

Energy Consumption, CO₂ Emissions and the Economic Growth Nexus in Bangladesh: Cointegration and Dynamic Causality Analysis

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Abstract

The paper investigates the existence of dynamic causality between the energy consumption, environmental pollutions and economic growth using cointegration analysis for Bangladesh. First, we tested whether any long run relationship exist using Johansen bi-variate cointegration model which is complemented with auto-regressive distributed lag model introduced by Pesaron for the results robustness. Then, we tested for the short run and the long causality relationship by estimating bi-variate vector error correction modeling framework. The estimation results indicate that a unidirectional causality run from energy consumption to economic growth both in the short and the long run; a bi-directional causality from electricity consumption to economic growth in long run but no causal relationship exists in the short run. A uni-directional causality run from CO2 emissions to energy consumption in the long run but it is opposite in the short run. CO2 granger cause to economic growth both in the short and in the long run, which is conflicting to the familiar environmental Kuznets curve hypothesis. Our results are different from existing analysis for electricity consumption and economic growth, however. The result of dynamic linkage between energy consumption and economic growth significantly reject the 'neo-classical' assumption that energy use is neutral to economic growth. Hence clearly an important policy implication, energy can be considered as a limiting factor to the economic growth in Bangladesh and conservation of energy may harm economic spurs. Therefore, it is a challenge for the policy makers to formulate sustainable energy consumption policy to support smooth energy supply for sustainable economic growth.

1. Introduction

The causality relationship between energy consumption and income is widely analysed since the seminal work of Kraft and Kraft (1987). The empirical evidence is mixed and is unidirectional, bi-directional causality to no causality. It varies across different countries as it depends on country's development path, sources of energy uses, energy policies, level of energy consumption, institutional arrangements etc. The causality relationship between energy consumption (electricity consumption as well) and economic growth is an important discussion

in the literatures because of its high importance. There are two kinds of view exist in the literatures, first, a neo-classical view that is, the economic growth of a country can be 'neutral' to the energy consumption, therefore, the country can set energy conservation policy to reduce CO₂ emissions for saving environmental degradation without compromising the pace of the economic growth which is defined as a 'neutrality hypothesis'. Second, the country's economic growth can be highly associated with the energy consumption; therefore, like any other factors of production, the energy consumption can be a limiting factor to the economic growth. Stern (1993, 2000) found that energy is a driving factor to the economic growth in US; the similar results found by Mashi and Mashi (1996) in India, Wolde-Rufeal (2005) in Algeria, Cameron, Congo DR, Egypt, Nigeria; Wolde-Rufael (2004) in Shanghai; Soyatas and Sari (2003) in France, Germany and Japan; Chontanawat, *et al.*, (2006, 2008) in Kenya, Nepal and the Philippines, therefore, reduction in energy tends to reduce output growth. In this case, energy conservation policies might be harmful to the economy and in a way 'neo-classical' hypothesis that energy is neutral to the economic growth can be rejected. Payne (2010a) and Payne (2010b) provide a comprehensive survey on the literatures of causal relationship between energy consumption, electricity consumption and economic growth. Mozumder and Marathe (2007) also list a detail review of literatures on the energy consumption and economic growth nexus.

There is a growing concern of scarce energy sources in one hand, and a new paradigm of a green economy on the other as because of the global warming problem. The causality relationship between economic growth and environmental damage because of CO₂ emissions is also much more intense debated over the past decades. The emission of CO₂ is a core cause of global warming. Therefore, it is also much important and utmost necessary to investigate whether higher economic growth and energy consumption lead to higher environmental damage. The familiar environmental Kuznets Curve (EKC) (Kuznets, 1955) has also been well discussed in the literatures where it postulates that there is an inverse U-shaped relationship between economic activity and environmental pollution. It explains that environmental degradation initially increases with the increase of income, reaches a threshold point and then it declines with increases income (Grossman and Krueger, 1991; Selden and Song, 1994; Stern,

Common and Barbier, 1996). Using Toda and Yamamoto (1995) approach, Soytas and Sari (2007) found that CO₂ emissions granger cause energy consumption in Turkey but not vice-versa. So, whether continued increase in national income brings more degradation to the environmental quality is much critical for the design of development strategies for developing economies (Ang, 2007). The author found that CO₂ emissions granger cause to the output which is conflicting to the EKC hypothesis. Elif *et al.*, (2009) found that a monotonically increasing relationship between CO₂ and income in Turkey. However, the empirical evidence remains controversial and ambiguous until to date and there is no agreement in the literature on the economic level at which environmental degradation starts declining (Dinda, 2004).

