RELATIONSHIP BETWEEN ECONOMIC GROWTH, ENERGY CONSUMPTION, TRADE LIBERALIZATION, POPULATION DENSITY, AND CO_2 EMISSIONS: BANGLADESH CASE

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Abstract- This study investigates the relationship between economic growth, energy consumption, trade openness, population density, and carbon dioxide (CO_2) emissions in Bangladesh for the period of 1975 to 2013. It applies the Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration for establishing the existence of a long-run relationship. The bounds tests suggest that the variables of interest are bound together in the long-run when CO_2 emissions is the dependent variable. The results indicate that energy consumption has statistically significant positive effect on CO2 emissions both in the short-run and long-run. The effect of population density is significant in long-run, but not in short-run. The estimated coefficients for economic growth and trade liberalization are negative and insignificant both in short-run and long-run. The paper suggests that the Government of Bangladesh should undertake the policy actions to develop alternative energy sources which would not emit much CO_2.

Key words- ARDL, carbon dioxide (CO_2), economic growth, trade liberalization, population density

I. INTRODUCTION

After independence in 1971, Bangladesh pursued the import-substitution industrialization strategy. It was the regime of highly restricted trade and exchange rate policy characterized by high tariffs and non-tariff barriers to trade. Since the restricted trade policy didn't realize the expected outcome, the country implemented the large-scale liberalization of trade in the early 1990s. Trade liberalization played a vital role to develop the country's economy.

Over the last decades since 1994, Bangladesh's economy is growing steadily more than 5%. While this growth has brought many socioeconomic benefits, its impact on environmental degradation have been in the centre of growing debate in the recent years. Bangladesh is one of the heavily densely populated countries of the world. The population density in 2015 was 1,236.81 persons per square kilometre. High density of population can have impact on environmental degradation through CO_2 emissions. In this situation, it is interesting to know the relationship between economic growth, energy consumption, trade openness, population density, and carbon dioxide (CO_2) emissions.

Figure 1 exhibits the trend in each series in logarithmic form over the period 1975–2013 for ready reference. A glance at Figure 1 makes it clear that CO_2 emissions per capita (ln CO), real GDP per capita (ln Y), energy consumption per capita (ln E), and population density (ln P) in Bangladesh have been witnessed a steady upward trend during 1975–2013. However, trade openness (ln O) witnessed downward trend from 1980 till 1992 due to the import-substitution industrialization strategy which was characterized as highly restricted trade regime.

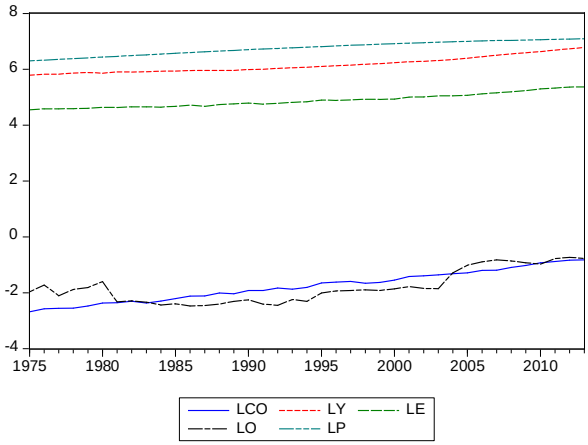


Figure 1: Trends in economic growth, energy consumption, trade openness, population density, and CO_2 emissions

II. LITERATURE REVIEW

Numerous studies have examined the relationship among CO2 emission, energy consumption, and economic growth. In the previous studies (Hossain & Syed, 2016; Islam et al., 2012; Rahman, 2011, Zaman, 2011), trade openness and economic growth have taken into account to examine their effects on carbon dioxide (CO_2) emissions. However, most of the previous studies have not taken into account the population density in Bangladesh context. Population growth and its density are responsible for environmental degradation. As population rises, the demand for energy and fuel, demand for industrial good and transportation would also rises (Mahmood & Chaudhary, 2012). Bangladesh is one of the most populous country in the world and placed in the list of top ten countries by population density. In this regard this study is an attempt to remedy the limitation of the previous paper by focusing on comparing the relationships between economic growth, trade

openness, population density, and carbon dioxide (CO_2) emissions in the case of Bangladesh.

