



IS ENVIRONMENTAL KUZNETS HYPOTHESIS VICE-VERSA FOR BANGLADESH ESPECIALLY IN THE TIMES OF GLOBAL CLIMATE CHANGE? – AN ARDL ECONOMETRIC MODELING APPROACH



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ABSTRACT

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The relationship between economic growth and environmental degradation has been one of the most studied topics especially in developing countries around the world. This paper intends to investigate whether the Environmental Kuznets Hypothesis holds for Bangladesh when the country is experiencing a phenomenal rate of economic growth amidst global climate challenges. By exploiting the data from 1981 to 2019 for Bangladesh, a developing country highly vulnerable to the threats posted by the recent global climate changes, the integration between CO₂ emission and economic development has been explored and the validity of the Kuznets hypothesis has been checked through the lens of an Autoregressive Distributed Lag (ARDL) bound test process. The findings ascertain that there is a positive relationship between environmental degradation and economic growth of Bangladesh which represents a vice-versa trend in terms of Kuznets hypothesis. An increase in one kiloton of CO₂ emission leads the growth of GDP by 0.016 per cent. Furthermore, the study also lists some of the policy approaches to help prepare Bangladesh to confront the impending consequences from climate changes and to promote environment friendly economic development.

Contribution/ Originality: This study contributes to the existing works of literature by checking the relevance of Kuznets hypothesis and researching the trends of relationship between CO₂ emission and economic growth by using a different econometric approach specifically in the context of Bangladesh. Another important contribution is the proposed policy guidelines which can be very useful for appropriate policy formulation.

1. INTRODUCTION

Countries around the world especially the emerging economies are continuously facing the challenges from global climate change while focusing on achieving economic growth. In recent years, Bangladesh, one of the South Asian growing economies, has achieved lower middle-income status and will soon graduate from Least Developed Countries (LDCs) as the country is in the middle of its grace period before LDC graduation. There are several factors that have led majority of the developing countries to use natural resources more and more such as growing industrialization, increasing reliance on trade of industrial goods and rising demand of industrial products arising from global population growth. As a results, there has been an acceleration in the use of environmental resources and degradation of environmental quality.

Given this overdependence on environment, Bangladesh has a herculean task ahead specifically for achieving Sustainable Development Goals (SDGs) by 2030. A number of countries around the world are going for appropriate

policies that are initiated by both public and private sectors for upgrading environmental status and reducing pollutions. Nevertheless, the importance of social awareness, environmental education and moral behavior is undeniable (Xia, Abbas, Mohsin, & Song, 2020). Many developed countries around globe have taken some notable measures to curb Carbon dioxide (CO₂) emission and dissociate the economic development process from extensive use of Carbon dioxide (CO₂). With a view to achieving this environment friendly targets, many of these countries have opted for some substantial institutional revolutions such as emphasizing on the use of renewable energy, facilitating investment in this sector, compliance with worldwide environmental standard, increasing financial support for environmental quality assurance, disseminating environmental education, appropriate taxation methods and encouraging people to use environment friendly goods (Nair, Arvin, Pradhan, & Bahmani, 2021).

For the abovementioned reasons, the necessity of studying the relationship between Carbon dioxide (CO₂) emission and economic growth has gained much attraction these days. While studying the correlation between these two, checking the application of Environmental Kuznets Curve (EKC) hypothesis is very crucial especially for developing economies because it helps the concerned authorities better understand the impacts of the policies already administered and work accordingly (Narayan & Narayan, 2010). As a result, the outcome of this research might assist the appropriate policymakers of Bangladesh to formulate most effectual strategies which can help the country to achieve both short- and long-term goals in environment friendly ways. In recent times, Environmental Kuznets Curve (EKC) hypothesis has been employed to study sustainability and human development and it is found that EKC hypothesis, along with other crucial factors, contributes significantly to effective environmental policymaking approaches (Farhani, Mrizak, Chaibi, & Rault, 2014). Some studies have also been conducted to test EKC hypothesis in few least developed, developing and developed countries found a statistically significant negative relationship between environmental quality and economic growth. As far as the results are concerned, the validity of EKC hypothesis depends upon the economic status of a country- it differs according to the income level of a country (Azam & Khan, 2016).

Nevertheless, the scenario for smaller emerging countries has remained understudied especially in Southeast Asian countries like Bangladesh. Therefore, to fill this substantial research gap, this paper intends to study the effects of CO₂ emission on economic performance of Bangladesh and to check the validity of Environmental Kuznets Curve (EKC) hypothesis in context of this country.

