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Does Energy Consumption, Economic Growth, and Foreign Direct Investment Contribute to CO_2 Emission? Evidence from Bangladesh

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Abstract
This work used the Johansen Cointegration Test and the Vector Error Correction Model (VECM) cointegration methodology to assess the long-run cointegrating relationship and short-run dynamics in Bangladesh between energy consumption economic growth, foreign direct investment, urbanization, population growth, and carbon emissions. To assess the long-term association between these variables, we examined data from 1972 to 2014, and empirical estimation revealed that all factors are significant at the 1% level of significance in the case of Bangladesh. Thus, energy consumption, economic growth, foreign direct investment, urbanization, population growth, and carbon emissions all have shown the predicted sign and are statistically significant, indicating that increased energy consumption, gross domestic product, and population increase all are responsible for increased carbon emissions in Bangladesh. Higher FDI inflows, on the other hand, cut per capita carbon emissions in Bangladesh. On the other hand, the empirical outcome has revealed that there is no substantial causal association between carbon emissions and urbanization.
Keywords: CO_2; FDI; GDP; population growth; energy consumption; VECM
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1. Introduction

Over the past several decades, the most critical global issues are air pollution and global warming. We considered carbon dioxide (CO_2) emissions as one of the major causes of these problems. Intergovernmental panels on Climate Change (IPCC) (2013) highlighted the role of CO_2 emissions in greenhouse gas (GHG) emissions. According to the research, CO_2 emissions account for around 76.7 percent of GHG emissions. Emerging nations aim to raise their national output and accelerate their development rates to improve their economic conditions. As a result, knowing the reasons for emerging nations' CO_2 emissions is critical for policymakers. According to the environmental Kuznets curve (EKC) hypothesis, economic growth and environmental pollution have a reversed U-shaped connection. According to this theory, environmental contamination rises in the early phases of economic development before declining in the later stages (Ozturk and Acaravci 2010). The association between environmental toxins and economic growth using the EKC hypothesis has been widely examined in the energy economics literature throughout the last era (e.g., Alam et al. 2016). However, there is a paucity of research on applying the EKC to nations with different characteristics such as energy consumption, population growth, urbanization, and foreign direct investments (FDI). Foreign direct investment (FDI) is critical to the economic progress of emerging nations that lack adequate resources to invest. FDI helps developing countries expand economically not just by providing cash but also by increasing productivity by transferring superior manufacturing technologies, management skills, and know-how to modernize the economy and foster innovation. FDI also offers new employment opportunities and promotes entrepreneurship and competitiveness, which are critical instruments for developing nations' rapid growth (Mallampally and Sauvant 1999; Hermes and Lensink 2003; Batten and Vo 2009; Reiter and Steensma 2010; Fernandes and Paunov 2012; Lee et al. 2013). FDI may have a variety of effects on CO_2 emissions and environmental degradation, and there have been continuing debates over the net impact of FDI on pollution. According to some studies, FDI contributes to environmental conservation. Being damaging FBI may be transmitted inefficient industrial technologies, which can assist countries in minimizing air pollution (Stretesky and Lynch 2009).

Many other researchers, on the other hand, think that FDI adds to air pollution. They claim that FDI boosts economic growth by improving productivity, which leads to increased energy consumption. Therefore, environmental contamination results from increased CO_2 emissions as a result of increased energy use. On the other hand, superior foreign technology can serve as a model for the technical growth of the local market through presentation, imitation, and other means. Therefore, we can also cut CO_2 emissions by employing this ecologically beneficial technology.

Furthermore, polluting companies may opt to invest in developing nations with lax environmental restrictions to reduce production costs, resulting in a rise in the country's energy consumption (Jensen 1996; Acharyya 2009; Lau, Choong, and Eng 2014). As a result, weak environmental restrictions that allow businesses to expand their CO_2 emissions may entice overseas investors, increasing FDI inflow. This link is formalized by the pollution haven hypothesis. The purpose of this study is to find out more about the long-term equilibrium link between CO_2 emissions, economic development, energy consumption, population increase, urbanization, and foreign direct investment in Bangladesh, which is an energy-dependent growing nation.

