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Testing Causality between Energy Consumption, Carbon Dioxide Emission and Economic Growth in Bangladesh

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Abstract
This paper investigated the causal relationship between energy consumption (gas, oil and coal), carbon dioxide emissions and economic growth in Bangladesh at the disaggregated level, during the period 1976-2015, within a multivariate framework by including measures for capital and labor in the aggregate production function. The causal relationship between energy consumption and economic growth is examined using a modified version of the Granger causality test due to Toda and Yamamoto (1995) to avoid problems resulting from wrong determination of the order of integration of the different time series. The empirical results from Granger causality Toda-Yomamoto test and Granger causality test strongly supports a bidirectional causality coming between energy (gas) consumption and GDP. The results of this study also indicate that there is no statistically significant causality between other variables, which supports the neutrality hypothesis. This suggests that Bangladesh do not need to sacrifice economic growth or reduce its energy consumption or both in order to reduce pollutant emissions. Results also suggest that energy consumption has to maintain sustainable development for economic growth.

Keywords: *Energy Consumption, Carbon Dioxide Emission, Economic Growth, Causality, Bangladesh*

JEL Classification: *C32, N15, O44, Q41*

I. Introduction

I.A Background of the Study

Energy is an important source which contributes to the economic growth of a country or a region. It is also essential in human development and in the well-being of society. This is because energy is an input in many production and consumption activities. It is well said that energy is the lifeblood of any modern economy. Among all of the goods and services we find today it is the one of the crucial input in development procedure. Secure and reasonably priced energy supplies are vital to maintaining and improving living standards of billions of people across the globe. The relationship among economic growth, energy consumption and pollutants emissions becomes a hot topic and it has been investigated by many research institutes. Most of developed countries have taken that issue seriously to save their energy resources particularly the nonrenewable energy. During the last decades, economic situation into some of Asian and European countries have improved speedily, that led to more consumption of energy which causes pollution in their environments.

The relationship between energy use and output nexus suggests that economic growth is closely linked to energy use; higher economic development demands higher use of energy. On the other hand, for energy to be used efficiently, it is necessary to have a developed economy. A wide range of meticulous research has been conducted on the nexus between economic growth and environmental degradation, as well as, on economic growth and energy consumption over the past few decades. Higher emissions, which act as an indicator of the ambient quality of the environment, have been found to be a result of increased energy consumption, which in turn is thought to be the result of increased economic growth. It is generally believed that renewable and nuclear energy are practically carbon free energy sources and are seen as major solutions to the problems associated with global warming and energy security (D. Elliott, 2009). However, the empirical evidence remains controversial and ambiguous to date.

In Bangladesh, gas, coal, petroleum, total energy consumption and GDP are independent where coal and petroleum/oil favors neutrality hypothesis, therefore, energy conservation policies may not effect economic

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growth. Several factors have exacerbated the energy problems in Bangladesh. These include the expanding energy demand, shortages in natural gas supplies, aging generation and transmission infrastructure as well as stagnant investment in the energy sector. There is an increasing trend of total energy consumption and per capita energy consumption in Bangladesh from 1991 to 2012 where the total energy consumption has been increased nearly three times from 12.55 mtoe (million tone oil equivalent) in 1991 to 33.17 mtoe in 2012. They have found that the growth of carbon dioxide emission found to be higher than the growth of GDP and energy consumption in Bangladesh. The yearly average growth of carbon dioxide emission has estimated by 6.7% which is higher than the annual average growth of GDP and energy consumption as of 5.25% and 4.77% respectively (Bangladesh Economic Review, 2014).

However, there is still need some concrete strategies and actions to reduce carbon dioxide emissions by the power generation, transport, manufacturing, residential and other sectors. Implementation of actions is very crucial to achieve the goal. It can be mentioned that carbon dioxide emissions will not spontaneously decrease if the country continues to develop its economy without adopting instruments for mitigating climate change. Thus, mitigation options are important to reduce the Greenhouse Gas (GHG) emissions which can promote sustainable energy use, reduction of global warming as well as the environmental sustainability. Some cost effective mitigation options such as a forestation, sustainable forest management, reduction of deforestation, cropland management etc. need to be promoted in Bangladesh. There is also need energy efficient technology, decarbonizing electricity generation, hydrogen and electric vehicles and behavioral changes of the people. Renewable energy resources is one of the most efficient and effective solutions for clean and sustainable energy development in Bangladesh (M. Ahiduzzaman *et al.*, 2011).

I.B Objectives of the Study

The aim of this study is to analyze the causality between energy consumption and carbon dioxide gas emission on economic growth in Bangladesh over the period of 1976 to 2015. The specific objectives of this study are to:

i) What are the causal relationship between energy consumption (Gas, Oil, coal) and GDP, and energy consumption and carbon dioxide emissions?

ii) How to investigate the causal relationship between GDP, energy consumption and carbon dioxide emission in Bangladesh?

Following the introduction, section II reviews the relevant literature review. Section III outlines the overall of Bangladesh. Section IV discusses the empirical methodology including existence of unit root, co-integration, granger causality and estimate Seemingly Unrestricted Regression (SUR) analysis, and the sources of data; and section V presents the empirical results. Finally draws the concluding remarks into section VI.