1.1. Objectives

1. To test whether Environmental Kuznets Curve (EKC) hypothesis holds for Bangladesh.
2. To find the effects of rising CO₂ emission on the Gross Domestic Product (GDP) of Bangladesh.
3. To propose some appropriate policies those are helpful for the economic growth of Bangladesh in this time of climate change.

Following this introduction, the other parts of the paper are arranged as follows. Section 2 discusses both empirical and theoretical literature extensively, whereas section 3 and 4 cover data and methodology respectively which incorporate method, materials and estimation procedures. The results are displayed and analyzed in section 5. This paper proposes some policy recommendations in section 6.

2. LITERATURE REVIEW

The correlation between Carbon dioxide (CO₂) emission and economic growth has been investigated extensively in recent times. Most of the results in existing literature represent that to have an increasing level of economic growth, countries around the world have raised the use of Carbon dioxide (CO₂) which in turn fuels global warming and causes climate change (Ameyaw & Yao, 2018). Some developed economies, with strong institutional reforms, have been able to find other potential energy sources but the scenario is different for developing countries because in most of the cases their economic growth is reliant on the use of fossil fuels which is responsible for

environmental degradation (Nair et al., 2021). Economic growth and emission of greenhouse gasses are positively related though increasing the use of greenhouse gasses has dire consequences for the environment (Mohsin, Kamran, Nawaz, Hussain, & Dahri, 2021). Studying the effects of GDP on CO₂ emission in some West African countries, it is found that there exists a positive correlation between these two. Depending on the results, it is predicted that to reach environmental goals, forecasting future CO₂ emission level consistent with future consumption level and using appropriate energy policies are very critical for these countries (Ameyaw & Yao, 2018). Additionally, Anwar, Younis, and Ullah (2020) examined the primary factors responsible for CO₂ emission in some Far East countries and found that growth of cities, economic boom and promotion of free trade largely dictate CO₂ emission in these countries. Chen and Huang (2013) applied panel unit roots, cointegration in heterogeneous panel and panel causality test to study the relationship between per capita CO₂ emission and economic growth. The results showed that there is a positive long run relationship between these two. There also exists a bi-directional causality between CO₂ emission and electricity consumption. The relationship status between CO₂ emission and economic growth is different in emerging economies from what persists in developed countries. To understand this difference it is crucial to know the essence of Environmental Okun's Law that actually represents a cyclical relation between emissions and real Gross Domestic Product (GDP) (Cohen, Jalles, Loungani, & Marto, 2017). Employing the concept of global supply chain and using data from forty developed and developing countries over the time period of fourteen years to find the factors working behind increasing CO₂ emission, De Vries and Ferrarini (2017) found that surging domestic consumption is mainly responsible for high level of CO₂ emission in both types of countries. Fakhri, Hassen, and Wassim (2015) examined the effects of CO₂ emissions on per capita growth and other things like energy use and life expectancy in both short run and long run in some Middle East and North Africa MENA countries. Their findings showed that, in short run for all countries, CO₂ emission is unidirectional to energy usage but it is negatively associated to life expectancy and substantially negatively related to per capita GDP while, in the long run, most of the economic strategies are dependent on environment friendly activities. A working paper by Haas and Popov (2019) revealed that countries that follow two different ways- stock market based investment for reducing environmental pollutions and use of carbon intensive strategies have comparatively lower per capita CO₂ emission if these economies tend to be equity-funded. Nosheen, Iqbal, and Khan (2021) applied unconventional unit root tests- Covariate Augmented Dickey Fuller CADF and Cross-Sectionally Augmented IPS Test for Unit Roots CIPS, Environmental Kuznets Curve (EKC) framework along with Linear Model LM bootstrap panel cointegration test to measure the impact of GDP, tourism, usage of energy, domestic and international trade, improvement in financial services and development of cities on CO₂ emission for some Asian countries using the data from 1995 to 2017. According to the results they found, tourism development is the key factor responsible for environmental pollution. What is more, other factors such as trade, energy consumption, introduction of advanced financial system and urbanization have significantly negative effects on the environment in these Asian countries. That is why, all these economies should promote use of renewable energy sources and adopt strategies that help improve environmental quality.

