreign direct investment (FDI) contributes not only to the rapid expansion of host economies but also to a dramatic increase in greenhouse gas emissions. Because of this, numerous previous research has concentrated on learning whether or not FDI inflows have an effect on carbon emissions. Trends in CO_2 emissions (in metric tons per person) and FDI net inflows (as a share of GDP) in Bangladesh are displayed in Figure 1. Within the last 30 years, CO_2 emissions in Bangladesh has been increased by five times. While there was an upward trend in foreign direct investment (FDI) in Bangladesh between 2005 and 2008 and again between 2013 and 2015, this development has been erratic. Foreign direct investment peaked in 2013, at a rate that was 1.74 percent of GDP. Yet, there has been a declining tendency in the flow of FDI in recent years.

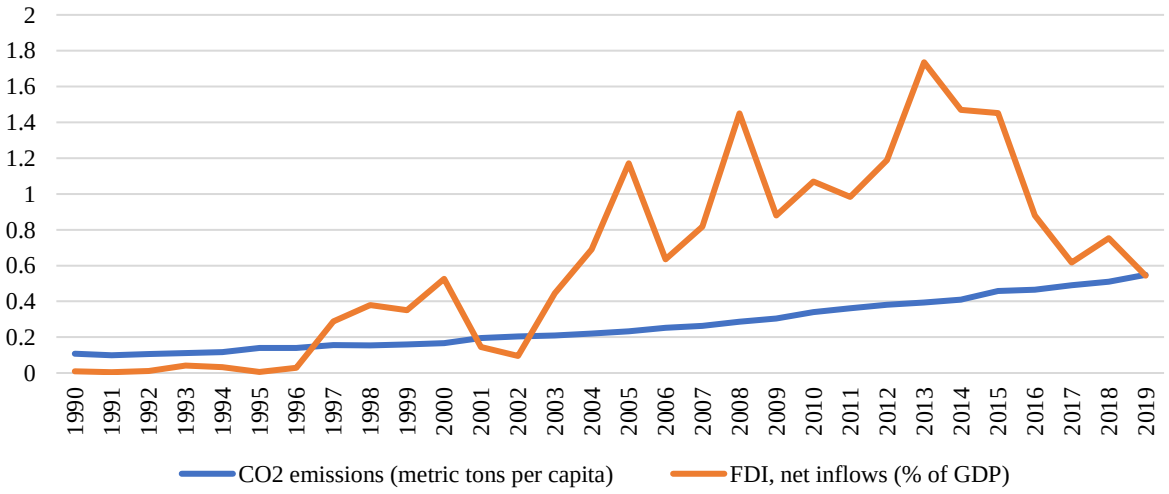

Figure 1. Annual trends of CO_2 emissions and FDI in Bangladesh

The pollution haven hypothesis (PHH) postulates that polluting industries will relocate to countries with laxer environmental restrictions since doing business there will save them money. PHH claims that foreign direct investment (FDI inflow) is directly related to environmental degradation (Huang et al., 2022). On the other hand, some research has shown that FDI can help improve environmental quality by serving as a means by which advanced technologies can be transferred to developing countries (Arif et al., 2022). The connection is still up for empirical discussion; studies conducted in Bangladesh have both supported and refuted the PHH (Firoj et al., 2022). As the empirical results showed contradictory results, it made the FDI's actual effect confusing with dilemma. Hence, there is a research gap on the actual effects of FDI on environmental quality. Consequently, it arises a question whether EKC and PHH hypotheses are valid in the context of Bangladesh. Therefore, this article investigated the presence of the EKC and the PHH in Bangladesh by using the yearly data from 1990 to 2019. The novelty of the study is that it explored the environmental influence of economic growth, FDI, trade, and energy use in Bangladesh by providing the validity of EKC and PHH hypotheses in the case of Bangladesh. The research used the autoregressive distributed lag (ARDL) test to analyze the effects of economic growth, FDI, trade, and energy consumption on CO_2 emissions in Bangladesh. This paper has the following outline: the second part of the paper is devoted to a review of the relevant literature; the third to the research methods; the fourth to the findings and discussion; and the fifth to the conclusions and policy suggestions.

