Bangladesh Journal of Political Economy

Vol. 39, No. 1, June 2023, pp. 111-130
Bangladesh Economic Association
ISSN 2227-3182
DOI: http://doi.org/10.56138/bjpe.v39n1.07

The Effects of Industrialization, Energy Consumption and Economic Growth on Carbon Emissions in Bangladesh

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Abstract

The economy of Bangladesh has been growing rapidly over the last few decades. In its pursuit of economic growth, industrialization has played a formidable role. Consequently, the rapid industrialization has led to huge energy demand, causing Bangladesh to rely heavily on fossil fuels, resulting in significant carbon emissions. This paper investigates the effects of industrialization, economic growth, and energy consumption on carbon emissions in Bangladesh from 1974 to 2019 using the Auto Regressive Distributed Lag (ARDL) model. The estimated long-run coefficient for industrialization is positive, suggesting that industrialization is associated with higher carbon emissions in Bangladesh. The long-run coefficient of energy consumption is positive, confirming the positive long-term relationship between energy consumption and carbon emissions. The long-run coefficient on economic growth is positive but statistically insignificant, suggesting that economic growth has no detrimental effect on carbon emissions. As a country vulnerable to climate change, Bangladesh needs to adopt energy-efficient technology and an energy mix for its industrialization rather than relying solely on fossil fuels.

Keywords: *ARDL · industrialization · fossil fuel · reducing CO_2 · GDP · RMG · urbanization*

1. Introduction

Every country all over the world aspires to higher economic growth. The apparent desire for higher economic growth has led to raising the levels of CO_2 emissions as well as other greenhouse gases in the atmosphere (Ahmad et al., 2016). The intensifying trend of global economic activity over the past few decades has been reflected in industrialization and in the considerable consumption of energy sources such as coal, natural gas, and oil for energy and transportation. Therefore, reducing the emissions of CO_2 and other gases in the atmosphere and improving the quality of the environment has become a global concern in order to mitigate the adverse effects of climate change and ensure sustainable

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development (Begum et al., 2015; Raihan & Said, 2022).

Bangladesh is emerging as one of the world's rapidly growing economies (Bangladesh Planning Commission, 2022). Over the last couple of years, Bangladesh's economy has been growing at an average annual rate of 6.0 percent. The GDP growth rate in Bangladesh has accelerated since the early 1990s. Bangladesh's GDP is usually classified into three broad categories: agriculture, industries, and services. Over the last couple of years, the share of industry in Bangladesh's GDP has steadily increased, making a huge contribution to the country's economic growth. According to the Bangladesh Bureau of Statistics (BBS), the industry sector's share of GDP reached 35.5 percent in FY'22, up from 14.7 percent in FY'73 (BBS, 2022). However, rapid industrialization and accelerated economic growth come at the cost of environmental degradation, as they necessitate high consumption of fossil fuels such as crude petroleum, coal, and natural gas. In Bangladesh, due to limited green energy alternatives, crude and refined petroleum, along with natural gas, serve as the primary inputs for the transportation sector, manufacturing plants, and electricity generation. In 2021, the country's energy portfolio was over 99% fossil fuels, consisting of natural gas, oil, diesel, and coal (BP Statistical Review of World Energy, 2022). Over the last three decades, massive industrialization, especially the rapid growth of the RMG and leather industries, has occurred in Bangladesh without regard for environmental issues. Most RMG and leather factories lack effluent treatment plants and discharge waste into surrounding areas, causing significant environmental degradation near major cities such as Dhaka, Chattogram, Gazipur, and Narayangonj. With the rise in industries, the increase in energy combustion plants comes at the expense of environmental quality. There is a strong relationship between the consumption of these energy sources and carbon emissions across countries (Rahman & Kashem, 2017). Moreover, the rapidly growing industrialization in Bangladesh is contributing to this process, driven by the poor treatment of waste by backwardly linked industries in the RMG sector (Rahman & Kashem, 2017).

