Nexus between carbon emissions and manufacturing growth in Bangladesh

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Abstract

The main objective of this study is to examine the empirical cointegration, long and short run dynamics and causal relationships between carbon emissions and industrial growth in Bangladesh over the period 1972 to 2015. For such, we applied the ARDL/Bounds Testing methodology developed by Pesaran and Shin (1999) and Pesaran et al. (2001)and the Toda-Yamamoto Procedure of Granger Causality in an augmented VAR framework. Using three variables growth of carbon emissions, energy consumption and per capita industrial production, the ARDL bounds tests as well as additional cross-checking test convincingly confirmed long run cointegration between growth of carbon emissions and growth of per capita industrial production (i.e. economic development in other sense) in Bangladesh. The estimated long and short-run results indicate that, growth in per capita industrial production has significant positive impact, both in the short and long-run, on growth of carbon emissions. The coefficient of the error correction term is statistically significant, has the expected negative sign, and signified a very strong and faster speed of adjustment to equilibrium (100%). Likewise, Granger causality analysis indicated a unidirectional causation both from growth in per capita industrial production and energy consumption to growth in carbon emissions i.e., the industrial development or economic development in Bangladesh is taking place at the cost of carbon emissions.

1.0 Introduction

After it's emergence in 1971 Bangladesh economy did not performed well until late eighties. However, after restoration of democracy in early 1990s, subsequent massive policy reforms and rapid growth of foreign remittance influx has accelerated the economic development remarkably. Looking at this amelioration of the recent socio-economic indicators the whole world is praising Bangladesh. But this development process is going on through the indiscriminate installation of industrial units particularly in the surrounding areas of capital city of Dhaka and port city of Chittagong which also causes unplanned urbanizations and environmental crisis in those areas. Due to this unsystematic growth of manufacturing sector, population density and environmental degradations are also taking place with a similar pace. There is ample theoretical and empirical evidence of correlation, cointegration and causality between economic development in the early stage occurring at the expense of adverse impact on environment. Bangladesh could not escape itself from this common maelstrom of developing countries. Due to staying in low level development stage and becoming one of the densely populated and the highest population growth rate country in the world Bangladesh has small capacity to pay attention in environmental development issues. That is why despite this ominous environmental catastrophe both the policy makers and researchers are ignoring the issue for about last two and half decades. This paper is an attempt just to fill up this existing literature gap. Against this backdrop, this study makes an effort to investigate the empirical cointegration, long and short-run dynamics, and causal relationships between economic development and environmental decadence in Bangladesh. The main objectives of the study are as follows:

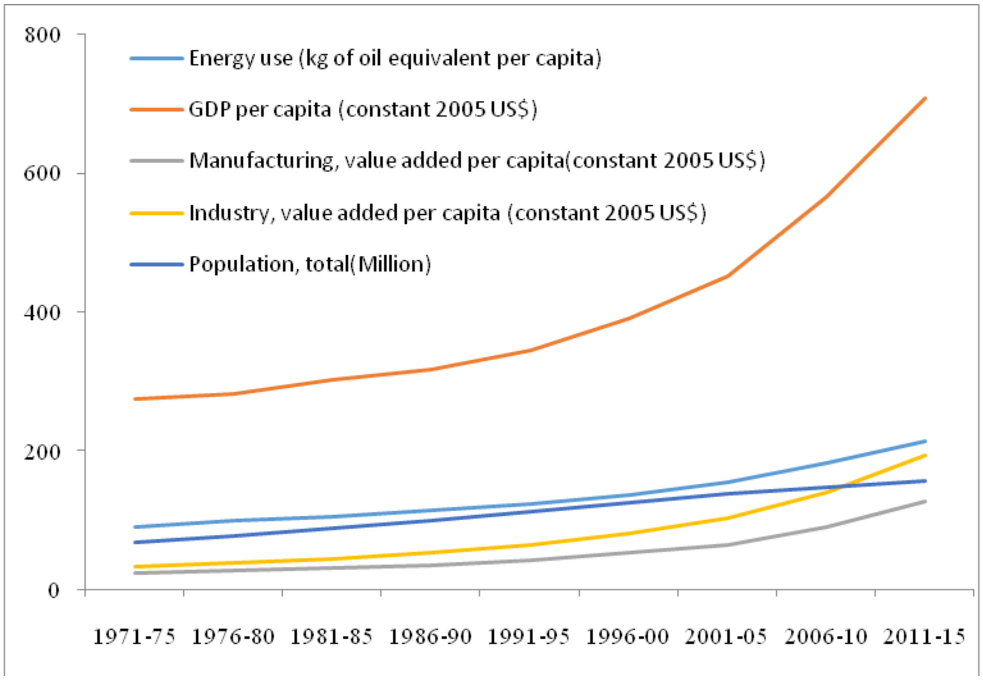
1) To find out whether economic development threatens environmental condition of the country;

2) To unfold the long and short-run dynamics between economic development and environmental degradation in Bangladesh;
3) To assess the form of causal relationship (no direction, unidirectional or bi-directional/feedback) between economic development and environmental deterioration.

2.0 Environmental condition and economic development in Bangladesh: A Brief Overview

An anomaly in usual economic development phenomenon is set by Bangladesh which is that despite high population growth (about an average of 1.5 percent since 2000) per capita GDP growth in Bangladesh is about 5 percent since 2002. In such impressive development of people living standard is contributed mostly by rapid growth of manufacturing and service sectors of the economy. In developing countries usually growth of these two sectors stems from high consumption of fissile fuels such as coal, crude oil, natural gas etc., and Bangladesh is not out of this trend. In absence of green energy crude and refined petroleum oil and natural gas are the prime input of transport sector, electricity producing and manufacturing plants of this country. There is a close relation between consumption of such energy inputs and carbon emissions regardless of the country. Further, low treatment of wastage by the backwardly linked industries of rapidly growing RMG sector is also providing stoke in this process. Figure 1 bellow is explicitly showing that there is a increasing and positive relationship among the per capita energy consumption, per capita GDP growth and per capita manufacturing production. The co-movements of these depicted variables is hinting that perhaps some positive relationship is existing among them. Accordingly, Environmental degradation and natural resources depletion in Bangladesh are major threats to sustainable economic growth (Faridul et. al. 2013).

Figure 1: Positive relationships of per capita energy consumption, GDP and Manufacturing production in Bangladesh.



In general, Bangladesh suffers from the lack of environmental consciousness, all stakeholders like policy makers, researchers and ultimate impact bearers, which causes environmental degradation and emissions of Green House Gases to the environment. For such lack awareness and geographical position of Bangladesh is frequently affecting the country by the natural calamities such as cyclone, over rainfall, droughts, floods and tidal-surge.

The data as presented in Table 1 below shows that the five-year periodic averages of almost all the indicators of the economy and environment display mostly of steady increasing trend, indicating the probable linkage among them over time is hold over this period.