A number of studies have analyzed the association between CO₂ emission and economic growth by using EKC framework which asserts that countries, at the initial stage of economic growth, generally sacrifice environmental quality for achieving economic goals that means per capita income whereas environmental degradation go towards same direction initially but after a certain period when these economies achieve a lot in terms of GDP they pay attention to environmental quality and reduce pollutions (Kuznets, 1955). The inverted 'U' hypothesis is validated as it is evident from a study by Aye and Edoja (2017) where they employed dynamic panel threshold framework by considering data from 31 developing countries. In contrast, another study by Alam (2014) found that EKC hypothesis does not hold for Bangladesh. This paper examined the dynamics of economic growth and CO₂ emission with GDP per capita in Bangladesh using World Bank data from 1972 to 2010. The primary result of this paper indicates that recent transition from agriculture to industry and tendency to shift towards services are key factors

behind the surging level of CO₂ emission. Furthermore, there are few studies that utilized the data of exports, imports and power consumption while analyzing the correlation between CO₂ emission and economic growth. One of these papers by Bouznit and Pablo-Romero Gil-Delgado (2016) showed, by applying Autoregressive Distributive Lag (ARDL) model, that one of the CO₂ emitting African countries Algeria needs to sacrifice economic growth in order to achieve the target of reduction in CO₂ emission.

The relationship between economic growth, allocation of income and environmental change propelled by CO₂ emission is explained by Rezai, Taylor, and Foley (2018) where they employed Keynesian aggregate demand structure labor productivity growth framework to measure the impacts of climate change. The study estimates that environmental degradation imposed by the extensive use of greenhouse gas fuels to reduce profitability, discourage investment, and curtail output both in short run and long run. In short run, employment goes down because of demand deficiency while, in the long run, growth of income is affected negatively due to sloppy growth of productivity. CO₂ emission has also adverse effects on agricultural production-both traded and non-traded agricultural goods and household welfare but livestock remains unaffected (Mulatu, Eshete, & Gatiso, 2016). Using Computable General Equilibrium (CGE) model, this paper also finds that among the affected households, low-income households of the village areas are more sensitive to this environmental change. Schröder and Storm (2020) undertook a study by using transparent kaya identity and Carbon-Kuznets-Curve framework to investigate the suitability of the reduction of CO₂ emission with a view to limiting global warming. The finding of the study from panel data regression represent that it is possible to restrict projected global warming, but it has to be done at the cost of economic growth, relying on the successful delinking of economic growth from CO₂ emission.

3. DATA

In this study, the data for the time series investigation has been considered from the year 1980 to 2019 (40 years). This analysis incorporates growth of gross domestic product (GDP growth) which is denoted by "*g*" and the carbon emission kiloton is converted by log transformation which is demonstrated in this paper by "*lcekt*". The general statistical features of the time series data are portrayed in Table 1.

Table 1. Statistical properties.

Name of Statistics	Name of Series	
	<i>g</i>	<i>lcekt</i>
Mean	5.14	10.22
Median	5.15	10.19
Maximum	8.15	11.60
Minimum	0.82	8.94
Std. Dev.	1.61	0.80
Skewness	-0.39	0.02
Kurtosis	3.00	1.76
Jarque-Bera	1.03	2.58
Probability	0.60	0.27
Observations	40	40

Table 1 demonstrates the statistical description of the series "*g*" (growth of GDP) and "*lcekt*" (log of carbon emission kiloton) respectively. The mean (maximum) value of the GDP growth and carbon emission are 5.14 (8.15) and 10.22 (8.94) respectively. The Jarque-Bera (J-B) statistic for economic growth is 1.03 with the probability 0.59 which is also analogous with the series CO₂ emission kiloton having the value of J-B is 2.58 with probability 0.27 which implies that both series are distributed normally.

Both series show upward trend (as can be seen in Figure 1) over the time path from 1980 to 2019. Firstly, CO₂ emission has a constant upward pattern whereas the path of GDP growth experience substantially ascensive trend subject to sequential fluctuations over the time.

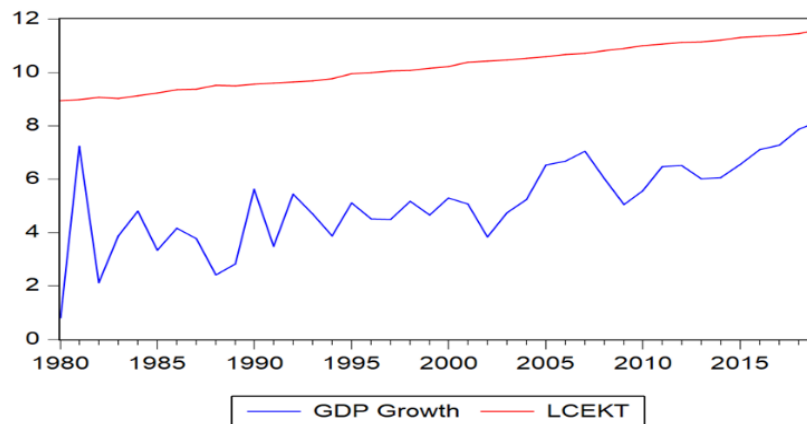


Figure 1. Pattern of GDP growth and CO₂ (LCEKT) emission kiloton.