The acceleration of industrialization and the rapid increase in energy consumption from fossil fuels are leading to rapid environmental degradation. Besides, Bangladesh has been facing challenges stemming from rapid economic growth during its early development phases, as well as from climate change driven by increased greenhouse gas emissions. According to data from the International Energy Agency (IEA), Bangladesh emitted approximately 11.42, 20.95, 49.9, and 81.97 million tons of CO2 in 1990, 2000, 2010, and 2018, respectively. The CO2 emissions in 2018 were 617.78% higher than in 1990. The CO_2 emissions in Bangladesh during this period were primarily due to its heavy reliance on fossil fuels for energy consumption. Figure 1 and Table 1 show the positive

relationship among the per capita GDP, per capita industrial growth, and energy consumption.

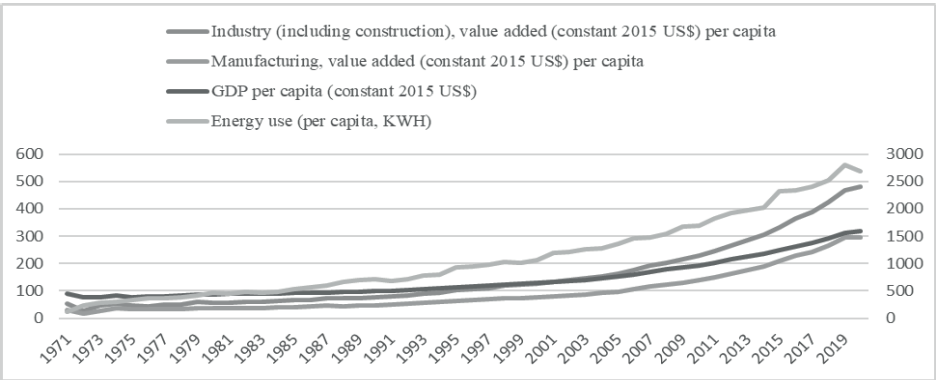

Figure 1. Relationships of Per Capita GDP, Per Capita Energy use & Per Capita Industrial Production

Source: WDI (March 2024), Our World in Data.

Table 1. Trends of Variable of Interest

Year	GDP per capita (constant 2015 US$)	Industry value added (constant 2015 US$) per capita	Manufacturing value added (constant 2015 US$) per capita	Energy use (KWH) per capita	Population, total (Million)
1971-1980	411.65	48.53	32.32	327.64	75.69
1981-1990	462.47	66.91	41.94	564.59	96.87
1991-2000	569.83	103.50	64.16	893.06	118.96
2001-2010	795.77	174.93	105.30	1416.06	140.93
2011-2020	1291.48	355.78	221.18	2280.53	158.83

Source: WDI (March 2024), Our World in Data.

The data presented in Table 1 and Figure 1 indicate that GDP growth, industrial production, energy usage, and carbon dioxide emissions display synchronized patterns over the time period analyzed. Bangladesh is facing alarming levels of pollution and environmental health risks, and it disproportionately affects the poor, children under five, the elderly, and women (World Bank, 2023). Though Bangladesh is recognized as one of the fastest-growing economies, very little attention is paid to the environmental impact of this rapid growth. Moreover, Bangladesh aspires to become a middle-income country by 2031 and to fulfill the SDGs, so transitioning to renewable energy is essential for industrialization while balancing economic growth and environmental protection.

Several Studies such as Amin et al. (2012), Shahbaz et al. (2014), Murad et al. (2015), Ahad & Khan (2016), Alom et al. (2017), Islam et al. (2017), Sharmin & Tareque (2018), Nomani et al. (2022), Rahman et al. (2021), Raihan et al. (2022) and Islam et al. (2023) examined the impact of GDP growth, industrialization, and energy use on carbon emissions in the context of Bangladesh. However, these studies suggest no clear consensus on these issues. In this context, this study investigates the short- and long-run effects of industrialization, energy use, and GDP growth on CO2 emissions in Bangladesh to inform appropriate policy recommendations.

The remaining part of the paper is organized as follows: Section two provides a literature review; Section three elaborates on the data, model, and methodology employed; Section four presents the estimation results; Section five discusses the results; and Section six outlines the conclusions and policy implications.

