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Economic growth, CO_2 emissions and energy consumption: The case of Bangladesh

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Abstract: Issues on climate change have been recognized as serious challenges for regional sustainable development both at a global and local level. Given the background that most of the artificial carbon emissions are resulted from the energy consumption sector and the energy is also the key element resource for economic development, this study examines economic growth, CO_2 emissions and energy consumption relationship in Bangladesh by using cointegration test. For this purpose 1972-2011 periods taken and annual data of Gross Domestic Product (Y), Carbon Dioxide Emissions (CO) and Energy Consumption (EC) are used. The obtain results from this paper indicated that energy consumption has a positive and significant impact on economic growth while carbon emission has a negative and insignificant effect, ensuring that economic growth in Bangladesh can be achieved without degrading the quality of the environment.

Keywords: Economic Growth, CO_2 Emissions, Energy Consumption, Bangladesh, Cointegration Test

1. Introduction

Over the past century, every economy has seen economic growth as one of the principle objectives to be achieved in the macroeconomic stabilization policy area. Kuznets (1973) defined economic growth as a long-term rise in capacity to supply increasingly diverse economic goods to its population, this growing capacity based on advancing technology and the institutional and ideological adjustments that it demands. Also, economic growth as the steady process by which the productive capacity of the economy is increased over time to bring about rising levels of national output and income (Todaro and Smith, 2011). Moreover, it has been the only medium anticipated against poverty eradication, more often than not facing the developing countries. For instance, an economy agitating to achieve a desired growth rate over a particular period, such economy must have the basic resources like energy and other natural resources. In order to make economic development sustainable, resources such as energy supply must be available and utilized in such a way that there is enough for the present generation as well as the upcoming generation. Energy consumption is the total amount of energy which is spent by industries (plants and machineries, office equipments) and households (appliances) in an economy. The amount of energy used per industry depends on machineries, climate etc. While household depends on the standard of living, climate, age, type of residence etc (Masuduzzaman, 2012) and this energy consumption is driven by such important factors as industrialization, extensive urbanization, population growth, rising standard of living and even the modernization of the agricultural sector.

Today, energy has been the heart of most critical economic, environmental and developmental issues in the global world which has also contributed significantly to climate degradation through carbon emission- a gas in the atmosphere causing radiation within the environment. Higher economic growth requires a higher level of energy consumption and is responsible for higher levels of CO_2 emissions. This notion attracted the world’s attention in the 1990s because of the potential threats to the ecosystem. It became the general consensus that higher economic growth should not be pursued at the expense of the environment and this issue raised the question of how economic growth can be made more sustainable. International organizations around the world continuously attempt to reduce the adverse impacts of global warming. One such attempt is the Kyoto Protocol agreement, entitled the United Nations Framework Convention on Climate Change (UFCCC), made in 1997 as an attempt to reduce the adverse impacts of global warming. Among the variety of polluting substances, CO_2 is a major one and represents 58.8 percent of greenhouse gas emissions (World Bank, 2007). There have been debates for quite some time on the relationship between economic growth and development and environmental quality (Bozkurt & Akan, 2014). Experts have been trying to explain this relationship between economic growth and environmental pollution with the Environmental Kuznets Curve (EKC) in recent years. According to EKC hypothesis, the income growth from industrialization will cause both income inequality and environmental damage in the initial stage of the economic development but this trend will be reversed in further phases when a certain income level is achieved.

This paper attempts to investigate empirically the long-run effect of carbon emissions and energy use on economic growth in Bangladesh over the period 1972 to 2011. The structure of this paper is organized as follows: Section 2 presents theoretical framework. Section 3 provides the literature review for the studies that examined the relationship between economic growth, CO_2 emissions and energy consumption whereas section 4 presents the data and methodology used for this study. Empirical results are discusses in section 5. The final section draws some concluding remarks.