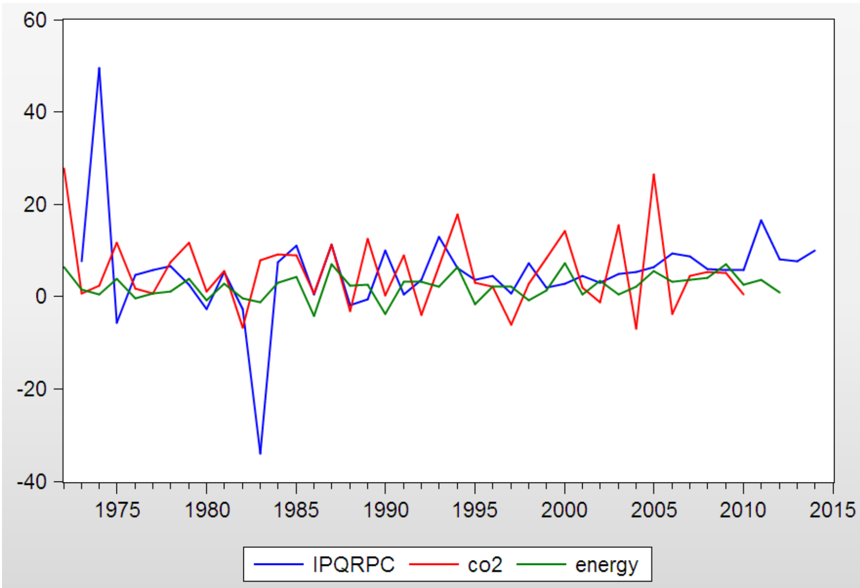
Table 1
Trends in the Indicators of Financial Development and Economic Growth in Bangladesh

	Energy use (kg of oil equivalent per capita)	GDP per capita (constant 2005 US$)	CO2 emissions (metric tons per capita)	Manufacturing, value added per capita(constant 2005 US$)	Industry, value added per capita (constant 2005 US$)	Manufacturing, value added (constant 2005 US$)	Industry, value added (constant 2005 Million US$)	Population, total(Million)
1971-75	90.68	273.76	0.05	22.81	32.57	1572.43	2241.78	68.75
1976-80	99.44	281.25	0.08	27.41	38.19	2115.88	2952.77	77.05
1981-85	104.82	300.52	0.10	29.93	44.08	2643.90	3896.37	88.24
1986-90	113.99	315.32	0.13	34.44	52.37	3473.40	5284.34	100.77
1991-95	123.76	344.59	0.16	42.00	63.25	4778.37	7194.22	113.46
1996-00	136.32	390.14	0.20	53.33	81.20	6736.62	10260.64	126.15
2001-05	153.91	451.07	0.26	64.65	101.99	8966.99	14146.45	138.48
2006-10	182.00	564.72	0.34	90.30	139.79	13404.68	20750.90	148.24
2011-15	213.19	707.22	0.37	127.36	193.56	20046.85	30465.22	157.18

Source: WDI, 2016 by WB.

We did not included all of the variables included in the Table 1 and Figure 1. As a surrogate of them we considered the level of carbon emissions (dependent variable), energy consumption and industrial production levels (in index form) as explanatory variables. All these three variables are displayed in figure 2 in growth form. Again, as can be seen from the Figure 2, the yearly growth of these concerned variables in Bangladesh also maintained synchronized co-movement, displaying a somewhat similar pattern in their progress and moving approximately together which can be helpful to infer that CO2 emissions have a close association with industrial progress in Bangladesh.

Figure 2
Trends in the Economic Growth in Bangladesh



In such backdrops, this study underpins to get a clear understanding of the nexus among the level of CO2 emissions, energy consumptions and industrial growth in Bangladesh. The paper contributes to examine the dynamics and causal linkages among these variables for the period of 1972 to 2015. Applying ARDL cointegration bound testing approach and Granger causality testing method through taking care of the stochastic properties of the regarded data we have got very intuitive results. Many important policy implications can be inferred by the results of the study. The vast portion of literati of environmental economics in Bangladesh is absolutely unaware about the process and efficacy of the government environmental protection policy in Bangladesh. So, the paper is a big contribution in the fulfilling of existing literature gap regarding pursued environmental policy in case of Bangladesh as it is basically, to the best of our knowledge, one of the very few output of its kind. Besides the empirical result of this study will provide policymakers a better understanding of energy consumption, CO2 emissions and economic growth nexus to formulate energy and climate policies to ameliorate the environment by minimizing its' pollution level.

3.0 Literature Review

The first empirical studies to investigate the economic growth and environmental degradation (or specifically CO_2 emissions) link is Kraft and Kraft's (1978) paper which uses data for United States from 1974 to 1974 and finds evidence of a Granger causality from output to energy consumption. After that seminal paper a wave has swept over the researchers across the world to find out empirical relationships in such variables. As a natural outcome of this prototype research and researchers growing interest on this issue, a vast amount of articles in the context of relationship between economic growth and environmental pollution have emerged which can be segregated in two groups: a single country and a group of countries research works. The context of Bangladesh is not out of this flow as well. We have got three papers based on Bangladesh in this issue. First of all, Faridul et. al. (2012) gets positive results on energy consumption-CO_2 emissions and urbanization-CO_2 emissions relationships which presented a convincing evidence that existence in a preliminary stage of economic development, Bangladesh economic progress is causing environmental degradation. Using ARDL and Vector Error Correction Model (VECM) methods they have found the evidence of existence of Environmental Kuznet Curve (EKC) in case of Bangladesh. Almost a similar result is also found by Faridul et. al. (2013) where using the same techniques for the data used for 1971 to 2010 they have reached in the conclusion that along with energy consumption and urbanization, economic growth and openness (i.e. increasing international trade) too contributes in CO_2 emissions in Bangladesh. Same result was found in another paper by Alam et. al. (2012) where they used a group of data for the period of 1976-2006. Using Johansen (1990) cointegration test for energy consumption, economic growth and electricity consumption they have got uni-directional causality from energy consumption and economic growth both in short and long-run. However, bi-directional causality of electricity consumption and economic growth was also found by them in the same paper. Again, using ARDL procedure between CO2 emissions and energy consumption they have got a uni-directional relationship between them in long-run but in short-run, unlike Faridul et. al. (2012), the result was opposite which conflict the well known EKC hypothesis.

In case of other country papers we have got some impressive and intuitive empirical findings. For the brevity of the paper we are going highlight here only some of them those we believe truly have important implications in environmental research all over the world. Keeping coherence with EKC concepts we have also focused the matter of similar development stages in country selection during make a choice of the paper to be mentioned in this article so that no contradiction of development stage with Bangladesh arises. As Bangladesh and India are in similar stage of development that is why perhaps the empirical relationships stemmed from the researchers are also same. Using various techniques like Johansen Cointegration (1990), Pesaran and Shin (2001) ARDL bound testing, VECM and VAR for the different sample periods Mohapatra et. al. (2015), Tiwari (2011), Tiwari (2012), Ozturk et. al. (2002) almost all of them have got positive relationships among CO2 emissions, environmental degradation and GDP growth for India. Though there are some dissimilarities in their short-run and long-run relationships result of these papers reached in the decision that economic development in India surely causes environmental degradation over the last few decades. Mahmud et. al. (2010) have got one to one relationship among, what they call E-E-E, energy, environment and economy. Using different econometric methods such as ARDL bound testing approach, VECM and Granger causality they have got both long-run and short-run relationships among carbon emissions, energy consumptions and economic development process. Getting no EKC relationship among these variables in case of Pakistan they have pointed out that if Pakistan does not take initiatives for using of green energy for economic development, it will fall serious environmental challenges in future. For the data period of 1971-2004 empirical and statistical finding for Tunisia, Chebbi et. al. (2008) pointed out that economic growth, energy consumption and carbon emissions are related in the long-run meaning that Tunisia may pursuing an inefficient energy policy. However, in short-run they did not get such relationships. Further, impulse response tests also did not confirmed the relationships they got for long-run. So, according to their findings using an energy policy which is environmental harmless for Tunisia may not hamper the economic development the country in short-run. For Turkey Buzkurt et. al. (2014) have got an opposite result that of Chebbi et. al. (2008) for Tunisia. Using yearly data of GDP, CO2 emissions and energy consumptions for the period of 1960-2010, their research indicates that CO2 emissions affects economic growth negatively while energy consumption affects it positively. According to this result they have decided that Turkey may have crossed the peak point of EKC and, hence, if it pursue a policy of sustainable economic development by less CO2 emissions and less energy use its' economy will not suffer from any slow down.