II. Review of the Literature

II.A Theoretical Foundation

The relationship between economic growth and pollutant emissions has widely been taken into consideration. According to the Environmental Kuznets's Curve (EKC) hypothesis, it is assumed that there exists an inverted U-shaped relationship between environmental degradation and economic growth. (G. Grossman *et al.*, 1993) was the initial proponent of this thought and then popularized this hypothesis. Their analysis showed that ambient levels of pollutants first increased along with the country's per capita GDP but later decreased as the GDP per capita rose further. During the last few decades, there have been a number of studies addressing with the issue of causality between economic growth and energy. Since the seminal work of (J. Kraft *et al.*, 1998), recent studies (J. E. Payne 2010), (N. M. Odhiambo 2009), (M. Bellourni 2009), (M. Zamani 2007), (P. K. Narayan *et al.*, 2005), (S. H. Yoo 2005), (A. Shiu *et al.*, 2004), (R. Morimoto *et al.*, 2004), (A. B. L. Jumbe 2004), (R. Sari *et al.*, 2003), and (S. Ghosh 2002) have focused on the causal relationship between energy consumption and economic growth for several developing countries.

The initial work on causal relationship between energy consumption and output by (J. Kraft *et al.*, 1998) the topic became widely discussed in the global scientific literature. Although no single agreement about the causation was found according to (N. Apergis *et al.*, 2009, 2010) the relationship between energy and GDP can be categorized into four hypotheses.

"Growth" Hypothesis: Energy Consumption → GDP: Unidirectional

First the "growth" hypothesis indicates that energy contributes towards economic growth both directly in the production process and/or indirectly as a complement to labor and capital. In the Granger causality framework, the "growth" hypothesis is supported if the increase in energy consumption causes an increase in output. The implication of such a hypothesis is that policies aimed at energy conservation may potentially have a detrimental impact on economic growth.

"Conservation" Hypothesis: GDP → Energy Consumption: Unidirectional

Second the "conservation" hypothesis asserts that energy conservation policies that are aimed at reducing carbon dioxide emissions, efficiency improvement and waste management do not necessarily reduce GDP. This type of hypothesis is supported if the increase in GDP Granger causes an increase in energy consumption. Although it is very unlikely (at least theoretically) but an increase in GDP may also Granger cause a decline in energy consumption. According to (J. E. Payne 2010) this can occur when growing economy constrained by political, infrastructural, or mismanagement of resources generates inefficiencies and the reduction in the demand for goods and services, including energy consumption.

"Feedback" Hypothesis: GDP ↔ Energy Consumption: Bidirectional

Third the "feedback" hypothesis implies the interdependent relationship between GDP and energy consumption where each component may act as a complement to each other. In the presence of such a relationship, increase (decrease) in energy consumption results in increase (decrease) in GDP and the other way round increase (decrease) in GDP may result in increase (decrease) in energy consumption. Therefore, feedback hypothesis is supported by the evidence of bidirectional Granger causality between GDP and energy consumption.

"Neutrality" Hypothesis: GDP ≠ Energy Consumption: No Causality

Fourth, the "neutrality" hypothesis considers energy consumption to be relatively minor component of real GDP and thus energy consumption should have no significant impact on economic growth. Similarly as in the case of the "feedback" hypothesis, energy conservation policies may have little or no affect on GDP. The neutrality hypothesis is supported if there is no evidence of Granger causality between energy consumption and real GDP.

The hypotheses mentioned above were derived mainly from testing the relationship between the economic growth and energy consumption. So according to (N. Apergis *et al.*, 2009, 2010) found the possible outcome for this study as shown in table 1.

Table 1: Hypothesis to be tested and possible outcome

EC → CO2	GDP → EC	CO2 →GDP
EC ← CO2	GDP ← EC	CO2 ← GDP
EC ↔ CO2	GDP ↔ EC	CO2 ↔ GDP
EC ≠ CO2	GDP ≠ EC	CO2 ≠ GDP

II.B Empirical Studies

The empirical literature generally considered that energy consumption associated with economic growth and efficient use of energy increase the national income overall. (A. M. M. Masih *et al.*, 1996) tested for cointegration between total energy consumption and real income for six countries: India, Pakistan, Malaysia, Singapore, Indonesia and the Philippines. They found that for these 3 countries, temporal causality results imply at least one-way Granger-causality, either unidirectional or bi-directional. Causality results were unidirectional from energy to income for India, exactly the reverse for Indonesia, and mutual causality for Pakistan. The simple bivariate vector- autoregressive models did not indicate any direction of causality for the non-integrated systems (Malaysia, Singapore, and Philippines).

A. Aqeel *et al.*, 2001 investigated the causal relationship between energy consumption and economic growth and energy consumption and employment in Pakistan. By applying techniques of co-integration and Hsiao's version of Granger causality, the results infer that economic growth causes total energy consumption. (R. Sari *et al.*, 2003) examined the causality relationship between the two series in the top 10 emerging markets excluding China due to lack of data and G-7 countries. They found bi-directional causality in Argentina, causality running from GDP to energy consumption in Italy and Korea, and from energy consumption to GDP in Turkey, France, Germany and Japan.