We have chosen Bangladesh as a case study for some important reasons. First, the energy sector is not well organized (Mozumder and Marathe, 2007) in Bangladesh. It is suspected that economy grows with energy consumption grow. It is an energy deficit country. The major energy consists of natural gas (from which almost half of total is used for electricity production), petroleum and coal (BBS, 2005). The growth rate of economy is about 6% which is expecting (by policy makers) to rise over time. Since independence, the economy is growing moderately ranging from average economic growth 4 to 6 per cent per annum (BBS, 2005). The government makes strategic policies to increase the gross domestic product (GDP) growth at least by 2% more by 2015 (Six-five year plan, GOB, 2010). If GDP growth is associated with higher energy consumption and causality runs from energy to GDP, therefore, very often lack of smooth energy supply might be a serious constraint in the future to continue the same growth or to increase as planned. This can be true in the case of electricity consumption (when electricity consumption is used as a proxy for energy) in Bangladesh as well.

Second, in the forthcoming 6th five year plan of Bangladesh, the country set a target to eliminate or at least to reduce considerable rate of poverty by 2015 by increasing GDP growth, remains all other natural constraints constant, and assuming GDP growth is pro-poor. In the last few years, the country have been confronted with a challenge of producing more energy (electricity) to meet growing demand, Therefore, the policy makers and the development practitioners are very much concern whether the economic growth performance will be in the

same path or will be possible to trigger to the target of reducing poverty if the energy consumption is associated with the economic growth, otherwise, future target has to be compromised. But if the economic growth doesn't necessarily relate to the energy consumption and not even associated with CO₂ emissions, it is the case where energy conservation policy could be a feasible policy option and energy conservation or energy efficiency policy wouldn't harm the economic growth.

Third, Bangladesh is one of the countries most likely to suffer extremely from the adverse effect from climate change because of global warming problem which is caused from the environmental degradation. The Intergovernmental Panel on Climate Change (IPCC, 2001) predicts a high frequency of extreme climate events, like sea level rise, droughts, floods and cyclones for Bangladesh. The country's contribution to global climate change via emissions of CO₂ from energy systems is very insignificant. But remains to be done whether country's economic growth and emission is associated each other and it is in the line of EKC hypothesis.

Fourth, the choice of Bangladesh is also motivated by the fact that, so far, there is only a study conducted by Mozumder and Marathe (2007) that analysed the causal relationship between electricity consumption and economic growth using Johansen vector error correction model. The authors found that there is a uni-directional causality run from economic growth to electricity consumption in the long run. Therefore, the electricity saving policy might not be harmful to the economic growth. In our study we argue that analyzing only the electricity consumption would provide a partial result as only about 50% of the country's natural gas is used for electricity production (BBS, 2005). It is not only electricity consumes at the industrial, manufacturer, agricultural and commercial level, but also the natural gas, coal and petroleum. So, using electricity consumption as a proxy for energy might be less reflecting to energy consumption from different sources. Moreover, the empirical results presented by Mozumder (2007) show that there are two cointegrating relationship between the variables with a bi-variate model which means that the model might not be correctly identified. In a bi-variate model, when the number of cointegrating relationship (also called cointegrating rank in Johansen, 1990) is equal to the number of endogenous variable, the rank is invertible and the

variables in level are stationary meaning that no co-integration exists (please see also Johansen cointegration in the methodology section for detail). That is why our motivation is also to revisit the dynamic linkage between electricity consumption and the economic growth.

To our knowledge, this is the first study that analyzes the real GDP (proxy for economic growth), energy consumption, electricity consumption and CO₂ emissions (proxy for environmental degradation) nexus in Bangladesh in a same study using modern time series econometric methodology. The findings of this study have significant policy implications for energy consumption, environmental pollution and the economic growth in Bangladesh. For example, in the case of energy consumption and the economic growth, if a uni-directional causality run from energy consumption to income growth in the long run would imply that energy deficit could limit the economic growth. In contrast, the inverse would imply that energy conservation policy can be implemented without compromising the pace of economic growth. No causal relationship would imply the 'neutrality hypothesis' meaning that neither the economic growth nor the energy consumption drive each other and hence, reducing energy use may not effect income and energy conservation policies may not affect economic growth (Asafu-Adjaye, 2000; Cheng, 1998). Again, in the case of economic growth and the Co₂ emissions is associated each other and causality run from emissions to economic growth imply that environmental pollution might have a long run affect to human health which cause poor productivity. The inverse would imply that it is very critical for the policy makers to design development strategies keeping in mind the environmental degradation because of the economic growth which cause emissions as Bangladesh is also a signatory country in the Kyoto protocol.