Further, we have got several papers using various panel data techniques based on multiple countries data and some of them are truly noteworthy. Shahbaz et. al. (2016) have examined the tri-variable relationship among economic growth, energy consumption and CO2 emissions for NEXT-11[1] countries which pact also includes Bangladesh. Applying time-varying Granger causality method for the period of 1972-2013 of these eleven countries they have detected economic growth is the cause of CO2 emissions for Bangladesh and Egypt. Economic growth

[1] Member of N-11 are Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Turkey, South Korea and Vietnam.

causes energy consumption in the Philippines, Turkey and Vietnam but the feedback affect exists between economic growth and energy consumption in South Korea. For Indonesia and Turkey they find the uni-directional time-varying Granger causality running form economic growth to CO2 emissions which they thought the validity of EKC hypothesis for this couple of countries, also meaning that economic growth for these two countries is achievable by decreasing the environmental degradation rate.

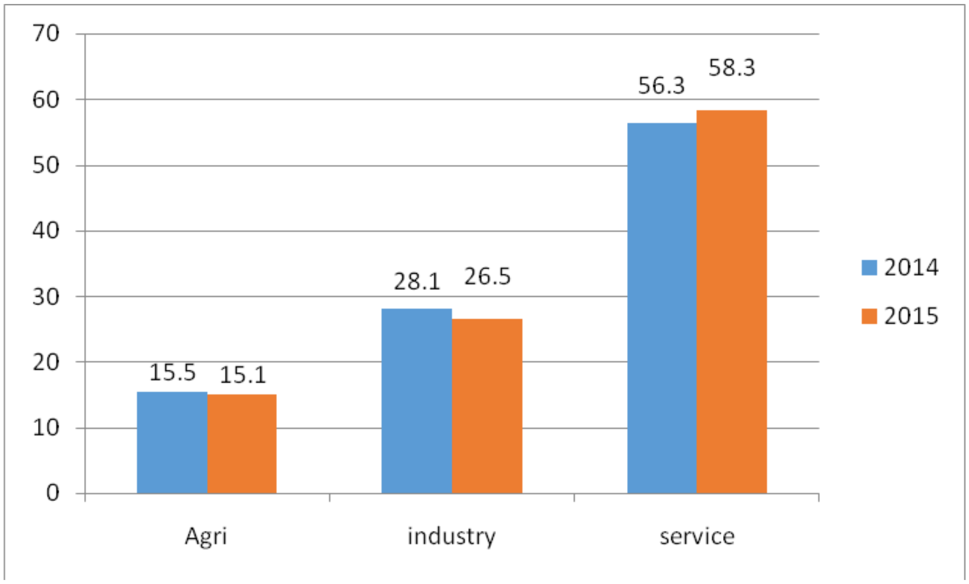
Lean et.al. (2013) has made an investigation for ASEAN countries using the annual data for the period of 1980-2006. Using panel cointegration and Granger causality techniques they have got positive association among economic growth, electricity consumption and CO2 emissions. Though they have failed to get any long-run relationship among these three variables of the ASEAN area for their selected period, they have got uni-directional Granger causality running from electricity consumptions and CO2 emissions to economic growth. Hamilton et. al. (2000) have analysed the sources of growth of CO2 emissions for OECD countries over the period of 1982-1997. Employing decomposition formula they separated out the effects of changes in population growth, economic growth, energy intensity of output, primary energy use in final energy consumption, the share of fissile fuels and the carbon intensity of fissile fuel combustion. They have shown that the growth in emissions depends on how effectively energy use can be changed to offset the effects of economic growth. According to their empirical findings, across the OECD countries, growth in emissions has been mainly due to economic growth and an increase in primary energy required for final energy consumption. As per their results, besides of sharp differences between countries with population growth and energy source mix the overall and large fall of energy intensities in OECD countries over the 1982-1997 has been driven primarily by falling energy intensities in the services and industry sectors. Farhani et. al (2012) have applied the panel unit root test, panel cointegration and panel causality tests to investigate the relationship between energy consumption, GDP growth and CO_2 emissions for 15 MENA[2] countries covering the annual period 1973-2008. By taking care of the heterogeneity in countries and the endogeneity bias in regressors econometrically, the finding of their study reveals that there is no causal link between GDP growth and energy consumption growth; and between CO_2 emissions and energy consumption growth in the short run in those countries. However, in the long run, there is a uni-directional causality running from GDP growth and CO_2 emissions to energy consumption. We have also studied some papers which have made investigation based on panel of vast amount of countries like Saidi et. al. (2015) consisting 58 countries, Stolyarova (2010) on 93 countries, Maddison et. al. (2008) on 134 countries, Dinda et. al. (2001) for 88 countries across the world. In this list Stolyarova (2010) and Maddison et. al. (2008) papers included Bangladesh in their sample. Applying annual data for different time periods the authors of these papers have sub-divided the sample among different countries to maintain homogeneity among them. Except Maddison et.al. (2008), all other authors have been confirmed about positive relation between the growth rate of GDP and CO2 emissions. Saidi et. al. (2015) have got long-run and, Stolyarova (2010) and Dinda et. al. (2001) have got bi-directional or feedback relationship between GDP and CO2 emissions growth rates.

According to the above investigation of papers except Hamilton et. al. (2000) all other papers have tried to get the relationship between GDP growth rate and CO2 emissions growth rate. But in our understanding such analysis is not suitable for Bangladesh as more than 70 percent of GDP growth in Bangladesh (Figure 1) is driven by service and agricultural sectors, because

[2] MENA means a group of Middle East and North African countries

being a developing country, which are basically less energy intensive sectors. That is why like Hamilton et. al. (2000) we have focused how industry sector can explain the CO2 emissions and energy consumptions in Bangladesh.

Figure 1: Contribution of three sectors in GDP of 2014 & 2015



Source: Economic Trend, A monthly publication of Bangladesh Bank, Sept.-2016.

4.0 Data and Methodology

4.1. Variables and Data

In order to gain valuable insights into the long-run and short-run dynamics as well as the causal relationships between industrial development and carbon emissions in Bangladesh, two variables have been used in the growth form. Using a variable in growth form conveys information regarding the direction of movements of the variable in the current period with respect to the previous period which reveals the dynamic relations among the concerned variables and can be used to gain valuable intuition regarding future movement of the variable as well. However, a variable in simple ratio form gives information on the variable for the current period only. Therefore, we can gain more information by using a variable in the growth form rather than using it in simple ratio form.

In this study, we are using growth of carbon emissions as dependent variable. Remaining two variables growth in energy consumption and growth per capita industrial production where the later one represents economic development in Bangladesh.