B. M. Chima *et al.*, 2005 explained that relationship between energy consumption and economic growth for the U.S.A. from 1949–2003 is presented along with mathematical models. The empirical result shows a bi-directional causality goes both ways: from energy to the components of GDP, and from GDP to energy consumption. Salim et. al. (2008) found that the short-run and long-run causal relationship between energy consumption and output in six non-OECD Asian developing countries. Based on cointegration and vector error correction modeling, the empirical result shows a bi-directional causality between energy consumption and income in Malaysia, while a unidirectional causality from output to energy consumption in China and Thailand and energy consumption to output in India and Pakistan. Bangladesh remains as an energy neutral economy confirming the fact that it is one of the lowest energy consuming countries in Asia.

M. Belloumi, 2009 estimated results indicate that there is a long-run bi-directional causal relationship between the two series and a short-run unidirectional causality from energy to gross domestic product (GDP) for Tunisia during the period 1971–2004. (N. Apergis *et al.*, 2010) investigated the energy consumption has a positive and significant effect on the pollutant emissions in the long run. Whereas the real output exhibits a quadratic relationship with the carbon dioxide emissions, associated with the Environmental Kuznets Curve (EKC) hypothesis for eleven countries of Commonwealth of Independent States over a period of 1992-2004. In the short run, both energy consumption and economic growth cause carbon dioxide emissions. (K. Imran *et al.*, 2010) showed empirical results fully support a cointegration relationship between energy consumption and the economic growth in the long run for the panel of three SAARC countries. But from the causal point of view there is long run unidirectional causality running from energy consumption to the economic growth and no causality was found in the short run.

M. J. Alam et. al. 2011 used the Toda-Yamamoto (TY) approach and conclude that bidirectional causality exists between energy consumption and carbon dioxide emissions both in the long run and short run. (Amin *et al.*, 2011) investigated the causal relationship between energy and output in Bangladesh using annual data from 1973-2007 in a bivariate framework. The empirical findings indicate that there exists long run cointegration among the variables. (S. Hossain 2012) found the dynamic causal relationship between carbon dioxide emissions, energy consumption, economic growth, foreign trade and urbanization using time series data for the period of 1960-2009 in Japan. (A. A. Azlina *et al.*, 2012) also investigated the causal relationships between energy consumption, economic growth and pollutant emissions for Malaysia over the period 1970-2010. Results also point to a unidirectional causality running from economic growth to energy consumption, from pollutant emissions to energy consumption and from pollutant emissions to economic growth.

Chen et. al. 2013 investigated the nexus between carbon dioxide emission per capita and economic growth in Next Eleven (N-11) over the period 1981-2009. This paper also proves bi-directional causality between carbon dioxide emission and electric power consumption. (M. A, Khan 2003) applied Toda and Yamamoto 'Granger no-causality approach' and found the bidirectional causality between energy consumption and economic growth; and unidirectional causality from carbon dioxide emissions to economic growth. (P. Withey 2014) found that there is bi-directional direct causality between income and energy use in Canada for the period 1960- 2005. Similarly, there is a unidirectional causality running from total final energy consumption to real GDP in the long run and bidirectional causality in the short run for Croatia during the period 1952–2011 for the period 1960- 2005. (J. Alam 2014) estimated the environmental Kuznets curve hypothesis for the period 1972-2010, the existence of environmental Kuznets curve hypothesis "U" shape does not hold. (M. M. Uddin *et al.*, 2014) examined the causal relationship between carbon emissions and economic growth in seven SAARC countries shown that the estimated coefficients of emissions have positive and significant impacts on GDP in the long run.

A. N. Rezitis *et al.*, 2015 showed the dynamic relationship between energy consumption and economic growth in nine South and Southeast Asian countries (including Bangladesh) during the period 1990–2012. The short- and long-run causality results support the growth hypothesis in which unidirectional causality runs from energy consumption to economic growth, meaning that the economy of these countries is energy dependent. (M. F. Sharaf 2016) emphasized on the causal relationship between energy consumption and economic growth in Egypt during the period 1980-2012, within a multivariate framework by including measures for capital and labor in the aggregate production function. The findings of this study provide empirical evidence that energy conservation policy has no negative effect on the growth prospects of the Egyptian economy in the long-run.

Aforementioned, relationship among the energy with Green house gas and GDP is not found in Bangladesh in any paper at all. We have known to our research gap and have badly needed to know about this analysis. We will test the causal relationship among these variables to realize the present situation of our country and what we will do in future.

III. Stylized Fact

III.A Energy Consumption in Bangladesh

Bangladesh has a probability to progress towards increasing the demand of energy as it's a developing country. But now in this era Bangladesh is facing energy crisis. Around 70% of people having lack accesses to electricity and maximum numbers are living in the village, among them about 40% of them are living in below poverty line. Two-thirds of the country's total population level in rural areas, meeting most of their energy needs (domestic, commercial and industrial) from traditional biomass fuels. Bangladesh has experienced rapidly growing energy consumption over the past two decades. Around 32% have access to electricity, while in rural areas the availability of electricity is only 22%. This trend will intensify further in the coming years as economic growth and development efforts accelerate-Bangladesh strives to turn into a middle-income country by 2021.