To our knowledge, many studies investigate the interactions between CO_2 emission, economic growth, and FDI in Bangladesh. But in our work, we try to include some more important variables like population growth and urbanization, which makes our work sounder. Many are using the ARDL approach; many are using the VECM approach depends on their variable. If all variable is stationary at level (I_0), then we use OLS. When all variables are stationary at the first difference (I_1), we use the cointegration test. If found cointegration, then we use the VECM approach. However, when we face some stationary variables at level (I_0), and some are stationary at the first difference (I_1), we use the ARDL bound testing approach. The following sections address empirical research from the literature.

2. Literature Review

When fossil fuels are burnt, carbon dioxide is released, which may contribute to long-term climate change, according to Stoker and Judson (1995), who used reduced-form models to forecast climate change through 2050 using national-level panel data from 1950 to 1990. They discovered an actual 'Inverse U' relationship between carbon dioxide emissions and energy consumption per capita and per capita income.

Using an updated and revised panel data set, Harbaugh, Levinson, and Wilson (2000) evaluated the sensitivity of the pollution–income connection to functional forms, new variables, and changes within nations, cities, and years. They also discovered that the results are pretty sensitive to such modifications, concluding that there is no empirical support in these data for an inverted U-shaped link between numerous significant air contaminants and national wealth.

ARDL (autoregressive distributed lag) bounds testing approach was used to assess cointegration, Hossain and Hasanuzzaman (2012) investigated the long-run cointegrating relationship and short-run dynamics among carbon emissions energy consumption, economic growth, urbanization, financial development, and trade openness in Bangladesh from 1975 to 2010. At a 1% significance level, the research claimed a long-run link between the variables in Bangladesh. Energy consumption and urbanization have a positive influence on CO_2 emissions per capita, whereas real GDP per capita has a negative influence, and financial development and trade openness have no effect.

Shahbaz et al. (2014, 2015) used the Zivot–Andrews unit root test and the ARDL limits testing strategy, as well as the VECM Granger causality methodology and the causal analysis' robustness, to investigate the links between economic growth, energy consumption, financial development, trade openness, and CO_2 emissions in Indonesia from 1975:Q1 to 2011:Q4. According to empirical research, economic expansion and energy use raise CO_2 emissions, but financial development and trade openness reduce them.

Using the Granger Causality Test and Variance Decomposition Analysis, Akhmat et al. (2014) investigated the causative link between energy consumption and environmental pollution for the chosen South Asian Association for Regional Cooperation (SAARC) nations from 1975 to 2011. These findings suggest that energy use is a major contributor to rising pollution levels in SAARC nations. Begum et al. (2014) used the ARDL Bound Test, DOLS Test, and SLM U test to look at the dynamic effects of GDP growth, energy consumption, and population expansion on CO_2 emissions in Malaysia from 1970 to 1980. The article found that per capita CO_2 emissions fell as per capita GDP (economic growth) grew; but, between 1980 and 2009, per capita CO_2 emissions climbed dramatically as per capita GDP climbed. The findings also show that per capita energy consumption and per capita GDP have a positive long-term influence on per capita carbon emissions. The population growth rate, on the other hand, had no substantial influence on CO_2 emissions per capita.

Dogan and Turkekul (2015) used limits testing for cointegration to analyze the link between carbon dioxide (CO_2) emissions, energy consumption, real output (GDP), the square of real output (GDP^2), trade openness, urbanization, and financial development in the United States from 1960 to 2010. They discovered that energy use and urbanization contribute to environmental damage in the long run. At the same time, it was unaffected by financial development, and commerce led to environmental benefits. The creation of appropriate energy policy is expected to lead to decreased CO_2 emissions while having no negative impact on actual production. CO_2 emissions, energy consumption, economic development, and foreign direct investment (FDI) are all used as factors, Gokmenoglu & Taspinar (2015) explored the applicability of the environmental Kuznets curve (EKC) hypothesis in Turkey over the period 1974–2010 using the ARDL bound test and Toda–Yamamoto causality test. They discovered that the contribution of energy consumption, economic growth, and FDI causes CO_2 emissions to converge to their long-run equilibrium level at a 49.2 percent annual rate of adjustment.