Literature Review

Economic growth and CO_2 emission

The correlation between economic expansion and increased CO_2 emissions has been the subject of a large body of empirical research (Raihan et al., 2023b). Examining the EKC for its validity is a common topic among researchers in this field. Several studies were taken into account, from a wide range of countries, circumstances, and study methods. Even so, results tend to vary widely from one nation to the next. Several studies have found a link that resembles an inverted U, called an Environmental Kuznets Curve. The inverted U-shaped EKC was discovered by Zanin and Marra (2012) in France and Switzerland. The existence of inverted EKC was verified by Suki et al. (2020) in Malaysia. Quantile autoregressive distributed lag (QARDL) approach was used to verify this curve using quarterly data from 1970 to 2018. Using a dynamic spatial model, Chang et al. (2021) examined the environmental Kuznets curve for 284 Chinese cities between 2004 and 2015. The authors were able to thus verify the presence of EKC for CO_2 emission in the country. In addition, by utilizing data for Malaysia from 1971 to 2016, and employing ARDL bound testing and the VECM method, Aslam et al. (2021) came to the same conclusions. Using annual data from 1984 to 2018, Ahmed et al. (2012) analyzed the connection between economic growth and CO_2 emission in Pakistan. The study used the cutting-edge augmented ARDL estimation method to decipher the short- and long-run elasticities. The data seems to support the idea that the EKC hypothesis holds true in Pakistan both in the short and long term. There is a positive correlation between economic growth and CO_2 emissions over time, hence the finding from Islam et al. (2023) regarding the EKC hypothesis is not substantiated in the case of Bangladesh. The results from the past suggest that the authors' selection of control variables accounts for the conflicting evidence supporting the EKC hypothesis.

Energy use and CO_2 emission

Carbon dioxide emissions in Bangladesh were studied by Chen et al. (2022) from 1980 to 2019. They found that both energy use and economic growth had significant effects on the country's emissions. Results confirmed the environmental Kuznets curve hypothesis for Bangladesh. Also, it was thought that a rise in energy use would eventually lead to an increase in carbon dioxide output. In a study spanning from 1990 to 2019, Rahaman et al. (2022) analyzed how foreign direct investment, electricity use, and economic growth affected CO_2 emissions in Bangladesh. The findings demonstrated an inverted U-shaped relationship between CO_2 emissions and economic development in Bangladesh. Hence, the EKC hypothesis can be demonstrated to be valid. Due to substantial population growth and economic development, Bangladesh's energy demand expanded quickly. Carbon emissions are rising in tandem with the growth of economic activities and industrialization, owing to the combustion of fossil fuels. Bangladesh's CO_2 emissions increased from 0.20 metric tons per capita in 1996 to 0.53 metric tons per capita in 2016, an average annual increase of 8.25%. Therefore, the country is highly concerned about the growing emission intensity, especially from the energy sector. By using ARDL, DOLS, FMOLS, and CCR techniques, Raihan et al. (2022d) reported that energy consumption deteriorates Bangladesh's environmental quality in the long run. Oh and Bhuyan (2018) reported that energy consumption in Bangladesh has statistically significant positive effect on CO_2 emissions both in the short-run and long-run.

Foreign direct investment and CO_2 emission

While much earlier research has used energy consumption as an independent variable for environmental deterioration, few have considered other potential macroeconomic factors, notably in Bangladesh (Raihan et al., 2022f). Foreign direct investment, trade liberalization, and industrial production are supplementary factors. Since FDI and trade openness

might have an impact on environmental quality, they are included as control variables in the analysis even though the focus of the study is on EKC. There may be two ways in which FDI contributes to the correlations between CO_2 emissions and economic output. To begin, there may be a positive relationship between per capita CO_2 emission and foreign direct investment because of the potential growth in national revenue. Foreign direct investment (FDI) can help the economy flourish, but it also has the potential to worsen environmental conditions by increasing industrial pollutants. Firoj et al. (2022) used the ARDL technique to look into whether or not the PHH was genuine in Bangladesh, and whether or not the EKC hypothesis existed there. The results of the ARDL cannot support the EKC and PHH in Bangladesh since they found long-run cointegration between the variables. Polluting industries and businesses will likely be relocated to underdeveloped countries with lax environmental regulations in order to save money on costly environmental regulations. Second, increased FDI in the country can lead to the usage of more advanced production technologies, which in turn reduces CO_2 emissions per person. For instance, Arif et al. (2022) found that industrialized countries benefit ecologically from attracting foreign direct investment. To a similar extent, Perkins and Neumayer (2008) found that more FDI leads to better environmental quality because of increased energy efficiency. The authors employed econometric methods applied to a panel of up to 114 nations from 1980 to 2000 to investigate the dynamics and drivers of two pollutants, carbon dioxide (CO_2) and sulfur dioxide (SO).