In Bangladesh, low rate of growth in GDP (around five to six percent) is associated with poor physical infrastructure facilities such as shortage of power and energy supplies. (According to Bangladesh Economic Review 2016) Power and energy represents a very tiny share in the GDP of the economy. In Fiscal Year (FY) 2013-14, and FY 2012-13, the contribution of power and In FY 2013-14, the rate of growth in power and energy decreased to 6.31 percent from 9.17 percent and 8.76 percent in FY 2012-13 and FY 2011-12 respectively. Energy sector was only 1.55 percent which was 1.51 percent in FY 2011-12; presents only a 0.02 percentage point increase in two years. In FY 2013-14, the rate of growth in power and energy decreased to 6.31 percent from 9.17 percent and 8.76 percent in FY 2012-13 and FY 2011-12 respectively presenting that the growth rate decreased by 2.86 and 2.45 percentage point respectively in this fiscal year than the previous two corresponding fiscal years. By the meantime the rate of growth in GDP has also decreased.

III.B Carbon Dioxide Emission in Bangladesh

Bangladesh's energy needs are met by natural gas (56%), traditional biomass and waste (24%), oil (16%), coal (3%), and hydropower and solar (1% combined). Demand for electricity is growing by an estimated 500MW per year due to population growth, industrialization, and use of modern household appliances. The Second National Communication (SNC) projected a threefold increase in energy sector GHGs from 2005 to 2030, with industrial energy use driving the growth, followed by transportation. In power generation, the SNC also noted that planned expansion of 10,000MW of coal fired capacity would increase emissions. Textile, leather, fertilizer, and brick production also be major sources of carbon dioxide from industry and road transport taking an increasing share of all transportation carbon dioxide emissions.

Bangladesh's Greenhouse Gas (GHG) emission from various sectors, as well as, agriculture is the leading contributor with 39% of total emissions. The energy sector is the second highest emitter, with energy sub-sectors as follows: electricity and heat production (46%), other fuel combustion (21%), manufacturing and construction (20%), and transportation (14%). Land-use change and forestry and Waste represent the third and fourth highest emitters, accounting for 31% and 18%, respectively. According to World Resources Institute Climate Analysis Indicators Tool , Bangladesh's carbon dioxide emissions grew 59% from 1990 to 2012. The average annual change during this time was 2%, with sector-specific annual change as follows: agriculture (1%), energy (7%), land-use change and forestry (0%), waste (2%), and industrial processes (17%) (Bangladesh Economic Review, 2016).

III.C Economic Growth in Bangladesh

Bangladesh achieved a consistently improving GDP growth steadily over the past 40 years after independence. From early 1970s till late 1980s, the growth rate expansion was subdued, below 4 percent per annum. The growth rate expanded significantly since early 1990s, shooting up to over 5 percent per annum on a 10 year average, but importantly exceeding the 6 percent mark for a number of years during 2000s. The expansion of growth did face a break in the wake of the global food, fuel and financial crisis of 2008-10, but this slowdown was fairly moderate by global standards and speaks well of the cautious macroeconomic management by policymakers over a long period. The rising trend of long-term growth gives comfort that even higher growth is possible provided policy reforms further strengthen the determinants of past growth (BBS, 2017). Bangladesh is now progressing towards attending a growth rate of 7-8 percent per annum which will graduate Bangladesh towards a middle income country very soon.

In developing countries like Bangladesh, low rate of growth in GDP (around six percent) is associated with poor physical infrastructure facilities such as shortage of power and energy supplies. Power and energy represents a very tiny share in the GDP of the economy. In Fiscal Year (FY) 2013-14, and FY 2012-13, the contribution of power and energy sector was only 1.55 percent which was 1.51 percent in FY 2011-12; presents only a 0.02 percentage point increase in two years. In FY 2011-12, the rate of growth in GDP was 6.52 which decreased to 6.03 and 6.12 in FY 2012-13 and FY 2013-14 respectively which represents a 0.49 and 0.40 percentage point decrease (Bangladesh Economic Review, 2016).

IV. Methodology

IV.A Econometric Model

To examine the causal relationship among GDP, energy consumption[1] and main GHG carbon dioxide emissions a methodology that has been used extensively to provide sufficient explanation of the possible connections among variables is the Granger causality test. To test for long run Granger causality, the (H. Y. Toda *et al.*, 1995) procedure in a multivariate setting has been employed following a number of papers (R. Sari *et al.*,2009).

The Toda and Yamamoto procedure starts with an augmented Vector Autoregressive (VAR) *(k+dmax)*, where 'k' is the optimum lag length (determined by examining five different information criteria) and 'dmax' is the maximum order of integration among the variables in the VAR system. The standard Wald tests for testing Granger no-causality increases efficiency when Seemingly Unrelated Regression (SUR) models are employed in the estimation (Rambaldi *et al.*,1996). The seemingly unrelated regression (SUR) method, also known as the multivariate regression, or (A. Zellner's 1962) method, estimates the parameters of the system, accounting for heteroskedasticity and contemporaneous correlation in the errors across equations. The estimates of the cross-equation covariance matrix are based upon parameter estimates of the un-weighted System. Toda and Yamamoto Granger no-causality test is employed in this study by estimating the following VAR model of augmented production function using the SUR method respectively. Here we draw three different equations for gas, oil and coal:

For Gas

$$\begin{pmatrix} \ln RGDP_t \\ \ln GAS_t \\ \ln GAS\_CO_{2t} \end{pmatrix} = A_0 + A_i \begin{pmatrix} \ln RGDP_{t-1} \\ \ln GAS_{t-1} \\ \ln GAS\_CO_{2t-1} \end{pmatrix} + \ldots + A_k \begin{pmatrix} \ln RGDP_{t-k} \\ \ln GAS_{t-k} \\ \ln GAS\_CO_{2t-k} \end{pmatrix}$$

$$+ \ldots + A_{k+d} \begin{pmatrix} \ln RGDP_{t-k-d} \\ \ln GAS_{t-k-d} \\ \ln GAS\_CO_{2t-k-d} \end{pmatrix} + \gamma_1 K_{1+} \gamma_2 L_2 + \begin{pmatrix} e^{RGDP_t} \\ e^{GAS_t} \\ e^{GAS\_CO_{2t}} \end{pmatrix}$$

For Oil

$$\begin{pmatrix} \ln RGDP_t \\ \ln OIL_t \\ \ln OIL\_CO_{2t} \end{pmatrix} = A_0 + A_i \begin{pmatrix} \ln RGDP_{t-1} \\ \ln OIL_{t-1} \\ \ln OIL\_CO_{2t-1} \end{pmatrix} + \ldots + A_k \begin{pmatrix} \ln RGDP_{t-k} \\ \ln OIL_{t-k} \\ \ln OIL\_CO_{2t-k} \end{pmatrix}$$

$$+ \ldots + A_{k+d} \begin{pmatrix} \ln RGDP_{t-k-d} \\ \ln OIL_{t-k-d} \\ \ln OIL\_CO_{2t-k-d} \end{pmatrix} + \gamma_1 K_{1+} \gamma_2 L_2 + \begin{pmatrix} e^{RGDP_t} \\ e^{OIL_t} \\ e^{OIL\_CO_{2t}} \end{pmatrix}$$

For Coal

$$\begin{pmatrix} \ln RGDP_t \\ \ln COAL_t \\ \ln COAL\_CO_{2t} \end{pmatrix} = A_0 + A_i \begin{pmatrix} \ln RGDP_{t-1} \\ \ln COAL_{t-1} \\ \ln COAL\_CO_{2t-1} \end{pmatrix} + \ldots + A_k \begin{pmatrix} \ln RGDP_{t-k} \\ \ln COAL_{t-k} \\ \ln COAL\_CO_{2t-k} \end{pmatrix}$$

$$+ \ldots + A_{k+d} \begin{pmatrix} \ln RGDP_{t-k-d} \\ \ln COAL_{t-k-d} \\ \ln COAL\_CO_{2t-k-d} \end{pmatrix} + \gamma_1 K_{1+} \gamma_2 L_2 + \begin{pmatrix} e^{RGDP_t} \\ e^{COAL_t} \\ e^{COAL\_CO_{2t}} \end{pmatrix}$$

Where, Ai's are vectors of coefficients of the growth variable (GDP), Energy Consumption (EC) and emission variable (carbon dioxide) with A_0 as an identity matrix in the augmented production function framework following B. (N. Huang *et al.* 2008). Besides the variables of interest GDP, EC and CO_2 ; real variables coming from the augmented production function are labor (L) and capital (K) which are considered to be important factors for generating GDP growth.

Before starting the basic steps of Toda and Yamamoto (TY) procedure, it is needed to determine the order of integration of the system Augmented Dickey-Fuller (ADF), has been performed. Three steps are involved with implementing the Toda and Yamamoto procedure. The first step includes determination of the lag length *(k)* and the maximum order of integration *(dmax)* of the variables in the system above the equation. The

1. The Bangladesh bureau of Statistics (BBS) provides statistics on gross energy consumption which are adjusted for foreign trade so what we have energy consumption = production + imports.

appropriate lag structure of the VAR can be determined using standard information criterion. Secondly, given VAR *(k)* selected, and the order of integration dmax is determined, levels VAR can then be estimated using SUR method with a total of *[k+ dmax]* lags. The final step is to apply standard Wald tests to the first k vector autoregressive (VAR) coefficient matrix (but not the extra lagged coefficient) to make Granger causal inference, that is, to see if the coefficients of the lagged variables excluding the extra one are jointly zero in the system equations.

IV.B Data[2]

For the purposes of econometric analysis, we attempt to observe the impact of energy consumption and green house gas emission on the economic growth of Bangladesh. Time series data for the period of 1976 to 2015 has been analyzed for this purpose. Data for Gross Domestic Products (GDP) is obtained during the period of 1976-2015 from the *World Development Indicators* (WDI), World Bank database, 2017. Energy consumption (gas and oil in million metric tons) record is collected From BBS, BPDB, and Petro Bangla. Coal consumption is also collected from the same source in thousand metric tons. Green House Gas (Million Metric tons) data is collected from World Economic Outlook and IEA etc.

Despite the fact that it has been recognised that the interrelationships between environmental pollution, capital accumulation and other growth variables are of central importance in growth theory, there are not many studies that have investigated the causal relationship between economic growth, energy consumption and pollutant emissions, which also include labor and capital in the analysis. Recently however, a few studies have attempted to highlight the importance of both energy and pollutant emissions as additional variables to capital and labour in the growth process for some countries (R. Sari *et al.*, 2009) (N. Apergis *et al.*, 2009). We also included here the total labor force and capital formation (in million US$) dataset from WDI. We used here the natural log of the all data for simplicity of the working procedure.