2. Literature Review

Carbon dioxide (CO_2) emissions are strongly influenced by industrialization, energy consumption, and a country's economic development, as measured by GDP. Past empirical research has shown that industrialization and CO2 emissions are positively related, meaning that as industrialization increases, CO2 emissions rise. On the same note, it has also been established that energy consumption has a positive impact on CO2 emissions, implying that increasing energy consumption increases CO2 emissions. Also, GDP growth has been linked to increased CO2 emissions, meaning that as the economy grows, so do CO2 emissions

Over the last few decades, numerous empirical studies have examined the relationship between environmental degradation and economic variables, such as globalization, industrialization, economic growth, energy use, financial development, urbanization, and foreign direct investment, across countries and regions. The initial influential work was developed by Griffin & Schiffel (1972) which focused on the environmental Kuznets curve and addressed the nexus between GDP growth and CO_2 emissions. Later on, Grossman & Krueger (1991) updated the relationship between GDP growth and CO_2 emissions.

Several empirical studies have examined the relationship between economic growth and environmental degradation at the country level. Studies such as Selden & Song (1994), Galeotti et al. (2009), Saboori et al. (2012), Fujii & Managi (2013), Wang & Liu (2017), and He et al. (2017) provided empirical evidence on the validity of the EKC hypothesis. On the contrary, studies such as Zou (2018), Mansoor & Sultana (2018), Huang (2021), Uddin et al. (2022), and Sheik & Hassan (2023) did not find the relationship between GDP growth and CO_2 emissions.

Other areas of contemporary literature focus on the role of industrialization in rising CO_2 emissions, both in developed and developing countries. Numerous studies examine the link between industrialization and environmental degradation. However, there is no clear consensus. The empirical findings of Mahmood et al. (2020) for Saudi Arabia, Ullah et al. (2021) for Pakistan, Ayitehgiza (2020) for Ethiopia, Rauf et al. (2020) for 65 Belt and Road Initiative countries, and Samreen & Majeed (2020) For 89 countries, it is concluded that industrialization negatively affects environmental quality. On the other hand, the results of Chowdhury et al. (2020) for 92 economies, Hong et al. (2019) for South Korea, Li et al. (2019) for China, and Congregado et al. (2016) for the United States proved that industrialization improves environmental quality.

In the empirical literature, some studies emphasize energy consumption as a driver of CO2 emissions. Studies such as Soytas & Sari (2009); Halicioglu (2009); Zhang & Cheng (2009); Wang et al. (2011); Begum et al. (2015); Ahmad et al. (2016); Mirza & Kanwal (2017); Dogan & Aslan (2017); Acheampong (2018) assessed the impact of the energy consumption on carbon emissions. The outcomes have reported mixed evidence; the relationship varies from region to region.

The above-mentioned empirical literature on forging suggests no consensus on the impact of industrialization, energy use, and GDP growth on CO_2 emissions.

In Bangladesh, several studies have examined the effects of GDP growth, industrialization, and energy consumption on CO_2 emissions. However, there is no clear consensus on this issue.

Amin et al. (2012) examined the relationship among energy use, economic growth, and CO_2 emissions in Bangladesh for the period of 1976 to 2017. This study found no causal relationship between economic growth and CO_2 emissions in Bangladesh. Moreover, the findings of this research suggested that industrialization may not necessarily lead to increased CO_2 emissions.

Shahbaz et al. (2014) examined the relationship among Industrialization, electricity consumption, and CO_2 emissions in Bangladesh from the period of 1975 to 2010. The paper finds that economic growth is the cause of CO_2 emissions in Bangladesh.

Murad et al. (2015) studied the causality between carbon emission and industrial production in the case of Bangladesh using the VECM method for the period of 1990 to 2007, and also found no causal relationship between industrial production and CO_2 emissions in Bangladesh.

Ahad & Khan (2016) investigated the effects of globalization, industrial production, energy consumption, and economic growth on environmental degradation in Bangladesh between 1972 and 2015. This study concluded that environmental degradation is positively related to energy consumption.

Alom et al. (2017) studied energy use, CO_2 emissions, urbanization, and financial development in Bangladesh between the years 1985 and 2015. The study's authors established a unidirectional causal relationship between industrial value addition and CO_2 emissions in Bangladesh.

Islam et al. (2017) analyzed the question of whether there is any relationship or correlation between carbon emission (CO2), GDP, industrial production, and energy consumption in Bangladesh from 1998 to 2013. It concludes that the effect of industrial production and GDP per capita on carbon emissions is significant. Another reason mentioned in this paper is that economic growth increases energy consumption and, therefore, CO_2 emissions in Bangladesh.