Trade and CO_2 emission

When it comes to the state of the planet, foreign direct investment isn't the only factor that matters. Globalization's greater reliance on FDI for economic expansion has eroded environmental quality (Raihan 2023a). Also, it has been established that international trade is a contributor to environmental deterioration. Trade openness was found to have a positive effect on CO_2 emissions in Bangladesh (Firoj et al., 2022). Basri and Kongcharoen (2021) showed that energy consumption, financial development, and urbanization upturn CO_2 emissions, while trade openness lowers CO_2 emissions in Bangladesh. Islam et al. (2021) scrutinized the effect of globalization, foreign direct investment, economic growth, trade, innovation, and energy consumption on CO_2 emissions in Bangladesh over the period 1972-2016 by utilizing dynamic ARDL simulations' model. The investigated results depicted that globalization, foreign direct investment, and innovation have a negative effect on CO_2 emissions in improving environmental quality while economic growth, energy consumption, and trade positively impact CO_2 emissions and hence stimulate environmental degradation both in the long and short run. On the other hand, Oh and Bhuyan (2018) reported the negative and insignificant coefficients for economic growth and trade liberalization in short-run and long-run in Bangladesh.

According to Copeland and Taylor (2004), there are three distinct consequences of trade liberalization on environmental quality: scale, technique, and composition effects. A rise in the outputs and inputs of the economy, according to the scale effect, is likely to significantly increase pollution (Raihan and Tuspekova, 2022f; Raihan, 2023b). As a result, expanding economies are accused of degrading ecosystems (Raihan and Tuspekova, 2022g; Voumik et al., 2022a; Raihan et al., 2022g). Second, a shift in the monetary and industrial order of the economy is necessary for the composition impact to take place. Rezek and Rogers (2008) argue that improvements in environmental quality accompany the shift from an industrialized to a service- and knowledge-based economy. In other words, it shows that economic growth has a beneficial impact on pollution levels in the environment (Raihan and Tuspekova, 2022h; Raihan et al., 2022h; Voumik et al., 2022b; Raihan 2023c). Last but not least, the technology or productivity effect suggests that developed countries are better able to invest in R&D, leading to faster economic expansion (Raihan et al., 2023c; Raihan 2023d). Thus, new and cleaner technologies could be developed and used to replace old and polluting ones, thereby enhancing environmental quality (Raihan et al., 2022i; Raihan and Tuspekova, 2023a).

The purpose of this study is to address this knowledge gap by investigating the connection between GDP growth and CO_2 emissions in the context of Bangladesh, taking into account factors such as foreign direct investment (FDI), trade, and energy usage. Two factors led to the selection of Bangladesh. To begin, over the past 30 years, Bangladesh has seen significant growth, with increased FDI inflows and rising international commercial operations. Perhaps the improvement in environmental quality is a direct result of this development. Exogenous elements like climate change policies and trade are studied in depth in a particular country over a period of time.

Methodology

Data

The dependent variable in this research is CO_2 emissions while the independent factors are economic growth, FDI, trade, and energy usage. From 1990 to 2019, yearly time-series data was used to examine the relationships between these factors. This information was obtained from the World Development Indicators (WDI) database (World Bank, 2023). This study used logarithms of variables to help choose appropriate time series models and estimate the direct elasticities of coefficients. The description of the variables is presented in Table 1.

Table 1. Data description

Variables	Description	Logarithmic structures	Measurement unit
C	CO_2 emissions	LC	CO_2 emissions (metric tons per capita)
Y	Economic growth	LY	GDP per capita (constant 2015 US$)
F	Foreign direct investment	LF	Net inflows (% of GDP)
E	Energy use	LE	Kg of oil equivalent per capita
T	Trade	LT	Percentage of GDP

Descriptive statistics of the dataset is presented in Table 2. The analysis revealed that the mean values of the variables are within the normal range, confirming that the dataset contains no outliers. Moreover, the predicted skewness of all applied parameters is close to zero, indicating normality of the data. The derived Kurtosis value is less than three for all factors taken into account. The Jarque-Bera value and probability support the conclusion that all used parameters are normally distributed. This allowed the inquiry to go further with the provided datasets to produce estimation and empirical studies.