The remainder of this paper is organized as follows. Section 2 presents an integrated econometric methodology. The result and discussions are discussed in section 3. Last section draws conclusions and policy implications.

2. Data and the econometric models

2.1 Data

The study uses annual time series data for Bangladesh which were taken from world development indicator database (CD-ROM, 2010), the World Bank. The total gross domestic product (GDP) in US\$ constant price (2000 prices) was converted to the per capita real GDP. It was used as a proxy of economic growth. The per capita energy consumption, electricity consumption and CO₂ emission (as a proxy of environmental pollution) data was collected also from the same sources. The converted data then defined as, Y is per capita real GDP, EN is per capita energy consumption, EL is per capita electricity consumption and CO₂ is per capita CO₂ emissions. For capturing better results, the data was converted to the natural logarithm in the case of the energy consumption and the economic growth model. The study covered the data period starting from 1972 to 2006 based on the times series data availability.

2.2 Econometric models

Our first step of testing cointegration is to testing time series variables for their stationarity. According to the Engle and Granger (1987), a linear combination of two non-stationary series can be stationary and if such a stationary exists, the series are considered to be cointegrated. But it requires that series to has be in the same order of integration. Therefore, augmented Dickey-Fuller (ADF) (1979) and the Phillips-Perron (PP) (1988) test were performed to test whether the data are difference stationary or trend stationary and to determine the number of the unit roots at the level. We tested the null of a unit root against a stationary alternative for both the ADF and the PP tests. We also checked any of the variables are in the order of integration 2 as we attempt to estimate the level based auto-regressive distributed lag model for bound test for results robustness.

Johansen Cointegration

Once we found the variables are non-stationary at their level and are in the same order of the integration, we apply Johansen (1990) cointegration test, begins with an unrestricted vector auto-regressive model in which a vector of variables ($X \times 1$) at time t are related to the vector of past variables. According to Granger representation theorem, the vector X_t has a vector auto-regressive error correction representation in the following specification:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + \omega_t \quad (1)$$

$$\text{Where } \Pi = \sum_{i=1}^p A_i - I \text{ and } \Gamma_i = -\sum_{j=i+1}^p A_j$$

X_t is a $(X \times 1)$ dimension vector corresponding to the number of the variables (here Y , EN , EL and CO_2) in which all the variables are $\sim I(1)$, the Π , Γ_i and Φ are parameter matrices $(X \times X)$ to be estimated, D_t is a vector with deterministic elements (constant, trend and dummy) and ω_t is a $(X \times 1)$ random error follows as usual Gaussian white noise process with zero mean and constant variances. From the equation (1), there can never be any relationship between a variable $I(1)$ and a variable $I(0)$. Therefore, three cases are permissible from our model. If $\Delta X_t \sim I(0)$, then Π will be a zero matrix except when a linear combination of the variables in X_t is stationary. So our specific interest of testing is, the rank of matrix (Π) which contains long run information and the speed of the adjustment. First case, If $\text{rank}(\Pi) = X$, then Π is invertible and all the variables in levels are stationary meaning that no co-integration exists, Second, if $\text{rank}(\Pi) = 0$, i. e., Π is a null matrix meaning that all the elements in the adjustment matrix has value zero, therefore, none of the linear combinations are stationary, and can be estimated an unrestricted VAR model to identify the short run dynamics only. Third, according to the Granger representation theorem, when $0 < \text{rank}(\Pi) = r < X$, there are r cointegrating vectors or r stationary linear combinations. For example, if $\text{rank}(r)$ of matrix Π is equal to one, there is single cointegrating vector or one linear combination which is stationary such that the cointegrating rank matrix Π can be decomposed into $\Pi = \alpha\beta'$ where α is the vector of speed of the adjustment and β is the long run equilibrium. In this case X_t is $I(1)$ but the combination $\beta'X_{t-1}$ is $I(0)$. The Johansen method is to estimate the Π matrix from an unrestricted VAR and to test whether we can reject the restriction implied by the reduced rank Π . There are two methods of testing for reduced rank (Π) , the trace test and maximum eigen value which are as follows:

$$\lambda_{\text{trace}} = -T \sum_{i=r+1}^n \ln(1 - \hat{\lambda}_i^2)$$

$$\lambda_{\max}(r, r + 1) = -T \ln(1 - \lambda_{r+1})$$

Where, λ_i is the estimated ordered eigenvalue obtained from the estimated matrix and T is the number of usable observations after lag adjustment. The trace statistics tests the null hypothesis that the number of distinct cointegrating vector (r) is less than or equal to r against a general alternative. The maximal eigenvalue tests the null that the number of cointegrating vector is r against the alternative of r +1 cointegrating vector.