Sharmin & Tareque (2018) It investigated the impact of economic growth, globalization, industrialization, energy intensity, and urbanization on Bangladesh's per capita CO2 emissions using data from 1980 to 2014. The causality test and long-run estimated results suggested that growth drives energy consumption in Bangladesh, which ultimately leads to higher CO_2 emissions. Furthermore, the results indicate that, in the long run, more than 60 percent of Bangladesh's CO2 emissions stem from energy intensity, urbanization, industrialization, and growth.

Nomani et al. (2022) studied industrial development and climate change in Bangladesh and found that unplanned industrialization has become the main cause of environmental pollution, leading to air, water, and soil pollution and negatively affecting people living near industrial areas.

Rahman et al. (2021) estimated the Environmental Kuznets Curve (EKC) hypothesis of Bangladesh in 1972-2013, with the Fully Modified Ordinary Least Squares (FMOLS) approach, and reported that energy consumption and economic growth have a positive relationship, which in turn increases pollution. The consumption of non-renewable energy was cited as the major source of pollution in Bangladesh.

Raihan et al. (2022) examined the nexus between carbon emission, economic growth, renewable energy consumption, urbanization, industrialization, technological innovation, and forest area in Bangladesh in the period between 1972 and 2018. This paper found that industrialization, urbanization, and economic growth are the drivers of carbon emissions in Bangladesh.

Islam et al. (2023) investigates the Environmental Kuznets Curve (EKC) hypothesis in Bangladesh using data from 1986 to 2014 and found that, in the long run, income has a very modest negative effect on the environment and pollution, and energy consumption is found to be a significant contributor to carbon dioxide emissions in Bangladesh, especially in the short run.

Faruq et al. (2024) examines the EKC hypothesis for Bangladesh between 1974 and 2018. This research found evidence of a long-term association among per capita CO2 emissions, per capita GDP, energy consumption, and financial development.

Insights from the previously mentioned empirical literature suggest disagreement about the impact of GDP growth, industrialization, and energy consumption on CO2 emissions in Bangladesh. To bridge the gap in the literature, this study aims to investigate the short- and long-run effects of industrialization, energy consumption, and GDP growth on carbon emissions in Bangladesh during the period 19974 to 2019.

3. Data, Model and Methodology

3.1 Data

This study uses yearly time-series data from 1974 to 2019. The relevant data, such as industry value added (constant 2015 USD) used as a proxy of industrialization, per capita GDP (constant 2015 USD) used as a proxy of economic growth, per capita energy use (KWH), is used as energy consumption, and CO_2 emissions per capita are used as carbon emissions. The data used in this paper are drawn from several sources, including the World Development Indicators (WDI) of the World Bank, Our World in Data, the Emission Database for Global Atmospheric Research (EDGAR), and the International Energy Agency (IEA) Statistics.

3.2 Model

There are several studies examining the impact of industrialization, GDP growth, and energy use on carbon dioxide emissions at the country, regional, and global levels. This study employs the following linear model based on existing literature, such as Rahman & Kashem (2017) and Shahbaz et al. (2014) where carbon emission is a function of industrialization, energy use, and GDP growth:

$$CO_{2t} = f(ind_t, eng_t, gdp_t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where, CO_{2t} is carbon emission per capita, ind_t is industrialization (industry value added), eng_t is energy use per capita and gdp_t is per capita GDP. The mathematical form of equation (1) can be written in the following form:

By taking the logarithm for all variables used in the model can be written in the following form:

$$CO_{2t} = \alpha_0 + \alpha_1 ind_t + \alpha_2 eng_t + \alpha_3 gdp_t + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

All variables are transformed to natural logarithms for analysis of the estimated parameter.

$$lnco_{2t} = \beta_0 + \beta_1 lnind_t + \beta_2 lneng_t + \beta_3 lngdp_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