Table 2. Descriptive statistics of the variables

Variables	LC	LY	LF	LE	LT
Mean	-1.4577	6.6828	-1.3141	5.1307	3.4446
Median	-1.4874	6.6078	-0.5471	5.0749	3.4229
Maximum	-0.6011	7.3511	0.5513	5.5457	3.8735
Minimum	-2.3112	6.2007	-5.4056	4.7443	2.9386
Std. Dev.	0.5342	0.3508	1.8206	0.2546	0.2673
Skewness	-0.0017	0.3612	-0.1072	0.1575	-0.1419
Kurtosis	1.7427	1.8814	2.1937	1.6696	2.2431
Jarque-Bera	1.9759	2.2165	2.7875	2.3367	0.8169
Probability	0.3733	0.3301	0.5555	0.3109	0.6649

Empirical model generation and econometric methods

Theoretically, CO_2 emission is associated with economic growth, FDI, energy use, and trade. Assuming the market clearing condition, where CO_2 emissions equal economic growth, FDI, energy use, and trade, this study came up with Equation (1) to assess the effects of the variables within the framework of EKC and PHH.

CO_2 emissions = (Economic growth, Foreign direct investment, Energy use, Trade) (1)

The current study employed the following economic functions within the framework of the Cobb-Douglas production function (Cobb and Douglas, 1928) at time t:

$$Ct = f(Y_t, F_t, E_t, T_t) \quad (2)$$

The study then made a quadratic function by adding GDP^2 in Equation 2. Such a criterion is necessary to confirm the existence of the EKC in Bangladesh and is thus incorporated into the model.

$$Ct = f(Y_t, Y_t^2, F_t, E_t, T_t) \quad (3)$$

To examine the long-run relationship between the variables, this study employed the following equation derived from Equation (3):

$$C_t = \tau_0 + \tau_1 Y_t + \tau_2 Y_t^2 + \tau_3 F_t + \tau_4 E_t + \tau_5 T_t + \varepsilon_t \quad (4)$$

where τ_0 and ε_t are the intercept and the error term. In addition, τ_1, τ_2, τ_3, τ_4, and τ_5 represent the coefficients.
The econometric analysis employed logarithms of all variables to determine the impact of regressors on the dependent variable's rate of increase. Hence, equation (4) can be extended into the natural logarithm form by the following equation:

$$LC_t = \tau_0 + \tau_1 LY_t + \tau_2 LY_t^2 + \tau_3 LF_t + \tau_4 LE_t + \tau_5 LT_t + \varepsilon_t \quad (5)$$

The first step in a time-series analysis of the stationarity of the variables was analyzed using unit root tests in this study. Unit root testing is necessary to prevent erroneous regression (Raihan and Tuspekova, 2023b). It separates the

variables in the regression to identify whether or not they are stationary, and then uses the stationary processes to estimate the desired equation. Before applying cointegration methods, empirical literature agrees that the integration sequence must be determined (Raihan and Tuspekova, 2022i). In order to check the stationarity of the highlighted variables in this article, the unit root test was employed. A variable is considered non-stationary when the probability distribution of its mean variance and covariance shifts with time. Several academics have suggested applying multiple unit root tests to identify the integration order of the series because of the variance in power and sample size between the tests (Raihan and Tuspekova, 2022j). The stationarity of the variables was examined using the Augmented Dickey-Fuller (ADF), Dickey-Fuller generalized least squares (DF-GLS), and Phillips-Perron (P-P) unit root tests.

When variables exhibit stationarity, the ARDL bounds testing method developed by Pesaran et al. (2001) was implemented. In addition, the ARDL framework can examine the existence of long- and short-run cointegration between variables. This strategy has many advantages over previous cointegration methods (Raihan and Tuspekova, 2022k). Before implementing earlier cointegration processes, the integration property of a series had to be determined; however, this method does not require such testing. Taking into consideration the lag length of the variable, the ARDL model can be utilized to account for endogeneity. Second, it is applicable in all investigative series integration circumstances (Raihan and Voumik, 2022a). The ARDL model retains its validity even with a limited number of observations. Hence, the ARDL method of cointegration provides accurate and efficient estimations of the variables' long-term connection (Raihan and Voumik, 2022b). The ARDL bound test offered two asymptotic critical value bounds when the independent variables are I(0) or I(1). Using the following equation, cointegration relationships between variables were estimated.