Autoregressive distributed lag (ARDL) bound test for cointegration

In addition to the Johansen cointegration rank test, we also performed an ARDL model for bound test introduced by the Pesaran *et al.*, (2001). Although Gonzalo (1994) presents Monte Carlo evidence that the full information maximum likelihood procedure of Johansen test performs better than others and the test is appropriate when the identification of exogenous variable is not possible *at prior*, but the Johansen test result is very sensitive in the case of small sample and the use of different lag length (Odhiaambo, 2009). ARDL bound test has many advantages over other cointegration tests in this regards. The ARDL does not impose any restriction that all the variables used under study must be integrated of the same order; therefore the test can be applied whether the selected variables are integrated of order zero or order one. The test is also not sensitive to the size of the sample. Moreover, the ARDL test generally provides unbiased estimates of the long run model and provides valid t-statistics even when some of the regressors are endogenous (Harris and Sollis, 2003). Pesaran and Shin (1998) show that it is possible to test the long run relationship between the dependent and the set of regressors when it is not known *a prior* whether the variables are stationary or non-stationary. Following Pesaran and Shin we have estimated the following equations to investigate the long run level relationships which are as follows

$$\Delta X_{i,t} = \mu_1 + \sum_{i=1}^{q1} \beta_i \Delta X_{i,t-i} + \alpha_i X_{i,t-1} + \varepsilon_{i,t} \quad (2)$$

The equation 2 can be rewritten as

$$\Delta X_{1,t} = \mu + \sum_{i=1}^{q1} \beta_i \Delta X_{1,t-i} + \sum_{i=1}^{q2} \beta_i \Delta X_{2,t-i} + \alpha_1 X_{1,t-1} + \alpha_2 X_{2,t-1} + \varepsilon_{1,t} \quad (3)$$

$$\Delta X_{2,t} = \phi + \sum_{i=1}^{q1} \beta_i \Delta X_{1,t-i} + \sum_{i=1}^{q2} \beta_i \Delta X_{2,t-i} + \alpha_1 X_{1,t-1} + \alpha_2 X_{2,t-1} + \varepsilon_{2,t} \quad (4)$$

Here, all the variables are previously defined. The cointegration is examined based on F-statistics. From the above equations 3 and 4, the presence of cointegration can be tested first estimating the models by OLS and then by restricting all estimated coefficients of lagged level variables equal to zero. So the null hypothesis $H_0: \alpha_1 = \alpha_2 = 0$ is tested against the alternative of $H_1: \alpha_1 \neq \alpha_2 \neq 0$. The number of lag was chosen based on likelihood ratio (LR) criteria. The estimated F-test has a non-standard distribution, however. Two set of critical values are provided for given significance level at Pesaron *et al.*, (2001). First set of critical values assumes that all the variables are I (0) and the second set assumes that the all variables are I (1). If the calculated F-statistics exceeds the upper bounds of I (1), then the null of no cointegration is rejected. If the estimated F-statistics is smaller than the lower bounds of I (0), then the null hypothesis of no cointegration can't be rejected. The test becomes inclusive if the calculated F-statistics falls into the bounds.

Granger causality in the VECM framework

Once the cointegration relationship confirmed from the Johansen and the ARDL bound test, we use the Granger causality in a Johansen vector error correction framework. The existence of cointegration in the bi-variate relationship implies long run Granger causality at least one direction which under certain restrictions can be tested Wald test (Masconi and Giannini 1992; Dolado and Lutkephol, 1996). If α matrix in the cointegration rank matrix (Π) has a complete column of zeros, no long run casual relationship exist, because there is no cointegrating vector appear in that particular block. For identifying the short run and the long run causal relationship, the equation (1) can be re-written in the case of bi-variate model as following two equations

$$\Delta X_{1,t} = \mu_1 + \sum_{i=1}^{k1} \beta_i \Delta X_{1,t-i} + \sum_{j=1}^{k2} \beta_j \Delta X_{2,t-j} - \alpha_1 ECT_{t-1} + \varepsilon_{t,1} \quad (5)$$

$$\Delta X_{2,t} = \mu_2 + \sum_{i=1}^{k1} \beta_i \Delta X_{1,t-i} + \sum_{j=1}^{k2} \beta_j \Delta X_{2,t-j} - \alpha_2 ECT_{t-1} + \varepsilon_{t,2} \quad (6)$$