Azam (2016) used classic panel estimate approaches covering fixed and random factors, as well as the results of Hausman's test, to study the influence of environmental degradation caused by CO_2 emissions on economic development in 11 Asian nations between 1990 and 2011. Due to the nature of the data, classic panel estimation approaches covering fixed and random effects were used. Environmental deterioration has a considerable detrimental influence on economic growth, according to empirical evidence, which is why he believes it should be regulated.

Khobai & Roux (2017) used yearly data from 1971 to 2013 to study the link between energy consumption, carbon dioxide (CO_2) emissions, economic development, trade openness, and urbanization in South Africa. According to Johansen's cointegration test, there is a long-run link in South Africa between energy consumption, CO_2 emissions, economic development, trade openness, and urbanization. The VECM findings also revealed a unidirectional causation running from CO_2 emissions, economic growth, trade openness, and urbanization to energy consumption, as well as a unidirectional causation running from CO_2 emissions, economic growth, trade openness, and urbanization to economic growth. Rahman and Kashem (2017) used the ARDL Bounds Testing technique and the Granger Causality test in an enhanced VAR framework to investigate the empirical cointegration, long and short-run dynamics, and causal linkages between carbon emissions, energy consumption, and industrial growth in Bangladesh from 1972 to 2011. The findings reveal that, both in the short and long term, industrial production and energy consumption have a major positive influence on carbon emissions. That is to say, Bangladesh's industrial or economic growth is occurring at the expense of environmental quality.

3. Data and Methodology

3.1 Data

This study used Time series data from 1972 to 2014, derived from the World Bank's 2019 World Development Indicators dataset. We take data from 1972-2014 because our dependent variable available only till 2014. The vector of variables included Carbon Dioxide (CO_2) emission (metric tons per capita), Gross Domestic Product (GDP) (constant 2010 US$), Energy (ENG) use (kg of oil equivalent per capita). Foreign direct investment (FDI), net inflows (% of GDP), Population growth (POPG) (annual %) and Urban population (UR) (% of total population). ENG, FDI, POPG, UR were included as control variables.

Every variable was in its natural log form. The estimates and analysis were carried out using the statistical program E-views 10.

3.2 Methodology

We analyzed the interaction between CO_2 emissions, FDI, GDP, population growth, and urbanization in Bangladesh using a time-series approach with the vector autoregressive regression. . Our study differs remarkably from the previous work running the unit root and cointegration tests. It also argues from the position mentioned above that it ignores structural changes in the series, whereas our research employed various variables and case studies. The following is a functional representation of the link between CO_2 emissions, economic growth, energy consumption, FDI, population growth, and urban population:

$$\ln CO_{2,t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln ENG_t + \beta_3 \ln FDI_t + \beta_4 \ln POPG_t + \beta_5 \ln UR_t + \varepsilon_t \quad (1)$$

Where, $\ln CO_{2,t}, \ln GDP_t, \ln ENG_t, \ln FDI_t, \ln POPG_t, and \ \ln UR_t$ are the logarithmic forms of CO_2 emissions, gross domestic product, energy consumption, foreign direct investment, population growth, and urban population, respectively.

We have further used the Breusch-Godfrey LM test for serial correlation and the Jarque-Bera test for the normality assumption of residuals for our model specification. Therefore, to avoid spurious correlation among variables of interest, which would affect our results and conventional statistical inference, the first concern is determining whether the time series for the variables used are cointegrated processes. In this respect, the following section will describe the unit root tests and then cointegration tests.

4. Econometric Tests

4.1 Unit root tests

A fundamental unit root attribute exists for most macroeconomic time series variables (Nelson and Plosser 1982). So, using the Augmented Dickey-Fuller (ADF) test, the initial step would have been to examine the variability of the mean and variance of the variables across time (Dickey and Fuller 1979). Cointegration tests would then be performed once all variables had been integrated into the same sequence (Engle and Granger 1991).