$$\Delta LC_t = \tau_0 + \tau_1 LC_{t-1} + \tau_2 LY_{t-1} + \tau_3 LY_{t-1}^2 + \tau_4 LF_{t-1} + \tau_5 LE_{t-1} + \tau_6 LT_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LC_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LY_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LY_{t-1}^2 + \sum_{i=1}^{q} \gamma_4 \Delta LF_{t-i} + \sum_{i=1}^{q} \gamma_5 \Delta LE_{t-i} + \sum_{i=1}^{q} \gamma_6 \Delta LT_{t-i} + \varepsilon_t \quad (6)$$

After establishing the long-term link between series, the short-run coefficient must be accounted for. This study evaluated the error-correction model (ECM) and derived the short-run coefficients. The equation displays the error-correction dynamics and long-term links between the series where q represents the lag length of the series, Δ is the first difference operator, and θ is the ECM's coefficient.

$$\Delta LC_t = \tau_0 + \tau_1 LC_{t-1} + \tau_2 LY_{t-1} + \tau_3 LY_{t-1}^2 + \tau_4 LF_{t-1} + \tau_5 LE_{t-1} + \tau_6 LT_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LC_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LY_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LY_{t-1}^2 + \sum_{i=1}^{q} \gamma_4 \Delta LF_{t-i} + \sum_{i=1}^{q} \gamma_5 \Delta LE_{t-i} + \sum_{i=1}^{q} \gamma_6 \Delta LT_{t-i} + \theta ECM_{t-1} + \varepsilon_t$$

Results and Discussion

Results of unit root tests

Before employing cointegration, unit root tests must be conducted to determine the nature of the stationarity of the parameters, followed by descriptive statistical analysis to determine normality. This stage is crucial since it not only assists in determining the type of stationarity of the employed parameter, but also in selecting an acceptable test for future research. This study employed the ADF, DF-GLS, and P-P unit root testing strategies. According to Table 3, all evaluated parameters are stable at the first difference. Thus, the data are suitable for co-integration and the ARDL estimator.

Table 3. The results of unit root tests

Logarithmic form of the variables	ADF		DF-GLS		P-P	
	Log levels	Log first difference	Log levels	Log first difference	Log levels	Log first difference
LC	0.277	-7.770***	0.208	-4.012***	0.993	-17.532***
LY	2.811	-3.574***	-0.023	-3.025**	0.334	-3.574***
LF	-1.959	-5.015***	-1.324	-4.459***	-2.293	-5.308***
LE	0.575	-7.126***	0.059	-3.863***	0.575	-7.155***
LT	-1.988	-4.775***	-1.248	-4.826***	-1.989	-4.775***

Notations of *, **, and *** indicate 10%, 5%, and 1% significance, respectively.

Results of ARDL bounds test for cointegration

The unit root assessment gives information regarding the dataset's stationarity. To establish whether or not a cointegration relationship exists between the employed parameters, the ARDL bounds test was conducted. Table 4 presents the outcomes of the cointegration investigation. Table 4 illustrates that the computed cointegration F-statistic (6.803716) exceeds the upper critical criterion. The finding from this research is that the variables are cointegrated.

Table 4. ARDL bounds test results

F-bounds test		Null hypothesis: No degrees of relationship		
Test statistic	Estimate	Significance	I(0)	I(1)
F-statistic	6.803716	At 10%	2.20	3.09
K	5	At 5%	2.56	3.49
		At 2.5%	2.88	3.87
		At 1%	3.29	4.37

Results of ARDL long and short-run estimation

The ARDL estimate outcomes are displayed in Table 5. Bangladesh's long- and short-term Environmental Kuznets Curves were inverted U shapes, with a positive sign for LY and a negative sign for LY2. By way of illustration, if economic growth were to increase by 1%, carbon emissions would rise by 0.54 percent (in the long run) and 1.02 percent (in the short run). In contrast, it decreases carbon emissions by 0.54 percent in the long run and 1.02 percent in the short term for a more developed economy (short run). The findings are supported by Chen et al. (2022), Rahaman et al. (2022), and Islam et al. (2023) who showed the validity of EKC in the case of Bangladesh. The results also showed a positive coefficient of FDI. Carbon emissions rise by 0.54% (long run) and 1.02% (short run) for every 1% increase in FDI. This research provides empirical support for the hypothesis that increases in foreign direct investment (FDI) in Bangladesh have a positive effect on the country's carbon dioxide (CO_2) output. Consequently, the result supports the existence of the Pollution Haven Hypothesis for Bangladesh. The findings are consistent with earlier studies on Bangladesh (Rahaman et al., 2022) and the research consists of large panels of Asian nations (Huang et al., 2022). Given the country's loose environmental regulations, this is not a positive indication, as foreign corporations are likely to take advantage of the situation by constructing facilities without using environmentally friendly production methods.