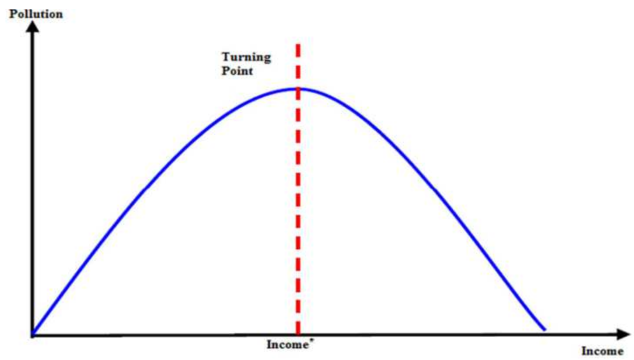
2. Theoretical Framework

The concept of Environmental Kuznets Curve originates from the work of Simon Kuznets (1955) who hypothesized the Kuznets curve as an inverted U-shaped relationship between actual income per person and income inequality. Kuznets (1955) observed that inequality tends to increase during the early stages of growth and to decrease later on, describing an inverted-U shaped relationship between per capita income (on the horizontal axis) and income inequality (on the vertical axis). In the 1990s, beginning with the work of G. M. Grossman and A. B. Krueger (1991), the Kuznets curve took on a new face becoming an instrument for describing the relationship between the levels of environmental quality and per capita income. The term Environmental Kuznets Curve was coined by Panayotou (1993) has given its resemblance to Kuznets' hypothesis. According to EKC, after economic growth reaches a certain level, it will remedy the environmental effect of the initial stages of economic development and compensate for it (Sun, 1999).

According to EKC hypothesis, the relationship between Gross Domestic Product (GDP) per capita and pollutant emissions per capita is in the shape of an inverted-U. It shows that economic growth may benefit environmental quality after a certain point (Niu and Li, 2014). EKC can also be explained with the following factors (Stern, 2003);

- Production scale input rates refer to production expanding with production range and status of technology.
- Different industries have different levels of pollution intensity and typically production range varies during the courses of economic development.
- Changes in input variety lead to substitute of more harmful inputs by less environmentally harmful ones (or vice versa).
- Certain emission changes in input per unit may result with less pollution due to developments in technology.

The EKC hypothesis suggests that increase in pollution will initially develop a country's industry and then it will be reduced after a certain economic development level is reached. Therefore, environmental damage in inevitable at the first stage of economic development and for this reason countries are obliged to endure it until the reversing effect. This situation is seen in Figure 1 below.

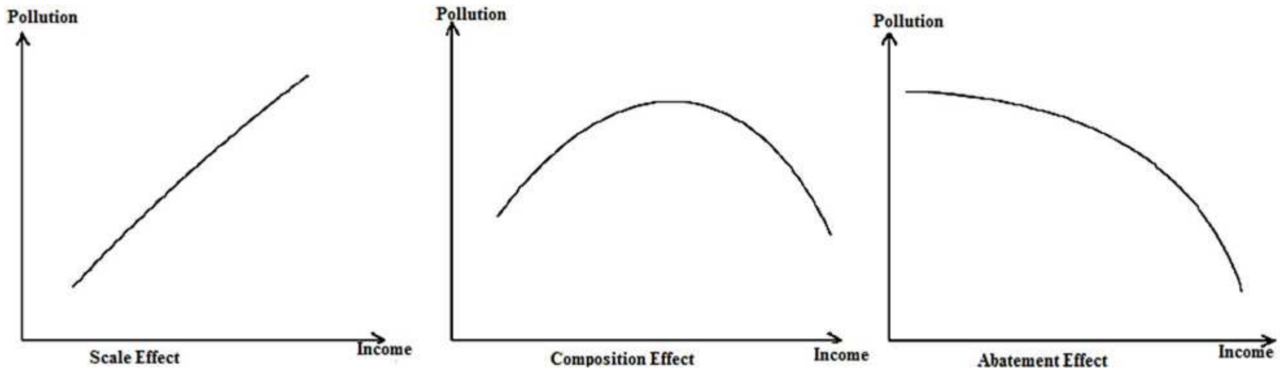


Source: Shahrin and Halim (2007)

Figure 1. *The Environmental Kuznets Curve (EKC)*

The level of environmental pollution in a region is affected by both the pollution emitted throughout that region and by natural factors like the status of soil, topography, and air. These factors can be named as the sub-determinants of environmental quality. Pollution intensity of GDP depends of two impacts. Pollution-generating works on the one hand and reducing and cleaning works on the other. Actual emission and thus the pollution intensity of GDP emerge as a result of these two opposite effects. While the rate of emission generation depends on reduction efforts, the generation pollution depends on GDP composition. Therefore, these two terms can be referred to as Composition or Structure Effect (C) and Abatement Effect (A). It is obvious that GDP per unit area represents Scale Effect (L) (Islam, Vincent and Panayotou; 1999). The impacts of different factors, such as economic growth, technological change, international trade, FDI, environmental regulations etc actually can be decomposed into the above three effects.