III. DATA COLLECTION AND METHODOLOGY

The study takes carbon dioxide emissions as dependent variable and economic growth, energy consumption, trade openness, and population density as independent variables. The time period used for the estimation is from 1975 to 2013 on yearly basis. The secondary data used in this paper have been obtained from World Development Indicators (http://data.worldbank.org). In the paper, the general functional form of the model for estimating the influence of economic growth, energy consumption, trade openness, population density, and CO_2 emissions is developed as Eq. (1).

$$(CO_2)_t = \beta_0 + \beta_1 Y_t + \beta_2 E_t + \beta_3 O_t + \beta_4 P_t + \varepsilon_t \quad ---(1)$$

Where CO_2 is the carbon dioxide emission, Y is real GDP per capita as a proxy of economic growth, E is energy consumption, O is trade openness, and P is population density. CO_2 emissions, measured in metric tons, were transformed into a per capita measure to adjust for the population size of the country. Economic growth is measured as real GDP per capita. Trade as share of GDP is the proxy for trade openness (trade liberalization). Population density is expressed in people per square kilometre. Energy consumption is measured in kilograms of oil equivalent per capita.

The Autoregressive Distributed Lag (ARDL) bounds testing approach has been employed in this paper to examine the impact of economic growth, energy consumption, trade liberalization, and population density on CO_2 Emissions in Bangladesh. The ARDL modeling approach was originally introduced by Pesaran and Shin (1999) and further extended by Pesaran, Shin and Smith (2001). Compared with other cointegration methods such as the two-step approach by Engle and Granger (1987) and the Johansen test (1988), the ARDL bounds testing approach for cointegration enjoys certain econometric advantages. This approach is based on the estimation of an Unrestricted Error Correction Model (UECM) which enjoys several advantages over the conventional type of cointegration techniques. The first one is that the ARDL does not need that all the variables under study must be integrated of the same order and it can be applied when the under-lying variables ae integrated of order one, order zero or fractionally integrated. The second advantage is that the ARDL test is relatively more efficient in the case of small and finite sample data sizes. The third advantage is that by applying the ARDL technique we obtain unbiased estimates of the long-run model (Harris & Sollis, 2003). Fourth, once the orders of the lags in the ARDL model have been appropriately selected, we can estimate the cointegration relationship using a simple Ordinary Least Square (OLS) method. The limitation of the ARDL bounds testing is that this approach is unable to provide any empirical results in the presence of I(2) series.

In view of the above advantages, ARDL used in the present study has the following form as expressed in Equation (2):

$$\Delta \ln CO_t = b_0 + \sum_{i=1}^{p} b_{1i} \Delta \ln CO_{t-i} + \sum_{i=0}^{q} b_{2i} \Delta \ln Y_{t-i} + \sum_{i=0}^{q} b_{3i} \Delta \ln E_{t-i} + \sum_{i=0}^{q} b_{4i} \Delta \ln O_{t-i} + \sum_{i=0}^{q} b_{5i} \Delta \ln P_{t-i} + b_6 \ln CO_{t-1} + b_7 \ln Y_{t-1} + b_8 \ln E_{t-1} + b_9 \ln O_{t-1} + b_{10} \ln P_{t-1} + \varepsilon_t \quad ----------(2)$$

where Δ is the operator of first-difference, ln represents natural logarithm transformation, b_0 is an intercept, t represents time, b_1, b_2, b_3, b_4, b_5 represent the short-run dynamic relationship and b_6, b_7, b_8, b_9, b_{10} denote the long-run dynamic relationship, while ε is a white noise error term, assumed to satisfy all the basic assumptions of the classical linear regression model. In the ARDL model, the bounds test is adopted to determine whether there is a long-run equilibrium between the variables, namely whether the cointegration relationship exists.