This study discovered a positive and significant association between energy consumption and CO_2 emissions, demonstrating that a 1% increase in energy consumption leads to a 0.59 percent (long-run) and 1.35 percent (short-run) increase in Bangladesh's CO_2 emissions. This is due to Bangladesh's increased propensity to use polluting fossil fuels including oil, gas, and coal for electricity generation. The present study's findings are supported by Chen et al. (2022), and Raihan et al. (2022d) who reported a positive association between energy use and CO_2 emissions in the case of Bangladesh. In a country like Bangladesh, where industry and urbanization are on the rise, higher energy consumption may be related to the resulting increase in demand for energy. Thus, unless shifting the economy to renewable energy sources, the emissions will continue to increase due to the increased demand for energy. Moreover, a positive correlation exists between LT and carbon emissions. The study found that for every one percent increase in trade, CO_2 emissions rise by 0.59 percent in the long run and 1.35 percent in the short term. The outcomes indicated that trade would increase CO_2 emissions in Bangladesh. The result of the positive relationship between trade and CO_2 emissions in Bangladesh is supported by Firoj et al. (2022) and Islam et al. (2023).

Table 5. ARDL long and short-run results: dependent variable LC

Variables	Long-run			Short-run		
	Coefficient	t-Statistic	p-value	Coefficient	t-Statistic	p-value
LY	1.1201***	3.0735	0.0042	0.7126***	2.6181	0.0071
LY^2	-0.0457**	-2.5341	0.0369	-0.0328**	-2.3768	0.0313
LF	0.0648***	2.4637	0.0054	0.0369**	2.6976	0.0123
LE	1.9935***	4.8576	0.0001	1.8249***	3.9407	0.0007
LT	0.0224**	2.2329	0.0177	0.0168*	1.9898	0.0666
C	21.461	3.9748	0.1849	-	-	-
ECM (-1)	-	-	-	-0.5612***	-2.4411	0.0039
R^2	0.9948					
Adjusted R^2	0.9939					

Notations of *, **, and *** indicate 10%, 5%, and 1% significance, respectively.

In addition, the ECM value indicates the rate of adjustment from short-term to long-term equilibrium. The coefficient is statistically significant at the 1% level, and the calculated ECM has a negative significant value. Therefore, the model's ECM value model's ECM value suggests that, on average, short-term fluctuations away from the long-run equilibrium are brought back to the long-run equilibrium trajectory by 56% every year. Any long-term disequilibrium among model variables will migrate or converge to the long-term equilibrium, as indicated by the statistically significant negative sign of the ECM coefficient. In addition, the long-run estimation R^2 and adjusted R^2 are 0.9948 and 0.9939, showing that the suggested regression model fits the data exceptionally well. This would imply that the independent causes can account for almost 99% of the variations in the dependent variable.

Results of diagnostic tests

This inquiry utilized multiple diagnostic tests to establish the dependability of the ARDL results. The Breusch-Godfrey Langrage Multiplier (LM) test for the autocorrelation test for serial correlation is presented in Table 6. According to the results, there is no serial association. The Breusch-Pagan-Godfrey test for Heteroskedasticity revealed that the data do not exhibit Heteroscedasticity. To examine the series' normality, the Jarque-Bera Normality test was performed. The Jarque-Bera statistic and p-value suggested that residuals possess a normal distribution. This study also evaluates the consistency of short-run beta coefficients in the ARDL method by applying the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests to the recursive residuals. Figure 3 depicts the results of the CUSUM and CUSUM square tests, which indicate that there is no structural inconsistency between GDP and independent variables at the 5% significant level. The tests verified the model's stability.