V. Validation of the Model

V.A Unit Root Tests

We first performed unit root tests on all the series in levels and first differences in order to determine the time series properties of the data. To investigate the presence of unit root in the variables, we conducted the Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) test with a constant term and also both constant and trend at first. We used the Schwarz Information Criterion (SIC) to determine the appropriate lag lengths of the variables for ADF test and Hannan-Quinn criterion for PP test. Results of the tests are shown in Table 2.

Table 2: Result of Augmented Dicky-Fuller and Phillips-Perron Test

Variable	ADF Test				PP Test				Integ. Order
	Level		First Differences		Level		First Differences		
	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend	
lnRGDP	3.83	0.19	-5.67***	-	4.88	0.61	-5.92***	-	I(1)
lnGAS	-3.26**	-	-	-	-3.26**	-	-	-	I(0)
lnOIL	-1.49	-5.31***	-	-	-1.07	-5.31***	-	-	I(0)
lnCOAL	-3.41**	-	-	-	-3.36***	-	-	-	I(0)
ln CO_2 _GAS	-3.41**	-	-	-	-3.23**	-	-	-	I(0)
ln CO_2 _OIL	-5.08***	-	-	-	-5.08***	-	-	-	I(0)
ln CO_2_COAL	-1.96	-3.56**	-	-	-1.65	-3.35*	-	-	I(0)
lnLABOR	-3.40**	-	-	-	-6.21***	-	-	-	I(0)
lnCAP	-2.51	-6.79***	-	-	-1.91	-5.38***	-	-	I(0)

Notes: ***, **, and * indicate rejection of null hypotheses of unit root hypothesis at the 1%, 5% and 10% level of significance respectively.

2. It would be difficult to use a time series over a longer period of renewable energy. It was not seriously considered as a possible source of energy due to there has no data available. However, the attempt to obtain a more frequent data on energy consumption, i.e quarterly or monthly. It is only available from 2005, while for CO_2 emissions, it is not available at all.

According to the ADF, the per-real GDP time series are non stationary at level across all specifications of the tests, and they become stationary at their first difference. In other words, the energy consumption series, the ADF tests show that the energy consumption (Gas, Oil and Coal) are stationary in level I (0). Carbon dioxide emission from different energy sources are also order of integration I (0). And finally the labor force and capital formation are also integrated at level I (0). Similarly, we also used the Phillips-Perron test statistics to recheck the level of integration. These results are also revealing the same result as ADF test. According to the Philips- Perron test statistics, the per-real GDP time series are non stationary at level across all specifications of the tests, and they become stationary at their first difference. For the energy consumption series, the PP tests show that the energy consumption (Gas, Oil and Coal) are stationary in level I(0). The labor force and capital formation are also integrated at level I(0).

V.B Lag Selection Criteria

In identifying the dynamics of a model determination of optimal lag length is important. The sequential modified LR test statistic (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and Hannan-Quinn Information Criterion (HIQ) lag selection criteria are used to determine optimal lag length of VAR system of this study. Result of the optimal lags under different criteria for VAR model of three different sections for gas, oil and coal are shown in table-3. All the criteria indicate that the optimum lag length of the variables is one for all the part of the model. Hence lag order of VAR (k) is 1. Therefore, the equations of the system according to Toda and Yamamoto (TY) methodology has to be estimated as a VAR*(k+ dmax)* = VAR(2).

Table 3: Lags under Different Criteria for VAR model (Gas, Oil and Coal) VAR Lag Order Selection Criteria Exogenous variables: LN_LABOR LN_CAP

Lag	LogL	LR	FPE	AIC	SC	HQ
Endogenous variables: LN_GAS LN_ CO_2_RGDP_US$						
0	74.02	NA	5.42e-06	-3.61	-3.22	-3.47
1	141.75	112.89*	2.09e-07*	-6.87*	-6.08*	-6.59*
2	148.34	9.89	2.45e-07	-6.74	-5.55	-6.33
3	150.47	2.83	3.76e-07	-6.36	-4.77	-5.81
Endogenous variables: LN_OIL LN_ CO_2 _RGDP_US$						
0	36.67	NA	4.32e-05	-1.54	-1.14	-1.39
1	78.65	69.95*	6.97e-06*	-3.37*	-2.58*	-3.09*
2	80.26	2.41	1.08e-05	-2.96	-1.77	-2.54
3	82.89	3.50	1.61e-05	-2.60	-1.02	-2.05
Endogenous variables: LN_COAL LN_ CO_2 _RGDP_US$						
0	-1.11	NA	0.000352	0.56	0.96	0.69
1	46.18	78.82*	4.23e-05*	-1.56*	-0.77*	-1.29*
2	52.65	9.71	4.98e-05	-1.42	-0.24	-1.01
3	58.93	8.36	6.08e-05	-1.27	0.31	-0.72