4.2 Vector Error Correction Model

If there is at least one cointegration equation between the exogenous and endogenous variables, it would be applied vector error correction model. The restricted, generalized least squares (GLS) approach depicts both long-run and short-run dynamic relationships. These constraints are put in place to ensure accuracy and a more reliable estimate. The following is a representation of the model:

$$\Delta \ln CO_{2,t} = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta \ln CO_{2,t-i} + \sum_{i=0}^{n} \delta_i \Delta \ln GDP_{t-i} + \sum_{i=0}^{n} \gamma_i \Delta \ln ENG_{t-i} + \sum_{i=0}^{n} \eta_i \Delta \ln FDI_{t-i} + \sum_{i=0}^{n} \alpha_i \Delta \ln POPG_{t-i} + \sum_{i=0}^{n} \tau_i \Delta \ln UR_{t-i} + \varphi z_{t-1} + \varepsilon_t \quad (2)$$

The OLS residuals from the following long-run cointegrating regression are represented by z, which is the error correction term.

$$\ln CO_{2,t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 \ln ENG_t + \beta_3 \ln FDI_t + \beta_4 \ln POPG_t + \beta_5 \ln UR_t + \varepsilon_t \quad (3)$$

and is define as,

$$Z_{t-1} = ECT_{t-1} = \ln CO_{2,t} - \beta_0 - \beta_1 \ln GDP_t - \beta_2 \ln ENG_t - \beta_3 \ln FDI_t - \beta_4 \ln POPG_t - \beta_5 \ln UR_t \quad (4)$$

Here, ε_t is the white noise stochastic disturbance term in this model, with as the differencing notation. The phrase "error correction" refers to how the past period's divergence from long-run equilibrium (the error) affects the dependent variables' short-run dynamics. The speed of adjustment is measured by the coefficient of ECT, which indicates how quickly Y recovers to equilibrium after a change in X. The calculated model's suitability was verified using residual analysis, particularly for serial correlation and normalcy assumptions.

5. Empirical analysis of estimated results

A unit root test was conducted according to Elliot et al. (1992), Hatanaka (1996), and Gujarati et al. (2017). The summary of the test results is presented in Table 1. Here, at the level, the absolute value of ADF test statistics of all variables is less than the absolute value of a 5% critical level. And also, their p-values are more significant than the 0.05 significance level, which indicates the not rejection of the null hypothesis of an existing unit root.

Table 1. Unit root test including intercept term

Source: Calculated using E-views 10, Null Hypothesis: Variable has a unit root. *Lag length is automatic

Variable's Name	At Level				At First Difference			
	Lag Length*	ADF Test statistic	5% Critical Value	Prob**	Lag length*	ADF Test statistic	5% Critical Value	Prob**
$\ln CO_2$	1	-0.3706	-2.935	0.9048	0	-9.626	-2.935	0.0000
$\ln GDP$	0	2.624450	-2.933	1.0000	0	-7.590	-2.935	0.0000
$\ln ENG$	1	2.227156	-2.935	0.9999	0	-8.334	-2.935	0.0000
$\ln FDI$	0	-2.0550	-2.933	0.2633	0	-8.119	-2.935	0.0000
$\ln POPG$	2	0.755960	-2.9369	0.9919	1	-5.304	-2.937	0.0001
$\ln UR$	3	-4.0837	-2.9390	0.0987	2	-4.252	-2.939	0.0018

based on SIC, max lag=9** Mackinnon (1991) one-sided p values

Again, the absolute value of all variables' ADF test statistics is significantly larger than the absolute value of a 5% critical threshold, and their p-values are less than the 0.05 significance threshold, indicating rejection of the null hypothesis of an existent unit root. Furthermore, all variables had a unit root at the levels (before taking the first differences), but they became stationary after taking the first differences. As a result, all variables are included in order 1 (I_1). This suggests that we need to look for cointegration connections between the variables. The cointegration test results (Table 2) show that there is just one cointegrating relation in the equation. The Akaike Information Criterion (AIC) was used to determine the lag duration, which was lag 3.