Along with the economic growth, the scale of an economy tends to become larger and larger. As mentioned by Grossman (1995), a growing world needs more inputs to expand outputs, which implies that wastes and emissions as by-products of the economic activities will increase. This is the so-called scale effect. Obviously, the scale of economy is a monotonically increasing function of income, when the other two effects are controlled. Meanwhile, with the economic growth, the production structure will change, from clean agrarian economies to polluting industrial economies and further to clean service economies (Arrow et al., 1995). As Panayotou (1993) points out, when the production of an economy shifted mainly from agriculture to industry, pollution intensity increases. It is because more and more resources are exploited and the exhaustion rate of resources begins to exceed the regeneration speed of resources. When the industrial structure enhances further, from energy-intensive heavy industry to service and technology-intensive industries, pollution falls as income grows. This is the structure effect. It is probably to be a non-monotonic function of income, like inverted U-shape curve. Actually, technology effect goes with the structure effect. The upgrading of industrial structure needs the support from technology. Technical progress makes it possible to replace the heavily polluting technology with cleaner technology. It is the trade off between scale effect and technology effect that the environment deteriorates at the first industrial structural change and improves at the second industrial structural change. So the relationship between environment and economic growth looks like inversed-U curve. The downward sloping portion of the environment and economic growth may be facilitated by advanced economies exporting their pollution intensive production processes to less-developed countries (Suri and Chapman, 1998). These varied impacts of income on pollution are shown in Figure 2:

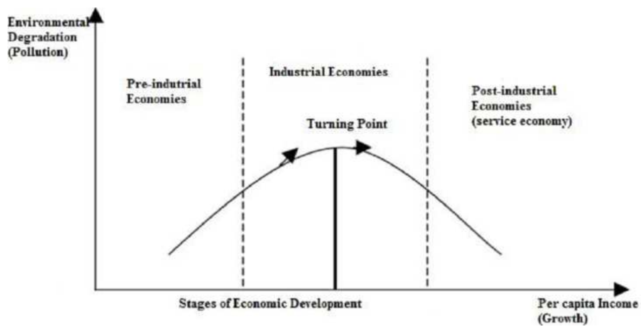


Source: Islam, N., J.Vincent and T.Panayotou (1999).

Figure 2. *Different Effects of Income on Environment*

Both the extent and intensity of environmental degradation in lower stages of development is confined with the impact of economic activities on resource demand and the amount of recycled waste. Depletion of resources and waste production increases as industrialization decreases and resource discovery and agricultural activities intensify. In higher stages of development, structural changes towards knowledge-based industry and services as well as more efficient technologies and demand for environmental quality become horizontal and the reduction in environmental degradation takes on a more stabilized course. This is shown in Figure 3 (Panayotou, 2003).

Upon examination of Figure 3, it can be seen that the issue of environmental degradation first goes through a monotone increase and then decreases in the same monotonic way. Seen in the development path of a country, it has grave effects on policy. The monotone increase in environmental degradation brought on by economic growth requires strict environmental regulations. On the other hand, the monotone decrease in environmental degradation requires policies that accelerate economic growth which does not necessitate open environmental policies and leads to rapid environmental improvement. If economic growth actually slows down, it may cause adverse effects which may slow down environmental development.



Source: Panayotou (2003)

Figure 3. *The Environmental Kuznets Curve: A Development-Environment Relation*

3. Literature Review

The relationship between energy consumption and economic growth, as well as economic growth and environmental pollution, has been the subject of intense research during the last decades. Studies in this field may be divided into three lines of research.

The first focuses on the relationship between economic growth and energy consumption dating back to the pioneering work by Kraft and Kraft (1978) and leading to the use of Granger causality test approach as a tool for studying the relationship between energy consumption and economic growth in different countries, e.g. Stern (1993), Aqeel and Butt (2000), Yuan et al., (2008), Ghosh (2010), Lau et al., (2011), Binh (2011), and Kaplan et al., (2011). A detailed literature review on energy-growth relationship can be found in the study of Ozturk (2010).

The second line of research focuses on the relationship between economic growth and environment, discussing the inverted U-shaped relationship between environmental pollutants and economic growth by testing the validity of environmental Kuznets curve (EKC) hypothesis. The empirical studies carried out by several authors drew different conclusions. Selden and Song (1994) and Galeotti, Manera and Lanza (2009) provided empirical evidences on the validity of EKC hypothesis. However, Holtz-Eakin and Selden (1995) found a monotonic rising curve and Friedl and Getzner (2003) found an N-shaped curve. On the other hand, Agras and Chapman (1999) and Richmond and Kaufman (2006) concluded that there is no significant relationship between economic growth and environmental pollutants.