Where, ECT stands for error correction term. In the equations (5 and 6), there are three possible cases of testing long run causality. First; if $\alpha_1 \neq 0$ and $\alpha_2 \neq 0$, which implies bi-directional causality that there exist a feed-back long run relationship between the selected variables. Two variables cause each other in the long run. Second, if $\alpha_1 = 0$ but $\alpha_2 \neq 0$, implies unidirectional causality meaning that variable X_2 granger cause to variable X_1 . Third, if, $\alpha_2 = 0$ but $\alpha_1 \neq 0$, implies uni-directional causality, variable X_1 granger cause to variable X_2 . There can never be both $\alpha_1 = 0$, $\alpha_2 = 0$ once there is a cointegration relationship exist. We also can test the short run causality from the equations 5 and 6 by using standard Wald test. We can examine the significance of all lagged dynamic terms by testing for example in equation 5, the null of $H_0: \beta_j = 0$. Non-rejection implies that variable X_2 granger cause to variable X_1 in the short run and the null of $H_0: \beta_i = 0$. in equation 6 implies that variable X_1 granger cause to variable X_2 .

3. Empirical results and discussions

The results of ADF and PP tests on each of the variables are reported in Table 1. The results indicate that all series are non-stationary at their level but stationary at their first differences irrespective the random walk model with drift or random walk model with slope. In time series econometrics, it is said that series are integrated of order one denoted by presenting $X_t \sim I(1)$ and series of integrated of order zero denoted by $\Delta X_t \sim I(0)$. Here, the order of the integration is one. Note that, the same order of integration is a pre-requisite when the Johansen framework is used for testing cointegration and the causality. Our Johansen test is complemented by the ARDL bound test. That is why we also have to check whether any of the variables is $I(2)$ because of the critical values provided by Pesaron *et al.*, (2001) are only for $I(0)$

and I (1). The results confirmed that all the selected variables for analysis are I (1), therefore, it allows for testing long run relationship both by Johansen (1990) and Pesaron (2001).

Table 1: Unit root results

Tests→ Variables↓	ADF		PP		I(d)
	Only drift	Drift & trend	Only drift	Drift & trend	
Gross domestic product (Y)					
Y	5.648	1.686	23.628	9.815	I (1)
ΔY	-0.321	-7.152***	-4.123***	-7.152***	
LnY	2.923	-0.098	10.741	2.992	I (1)
ΔLnY	8.881***	-9.024***	-6.373***	-16.129***	
Electricity (EL)					
EL	4.261	2.127	9.279	2.546	I (1)
ΔEL	0.415	-5.885***	-3.113*	-6.681***	
Energy (En)					
EN	4.512	-0.998	4.413	-0.381	I (1)
ΔEN	-7.130***	-8.519***	-7.122***	-24.375***	
LnEN	1.627	-2.059	1.768	-1.800	I (1)
ΔLnEN	-8.245***	-8.794***	-8.595***	-30.963***	
CO2 emissions (CO2)					
CO2	3.083	0.989	4.088	-0.021	I (1)
ΔCO2	-4.889***	-4.890***	-5.860***	-12.412***	

Notes: Lag length for ADF test is decided based on Schwarz info criteria and maximum bandwidth for PP test is decided based on Newey-West (1994); *** & * indicates that unit root in the first differences are rejected at 1 % and 10% level; Critical values are -2.954 (5%), and -3.646 (1%) with drift and -3.548 (5%), and -4.253 (1%) with slope (MacKinnon, 1996); Ln means that the series are converted into logarithm