ARDL representation suggested by Pesaran et al. (2001), the equation (3) is as follows:

$$\Delta lnco_{2t} = \alpha_0 + \sum_{i=1}^{p} \beta_{1i} \Delta lnco_{2t-i} + \sum_{i=0}^{q} \beta_{2i} \Delta lnind_{t-i} + \sum_{i=0}^{r} \beta_{3i} \Delta lneng_{t-i} + \sum_{i=0}^{m} \beta_{4i} \Delta lngdp_{t-i} + \beta_5 lnco_{2t-1} + \beta_6 lnind_{t-1} + \beta_7 lneng_{t-1} + \beta_8 lngdp_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The error correction form of equation (4) is as follows:

$$\Delta lnco_{2t} = \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta lnco_{2t-i} + \sum_{i=0}^{q} \beta_{2i} \Delta lnind_{t-i} + \sum_{i=0}^{r} \beta_{3i} \Delta lneng_{t-i} + \sum_{i=0}^{m} \beta_{4i} \Delta lngdp_{t-i} + \gamma ecm_{t-1} + \epsilon_t \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

3.3 Estimation Strategy

This study used time-series data to investigate the impact of industrialization, energy use, and GDP growth on carbon emissions in Bangladesh. It is widely recognized that financial time series data are non-stationary. Therefore, it is necessary to test the data for stationarity. Firstly, this study tests the stationarity of the variables, including the log of carbon emissions (lnCO2), the log of industrialization (lnind), the log of energy use (lneng), and the log of GDP (lngdp), to avoid spurious regression. To test for stationarity, this paper employed the ADF test (Dickey & Fuller, 1979) and the PP test (Phillips & Perron, 1988). Secondly, based on the results of stationarity testing, this study employed the Auto Regressive Distributed Lag (ARDL) model proposed by Pesaran et al. (2001). Thirdly, to test whether the variables are co-integrated or not in the long run, the ARDL bound test approach is used.

3.4 The ARDL Model Estimation Process

Step 1: Check the stationarity of the variables such as lnCO2, lnind, lneng, and lngdp by using the ADF and PP tests.

Step 2: as some of the variables are I(0) and some are I(1), which allows us to estimate the ARDL model.

Step 3: Select the optimal lag for the ARDL model.

Step 4: Based on the optimal lag, the best ARDL model is selected.

Step 5: Test for cointegration among the model's variables using the ARDL bound test.

Step 6: If the variables are cointegrated, estimate the short-run and long-run parameters.

Step 7: check several diagnostic tests for heteroskedasticity (Breusch-Pagan-Godfrey test), serial correlation (Breusch-Godfrey LM test), normality (J-B test), and stability (CUSUM and CUSUM of squares test).

This study uses the ARDL model due to several advantages. Firstly, this approach is a well-suited method when the variables have mixed orders of integration, especially, I(0) or I(1). Additionally, this method is appropriate and provides a more precise estimate for small samples.

4. Estimation Results

4.1 Graphical Representations of the Data

To understand the features of the time series data, such as the presence and direction of trends, structural breaks, and stationarity, the primary step is to inspect the graphical presentation of the data. The graphical presentation of the variables lnind, lngdp, lnco2, and lneng is shown in Figure 2. It is evident from Figure 2 that each variable has an intercept and a deterministic trend.