4. METHODOLOGY

Autoregressive Distributed Lag Model (ARDL) cointegration bound test approach is used to find out the long-run and short-run causal relationship among the variables i.e. GDP growth and the emission of carbon in Bangladesh. In this paper, the target variable is growth whereas the log value of CO₂ (lcekt) is the independent variable. Though most of the research papers have examined the impact of economic growth on the carbon emission but in this research, we focus on the impact of emission on the economic progress of Bangladesh. There are several advantages to use ARDL bound test method i.e. ARDL approach encounters single equation so that model is free from the residual correlation and it also identify the cointegrating vector where multiple cointegrating vectors are present (Emeka & Kelvin, 2016). In the case of long run causation, the equation converges into reduced form equation which is embedded on the relationship between endogenous variable and independent variables (Pesaran, Shin, & Smith, 2001). Using a linear transformation, we can develop the ECT (Error Correction Term) from the short run and adjust it with the long run dynamics (Emeka & Kelvin, 2016).

Checking the stationarity (unit root) of time series variable is the first step Figure 2 towards employing the ARDL approach. It must be confirmed that no series is I (2) but the series will be the mixture of I (0) or I (1) and also it requires to be confirmed that the regressed is I (1). Considering the optimal number of lags, the long run ARDL equation is developed and F-bound test is used to find out the long run cointegration among the variables. To find out the significance of the long run and short run unconditional coefficient in this stage Wald test must be comprehensive. Construction of the short run model and synchronization of it to the long run model through the ECT (Error Correction Term) is next dilution. The value of ECT must be negative and statistically significant for the long run equilibrium.

Diagnostic test is the pre-requisite for any standard procedure of time series modelling or econometric approach to establish acceptance to the audiences. In this paper, we introduce the residual normality for stochastic disturbance and to encounter the challenge of serial correlation we utilize the LM test while for the overall stability of the model we rely on the CUSUM and CUSUM square stability field.

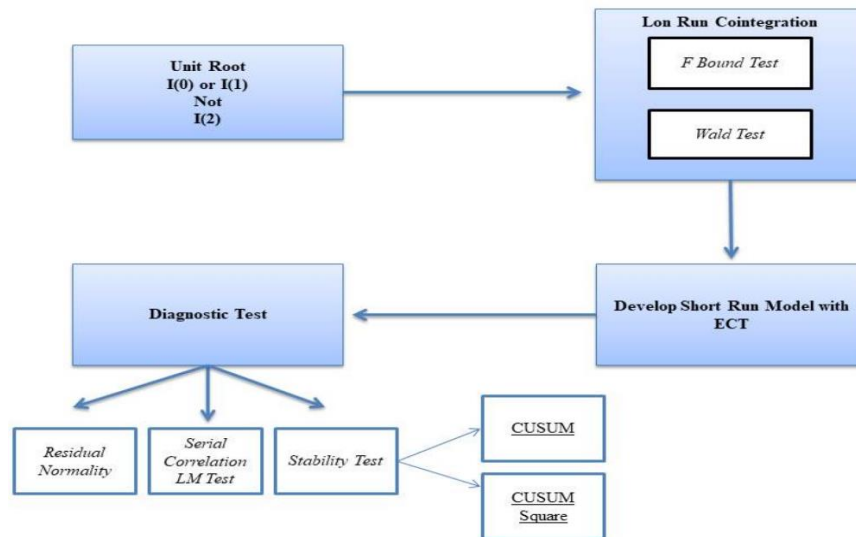


Figure 2. Standard procedure of ARDL bound cointegration approach.