The description of all the variables is as follows-

CO2 : Growth of Carbon Emissions

ENRG: Growth in Energy Consumption

IPQIPC: Growth in Per Capita Industrial Production Quantum Index

We have used the time series data of Bangladesh economy for the period of 1972 to 2015. The data source is the Word Development of Indicator (WDI), 2016 of World Bank and various issues of the Economic Trends (IPQI) of Bangladesh Bank, the central bank of Bangladesh. Keeping view with the prime objective of the study, the functional form of the model is as follows:

Carbon Emissions = f (Energy Consumption, Industrial Development)

The econometric form of the above model is as follows:

$$CO2_t = \boldsymbol{\alpha} + \boldsymbol{\beta}_1 ENRG_t + \boldsymbol{\beta}_2 IPQIPC_t + \boldsymbol{\varepsilon}_t$$

Where all the variables are same as described above, $\boldsymbol{\alpha}$ is the intercept and β_1-β_2 are coefficients of explanatory variables.

4.2 Unit Root Testing

In general, the stationarity issue holds supreme importance in the econometric analysis of times series data, since a stationary series would have time invariant mean and variance. Also, even in the absence of any meaningful relationship among the variables, non-stationary series containing unit root will result in a high co-efficient of determination (R^2), thereby leading to spurious regression (Granger and Newbold, 1974).

Although in ARDL approach of cointegration unit root pre-testing is not essential, the ARDL/Bounds Testing methodology of Pesaran and Shin (1999) and Pesaran *et al*. (2001) requires that no variable should be integrated of order 2 or I(2), as such data will invalidate the methodology. It is therefore, justified to test the stationarity of each variable before proceeding to the next level of analysis and inference. The Augmented Dickey-Fuller (ADF)and the Kwiatkowski-Phillips-Schmidt-Shin(KPSS) unit root testing methods will be used for the Unit Roots Testing of the variables under study.

4.3 Cointegration Testing Using ARDL Bounds Testing Approach

The ARDL (Auto Regressive Distributed Lag) bound testing technique developed by Pesaran and Shin (1999) and Pesaran *et al.* (2001) will be employed to investigate the possible existence of cointegration among the variables under study or whether they possess long run equilibrium relationship as well as extracting both the long-run and short-run dynamics.

The ARDL / Bounds Testing methodology of Pesaran and Shin (1999) and Pesaran *et al*. (2001) has a number of advantages over traditional cointegration testing as enumerated below:

- It is very flexible and allows analysis with a mixture of I (0) and I (1) data.
- It involves just a single-equation set-up, making it simple to implement and interpret.
- Unlike the conventional method, different variables can be assigned different lag-lengths in the model.
- It is very much suitable for small samples.

- It provides unbiased estimation of long run relationship and long run parameters (Harris and Sollis, 2005).
- The endogeneity problem is adequately addressed. In this approach Pesaran and Shin (1999) maintain that modeling ARDL with the appropriate number of lags will address autocorrelation and endogeneity problems. According to Jalil *et al.* (2008), endogeneity is less of a problem if the estimated ARDL model is free of autocorrelation.

The basic form of an ARDL regression model used in this study is:

$$CO2_t = \alpha + \sum_{i=1}^{p} \beta_i CO2_{t-i} + \sum_{i=0}^{q} \gamma_i ENRG_{t-i} + \sum_{i=0}^{R} \delta_i IPQIPC_{t-i} + \varepsilon_{t1} \ldots\ldots\ldots\ldots (1)$$

where CO2, ENRG, and IPQIPC are variables of the study and ε_{t1} is a "well-behaved" random "disturbance" term, i,e., ε_{t1} is serially independent, homoscadastic and normally distributed.

For bounds testing of cointegration, the above model is modified in the following manner:

$$\Delta CO2_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta CO2_{t-i} + \sum_{i=0}^{q} \gamma_i \Delta ENRG_{t-i} + \sum_{i=0}^{R} \delta_i \Delta IPQIPC_{t-i}$$
$$+\theta_0 CO2_{t-1} + \theta_1 ENRG_{t-1} + \theta_2 IPQIPC_{t-1} + \varepsilon_{t2} \ldots\ldots\ldots\ldots\ldots (2)$$

The model in equation (2) is a particular type of Error Correction Model (ECM), where the coefficients are not restricted. Pesaran et al. (2001) term it as a "conditional ECM".

The appropriate values for the maximum lags, p, q and q will be determined by using one or more of the "information criteria" - AIC, SC (BIC), HQ, etc.

Under the above equation the null and alternative hypotheses are as follows:

H_0 :No cointegration exist

H_1: cointegration exists.

The null hypothesis is tested by conducting F-test for the joint significance of the coefficients of the lagged levels of the variables. Thus

$H_0: \theta_0 = \theta_1 = \theta_2 = 0$

$H_1: \theta_0 \neq 0, \theta_1 \neq 0, \theta_2 \neq 0,$

The distribution of the test statistic is purely non-standard and exact critical values for the F-test are not available for an arbitrary mix of I(0) and I(1) variables. However, Pesaran et al. (2001) developed bounds on the critical values for the asymptotic distribution of the F-statistic. For various situations (*e.g.*, different numbers of variables, (k + 1)), they supply lower and upper bounds on the critical values. However, since the study is based on a relatively smaller sample size, we shall also compare the computed F-test value with the bounds critical value tables provided by Narayan (2005) as these are more suitable for small samples.

In each case, the lower bound is based on the assumption that all of the variables are I (0), and the upper bound is based on the assumption that all of the variables are I (1). If the computed F-statistic falls below the lower bound, the variables are I(0), so no cointegration is possible, by definition. If the F-statistic exceeds the upper bound, we conclude that we have cointegration. Finally, if the F-statistic falls between the bounds, the test is inconclusive and we will have to resort to other techniques of cointegration.

Following Giles, D. (2013), it is also necessary to conduct, as a cross-check, a "Bounds t-test" as stated below:

$$H_0 : \theta_0 = 0, \text{ against } H_1 : \theta_0 < 0.$$

The decision rule for this test is as follows:

If the t-statistic for $CO2_{t-1}$ in equation (2) is greater than the "I (1) bound" tabulated by Pesaran et al. (2001; pp.303-304), this would support the conclusion that there is a long-run relationship between the variables. If the t-statistic is less than the "I(0) bound", we would conclude that the data are all stationary.

Short run parameters are estimated using the regular error correction mechanism (ECM) as depicted is equation (3) below:

$$\Delta CO2_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta CO2_{t-i} + \sum_{i=0}^{q} \gamma_i \Delta ENRG_{t-i} + \sum_{i=0}^{R} \delta_i \Delta IPQIPC_{t-i} +$$
$$+\tau ECT_{t-1} + \varepsilon_{t3} \dots \dots \dots \dots \dots (3)$$

The error correction model results indicate the speed of adjustment back to long run equilibrium after a short run shocks. The ECM integrates the short-run coefficient with the long-run coefficient without losing long-run information. Under ECM technique, the long run causality is depicted by the negative and significant value of the error correction term (ECT) coefficient τ and the short run causality is shown by the significant value of other regressor variables.

4.4 Diagnostic Tests of the Model

One of the most important and crucial assumptions in the ARDL/Bounds Testing methodology of Pesaran et al. (2001) is that the errors of equation (2) must be serially independent and normally distributed. Therefore, both 'Q-Statistics' and 'Breusch-Godfrey Serial Correlation LM test' will be used for testing Serial Independence and 'Jarque-Bera' test will be used for testing Normality of the errors of the model. The heteroscedasticity will also be checked using 'Breusch-Pagan-Godfrey' test.

4.5 Stability Test of the Model

It is obligatory to ensure the 'dynamic stability' of any model having autoregressive structure. The stability of the model will be checked by using Recursive CUSUM and CUSUM of squares (Brown, Durbin, and Evans, 1975) estimates. These tests are also suggested by Pesaran and Pesaran (1997) for measuring the parameter stability.