* indicates lag order selected by the criterion

V.C Granger Causality Test

To find out the direction of causality of the variables of the model, the Granger causality procedure developed by Toda and Yamamoto is used. The optimal lag length *(k)* in the original VAR system is 1, the Toda and Yamamoto causality test involves estimation of an augmented VAR *(k+dmax)* at levels. Here with an order *(k+dmax)* = 1+1= 2 in the model, even though variables are each stationary and non-stationary. The system of all equations then is jointly estimated as a Seemingly Unrelated Regression (SUR) model by Maximum Likelihood. If the disturbances of the equations are correlated, the SUR estimator is more efficient than the standard regression, because it takes account of the entire matrix of the correlations of all of the equations and minimizes the determinant of the covariance matrix of the disturbances (A. Zellner, 1970). Finally, the procedure employs a standard

Wald test for restrictions on the parameters of the VAR *(k+dmax)*/ (2). (A study by H. Y. Toda *et al.*, 1994) using slightly different method (SVAR model) and taking into account only the renewable energy sources used for electricity generation reported similar findings of causal relationship coming from renewable energy consumption to carbon dioxide emissions. The Granger causality T-Y test itself does not provide information about the sign of causality and further tests are required. For that we used SUR (Seemingly Unrelated Regression) important information about the response of some variables to the shocks in other variables.

VI. Analysis of the Results

We reported the VAR order *(k+dmax)*, Wald statistics, associated p-values and direction of causality for tri-variate VAR model. From table-4, there have no Granger-causality between real GDP and carbon dioxide emission from gas sectors, the p-value is at 5% level of significance. Here we cannot reject null hypothesis rather accept that there is no causal relationship between RGDP and carbon dioxide emission. Finally gas consumption and carbon dioxide emission also proven that they have no causal relationship which supports the neutrality hypothesis as like RGDP and carbon dioxide emission.

Table 4: Toda and Yamamoto 'Granger no-causality test' VAR Model Results

Null Hypothesis (*Granger no-causality test*)	**Wald Stat_ GAS**	**Wald Stat_ OIL**	**Wald Stat_ COAL**	**Direction of Causality**
CO_2 does not Granger cause RGDP RGDP does not Granger cause CO_2	0.89 0.43	0.47 0.37	0.23 1.62	×
GAS (Energy Consumption)				
Gas does not Granger cause RGDP RGDP does not Granger cause Gas	8.98** 7.72**	- -	- -	GDP ↔ Gas
CO_2 does not Granger cause Gas Gas does not Granger cause CO_2	3.39 1.45	- -	- -	×
OIL				
OIL does not Granger cause RGDP RGDP does not Granger cause OIL	- -	0.98 1.73	- -	×
CO_2 does not Granger cause OIL OIL does not Granger cause CO_2	- -	0.98 0.61	- -	×
COAL				
Coal does not Granger cause RGDP RGDP does not Granger cause Coal	- -	- -	1.48 1.59	×
CO_2 does not Granger cause Coal Coal does not Granger cause CO_2	- -	- -	4.41 1.75	×

***, **, and * indicate rejection of the unit root hypothesis at the 1%, 5% and 10% level of significance respectively.

The results suggest that both null hypothesis of 'Granger no-causality from RGDP to gas consumption' and 'Granger no-causality from gas consumption to RGDP' can be rejected at 5% significance level. This indicates that there is two-way causality between economic growth and energy consumption. Energy consumption (gas) causes output growth as perception and output growth also causes gas consumption. That is, energy consumption does have significant role in economic growth and as feedback effect economic growth also result change in energy consumption. They are interrelated and may very well serve as complements to each other (N. Apergis *et al.*, 2009). The coefficients of the SUR estimation of gas consumption with time lags to GDP growth are found negative and highly significant, shown in Table 5. The coefficient of GDP growth with two-period time lag to energy consumption is found positive and significant. This suggests that in Bangladesh an energy policy oriented towards improvements in energy consumption efficiency would adversely affect real GDP (R. P. Pradan, 2010).

Table 5: Summery of the SUR estimation in VAR system

Variables	GAS			OIL			COAL		
	$\ln GDP_t$	$\ln GAS_t$	$\ln GAS\ CO_{2\,t}$	$\ln GDP_t$	$\ln Oil_t$	$\ln OIL\ CO_{2\,t}$	$\ln GDP_t$	$\ln COAL_t$	$\ln COAL\ CO_{2\,t}$
$\ln GDP_{t-1}$	0.50***	0.76	5.87	0.69***	1.39	0.15	0.65***	-10.57	-1.72
$\ln GDP_{t-2}$	0.48***	-1.25**	-7.76	0.34**	0.11	-2.53	0.36**	13.03	5.71
$\ln GAS_{t-1}$	-0.13***	0.79***	3.95	-	-	-	-	-	-
$\ln GAS_{t-2}$	0.09**	0.09	-2.36	-	-	-	-	-	-
$\ln GAS\_CO_{2\ t-1}$	-0.02	-0.01	-0.10	-	-	-	-	-	-
$\ln GAS\_\ CO_{2\ t-2}$	-0.01	0.07	-0.09	-	-	-	-	-	-
$\ln OIL_{t-1}$	-	-	-	0.01	0.19	0.35	-	-	-
$\ln OIL_{t-2}$	-	-	-	0.07	-0.06	0.13	-	-	-
$\ln OIL\_\ CO_{2\ t-1}$	-	-	-	0.06	0.04	-0.04	-	-	-
$\ln OIL\_\ CO_{2\ t-2}$	-	-	-	-0.05	0.04	-0.11	-	-	-
$\ln COAL_{t-1}$	-	-	-	-	-	-	0.03	0.58***	-0.09
$\ln COAL_{t-2}$	-	-	-	-	-	-	-0.04	-0.36**	-0.09
$\ln COAL\_\ CO_{2\ t-1}$	-	-	-	-	-	-	-0.07	-0.35	0.44**
$\ln COAL\_\ CO_{2t-2}$	-	-	-	-	-	-	0.01	0.42*	-0.21
$\ln K_t$	0.06*	0.02	0.83	-0.06	1.35	0.51	-0.04	-1.21	-4.99*
$\ln L_t$	0.03**	0.37**	0.38	0.03	-0.89	1.38	0.02	-0.60	0.10
C	-0.18	-0.61	-11.29	0.10	-2.53	-3.67	0.03	5.37	3.87