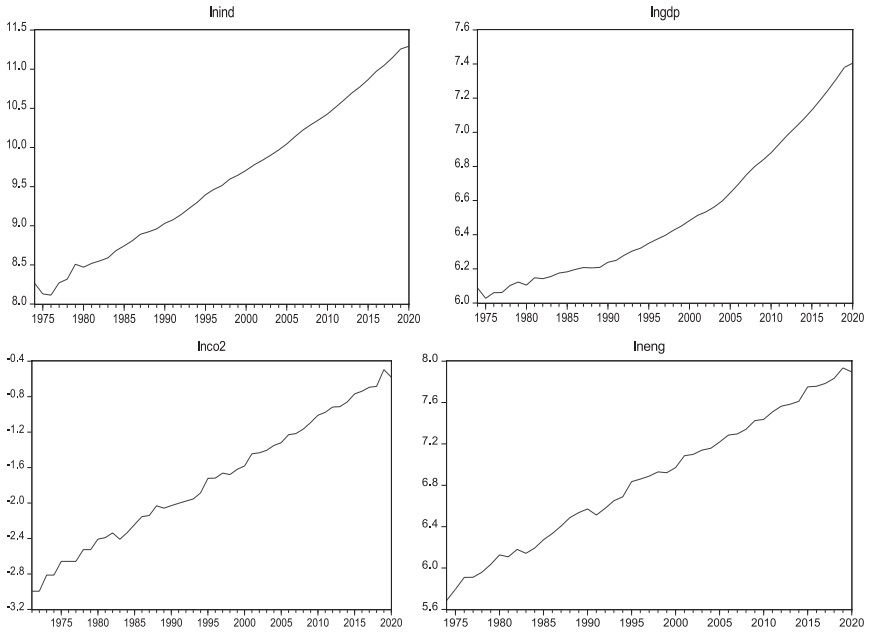

Figure 2. Graphical Representation of the Data

4.2 Unit Root Test Results

The ADF unit root test results are presented in Table 2. The unit root test results indicate that the variables, such as carbon emissions and energy use, are I(0) stationary at the level, while industrialization and GDP variables are I(1) stationary at their first difference. Similarly, the unit root test results for the PP test are reported in Table 3 and indicate the same specification as the ADF test. The variables carbon emissions and energy use are stationary at their levels, while the industrialization and GDP variables are stationary in first differences.

Table 2. Augmented Dicky-Fuller Unit Root Test Results

Variables	Model	Level	First Difference	Integration
$lnCO_2$	intercept & trend	-5.391*	…	I(0)
		[0.00]		
Lnind	intercept & trend	-1.998	-4.816*	I(1)
		[0.587]	[0.00]	
Lneng	intercept & trend	-4.930*	….	I(0)
		[0.00]		
Lngdp	intercept & trend	0.426	-13.463*	I(1)
		[0.99]	[0.00]	

* = significance at 1% level, P values are in parenthesis.

Table 3. Phillips-Perron Unit root test results

Variables	Model	Level	First Difference	Integration
$lnCO_2$	intercept & trend	-5.379*	…	I(0)
		[0.00]		
Lnind	intercept & trend	-1.633	31.209*	I(1)
		[0.764]	[0.00]	
Lneng	intercept & trend	-4.771*	….	I(0)
		[0.00]		
Lngdp	intercept & trend	1.123	12.623*	I(1)
		[0.99]	[0.00]	

* = significance at 1% level, P values are in parentheses.

The unit root test results reported in Tables 2 and 3 indicate that the variables in equation 3 have mixed integration orders. That's why the ARDL model is appropriate for examining the short and long-run relationships among the variables used in the study.

4.3 ARDL Bound Test Results

Table 4 presents the ARDL bound test results. The value of the F-statistic is 39.38, which is higher than the upper bound value of 4.66 at 1% level. The results of the F-Bound test indicate the presence of a long-run equilibrium relationship among the model's variables.

Table 4. The ARDL Bounds Test Results

F-Bounds Test		Null Hypothesis : No linear relationship		
Test Statistic	Value	Significance	I(0)	I(1)
F-statistic	39.38	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

4.4 Long-run Results

The long-run results are presented in Table 5. The results imply that the relationship between industrialization and carbon emissions is positive and significant at 5% level. The estimated coefficient for industrialization (lnind) is 0.19, implying that a 1% increase in industrialization would raise carbon emissions by 0.19%.

Table 5. Long-run Results

Dependent Variable: $lnCO_2$				
Independent Variables	Coefficient	Std. Error	t-Statistic	Prob.
lnind	0.198*	0.097	2.048	0.047
lneng	0.688*	0.100	6.875	0.000
lngdp	0.088	0.080	1.103	0.276
C	-8.839*	0.228	-38.779	0.000
* = significance at 1% level				

Moreover, the results also affirm the positive long-term relationship between energy consumption and carbon emissions. This result is significant at 1% level. The coefficient on energy consumption (lneng) is 0.69, implying that a 1% increase in energy consumption ultimately increases carbon emissions by 0.69%. This finding also reveals the pivotal role of energy sources in shaping environmental outcomes in Bangladesh. Furthermore, the coefficient on GDP is 0.09, which is positive and indicates that economic growth and carbon emissions are positively related. The positive coefficient indicates that economic growth may increase carbon dioxide emissions; however, the result is not statistically significant.