The bounds test is mainly based on the joint F-statistic which its asymptotic distribution is non-standard under the null hypothesis of no cointegration. The first step in the ARDL bounds testing approach is to estimate Equation (1) by ordinary least squares in order to test for existence of a long-run relationship among the variables by conducting an F-test for the joint significance of the coefficients of the lagged level variables, i.e., H_0: $b_6 = b_7 = b_8 = b_9 = b_{10} = 0$ (No cointegration) against the alternative H_1: $b_6 \neq b_7 \neq b_8 \neq b_9 \neq b_{10} \neq 0$ (Cointegration exists). Two sets of critical value bounds for the F-statistic are generated by Pesaran, et al. (2001). If the computed F-statistic falls below the lower bound critical value, the null hypothesis of no-cointegration cannot be rejected. Contrary, if the computed F-statistic lies above the upper bound critical value; the null hypothesis is rejected, implying that there is a long-run cointegration relationship amongst the variables in the model. Nevertheless, if the calculated value falls within the bounds, inference is inconclusive.

In the second step, if there is cointegration between the variables, the conditional ARDL long-run model for CO_t can be estimated as:

$$\ln CO_t = b_0 + \sum_{i=1}^{p} b_{1i} \ln CO_{t-i} + \sum_{i=0}^{q} b_{2i} \ln Y_{t-i} + \sum_{i=0}^{q} b_{3i} \ln E_{t-i} + \sum_{i=0}^{q} b_{4i} \ln O_{t-i} + \sum_{i=0}^{q} b_{5i} \ln P_{t-i} + \varepsilon_t \quad ----------(3)$$

The orders of the ARDL (p, q_1, q_2, q_3, q_4) model in the five variables are selected by using Schwarz Bayesian Criterion (SBC). In the third and final step, the short-run dynamic parameters by estimating an error correction model (ECM) associated with the long-run estimates have been obtained. The error correction model is specified as follows:

$$\Delta \ln CQ_t = b_0 + \sum_{i=1}^{p} b_{1i} \Delta \ln CQ_{t-i} + \sum_{i=0}^{q} b_{2i} \Delta \ln Y_{t-i} + \sum_{i=0}^{q} b_{3i} \Delta \ln E_{t-i}$$

$$+ \sum_{i=0}^{q} b_{4i} \Delta \ln O_{t-i} + \sum_{i=0}^{q} b_{5i} \Delta \ln P_{t-i} + \lambda ECM_{t-1} + \varepsilon_t \text{ ------(4)}$$

where, b_{1i}, b_{2i}, b_{3i}, b_{4i} and b_{5i} are the short-run dynamic coefficients of the model's convergence to equilibrium and λ is the speed of adjustment parameter and ECM is the error correction term that is derived from the estimated equilibrium relationship of Equation (2).

IV. EMPIRICAL RESULTS AND DISCUSSIONS

Before proceeding with the ARDL bounds test, test for the stationarity status of the selected time series data has been performed to determine their order of integration. This is to ensure that the variables should not be stationary at an order of I(2) because the computed F-statistics provided by Pesaran, Shin and Smith (2001) are valid only when the variables are I(0) or I(1). For this purpose, the augmented Dicky–Fuller (ADF) and Philip Perron (PP) unit root tests have been applied. The results of these tests reported in Table 1 show that CO_2 emissions per capita (ln CO_t), real GDP per capita (ln Y_t), energy consumption per capita (ln E_t), and trade openness (ln O_t) series are I(1), whereas population density (ln P_t) series is I(0).