4.6 Granger Causality Test using TY Method

First and foremost, Granger causality means in the case of two time-series variables, *X* and *Y*: "*X* is said to Granger-cause *Y* if *Y* can be better predicted using the histories of both *X* and *Y* than it can by using the history of *Y* alone". If two or more time-series are cointegrated, then there must be Granger causality between them - either one-way or in both directions. However, the converse is not true, (Dave Giles (2011). Again, according to Granger (1969), measuring the correlation between variables is not enough to construct a complete understanding about the relationship between two or more time series. This is because some correlations may be spurious and not useful, as there might be a hint of existence of a third variable that cannot be accounted for. Further, only correlation does not confirms causation between (/among) variables. That is, if we get our series are cointegrated, then we must need to cross-check on our causality results. This is the core idea of performing the Ganger causality test.

We can test for the absence of Granger causality by estimating the following VAR model:

$$Y_t = \mathrm{g}_0 + a_1 Y_{t-1} + ... + a_p Y_{t-p} + b_1 X_{t-1} + ... + b_p X_{t-p} + u_t \qquad (4)$$

$$X_t = h_0 + c_1 X_{t-1} + ... + c_p X_{t-p} + d_1 Y_{t-1} + ... + d_p Y_{t-p} + v_t \qquad (5)$$

Then, testing H_0: $b_1 = b_2 = ... = b_p = 0$, against H_A: X does not Granger cause Y. Similarly, testing H_0: $d_1 = d_2 = ... = d_p = 0$, against H_A: Y does not Granger cause *X*. In each case, a rejection of the null implies there is Granger causality. Note that X and Y series are in 'level' form which simply means that the data is not in 'difference' form where u_t and v_t are white noise error terms. In long run equilibrium these errors should zero. In these two equations, the series Y_t and X_t are co-integrated when at least one of the coefficients bi or di is statistically different from zero. If bi ≠ 0 and di = 0, then X_t will lead Y_t in the long run. The opposite will occur if di ≠ 0 and bi = 0. If both bi ≠ 0 and di ≠ 0, then feedback relationship exists between Y_t and X_t. But if both bi = 0 and di = 0, then no cointegration exists between Y_t and X_t such conflicting results (with prior result of ARDL) can come out if the sample size is too small to satisfy the asymptotics that the cointegration and causality tests rely on (Dave Giles, 2011). The coefficients a_i's and c_i's represents the short run dynamics between Y_t and X_t. If a_i's are not all zero, movements in the X_t will lead to Y_t in the short run and conversely, if c_i's are not all zero, movements in the Y_t will lead to X_t in the short run.

Following Toda-Yamamoto (1995) procedure[3], the Granger Causality among the variables under an augmented Vector Autoregression (VAR) framework will be estimated. We will determine the appropriate maximum lag length for the variables in the VAR by using the usual methods. Specifically, basis the choice of lag length is on the usual information criteria, such as AIC. We will also ensure that VAR is well specified that is VAR does not contains serial correlation in the residuals.

[3] For a detailed discussion with example of the procedure, see Dave Giles (2011)

5.0 Estimation, Analysis and Findings

The 'Unit Root Testing' of the variables, appropriate maximum lag lengths selection of the model &the ARDL model estimation, and Granger Causality along with all the diagnostics and stability testing of the model were done using E-Views 9.0 software**.** E-Views version 9.0 contains a full-functioning ARDL estimation option, together with bounds testing and an analysis of the long-run relationship between the variables being modeled.

5.1 Unit Root Testing

The Augmented Dickey-Fuller (ADF) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root testing results are displayed in the following table:

Table2

Results of Unit Root Test

Variables	ADF H_0: Variable has a unit root		KPSS H_0: Variable is Stationary	
	LEVEL		LEVEL	
	Intercept	Intercept &Trend	Intercept	Intercept &Trend
1) CO2	-5.7516*** (0.0000)	-5.6936*** (0.0002)	0.5000**	0.5000***
2)ENRG	-8.1199*** (0.0000)	-8.9973*** (0.0000)	0.3392	0.1031
3) IPQIPC	-5.2637*** (0.0000)	-2.7334*** (0.0000)	0.7105**	0.2001**
	First Difference		First Difference	
1) CO2	-6.5768*** (0.0000)	-6.7681*** (0.0000)	0.2921	0.2239***
2)ENRG	-8.7532*** (0.0000)	-8.6068*** (0.0000)	0.2397*	0.2431***
3) IPQIPC	-0.4671 (0.8869)	-4.8770*** (0.0016)	0.5265**	0.1779**

(*,**and***denotestatisticalsignificanceatthe10%,5%and1% levels respectively; p-values in the parentheses (.))

It can be inferred from the above estimates that under ADF test all variables are stationary at levels and hence of order *I (0)*. However under KPSS test, ENRG is non-stationary at levels by taking both only intercept or intercept and Trend but attain stationarity after first differences and, therefore, is of order *I (1)*, while other variables are stationary at the levels by both ADF and KPSS. Therefore, the true order of integration of the variable ENRG is inconclusive. This mix and uncertain order of integration of the variables justifies using the ARDL approach of cointegration. However, as required by the ARDL bound testing technique developed by Pesaran and Shin (1999) and Pesaran *et al.* (2001), the results of the ADF and KPSS unit root testing confirm that no variable is I(2).

5.2 ARDL model estimation

The 'Akaike Information Criterion (AIC)' has been used to determine the optimum lag length of the model. The selected model is ARDL (4,3,2). Therefore, the optimum lag lengths of the variables CO2, ENRG, and IPQIPC are: p= 4, q= 3 and R = 2 respectively.

5.3 Diagnostic Tests of the Model

As far as the diagnostic checks are concerned, this model is good fit and it passes all the diagnostic tests. The R-squared is 0.6838 (Adj-R^2:0.4881),implying that almost 68 percent variations in the dependent variable are explained by the model and the rest by the error term. The DW statistics is 2.1751, which confirms that the model is not spurious. Moreover, the computed F-statistic = 3.4937 (Prob. 0.0054) clearly rejects the null hypothesis that the regressors have zero coefficients. As illustrated in the table below, the model passes the test regarding serial correlation (Q-Statistics and Breusch-Godfrey Serial Correlation LM tests), Normality (Jarque-Bera test) and Heteroscedasticity ('Breusch-Pagan-Godfrey' test).

<u>Table 3</u>

Model Diagnostic Tests Results

Test	χ^2	Probability
Breusch-Godfrey Serial Correlation LM test	2.8069	0.2457
Breusch- Pagan-Godfrey Heteroskedasticity test	3.9068	0.6893
Jarque - Bera test	3.0450	0.2179

The Q-Statistics (E-Views output) in Figure 2 below also shows that all the spikes are within range in both the cases, therefore, re-affirming that the errors of the model is serially independent.

Figure 2

Q-Statistics result from E-Views 9.0

Date: 12/13/16 Time: 18:18
Sample: 1972 2015
Included observations: 35
Q-statistic probabilities adjusted for 4 dynamic regressors

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.156	-0.156	0.9293	0.335
		2	-0.019	-0.044	0.9432	0.624
		3	-0.103	-0.116	1.3756	0.711
		4	-0.137	-0.181	2.1598	0.706
		5	0.036	-0.031	2.2158	0.819
		6	-0.083	-0.119	2.5200	0.866
		7	-0.142	-0.238	3.4527	0.840
		8	0.029	-0.099	3.4936	0.900
		9	-0.021	-0.110	3.5166	0.940
		10	0.055	-0.087	3.6742	0.961
		11	0.120	0.029	4.4573	0.955
		12	-0.025	-0.043	4.4917	0.973
		13	-0.139	-0.237	5.6271	0.959
		14	0.042	-0.078	5.7383	0.973
		15	0.032	-0.011	5.8041	0.983
		16	0.083	-0.001	6.2743	0.985

*Probabilities may not be valid for this equation specification.