Table 2. Johansen cointegration test: unrestricted cointegration rank test (Trace)

Hypothesized No. of C.E. (s)	Eigenvalue	Trace Statistic	0.05 C.V.	Prob.**
None *	0.956291	244.2471	95.75366	0.0000
At most 1 *	0.774195	122.1690	69.81889	0.0000
At most 2 *	0.495297	64.13374	47.85613	0.0007
At most 3 *	0.449858	37.46615	29.79707	0.0054
At most 4	0.198927	14.16056	15.49471	0.0786
At most 5 *	0.131761	5.510234	3.841466	0.0189

Source: Calculation by E-views 10, Trace test indicates four cointegration equations at the 0.05 level, and the

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Max-eigenvalue test indicates two cointegrating equations at the 0.05 level *denotes rejection of the null hypothesis of existing cointegration. **Mackinnon (1991) p-values Lag Intervals at the first difference: 1-3.

5.1 Estimation of applying the VECM

After establishing a single cointegration connection among the variables, a VECM was calculated for the 1972–2014 sample period using rank r = 1 and three lagged differences. The Akaike Information Criterion was used to calculate all lag durations by minimizing the information criterion (AIC). Table 3 shows the estimated long-run cointegration relationship.

Table 3. Estimated long-run cointegration vector

$\ln CO_{2,t-1}$	$\ln GDP_{t-1}$	$\ln ENG_{t-1}$	$\ln FDI_{t-1}$	$\ln POPG_{t-1}$	$\ln UR_{t-1}$	C
1.000000	-1.3261	-1.1246	0.0439	-1.0449	0.12601	40.45973
	(0.16272)	(0.33236)	(0.00602)	(0.10290)	(0.17651)	
	{-8.1490}	{-3.3838}	{7.2885}	{-10.154}	{0.71397}	
	[2.787]	[2.787]	[2.787]	[2.787]	[2.787]	

Source: Calculation by E-views 10

Coefficients indicate significance at the 1% level. Figures in ( ) show standard errors, { } show the t-statistics and [ ] show the critical values at 1% level of significance. The null hypothesis of the zero coefficient will be rejected if the condition of $t_{calculated} > t_{critical}$ is fulfilled.

From Table 3, our long-run regression equation is:

$$\ln CO_{2,t-1} = -40.46 + 1.33\ln\mathrm{GDP}_{t-1} + 1.12ENG_{t-1} - 0.04FDI_{t-1} + 1.04POPG_{t-1} - 0.13\ln UR_{t-1} \quad (5)$$

As observed in Table 3, the coefficient of the first variable is normalized to unity. Estimates of the error correction model in the above equation show that gross domestic product is significant in increasing CO_2 emission. Energy consumption rises CO_2 emission, foreign direct investment decreases CO_2 emission, but population growth increases CO_2 emission. Here the urban population is insignificant; that is why we gave up this variable from our model. Where in a frictional condition, GDP, ENG, POPG leads to an environmental hazard. Their significance is not negligible at about 1.33%, 1.12%, and 1.04%, respectively, increasing CO_2 emission.

This means that any deviation from the long-run equilibrium does not affect reversing the equilibrium connection for these two variables. As a result, the single open variable in the equation can react to bring the system back into equilibrium. Table 4 shows the estimations for the loading matrix.

Table 4. Speed of adjustment coefficients (1972–2014)

	Coefficient	Standard. Error	t-statistic	Prob.
C (1) *	-1.296696	0.291393	-4.449996	0.0003
C (2)	0.144129	0.229907	0.626903	0.5382
C (3)	-0.045225	0.217432	-0.207998	0.8374
C (4)	0.034776	0.173138	0.200859	0.8429
C (5)	-0.112675	1.506353	-0.074800	0.9412
C (6)	0.401889	1.339224	0.300091	0.7674
C (7)	0.371946	1.155913	0.321776	0.7511
C (8)	0.178566	1.094970	0.163079	0.8722
C (9)	-1.095745	1.050187	-1.043381	0.3099
C (10)	0.043505	0.923711	0.047098	0.9629
C (11) ***	0.043808	0.025320	1.730196	0.0998
C (12) ***	0.039529	0.020249	1.952155	0.0658
C (13)	0.031673	0.020777	1.524453	0.1439
C (14)	-1.083574	1.777570	-0.609581	0.5494
C (15)	3.765066	2.607850	1.443743	0.1651
C (16) **	-3.010729	1.367323	-2.201914	0.0402
C (17) *	1.881220	0.545496	3.448644	0.0027
C (18)	0.915037	0.547681	1.670748	0.1112
C (19) *	1.758240	0.669785	2.625082	0.0167
C (20)	-0.146048	0.116911	-1.249231	0.2268