4.5 Short-run Results

The estimated short-run result is presented in Table 6. The ARDL (1,1,0,0) is selected as the best model based on the estimation results.

Table 6. Short-run Results

Dependent Variable: $lnCO_2$				
Independent Variables	Coefficient	Std. Error	t-Statistic	Prob.
C	-9.145	0.925	-9.887	0.000
lnind(-1)	0.205	0.105	1.963	0.057
lneng	0.712	0.121	5.898	0.000
lngdp	0.091	0.082	1.115	0.271
ECM_{t-1}	-1.035	0.070	-14.719	0.000

$ECM = lnCO_2 - (0.20*lnind + 0.69*lneng + 0.09*lngdp - 8.84)$

The short-run estimation results in Table 6 indicate that industrialization has a positive and significant impact on carbon emissions at the 10% level. Moreover, energy consumption has a positive and statistically significant (at 1% level)

impact on carbon emission in Bangladesh. On the other hand, economic growth has a positive impact on carbon emissions, but the effect is significant only overall. The value of the error correction term is 1.03, which is negative and greater than 1.0, and implies the oscillatory convergence to the long-run equilibrium (Narayan & Smyth, 2006).

4.6 Diagnostic Test Results

It is imperative to test the diagnostic tests to assess the model's validity. To do so, this study employed the Breusch-Pagan-Godfrey test for heteroscedasticity, the Breusch-Godfrey test for serial correlation, the J-B test for normality, and the CUSUM and CUSUM of square test for stability, and the results are presented in Table 7. The results of the heteroscedasticity test indicate that the model error is not significantly heteroscedastic and is therefore homoscedastic. The LM test indicates that there is no autocorrelation among the model's variables. The CUSUM and CUSUM of squares tests are used to assess the model's stability, and the results indicate that both are stable over the period.

Table 7. Diagnostic Test Results

Diagnostic Tests		
	Coefficients	Prob
Heteroskedasticity Test (Breusch-Pagan-Godfrey)	0.345	0.882
Serial Correlation LM Test (Breusch-Godfrey)	0.426	0.656
Normality Test (J-B)	0.216	0.897
Cusum test	Stable	
Cusum of square test	Stable	

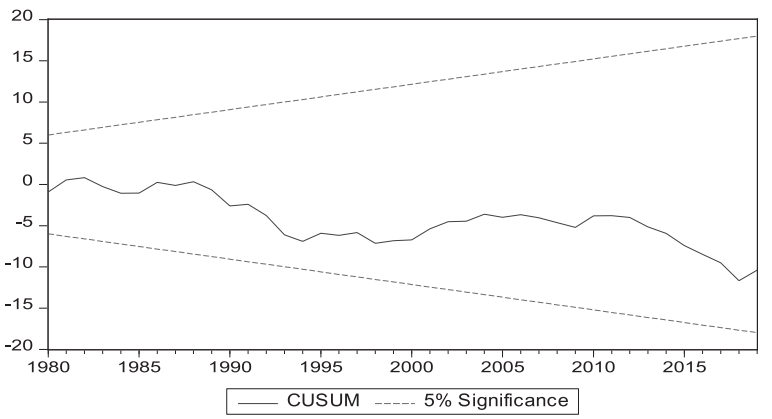

Figure 3.

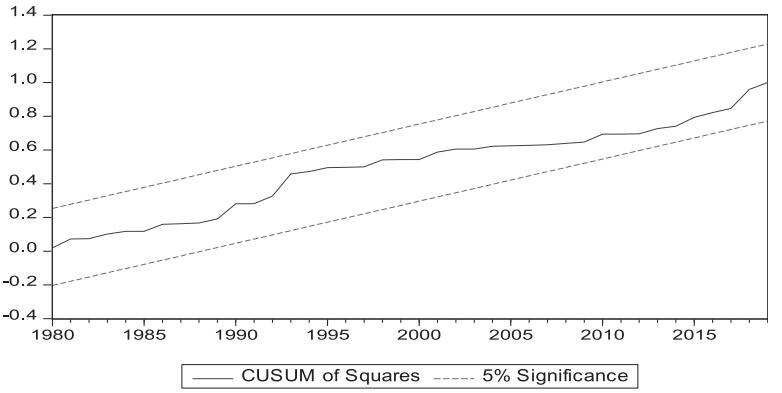

Figure 4.