The third line of research investigates the relationships between pollutant emissions, energy consumption and economic growth by considering them simultaneously in a modeling framework. These studies have attempted to analyze the causal relationships between theses three variables by combining the literature on EKC with the energy consumption-growth literature (Richmond and Kaufman, 2006; Soytas et al., 2007; Ang, 2007; Soytas and Sari, 2009; Akbostanci et al., 2009; Acaravci and Ozturk, 2010; Apergis and James, 2010; Ozturk and Acaravci, 2010; Arouri et al., 2011; and Wang et al., 2011).

Although the topic of CO_2 emissions is very important for Bangladesh but empirical literature put scant attention on this issue. Moreover, there has been no systematic investigation to analyze the relationships among economic growth, CO_2 emissions and energy consumption in Bangladesh. The proposed study is an attempt to fill these entire gaps.

4. Data and Methodology

The variables used in this study are Energy Consumption (EC) which is measured in kg of oil equivalent per capita, CO_2 emissions measured in metric tons per capita and GDP per capita measured in constant US$. The data of these variables come from the World Development Indicators of World Bank (WDI). The annual data are selected to cover the period from 1972 to 2011.

In this study we employ the Augmented Dickey-Fuller (ADF) unit root test to examine the stationarity of variables. The ADF test requires the equations as follows.

$$\Delta y_t = \propto_0 + \alpha_1 t + \theta y_{t-1} + \sum_{i=1}^{m} w_i \, \Delta y_{t-i} + \varepsilon_t$$

Where, Δ is the different operator, y is the series being tested, m is the number of lagged differences and $\boldsymbol{\varepsilon}$ is the error term. The null hypothesis is unit root and the alternative hypothesis is level stationary (Enders, 2004). If the coefficient of the lag y_{t-1} (θ) is significantly different from zero, the null hypothesis is rejected.

We apply Johansen and Juselius (1990) and Johansen (1988) maximum likelihood method to test for cointegration between the series of energy consumption, carbon emissions and economic growth. This method provides a framework for testing of cointegration in the context of Vector Autoregressive (VAR) error correction models. The method is reliable for small sample properties and suitable for several cointegration relationships. The cointegration technique uses two tests-the maximum Eigen value statistics and trace statistics in estimating the number of cointegration vectors. The trace statistic evaluates the null hypothesis that there are at most r cointegrating vectors whereas the maximal Eigen value test evaluates the null hypothesis that there are exactly r cointegrating vectors. Let us assume that y_t follows I(1) process, it is an nX1 vector of variables with a sample of t. Deriving the number of cointegrating vector involves estimation of the vector error correction representation:

$$\Delta y_t = \mu_0 + \Pi y_{t-m} + \sum_{i=1}^{m} \mu_i \, \Delta y_{t-i} + \varepsilon_t$$

The long run equilibrium is determined by the rank of Π. The matrix Π contains the information on long run relationship between variables, that is, if the rank of Π (usually denoted by r), is equal to zero, the variables are not cointegrated. On the other hand if rank is equal to one, there exists one cointegrating vector and finally if 1<r<n, there are multiple cointegrating vectors and there are nXr metrics of α and β such that Π= αβ', where the strength of cointegration relationship is measured α, β is the cointegrating vector and β'y_t.

The tests given by Johansen and Juselius (1990) are expressed as follows. The maximum Eigenvalue statistic is expressed as:

$$\lambda_{max} = -T In(1 - \hat{\lambda}_{(r+1)})$$

While the trace statistic is written as follows:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{k} In(1 - \hat{\lambda}_i)$$

Where, r is the number of cointegrating vectors under the null hypothesis and $\hat{\lambda}_i$ is the estimated value for the ith ordered eigen value from the matrix Π. To determine the rank of matrix Π, the test values obtained from the two test statistics are compared with the critical value from Mackinnon-Haug-Michelis (1999). For both tests, if the test statistic value is greater than the critical value, the null hypothesis of r cointegrating vectors is rejected in favor of the corresponding alternative hypothesis.