4.1. Unit Root

In time series analysis, it is widely prevalent to find out whether the series is either stationary or non-stationary. The autoregressive moving average process (ARMA) has a polynomial equation which consists of the characteristics root “1” that can be defined as unit root (Herranz, 2017). The unit-root procedure is deemed as a conventional way to identify whether the series has constant mean and variance or time-varying mean and variance. Considering that a series Z has n observations (Dickey & Fuller, 1979) with the sequence of $Z_1, Z_2, Z_3 \dots \dots Z_n$ and the autoregressive expression of the series Z for order 1 (one) or according to the Markov AR-1 (Gujarati & Porter, 2008) looks like the following Equation 1,

$$Z_t = \rho Z_{t-1} + e_t \quad [\because \rho = \pm 1, \text{unit root coefficient}] \quad (1)$$

The least squares estimation of ρ is demonstrated by Equation 2,

$$\hat{\rho} = \left(\sum_{t=1}^n Z_{t-1}^2 \right)^{-1} \sum_{t=1}^n Z_t Z_{t-1} \quad (2)$$

Given time series Z_t , it converges towards stationarity when $|\rho| < 1$; if $|\rho| = 1$, the time series variable is non-stationary and the variance of Z_t is time variant $t\sigma^2$. If the value of $|\rho| > 1$, the variance of the time series increases exponentially provided that the time (t) also goes up (Dickey & Fuller, 1979). To remove the one test bias in this paper we use Augmented Dickey-Fuller and Phillips –Perron test to identify the order of integration in the time series variable of this study.

Augmented Dickey-Fuller (ADF) test is widely used unit root test to identify the integrated order of the time series variables (Herranz, 2017). It is an extension of the Dickey-Fuller test (Dickey & Fuller, 1979) in which they augment the random walk model without intercept and trend, the random walk model with intercept and the random walk model with intercept and trend (Gujarati & Porter, 2008). To avoid the serial correlation of the error term (white noise), Dickey and Fuller add a lag order in the regressand. The Equation 3 is the general format of the ADF AR 1 model:

$$\Delta Z_t = \alpha + \alpha_1 t + \alpha_2 Z_{t-1} + \sum_{i=1}^n \alpha_3 \Delta Z_{t-i} + \omega_t \quad (3)$$

To consider heterogeneity in the series distribution, Phillips and Perron (PP) develop a non-parametric procedure by which one can identify the stationarity of series without adding lagged value in the regressand (Phillips & Perron, 1988). The Equation 4 of the PP AR1 model looks like the following:

$$Z_t = \pi + \pi_1 Z_{t-1} + \vartheta_t \quad (4)$$

4.2. Autoregressive Distributed Lag Model

Autoregressive distributed lag model (ARDL) is a widely used econometric tool by which one can estimate the causal relationship (short-run or long-run or both) among the time series variables whatever the order of integration it may be I(0) or I(1) or the combination of I(0) and I(1) but not any series which is I(2) (Pesaran et al., 2001). But it is important that the dependent variable or the regressand must be I(1).

ARDL model synchronizes the short-run components with long-run dynamics.

In a general hypothetical model:

$$\Delta X_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^p \gamma_i \Delta X_{t-i} + \sum_{i=0}^q \rho_i \Delta Z_{t-i} + \tau_1 X_{t-1} + \tau_2 Z_{t-1} + \vartheta_t \quad (5)$$

In the Equation 5, X is regressand and Z is regressor with the lag order p and q respectively. γ_i and ρ_i are considered as the short-run coefficients for the ARDL model while τ_1 and τ_2 are considered as the long-run coefficients along with ϑ_t which is deemed as the error term of the model. This error term is also known as the white noise error term with the properties like

$$\vartheta \sim N(0,1)$$

To incorporate the deterministic factors, the coefficients of α_0 and α_1 represent the intercept and trend respectively. Equation 5 above is expressed in a way that it demonstrates a causal combination of lagged value of dependent and independent variables on the dependent variable. Most importantly, the cointegration of the equation 5 has shown the evidence of short-run and long-run dynamics of the ARDL bound test approach (Menegaki, 2019). In the cointegrated bound test approach the statement of the null and alternative hypothesis is given below

$$H_0: \gamma_1 = \gamma_2 = \gamma_3 = \dots \gamma_p = 0$$

$$H_a: \gamma_1 = \gamma_2 = \gamma_3 = \dots \gamma_p \neq 0$$

and

$$H_0: \rho_1 = \rho_2 = \rho_3 = \dots \rho_p = 0$$

$$H_a: \rho_1 = \rho_2 = \rho_3 = \dots \rho_p \neq 0$$

This statement of hypothesis ascertains the presence of cointegration (long-run dynamic) using the F-statistic developed by Pesaran et al. (2001). The rejection of the null hypothesis does statistically consolidate the long-run causations among the variables. There are five alternative scenarios that have been taken under consideration by Pesaran et al. (2001) to exhibit the F critical value considering all alternative situations to track down the deterministic components from the basic ARDL bound testing equation. In case 1, the intercept and trend of the ARDL model are considered as obsolete [$\alpha_0 = 0$ and $\alpha_1 = 0$] and it converges to Equation 6,

$$\Delta X_t = \sum_{i=1}^p \gamma_i \Delta X_{t-i} + \sum_{i=0}^q \rho_i \Delta Z_{t-i} + \tau_1 X_{t-1} + \tau_2 Z_{t-1} + \vartheta_t \quad (6)$$