After testing the stationarity status of the selected time series data, Autoregressive Distributed Lag (ARDL) bounds testing approach has been employed to examine the impact of economic growth, energy consumption, trade liberalization, and population density on CO_2 Emissions in Bangladesh. Table 2 presents the result of ARDL bounds test for the cointegration relationship based on equation (2). The appropriate lag length was selected on the basis of Schwarz Bayesian Criterion (SBC) for the conditional ARDL. The Table result reveals that the calculated F statistic is obviously greater than be the upper bounds critical values when CO_2 emissions (ln CO_t) and population density (ln P_t) were used as dependent variables. Accordingly, the null hypothesis of no cointegration is rejected. It entails that a long-run relationship exists between CO_2 emissions, economic growth, energy consumption, trade openness, and population density in the case of Bangladesh over the period from 1975 to 2013.

Table 1: Results of ADF and PP unit root tests

Variable	ADF test statistics		PP test statistics		Decision
	Constant	Constant and trend	Constant	Constant and trend	
ln CO_t	1.1218	-1.9497	0.2515	-3.6377**	Nonstationary
ln Y_t	5.8371	1.3511	6.9129	1.7514	Nonstationary
ln E_t	2.5673	-0.7388	4.8488	-0.7859	Nonstationary
ln O_t	-0.3051	-1.7898	-0.1587	-1.6147	Nonstationary
ln P_t	-3.1139**	0.1388	-7.2227*	2.9965	Stationary
Δ ln CO_t	-6.4967*	-5.3250*	-11.714*	-14.279*	Stationary
Δ ln Y_t	-0.9749	-3.2948	-4.3068*	-7.1929*	Stationary
Δ ln E_t	-7.6031*	-8.7938*	-7.5760*	-16.202*	Stationary
Δ ln O_t	-6.7960*	-7.2851*	-6.7689*	-8.2983*	Stationary
Δ ln P_t	-1.3933	-3.5661*	0.2196	-4.2040*	Stationary

*Rejection of the null hypothesis of the existence of a unit root at 1 % level of significance

Table 2: ARDL Bounds tests for cointegration

Estimated ARDL Model	Optimal lag length	F statistics	Lower bound critical value at 5% level	Upper bound critical value at 5% level	Inference
F(ln CO_t \ ln Y_t, ln E_t, ln O_t, ln P_t)	(3, 0, 2, 3, 1)	10.895*	2.56	3.49	Cointegration
F(ln P_t \ ln CO_t, ln Y_t, ln E_t, ln O_t)	(2, 3, 2, 0, 0)	8.7999*	2.56	3.49	Cointegration

*Rejection of the null hypothesis of no cointegration at 5 % level of significance

Once the existence of cointegration relationship among the variables is confirmed, the long-run impacts of these variables on CO_2 emissions have been estimated.

According to Equation (3) and the principle of minimum SBC value, we single out the ARDL (3, 0, 2, 3, 1) model, and the estimated results for the long-term relationship are shown in Table 3.

Table 3: Estimated long-run coefficients from ARDL model

Variable	Coefficient	Standard error	t-statistic (prob.)
Constant	-14.355	0.604	-23.766 (0.000)
ln Y_t	-0.172	0.161	-1.067 (0.297)
ln E_t	1.596	0.209	7.600 (0.000)
ln O_t	-0.042	0.025	-1.620 (0.119)
ln P_t	0.863	0.113	7.588 (0.000)

* Significance at 1% level

Next, in order to check the short-run relationship between the variables the ECM is employed. The results of short-run dynamics are reported in Table 4. The result reveals that the estimated lagged error term (ECM_{t-1}) is statistically significant at the 5% level with a negative sign. This finding confirms the earlier long-run relationship between the series and shows the speed of adjustment from the short-run toward long-run equilibrium path.