5. Discussions

The short and long-run results indicate that the coefficient of industrialization is positive and significant. The coefficient on industrialization (lnind) is positive and significant, indicating that industrial production significantly worsens environmental quality, holding other factors constant. In the long run, a 1.0 percent increase in industrial output results in a 0.19 percent increase in carbon emissions in Bangladesh during the period under consideration. The reason is that over the last three decades, massive industrialization, especially the increasing number of RMG industries and leather industries, has increased in Bangladesh without consideration of environmental issues. Most RMG and leather factories lack effluent treatment plants and discharge waste into surrounding areas, causing significant environmental degradation near major cities such as Dhaka, Chattogram, Gazipur, and Narayangonj. Moreover, as the number of industries grows, the expansion of energy combustion plants comes at the expense of environmental quality. This finding is consistent with those of Murad et al. (2015), Alom et al. (2017), and Islam et al. (2017), but contradicts the finding of Amin et al. (2012) for Bangladesh.

The coefficients on energy consumption (lneng) in the short and long run are positive and significant at the 1% level. In the long run, the coefficient is 0.69, indicating that a 1.0 percent increase in CO2 emissions from energy consumption results in a 0.69 percent increase, while other factors remain constant. This finding implies that increased energy consumption leads to higher CO2 emissions. The finding is similar to the findings of Ahad & Khan (2016), Islam et al. (2017), Sharmin & Tareque (2018), Rahman et al. (2021) and Faruq et al. (2024). Moreover, the finding is supported by the fact that heavy reliance on fossil fuels for energy ultimately degraded environmental quality. Bangladesh's energy portfolio was over 99 percent fossil fuels, consisting of natural gas, oil, and coal in 2021 (BP Statistical Review of World Energy, 2022).

The coefficient of GDP growth (lnGDP) is positive in both the short and long run, but not significant. This finding is consistent with the findings of Amin et al. (2012) and Islam et al. (2017) but contradicts the findings of Shahbaz et al. (2014) and Sharmin & Tareque (2018) for Bangladesh. Economic activities in Bangladesh contribute to environmental degradation by using non-renewable energy sources such as gas, oil, and coal, thereby increasing CO2 emissions.

6. Conclusion and Policy Recommendations

This paper investigates the impact of industrialization, energy use, and economic growth on carbon emissions in Bangladesh between 1974 and 2019. To do so, this study employed the ARDL estimation strategy to examine the short- and long-run impacts of industrialization, energy use, and economic growth on carbon dioxide emissions. The results of this study reveal that the variables are co-integrated in the long run, with positive impacts of energy consumption and industrialization on carbon dioxide emissions. However, in the long run, economic growth has no impact on carbon dioxide emissions. These findings highlight the need for sustainable development strategies that account for the environmental impacts of industrialization, energy use, and economic growth in Bangladesh. Moreover, Bangladesh needs to implement measures to reduce CO2 emissions, such as promoting environmentally friendly industrial policies, adopting clean energy sources, and improving energy efficiency, to mitigate the negative environmental impacts of industrialization and energy use.

Given the detrimental effects of raw industrialization and energy use, the Government of Bangladesh should implement regulatory measures to mitigate environmental degradation. First, the government should mandate that all factories install and use effluent treatment plants and that none discharge untreated waste into the environment. Second, the government may encourage and offer incentives to industries to adopt energy-efficient technologies. Third, there is a need to reduce dependence on fossil fuels and to exploit renewable energy sources such as solar and wind power. Fourth, there is a need for comprehensive reform of Bangladesh's energy system to reduce fiscal spending and enhance efficiency. The existing energy subsidy mechanisms in Bangladesh incentivize inefficient and excessive energy consumption and also exacerbate the government's fiscal burden. Fifth, a sustainable, eco-friendly development model is required to ensure an energy mix and a more sustainable environment. Finally, to promote sustainable economic growth and strengthen energy security, regional cooperation and integration are necessary.

Special Notes: The views expressed here are the author's own and do not necessarily reflect the views of Bangladesh Bank.

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