***, **, and * indicate rejection of the unit root hypothesis at the 1%, 5% and 10% level of significance respectively.

Results show no causal relationship between total oil consumption and economic growth, supporting the neutrality hypothesis. As shown in table-4, the modified Wald Statistics are not statistically significant. Hence, we fail to reject the null hypothesis that total oil consumption does not Granger cause real GDP. Likewise, we also fail to reject the null hypothesis that real GDP does not Granger cause total oil consumption. So here for the other two relationships we have failed to accept all the three possible outcome growth, conservation and feedback hypothesis rather we accept only the neutrality hypothesis. The coefficients of the SUR estimation of oil consumption with time lags to GDP growth are found positive but insignificant, shown in table-5. The coefficient of GDP growth with two-period time lag to energy consumption is also found positive and insignificant. Carbon dioxide emission and real GDP with time lags to gas consumption is also insignificant. That is there is no relationship among them and they don't affect one another.

Finally Table 4 that there is no-causality between Coal consumption and GDP or GDP and carbon dioxide emission, as both the null hypothesis of 'Granger no-causality from coal to carbon dioxide and 'Granger no-causality from GDP to coal ' all are not rejected. This result suggests that Bangladesh have no need to conscious about coal consumption or its effect on weather and recent development. The coefficients of the SUR estimation of coal consumption with time lags to GDP growth and carbon dioxide emission are found somewhere positive or negative but insignificant. The coefficient of GDP growth with two-period time lag to coal consumption is also found insignificant, shown in table-5.

Therefore, though the green house effects is not very dangerous in our country but the effective consumption of different energy and increase the total real GDP and promote us the middle income country status very soon. So, it is generally found that in Bangladesh the relationship between energy consumption, green house gas emission and GDP growth is not well established where as it is going through a satisfactory conclusion in many other countries.

VII. Concluding Remarks[3]

This study utilizes a multivariate framework to test the causal relationship between renewable energy consumption, gross domestic product (GDP) and carbon dioxide emissions in Bangladesh using annual data from 1976-2015. This study explores these relationships using the Toda Yamamoto approach in a multivariate framework including labour and capital as auxiliary variables. We focused here into three portion along with energy consumption (gas, oil and coal), carbon dioxide emission from these sources and real GDP of Bangldesh in US$. The causal relationship between variables is examined using Granger no causality test in VAR framework. Results of unit root tests show that some variables are non-stationary in their level form and stationary in first difference form. The empirical results from Granger causality Toda-Yomamoto test and Granger causality test strongly supports a bidirectional causality coming between energy (gas) consumption and GDP. The results of this study also indicate that there is no statistically significant causality between the economic growth and oil and coal in this study, which supports the neutrality hypothesis and implies that energy conservation policies should not have a significant impact on economic growth for oil and coal. The empirical results also reveal that there is no causality between economic growth and carbon dioxide emissions for all of the energy consumption. This result is contrary to other results in the literature, and has different implications for energy and environmental policy. It may be due to the fact that Bangladesh has one of the lowest energy intensities in the world, which allows achieving one unit of GDP with a minimum input of energy and minimum carbon dioxide emissions. This suggests that Bangladesh do not need to sacrifice economic growth or reduce its energy consumption or both in order to reduce pollutant emissions. Results also suggest that growing energy use has to maintain for sustainable economic growth. Thus, this study proposes the following major policy recommendation towards reducing emission in Bangladesh:

i. To formulate an extensive national mitigation policy and actions towards establishing a low carbon society.

ii. To ensure regular inspection and monitoring of the industry and power plant for maintaining the level of emission.

iii. To strengthen institutional capacity and coordination among stakeholder to implement the policy and actions at different sectors and level.

iv. To promote green growth by incorporating environmental sustainability into the economic development plans and policies.

v. To stimulate the use of clean fuel, renewable energy, solar energy, wind energy and biomass energy.

vi. To promote research and development (R&D) related to green energy, green technology, renewable energy and energy efficiency.

vii. To ensure the proper implementation of projects with transparency and accountability.

3. The study can be improved by investigating more countries in a panel framework which would allow drawing a more generalized conclusion from results about the relationship between renewable energy consumption, CO_2 emissions and economic growth.

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