This study examines the long-run relationship between CO2 emissions, energy consumption and economic growth in Bangladesh. Data used in this study is composed of energy use (kg of oil equivalent per capita), CO2 emissions (metric tons per capita) and real GDP (constant 2005 US dollars per capita) for the period of 1972-2011. We use annual data and obtained the data from World Development Indicators of World Bank. This study follows closely the methodology of Soytas et al. (2007), Soytas and Sari (2009), Zhang and Cheng (2009) and Bozkurt and Akan (2014). The model is as the following:

$$V_t = \alpha + \beta_1 V_{t-1} + \beta_2 V_{t-2} + \dots\dots\dots + \beta_p V_{t-p} + \dots\dots\dots + \beta_{p+d} V_{t-p-d} + \varepsilon_t$$

Here, α: vector of constant, β: coefficient matrix, d: maximal order of integration of variables, p: optimal lag length of a VAR and ε_t: white noise residuals.

5. Empirical Results

The regression analysis of variables was examined using of ADF unit root test. ADF Stationarity test in levels shows that variable real GDP (Y) is stationary and carbon emissions (CO) and energy consumption (EC) are non-stationary in level form. In the next step of difference form, it is found that all the variables are stationary. This implies that the variables are integrated of order one, i.e. I(1). Results from the ADF unit root tests are presented in Table 1.

The results from Johansen and Juselius (1990) cointegration tests indicate that there is a unique long-term or equilibrium relationship between variables. Both trace statistics and λ-max statistics show that there exist two cointegrating vectors at 5% significance level (see Table 2). The long-run coefficients are obtained from VEC model. The long-run coefficients for the variable EC is positive while variable CO are negative. The estimated model that has passed several diagnostic tests those residuals has no evidence of serial correlation and heteroskedasticity; are multivariate normal distributions (see Table 3).

Table 1. *ADF Unit Root Test Results*

Variable	Level	First Difference	Result
Y	4.003646 (-3.529758)	-5.319632 (-3.533083)	I(1)
EC	0.204168 (-3.529758)	-7.886713 (-3.533083)	I(1)
CO	2.730696 (-3.529758)	-5.812612 (-3.533083)	I(1)

Notes: MacKinnon critical values at 5% are in ( ). Here we consider the variables with constant and trend both in level and first difference form.

Table 2. *Johansen-Juselius Cointegration Tests Results*

Hypothesized No. Of CE(s)	Trace Statistic	5% Critical Value	λ-max statistic	5% Critical Value
None**	66.77537	29.68	39.06772	20.97
At most 1**	27.70765	15.41	26.74408	14.07
At most 2	0.963566	3.76	0.963566	3.76

Notes: Number of optimal lags, 3 based on AIC, SIC and HQ information criteria's result. Trace test and λ-max test indicate 2 cointegrating equation(s) at 5% level of significance. Critical values used are taken from Osterwald-Lenum (1992).

Table 3. *The Estimated Long-Run Coefficients*

Variables	Coefficients	Standard Errors	t-Statistics
Constant	-105.0862	39.53578	-2.658003*
EC	3.723154	0.576659	6.456421*
CO	-327.1042	202.6327	-1.614272
Diagnostic Tests			
	Statistics	P-Value	
LM	0.024232	0.877142	
HET	1.71	0.168415	
NORM	2.636158	0.267649	

Notes: LM, HET and NORM are the Lagrange multiplier statistics for serial correlation, heteroskedasticity and normality of residuals, respectively.* indicate 1% significance level.

The obtained empirical results from this paper indicated that carbon dioxide (CO_2) emissions affect negatively economic growth while energy consumption has a positive effect on it. That is, 1% increase in energy consumption raises economic growth of about 3.72%. Although carbon dioxide (CO_2) have negative effect on economic growth but the coefficient is not statistically significant that means it does not bear any meaning. Impulse-response analysis employed the response to Cholesky one standard deviation innovations. An impulse response function traces the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables. The responses of per capita income to per capita energy consumption and per capita carbon emissions are positive. The responses of per capita energy consumption to per capita income and per capita carbon emissions are also positive. The responses of per capita carbon emissions to per capita energy consumption are positive but the responses of per capita carbon emissions to per capita income are negative during second years and then it responses are positive (see Figure 4).