Figure 2

Q-Statistics Square Test result from E-Views 9.0

Date: 12/13/16 Time: 18:19
Sample: 1972 2015
Included observations: 35

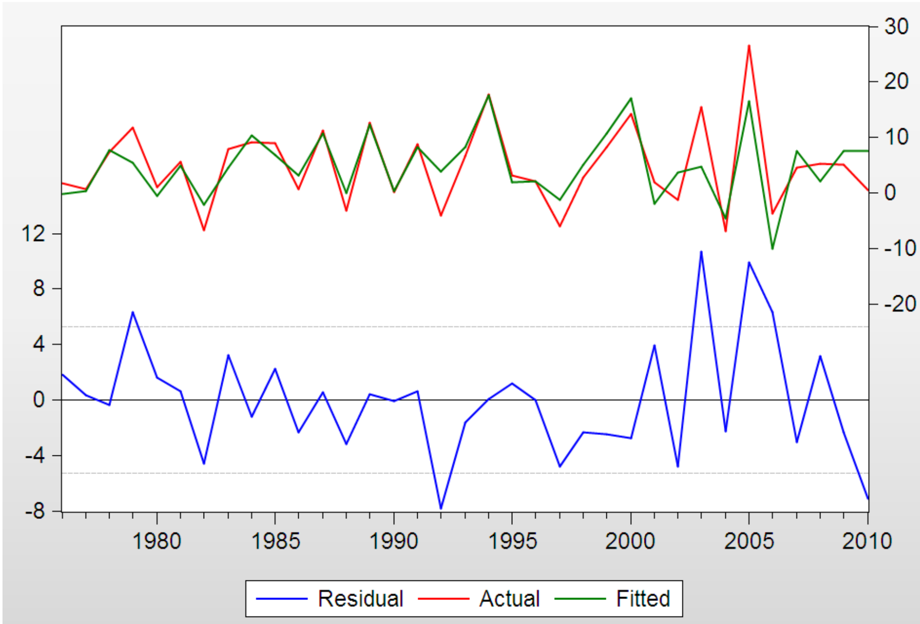
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.132	0.132	0.6641	0.415
		2	0.224	0.211	2.6399	0.267
		3	-0.159	-0.224	3.6657	0.300
		4	-0.251	-0.280	6.3018	0.178
		5	0.061	0.255	6.4646	0.264
		6	0.047	0.153	6.5639	0.363
		7	0.092	-0.161	6.9584	0.433
		8	0.058	-0.037	7.1218	0.524
		9	-0.026	0.142	7.1567	0.621
		10	0.046	0.092	7.2646	0.700
		11	0.162	0.129	8.6755	0.652
		12	-0.071	-0.228	8.9603	0.706
		13	0.073	0.010	9.2754	0.752
		14	-0.215	-0.014	12.121	0.597
		15	-0.060	-0.001	12.358	0.652
		16	-0.017	-0.058	12.377	0.718

5.4 Fit of the Model

The Actual/Fitted/Residual plot of the unrestricted ECM of our model shows that the fit of model is good enough in terms of explaining the level of GR variable (Figure 3).

Figure3

Actual/Fitted/Residual plot (E-Views 9.0 output)



5.5 ARDL Bounds Test

Since the model passed all the diagnostics tests, we now move to the next level of analysis, i.e., bounds test for cointegration. The associated F-test obtained is as follows:

Table4
Result of ARDL Bounds Testing

Variables	F-Statistics	Result
F(CO2/ENRG,IPQIPC)	14.0096***	Cointegration

(***significantat 1%significancelevel**)**

For k=2 (number of independent variables)the relevant critical values with unrestricted intercept and linear trend from table CI(v) on p.301 of *Pesaran et al. (2001)*, and for k=2, n≈45 the table for case (v) on p.1990 of *Narayan (2005)* is given below:

Table5
Bounds Testing Critical Values from Pesaran and Narayan

	Pesaran		Narayan	
Critical Values	Lower Bound I(0)	Upper Bound I(1)	Lower Bound I(0)	Upper Bound I(1)
1%	6.34	7.52	7.317	8.720
5%	4.87	5.85	5.360	6.373
10%	4.19	5.06	4.437	5.377

As the value of the computed F-statistic exceeds the upper bound even at the 1% significance level in both the Pesaran and Narayan relevant table of critical values, we can conclude that there is evidence of a long-run relationship between the time-series of our model (at this level of significance or greater).

Cross Checking for cointegration:

In addition, the t-statistic on $CO2_{t-1}$ is -4.3113. When we look at Table CII (v) on p.304 of Pesaran *et al*. (2001), we find that the I(0) and I(1) bounds for the t-statistic at the 1%, 5%, and 10% significance levels are [-3.96,-4.53], [-3.41,-3.95], and [-3.13,-3.63] respectively. As seen, at the 5% significance level, the computed t-statistic on $CO2_{t-1}$ exceeds the corresponding value for I(1), thus reinforcing our conclusion that there is a long-run relationship among the variables.

5.6 Long-Run and Short-Run Relationships

5.6.1 Long-Run Relationship

The long-run equilibrium relationship among the variables estimated using the ARDL approach is given in the table below:

Table6

Estimated Long Run Coefficients using ARDL Approach

Variables	Coefficient	t-Statistic	Probability
CO2(-1)	-0.749188***	-4.311291	0.0003
CO2(-2)	-0.540585**	-2.779005	0.0112
CO2(-3)	-0.731191**	-3.755516	0.0012
CO2(-4)	-0.353844**	-2.436762	0.0238
ENRG	1.317242***	2.975545	0.0072
ENRG(-3)	1.011448*	2.064928	0.0515
IPQRPC(-3)	-30679017**	-2.204936	0.0387
C	17.42030***	3.798761	0.0011

(*,**and***denotestatisticalsignificanceatthe1%,5%and10% levels respectively)

The above result shows that the coefficients are significant for the variables CO2 (Growth of ENRG) and IPQIPC (Growth of Per Capita Industrial Production Quantum Index). This indicates that energy consumption growth and Per capita Industrial Production growth has positive impact on the Carbon emissions growth in the long run which is confirmed by the sign and statistical significance of their coefficients as shown in the Table 6 above.

This result is similar to the result of Faridul et. al. (2012), Faridul et. al. (2013), Mahmud et. al. (2010) and Shahbaz et. al (2016). But it is in contrast to the result of Alam et. al. (2012), Buzkurt et. al. (2012), Farhani et. al. (2012), Lean et. al. (2013) and Saidi et. al (2015).