Table 6. The results of diagnostic tests

Diagnostic tests	Coefficient	p-value	Decision
Jarque-Bera test	1.203162	0.4181	Residuals are normally distributed
Breusch-Godfrey LM test	1.480083	0.3114	No serial correlation exits
Breusch-Pagan-Godfrey test	1.571144	0.2639	No heteroscedasticity exists
Ramsey RESET test	1.701619	0.4031	The model is properly specified

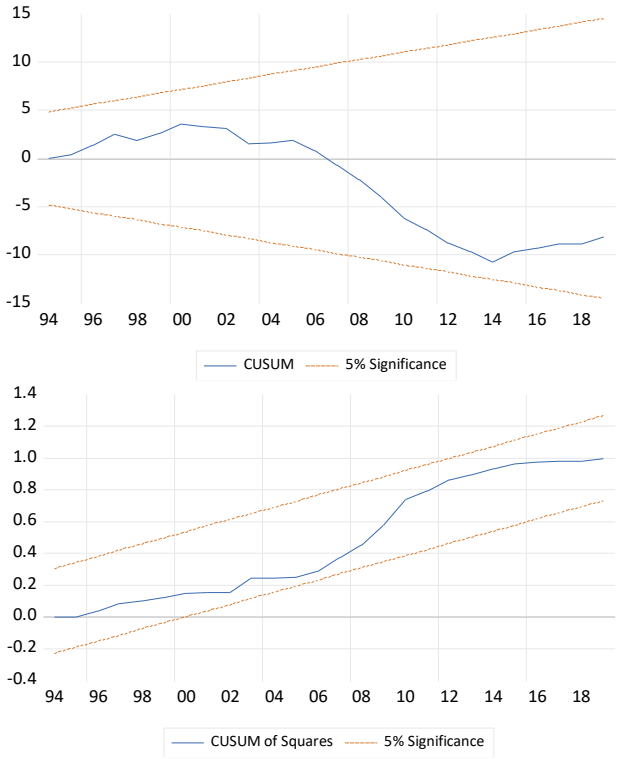

Figure 2. The plots of CUSUM and CUSUMQ tests

Conclusions and Policy Implications

The purpose of this study is to explore the EKC and PHH in the context of Bangladesh, and how energy use and trade affect the country's carbon footprint. The ARDL method was used to analyze data over a 30-year time span, from 1990 to 2019. While using the ADF, DF-GLS, and P-P unit root tests, this research determined the proper order for the dataset's integration. Long-term cointegration between the variables was proven by an ARDL bounds test. The results showed that the EKC followed the shape of an inverted U in both the short and long terms. Hence, increased economic growth may slow environmental damage by decreasing the intensity of emissions in Bangladesh. The results also showed that both long- and short-term FDI inflows are positively related to environmental degradation. This suggests that increasing foreign investment in Bangladesh could be detrimental to the environment. Therefore, both immediate and future environmental degradation in Bangladesh may be exacerbated by energy consumption. In addition, both short- and long-term increases in CO_2 emissions are associated with greater trade openness.

The present study's findings would help policymakers in Bangladesh make decisions that could slow the rate of environmental degradation. Foreign direct investment (FDI) can have positive or negative effects on the environment, depending on the type of technology that is imported. The

rate of environmental damage may be slowed if green technology were imported as a result of foreign direct investment. Hence, Bangladesh should enable more environmentally friendly technologies to enter the country in order to lessen its impact. Additionally, the country may be able to slow down environmental damage by increasing its use of renewable energy sources including biodiesel, solar, and hydro. The country's new carbon pricing system can also help protect the environment.

Based on the results of the investigation, the government of Bangladesh should implement a policy to encourage foreign nations and their enterprises to spend more in utilizing their cleanest production process for Bangladesh's sustained economic development and environmental protection. In this situation, governments should also prioritize establishing a relationship with foreign nations and their multinational enterprises from a social, economic, and political standpoint. This will make it easier for these nations and their multinational firms to deploy renewable energy technologies in Bangladesh in order to safeguard the environment. In addition, for the sake of environmental quality, the government should adopt a pragmatic strategy to ensure the prudent exploitation of the primary macroeconomic factors, such as economic growth, trade, and energy consumption. Also, the growth process in Bangladesh may not be valued at the expense of the environment.

Although the current study provides significant empirical insights into the existence of EKC and PHH in the case of Bangladesh, the investigation has a few limitations. The unavailability of data beyond the period of the study restricted the usage of the econometric approach. Furthermore, the study used CO_2 emissions as an indication of environmental degradation. Future studies could consider GHG emissions while investigating the EKC and PHH hypothesis. Future studies could also explore other variables, such as financial development, gross fixed capital formation, industrialization, and infrastructure development in the framework of EKC and PHH.

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