The stability of the long-run coefficient is tested by the short-run dynamics. Once the ECM model given by equation (4) has been estimated, the cumulative sum of recursive residuals (CUSUM) and the CUSUM of square (CUSUMSQ) tests are applied to assess the parameter stability. Figure 1 and 2 plot the results for CUSUM and CUSUMSQ tests. The results indicate the absence of any instability of the coefficients because the plots of the CUSUM and CUSUMSQ statistics fall inside the critical bounds of the 5% level of significance.

Table 4: Error Correction Representation for the Selected ARDL Model

(ARDL(3,0,2,3,1) selected based on Schwarz Bayesian Criterion)

Variable	Coefficient	Standard error	t-statistic (prob.)
Constant	0.021	0.073	0.297 (0.768)
$\Delta \ln Y_t$	-0.408	0.810	-0.503 (0.618)
$\Delta \ln E_t$	1.357*	0.303	4.472 (0.000)
$\Delta \ln O_t$	-0.012	0.044	-0.285 (0.777)
$\Delta \ln P_t$	0.408	2.555	0.159 (0.874)
ECM_{t-1}	-0.978*	0.400	-2.441 (0.0210)

Ecm = LCO + 0.1722*LY - 1.5961*LE + 0.0420*LO - 0.8634*LP + 14.3554

$R^2 = 0.450$

F-stat. = 4.759 (0.003)

DW-statistic = 2.031

* Significance at 5% level

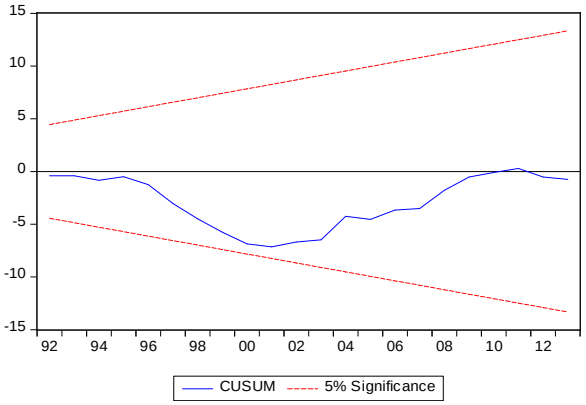


Figure 2: Plot of Cumulative Sum of Recursive Residuals

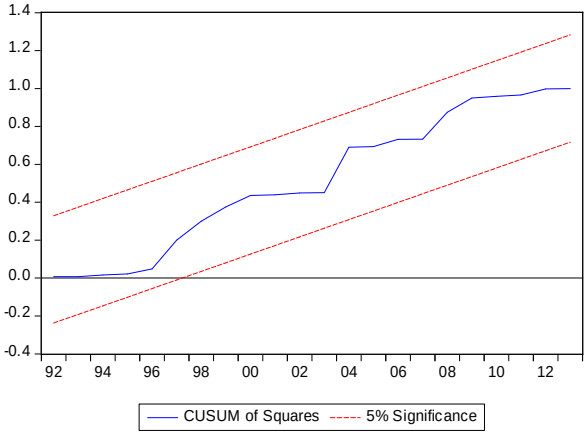


Figure 3: Plot of Cumulative Sum of Squares of Recursive Residuals

CONCLUSIONS

In this paper, annual time series data from 1975 to 2013 have been used to test the relationship between economic growth, energy consumption, trade openness, population density, and carbon dioxide (CO_2) emissions in Bangladesh.

The following conclusions are drawn. First, all the series other than population density appear stationary in the first difference for the logarithmic form. Second, the bounds tests suggest that the variables of interest are bound together in the long-run when CO_2 emissions is the dependent variable. The results also indicate that energy consumption has statistically significant positive effect on CO2 emissions both in the short-run and long-run. The effect of population density is significant in long-run, but not in short-run. The estimated coefficients for economic growth and trade liberalization are negative and insignificant both in short-run and long-run. The paper suggests that the Government of Bangladesh should undertake the policy actions to develop alternative energy sources which would not emit much CO_2.

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