Source: Calculation by E-views 10, the test statistics are significant if p values are less than 0.01 (*) or less than 0.05 (**) or less than 0.10 (***)

Where, C (1) is the error correction term, which is both negative and vital in this case. The negative value indicates that the short-term shock is restoring equilibrium at a rate of 129.67 percent. It also means that returning to the equilibrium level will take less than a year.

5.2 Analysis of Diagnostic tests

Here, we have conducted three residual diagnostics such as normality assumption, serial correlation, and Heteroskedasticity Test for the adequacy of the model. The Jarque-Bera test for residual normality assumes that the test statistics cannot be rejected since the P-value is substantially larger than 0.10. In this case, the Null Hypothesis says that the residuals are normally distributed. As a result, residuals in our model are normally distributed. The chi-square test statistics show a higher significant p-value than 0.05 levels in the Breush-Godfrey Serial Correlation LM test. As a result, the null hypothesis that no serial correlation exists cannot be discarded. It implies that in our model, there is no serial correlation. Here, lag is three taken as the AIC criteria. Finally, in Heteroskedasticity Test by ARCH, the chi-square test statistics have a more significant p-value than 0.05 levels. That means the null hypothesis that there is no Heteroskedasticity cannot be rejected. All the test results are given in Table 5. So, from Table 5 results, our model is adequate and specified.

Table 5. Tests for model adequacy

Theory	Name of the Test	Null Hypothesis H0	Test Statistic	Prob.	Decisions
Normality Assumption of Residuals	Jarque-Bera test	Residuals are normally distributed	0.0529	0.768	H_0 cannot be rejected at 1%, 5% and 10% level of significance
Serial Correlation	Breusch-Godfrey Serial Correlation LM test (lag 3)	There is no serial correlation	1.3010	0.087	H_0 cannot be rejected at 1%, 5% level of significance
Heteroskeda sticity	ARCH test (lag 3)	There is no Heteroskedasticity	1.6292	0.19	H_0 cannot be rejected at 1%, 5% and 10% level of significance

Source: Calculated by E-views 10

5.3 Findings and Recommendations

The findings show that lnFDI has a statistically significant negative impact on CO_2 emissions. Economic growth, on the other hand, has a statistically significant and beneficial influence on CO_2 emissions over time. Thus, in the long term, lnENG reduces CO_2 emissions in a positive and statistically meaningful way. To put it another way, rising GDP and more energy use result in higher levels of air pollution in Bangladesh. Furthermore, Population growth is the source of CO_2 emissions.

Global warming, climate change, and environmental concerns are becoming more prevalent in the South Asian area. And this mainly includes sea-level rise, deforestation, soil erosion, desertification, droughts, storms, cyclones, floods, glacier melt and subsequent glacial lake outburst floods, and urban pollution. Moreover, as we can see with increasing GDP, our carbon dioxide emissions are rising, so the government should import environmentally friendly machinery that means technological progress, which will reduce carbon dioxide emissions (Lee et al. 2013).

6. Conclusion

For the period 1972–2014, the interaction between carbon emissions, economic growth, energy consumption, population growth, urban population, and foreign direct investment in Bangladesh is explored. The Vector Error Correction Model (VECM) mechanism confirms the long-run equilibrium relationship between the variables examined. According to the error correction term due to the contribution of independent variables in the model, the low levels of CO_2 emissions converge to their long-run equilibrium level at a 129.67 percent speed of adjustment per year. Economic development, energy consumption, population expansion, and foreign direct investment are all long-term predictors of air pollution in Bangladesh, according to this finding.

Disclosure statement

There were no possible conflicts of interest revealed by the authors.

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