5.6.2 Short Run Dynamics

The following OLS equation is tested for the short run causality in ARDL(4,3,4) framework:

Table7

Estimates from the Error Correction Mechanism

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	6.89E-14***	1.75E-14	-3.924415	0.0012
D(CO2(-2))	5.02E-14***	1.30E-14	-3.854824	0.0014
D(CO2(-3))	3.18E-14***	8.74E-15	-3.636930	0.0022
D(CO2(-4))	1.26E-14***	4.14E-15	-3.042259	0.0078
D(ENERGY)	1.668122***	8.89E-15	1.88E+14	0.0000
D(ENERGY(-1))	1.03E-13**	4.16E-14	2.485968	0.0244
D(ENERGY(-2))	7.51E-14**	3.14E-14	2.393821	0.0293
D(ENERGY(-3))	4.36E-14*	2.11E-14	2.063837	0.0556
D(ENERGY(-4))	1.47E-14	1.07E-14	1.373596	0.1885
D(IPQRPC)	364.7879***	2.30E-07	-1.59E+13	0.0000
D(IPQRPC(-1))	-4.30E-07*	2.47E-07	-1.741113	0.1009
D(IPQRPC(-2))	-2.48E-07	2.36E-07	-1.050454	0.3091
D(IPQRPC(-3))	-2.34E-07	2.28E-07	-1.026118	0.3201
CO2(-1)	1.0000***	2.15E-14	-4.65E+13	0.0000
ENERGY(-1)	1.668122***	5.33E-14	3.13E+13	0.0000
IPQRPC(-1)	311.7070***	7.97E-08	-4.58E+13	0.0000
C	6.7374***	1.21E-13	5.57E+13	0.0000
Coint.Eq(-1)	-1.0000***	4.07E-15	2.45E+14	0.0000

(*,**and***denote statistical significance at the 10%,5% and 1% levels respectively)

The results corresponding to equation (3) are shown by the Table 7 above. We conclude that short-run dynamics is in conjunction with the long-run relationships as shown by the value and sign of lagged error correction term (ECT) coefficient α[CointEq(-1)]. As required, ECT has a negative sign and it is very significant even at 1% level. This represents that there exists long-term relationship between the dependent variable and the regressors. In addition, the value of ECT coefficient is -1.00 which signifies strong and a faster speed of adjustment to equilibrium. Thus nearly 100% of the disequilibrium converges back to the long term equilibrium within one period (one year).

Lag period of CO2, ENGR and IPQIPC has positive and significant impact on Carbon emissions in the short-run which is confirmed by the sign and statistical significance of the coefficients of its second, third and fourth lagged values in the first differences. Therefore, we may conclude that the overall impact of both energy consumption growth and per capita industrial production growth is time invariant, i.e., having similar short-run and long-run impact on Carbon emissions growth.

This result is partially similar to the result of Alam et. al. (2012), Mohapatra et. al. (2015), Tiwari (2011), Tiwari (2012), Ozturk et. al. (2002), Stolyarova (2010) and Dinda et. al (2015). However, this result is opposite to the result of Chebbi et. al. (2008).

5.7 Stability of the Model

To ensure the robustness of our results we employ structural stability tests on the parameters of the long-run results based on the cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residuals of squares (CUSUMSQ) tests as suggested by Pesaran and Pesaran (1997). A graphical representation of CUSUM and CUSUMSQ statistics are provided in Figure 4 and Figure 5 below. If the plots of the CUSUM and CUSUMSQ remain within the 5 per cent critical bound, it would signify the parameter constancy and the model stability. Both the plots indicate that almost none of the straight lines (drawn at the 5 percent level) are crossed by CUSUM and CUSUMSQ i.e., the plots of both the CUSUM and CUSUMSQ are within the boundaries (shown by the dotted red lines) where plots of the CUSUM has hovered around the zero line and CUSUMSQ line slightly crossed the lower bound for the tow data of 2001 and 2002, and therefore these statistics confirm the model stability and that there is no systematic change identified in the coefficients at 5% significance level over the study period.

Figure4

Plot of CUSUM Tests

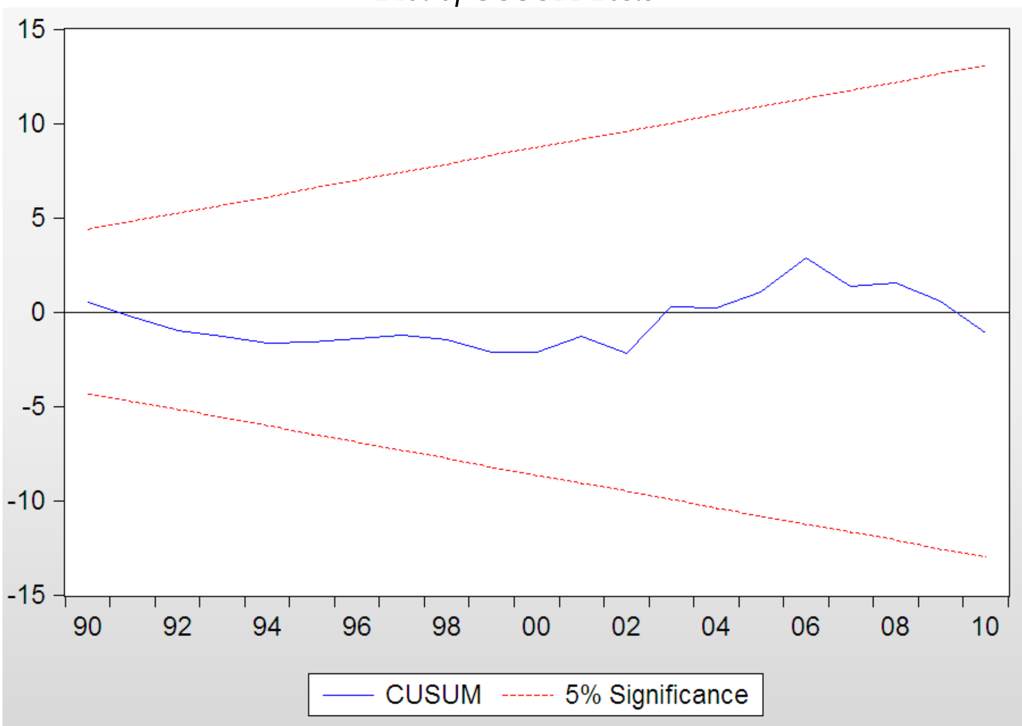
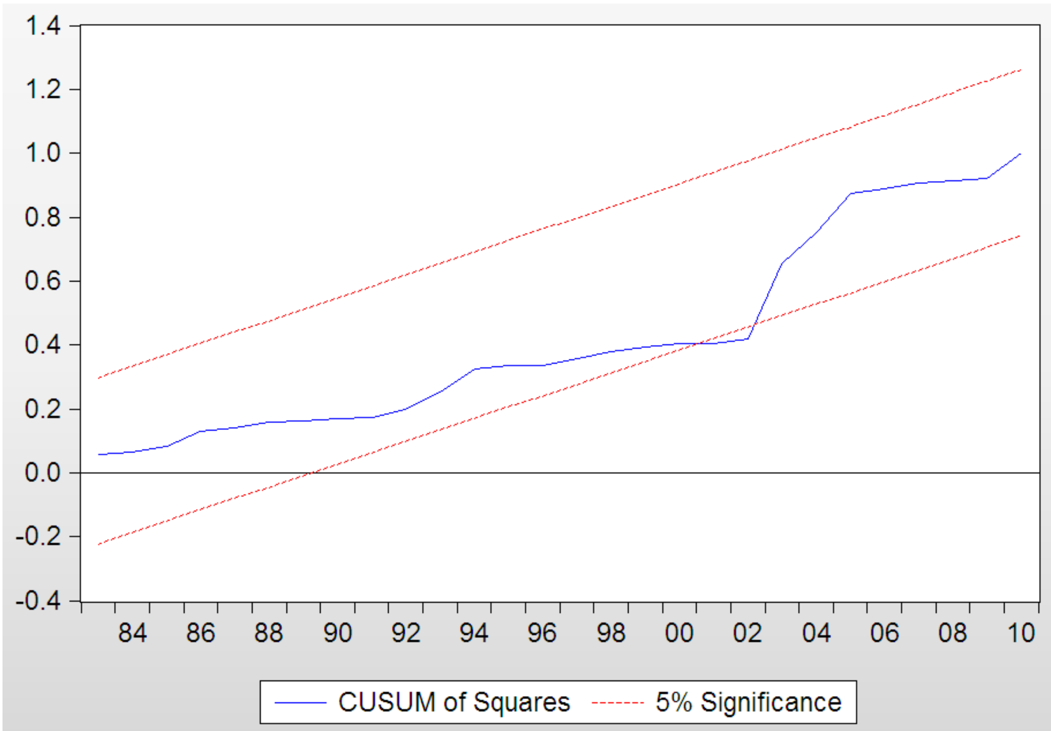