Imposing restriction on intercept and envisaging no trend [$\alpha_0 = -(\tau_1, \tau_2)\mu$ and $\alpha_1 = 0$] for case 2, the cointegrated equation looks like Equation 7,

$$\Delta X_t = \sum_{i=1}^p \gamma_i \Delta X_{t-i} + \sum_{i=0}^q \rho_i \Delta Z_{t-i} + \tau_1 (X_{t-1} - \mu_x) + \tau_2 (Z_{t-1} - \mu_z) + \vartheta_t \quad (7)$$

Case 3 is exhibit by Equation 8, imposing no restriction on intercept and no trend [$\alpha_0 \neq 0$ and $\alpha_1 = 0$] the ECM is

$$\Delta X_t = \alpha_0 + \sum_{i=1}^p \gamma_i \Delta X_{t-i} + \sum_{i=0}^q \rho_i \Delta Z_{t-i} + \tau_1 X_{t-1} + \tau_2 Z_{t-1} + \vartheta_t \quad (8)$$

In case 4 illustrated by Equation 9, it has been considered that the intercept is unrestricted, but trend is restricted [$\alpha_0 \neq 0$ and $\alpha_1 = -(\tau_1, \tau_2)\varphi$] then the long-run equation is:

$$\Delta X_t = \sum_{i=1}^p \gamma_i \Delta X_{t-i} + \sum_{i=0}^q \rho_i \Delta Z_{t-i} + \tau_1(X_{t-1} - \varphi_x) + \tau_2(Z_{t-1} - \varphi_z) + \vartheta_t \tag{9}$$

In case 5, the intercepts and trends both are considered unrestricted [$\alpha_0 \neq 0$ and $\alpha_1 \neq 0$], so the long-run dynamics is look like Equation 10

$$\Delta X_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^p \gamma_i \Delta X_{t-i} + \sum_{i=0}^q \rho_i \Delta Z_{t-i} + \tau_1 X_{t-1} + \tau_2 Z_{t-1} + \vartheta_t \tag{10}$$

5. RESULT ANALYSIS AND DISCUSSION

In Table 2, the result of unit root test has been demonstrated. The result shows that, using Augmented Dickey-Fuller (ADF) test and considering no trend and intercept, the series of economic growth (*g*) and carbon emission kiloton (*lcekt*) confirm the existence of non-stationarity in the series. To avoid the problem of single test bias, Phillips-Perron (PP) test is introduced which also helps detect the non-stationary phenomenon of the series considering no trend and no intercept and the test result is analogues with the ADF result. As the result represents, both series are in integrated order 1(i.e. $g \sim I(1)$ and $lcekt \sim I(1)$). When the first order difference is taken considering the absence of trend and intercept, the series converges to stationarity from non-stationarity. For the ADF with 1% level of significance, the statistics for series *g* and *lcekt* are -15.50 and -7.50 respectively and for the PP process the value for series *g* is -17.9 and for *lcekt* is -15.68. Both tests indicate that after taking the first difference, the series $g \sim I(0)$ and the series $lcekt \sim I(0)$.

Table 2. Unit root test.

Name of the Variable	Level (No Trend and No Intercept)	
	Augmented Dickey-Fuller Test	Phillips-Perron
<i>g</i>	2.15	0.34
<i>lcekt</i>	0.38	2.46
	First Difference (No Trend and No Intercept)	
	Augmented Dickey-Fuller Test	Phillips-Perron
<i>g</i>	-15.50***	-17.19***
<i>lcekt</i>	-7.50***	-15.68***

Note: *** denotes 1% level of significance.

Table 3. Model selection criteria.

Number of Alternative model	Selection Criteria Value					Model Specifications
	LogL	AIC	BIC	HQ	Adj. R-sq	
1	-34.14	2.28	2.59	2.39	0.75	ARDL(1, 4)
2	-33.48	2.30	2.65	2.42	0.74	ARDL(2, 4)
3	-31.69	2.31	2.75	2.47	0.75	ARDL(4, 4)
4	-33.12	2.34	2.73	2.47	0.74	ARDL(3, 4)
5	-36.96	2.38	2.65	2.47	0.71	ARDL(4, 0)
6	-36.89	2.43	2.74	2.54	0.70	ARDL(4, 1)
7	-36.12	2.45	2.80	2.57	0.70	ARDL(4, 2)
8	-39.12	2.45	2.67	2.52	0.68	ARDL(1, 2)
9	-41.49	2.47	2.60	2.51	0.66	ARDL(1, 0)

Note: Lowest values of AIC, BIC, HQ are used to select the appropriate model.