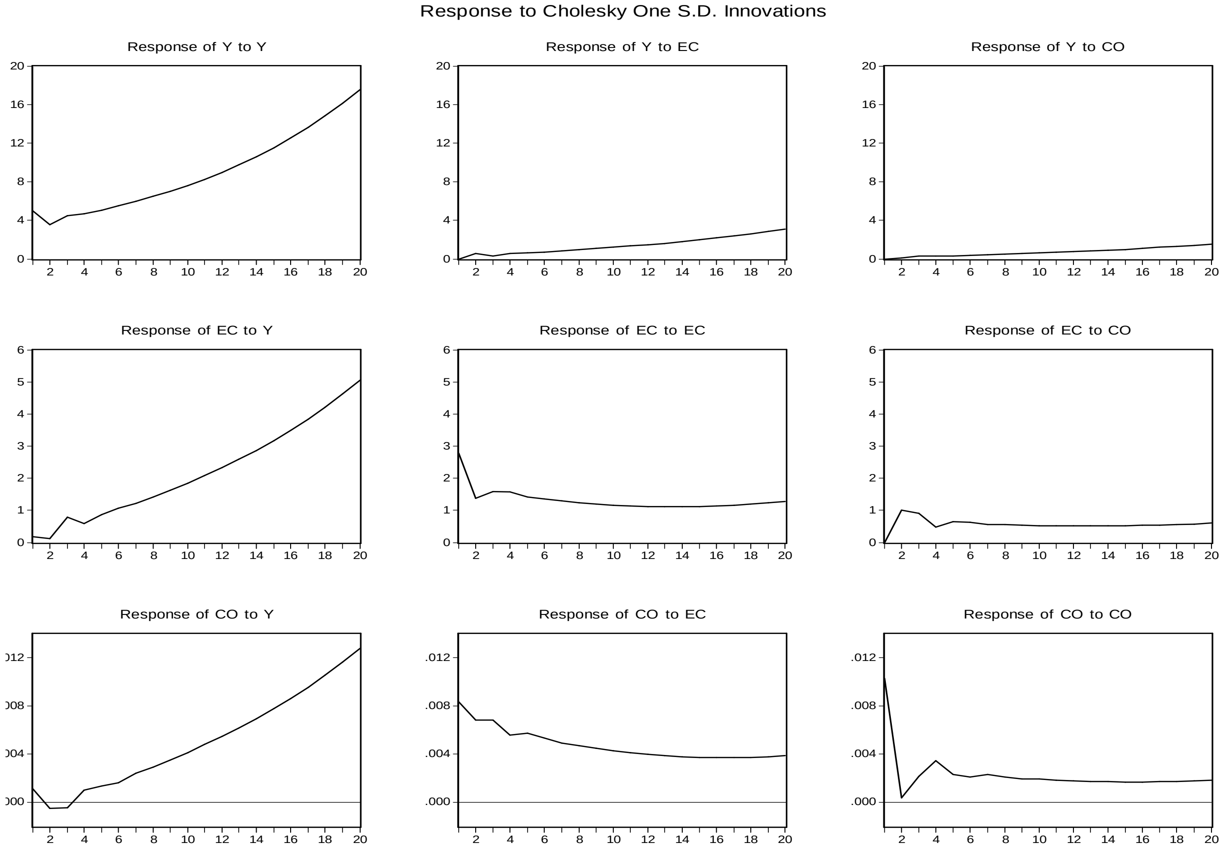


Figure 4. *Impulse-Response Analysis*

6. Conclusion

The purpose of this study is to examine the relationship between economic growth, CO_2 emissions and energy consumption for Bangladesh in period of 1972-2011. The findings show that energy use has a positive impact on economic growth while carbon emission has a negative effect. This conclusion is similar to the studies of Gojayev et al. (2002), Zeshan and Ahmad (2013) and Bozkurt and Akan (2014). But the relation between economic growth and carbon emissions is not statistically significant which ensures that in Bangladesh economic growth can be achieved without degrading the quality of environment. Energy use can cause CO_2 emissions which is a regular economic phenomenon. Though, Bangladesh's contribution to the global climate change is trivial in comparison to many other industrial nations. The country shares less than 0.1% of the global emissions as compared to the 24% emitted by the USA (Uddin & Taplin, 2008). The study reveals that EKC does not seem to hold when Greenhouse Gases (GHG) and income per capital are considered. The empirical results of our study further reveal that in Bangladesh, growth is not energy dependent, rather economic growth can ensure energy consumption. Economic growth causes expansion in the industrial and commercial sectors where energy is used as the basic input.

Our findings have important policy implication, as it suggests that energy restrictions do not seem to harm economic growth in Bangladesh. Thus, in context of Bangladesh, energy efficiency and conservation can ensure better economy and environment. In Bangladesh, output is environment friendly the reason behind which is our high dependency on the natural gas as the source of our energy. In the Fiscal Year 2010, natural gas accounted for about 84% of the power generation in our country. So, in the short run we do not have to be concerned about the environmental pollution coming from higher economic growth. However, in the long run, if the sources of energy are changed from natural gas to alternative sources of energy, then policies need to be revised and customized.

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