Figure 5

Plot of CUSUM of Squares Tests



5.8 Granger Causality Test

After examining the long-run relationship between the variables, we use the Granger causality test to determine the causality between the variables. As we found cointegration among the variables, we may expect uni or bidirectional causality among the series. We examine the causal relationships between energy consumption and carbon emissions growth in Bangladesh within an augmented VAR framework following Toda-Yamamoto (1995) procedure. The Table 8 and the arrow diagram for causal channels in Figure 6 below show the short-run Granger Causality among the variables.

We did not get the existence of a feedback/bidirectional relationship between carbon emissions growth with energy consumption growth and per capita industrial production growth, and between the per capita industrial production growth and energy consumption growth i.e. the relationships stem from Granger Causality analysis is known in theoretical paradigms is the "supply-leading hypothesis" not the "demand-following hypothesis". While the 'supply-leading hypothesis' posits a unidirectional causation that runs from energy consumption to carbon emissions' and from industrial production to carbon emissions, the 'demand-following hypothesis' posits an opposite direction of causality (Balago, G.S., 2014).

<u>Table8</u>

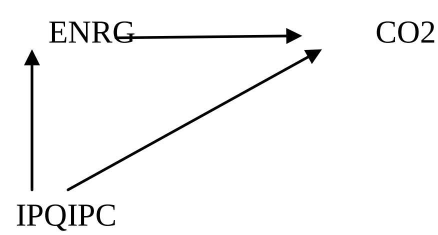
Granger Causality/Block Exogeneity Wald Tests

	Direction of Causality			
	CO2	ENRG	IPQIPC	
CO2	- - -	0.0336	0.0407	-----------------------
ENRG	8.1321***	- - -	1.5104	ENRG→CO2,
IPQIPC	2.9710**	3.5028**	- - -	IPQIPC→CO2;IPQIPC→ENRG

(*,**and***denotestatisticalsignificanceatthe10%,5%and1% levels respectively)

Figure6

Causal Channels



Rather, on the whole, there is evidence of strong uni-directional causality running from energy consumption and industrial production to CO2 emissions growth in Bangladesh which favors the findings of aforementioned papers of Mahmud et. al. (2010), Shahbaz et. al. (2016) and Lean et. al. (2013). However, this result sharply declines the Farhani et. al. (2012) findings for 15 MENA countries.

In this sense, we may conclude that the industrialization and energy consumption in Bangladesh are the reasons of carbon emissions growth and both energy consumption and industrialization are taking place in inefficient energy consumption and production process and occurring at the cost environmental pollution. Bangladesh does not using up-to-date green technology in its' economic growth and fuel utilization process.

6.0 Conclusion and Policy Implications

This paper has examined the empirical cointegration, long and short-run dynamics and causal relationships among the growth of per capita industrial production, energy consumption and CO2 emissions in case of Bangladesh over the period 1972 to 2015. Accordingly, we applied the ARDL/Bounds Testing methodology developed by Pesaran and Shin (1999) and Pesaran et al. (2001) to investigate cointegaration, Unrestricted Error Correction Model (UECM) of Pesaran and Shin (1999) and Pesaran et al. (2001) for long and short run dynamics and the Toda-Yamamoto Procedure of Granger Causality in a VAR framework.

The ARDL bounds tests as well as additional cross-checking confirmed both short and long-run cointegration between the growth of carbon emissions and per capita industrial production growth, carbon emissions and energy consumption, and per capita industrial production and energy consumption in Bangladesh. The coefficient of the error correction term is statistically significant at 1% levels of significance and has the expected negative sign with a value of (-1.00), which signifies a very strong and faster speed of adjustment to equilibrium. Thus nearly 100% of the disequilibrium convergence back to the long-term equilibrium within one year period. The estimated model passed all the diagnostics tests and was also found to be stable. The result was confirmed even by TY method of Granger causality test.

As the foregoing results imply, in Bangladesh industrial production growth is not indifferent to CO_2 emissions and energy consumption growth. Particularly its' industrial production is highly inefficient energy use and pollution dependent, and sudden shock to pollution and energy supply will lead the country to a adverse economic condition. As Bangladesh is an over populated country and presently existing in the early stage of development, the result of the study says that immediate reduction of CO_2 emissions and energy consumptions will seriously hamper the poverty and unemployment alleviation, and economic development process. The present development trends and techniques in Bangladesh are caused of grave water, soil, noise and air pollution as CO_2 emissions is increasing keeping up with economic progress. In this backdrop, immediate importing and installing of energy efficient technologies may cause social unrest. However, continuous environmental degradation through CO_2 emissions will incur an unsustainable development situations in the country in long-run too. In this dilemma government of Bangladesh should adopt very prudent policies to move through a sustainable development path. Efficient implementation of energy policies and environmental laws, exploring and shifting to environment friendly energy generating projects and exploiting sources like water, wind, solar, nuclear and hydrogen based energy, natural gas exploration and other low-carbon generating sources of energy and raising the productivity of the energy input. Crafting proper carbon taxation, subsidization and trading schemes, and encouraging existing and new investors for relying in efficient energy sources may help government to avoid financial and fiscal debacles towards its' policy reform for pollution free economic development. Moreover, switching from coal and petroleum and their derivatives based energy generation, raising awareness of different sections of the society like local, multinational and foreign investors, labourers and service holders in production plants, and above all, common folk for green and renewable energy sources will help the country to come out from such health hazardous and bad ecological conditions.

Our econometric results are also shedding light in many other directions too. The looming environmental crisis for over and inefficient using of energy is hinting that the future of environmental condition in Bangladesh is very paled and gloomy. The country needs to take steps energy conservation and environmental protection policies to save the economy and public health of the country in long-run. It badly needs to contemplate in reducing CO2 emissions and industrial pollution, and to struggle against energy waste and saving the energy intensive outputs without harming the economic development activities. The research and investment in clean energy should be the part and parcel of its energy policy to curb the CO2 emissions and to find alternative and green sources energy. Technological improvement through R & D, switching in clean energy, and proper formulation and implementation of environmental laws and policies are the targetable future recourse of Bangladesh. The present "do nothing policy" will decrease its' citizen's life expectancy, minimizes social welfare, bring persistent decline in output growth through a negative environmental externality, increases national health expenditures, increase the stock of brine water in the southern coastal area's wetlands and escalation of countrywide desertification and deforestation. Last but not least, Bangladesh also should not response positively with other countries when they try to reach in an agreement of pollution trade. Only secure, clean, cost effective and sustainable energy trade with the neighboring or other countries can be the viable option for the sake of the environment and long-run sustainable development of the country.

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