So, from the unit root test it is obvious that to determine the impact of carbon emission on the economic growth of Bangladesh, ARDL model can be extremely useful. To determine the optimal order of ARDL model, some criteria have been followed such as LogL (Log Likelihood), AIC (Akaike Information Criterion), BIC

(Bayesian Information Criterion), HQ (Hannan–Quinn Information Criterion) and adjusted R-square (Adj. R-sq). The model is optimal which has lower value of LogL, AIC, BIC and HQ and higher value of adjusted R-square. In the Table 3, the optimal orders of the ARDL model are 1 and 4 which imply that the model has autoregressive lag one and distributed lag four.

So the long-run ARDL model is,

$$g_t = \beta_0 + \beta_1 lcekt_t + u_t \tag{11}$$

And the short-run model with Error Correction Term (ECT) is,

$$\Delta g_t = \beta_0 + \delta_1 \Delta lcekt_t + \delta \Delta lcekt_{t-1} + \delta \Delta lcekt_{t-2} + \delta \Delta lcekt_{t-3} + Ect_{t-1} \tag{12}$$

The model is termed as Lin-Log model. In this type of model, the slop coefficient measures the absolute change in endogenous (g_t) variables due to the percentage change in exogenous ($lcekt_t$) variables¹. To avoid errors in the interpretation of the slop coefficient, it must be multiplied by 0.01 (or divide by 100) while explaining it.

In Equation 11, as can be seen from Table 4 (part A), the long- run coefficient of the model is 1.60 (8.42) which in turn implies that a one per cent (1%) increase in the carbon emission kiloton will raise the GDP growth of Bangladesh by 0.016 per cent. The long-run coefficient is positive and statistically significant which shows the long-run positive innovation of GDP growth due to the emission (pollution).

In part B of Table 4, the short-run coefficient value of Equation 12 is given and it exhibits that the constant and the coefficient value of lag 2 and 4 is statistically significant.

Table 4. Part A: Long run coefficient.

Name of Variables	Coefficient	Standard Error	t-statistics	P-value
<i>lcekt</i>	1.60	0.20	8.42	0.00

Table 4. Part B: Short run coefficient with ECT.

Name of Variables	Coefficient	Standard Error	t-statistics	P-value
<i>constant</i>	-7.9903	1.81	-4.39	0.00
$\Delta lcekt_{t-1}$	-3.8325	3.00	-1.27	0.21
$\Delta lcekt_{t-2}$	-7.0756	2.73	-2.58	0.01
$\Delta lcekt_{t-3}$	-3.3204	2.91	-1.13	0.26
$\Delta lcekt_{t-4}$	-8.7548	2.84	-3.07	0.00
<i>Ect₋₁</i>	-0.8596	0.16	-5.31	0.00

Table 5. Bound test and cointegration.

Estimates	Statistical Value	Significant Level	Bound		Decision
			Lower Bound	Upper Bound	
<i>F – Statistics</i>	13.64	10%	4.23	5	Cointegration
		5%	5.26	6.16	
		1%	7.62	8.82	
<i>t – Statistics</i>	-5.17	10%	-2.57	-2.91	Cointegration
		5%	-2.86	-3.22	
		1%	-3.43	-3.82	

Note: Finite Sample, n=35.

¹ $\frac{dg_t}{dlcekt_t} = \beta_2 \left(\frac{1}{lcekt_t} \right)$

Or, $\beta_2 = \frac{dg_t}{\frac{dlcekt_t}{lcekt_t}}$

So, $\beta_2 = \frac{\text{absolute change in } g_t}{\text{relative change in } lcekt_t}$

The value of error correction term (Ect_{-1}) is negative -0.85 and statistically significant. The error correction term calculates the speed of adjustment from the short-run dynamics to long-run equilibrium. If the long-term equilibrium deviates from the equilibrium point due to shocks, the Ect_{-1} shows how rapidly the diversion converges to the long-run equilibrium. The adjustment coefficient of this study implies that, in the current year, 85.96 per cent disequilibrium which occurs due to the previous year distortion has been corrected in current period.

Using half-life, the fifty per cent of the correction would be flutter, $HL = \frac{\ln(0.5)}{\tau} \approx \frac{-0.69}{\tau}$; where τ is the error correction coefficient, is 0.80 year or 9.6 months.

The cointegration of the coefficient in the ARDL model has enormous importance to forecast the long-run parameters for the purpose of appropriate policy implementation. In this regard, the bound test approach shown in Table 5, demonstrates that F-statistics and t-statistics at 1 per cent significance level excise the upper bound critical value, which implies the model has long-run causality. For the long-run and short-run causation of the co-efficient, Wald statistics provides more reliable result. In this estimation of ARDL model, the $\chi - square$ value of long-run coefficient is 27.28 which is significant at 1 per cent level Table 6 and for short-run coefficient $\chi - square$ value is 14.80 which is also significant at 1 per cent level implies both long-run and short-run coefficients have causation to explain the change of economic growth of Bangladesh due to the change of carbon emission. .

Table 6. Wald test.

Long run Coefficient		Short run Coefficient		Decision
Estimates	Statistical Value	Estimates	Statistical Value	
<i>F - statistics</i>	13.64***	<i>F - statistics</i>	3.70***	Causation
<i>χ - square</i>	27.28***	<i>χ - square</i>	14.80***	Causation

Note: *** denotes 1% level of significance.

Diagnostic test for the estimated ARDL (1,4) model on Table 7 shows the residual of the model is normally distributed (*Jarque-Bera is 1.97*) and model is free from the stigma of serial correlation ($\chi - square$ is 1.78).

Table 7. Diagnostic tests.

Name of Diagnostics	Estimates	Statistical Value	Hypothesis and Decision
Residual Normality	<i>Jarque-Bera</i>	1.97 (0.37)	H_0 : Normally Distributed. H_a : Not Normally Distributed. (accept null)
Serial Correlation LM	$\chi - square$	1.785107 (0.40)	H_0 : No serial correlation. H_a : Serial correlation. (accept null)

Note: '()' shows the probability value.

The figure of cumulative sum control chat (CUSM) and cumulative sum control of squares (CUSUM squares) depicted respectively in Figure 3 and Figure 4 sketch the statistical stability of estimated model.

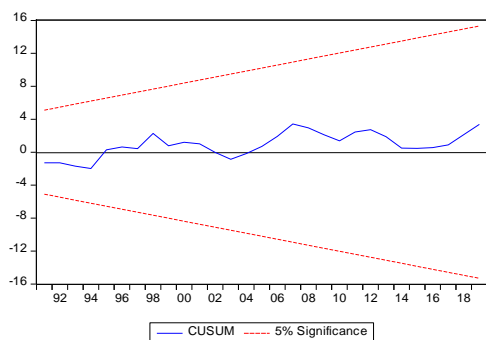


Figure 3. Stability test (CUSUM).

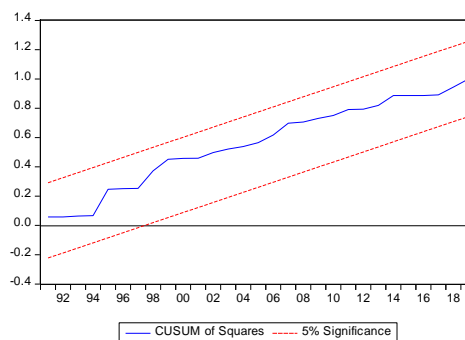


Figure 4. Stability test (CUSUM Squares).

Both of the figures illustrate that, at the 5 per cent critical value, the estimated stability lines do not exceed the critical lower and upper boundaries. So, technically and statistically, the estimated model does not only remain stable at short-run but also in long-run.

6. POLICY RECOMMENDATIONS AND CONCLUSION

Results of this study suggest that environmental degradation has positive association with economic growth of Bangladesh over the time span used in this study. These results can be of immense importance while formulating policies for environment friendly development activities. Below are some policy recommendations for environment friendly economic growth:

1. Pursuing environment friendly growth of cities-it paves the way for economic development but not by sacrificing environmental quality.
2. Implementing institutional regulations for industrial advancement.
3. Encouraging the use of renewable energy as a share of total energy utilization.

A number of studies have shown the effect of economic growth on emissions while this study does the opposite and helps understand how we can achieve economic growth keeping the environment unaffected. Additionally, as found in the results, Environmental Kuznets Curve (EKC) hypothesis might work differently for different countries around the world depending on their current development status like it does for Bangladesh.

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