Given that, the selected variables share common integration properties, we now proceed for testing long run relationship between the selected variables. We estimated four different bi-variate models. The estimated models are; the relationship between (a) economic growth

versus energy consumption (b) economic growth versus electricity consumption (c) economic growth versus environmental pollution and (d) energy consumption versus environmental pollutions. Given our small number of observations, the bi-variate models are best fit than the multi-variate model. The trace test (λ_{trace}) and maximum eigenvalue (λ_{max}) tests results are presented in Table 2. It is found that all the estimated bi-variate models contain one cointegrating vector that means one linear combinations that is stationary. For estimating the number of cointegrating vector from equation (1), the lag length was determined by minimization of AIC, SIC and maximization of LR but as the inclusion of the deterministic terms (constant and trend) in the cointegration space is sensitive to identify cointegration rank, therefore, we performed all the residual diagnosis tests before selecting final model. In all the cases the selected lag is 2 except in the case of model 3 (economic growth and Co2 emissions) in where the lag is 3 (based on selection criteria from an unconstrained VAR model). According to Harris and Sollis (2003) we estimated three realistic cases which are; first, restricts all the deterministic components to a constant in the cointegration space, second, allows linear trends in the level of the variables and third, the linear trend is allowed in the cointegration space. Again, we found that the case 3 fit best to the model 3 (economic growth versus Co2 emissions) but the second case is appropriate for all other models. The specification tests show that for selected models there are no problem of autocorrelation, heterosacdsticty and non-normality. We also have checked the VAR stability and found VAR satisfies the stability condition in that no roots are outside the unit circle². From Table 2, the results indicate that there is a long run relationship exists between energy consumption and economic growth; electricity consumption and economic growth; Co2 emissions (as a proxy for environmental degradation) and economic growth; energy consumption and Co2 emissions. In all the models, null of no cointegration is rejected at the 1% significant level by both the trace and the maximum eigenvalue tests. As the Johansen cointegration results suffer from the small sample bias and sensitive to lag lengths. That is why as complementary we performed level based ARDL cointegration tests for the results robustness and are presented in Table 3.

² For the brevity, we do not present the results of the models specification, but can be provided authors upon request

Table 2: Johansen cointegration test results

Hypothesis for cointegrating rank	Model 1		Model 2	
	EN versus Y		EL versus Y	
	$\lambda_{\text{trace}}, \lambda_{\text{max}}$	Critical values	$\lambda_{\text{trace}}, \lambda_{\text{max}}$	Critical values
Trace statistics (λ_{trace})				
$H_0: r = 0$ vs $H_1: r \geq 1$	35.491	15.495***	34.731	15.495***
$H_0: r \leq 1$ vs $H_1: r \geq 2$	2.476	3.841	1.009	3.841
Maxi eigenvalue (λ_{max})				
$H_0: r = 0$ vs $H_1: r = 1$	33.015	14.265***	33.721	14.265***
$H_0: r \leq 1$ vs $H_1: r = 2$	2.476	3.841	1.009	3.841
Hypothesis for cointegrating rank	Model 3		Model 4	
	Y versus CO2		EN versus CO2	
	$\lambda_{\text{trace}}, \lambda_{\text{max}}$	Critical values	$\lambda_{\text{trace}}, \lambda_{\text{max}}$	Critical values
Trace statistics (λ_{trace})				
$H_0: r = 0$ vs $H_1: r \geq 1$	32.233	25.872***	18.765	15.495***
$H_0: r \leq 1$ vs $H_1: r \geq 2$	8.332	12.518	3.124	3.841
Maximum eigenvalue (λ_{max})				
$H_0: r = 0$ vs $H_1: r = 1$	23.901	19.387***	15.641	14.265***
$H_0: r \leq 1$ vs $H_1: r = 2$	8.332	12.518	3.124	3.841

Note: *** indicates that the hypotheses are rejected at the 5% level

Our ARDL bound test results reported in Table 3 also show the same conclusion that in all the bi-variate estimated models contain one cointegrating vector as the estimated F-statistics exceeds the upper bounds of critical value, meaning that the null of no cointegration is rejected. So, evidence from Johansen and ARDL test indicates that the integrated variables have co-movement tendency in the long run.

Table 3: ARDL bound test results of cointegration

Models	F-statistics	Decision	Models	F-statistics	Decision
1). Y versus EN			2). Y versus EL		
Y	15.553***	cointegrated	Y	4.728**	cointegrated
EN	1.974		EL	1.435	
3). Y versus CO2			4). Y versus En		
Y	8.585***	cointegrated	EY	20.371***	cointegrated
CO2	2.303		CO2	1.832	

Bound critical values ^a

1% significance level		5% significance level		10% significance level		
<u>Lower bound</u>	<u>Upper bound</u>	<u>Lower bound</u>	<u>Upper bound</u>	<u>Lower bound</u>	<u>Upper bound</u>	
<i>I</i> (0)	<i>I</i> (1)	<i>I</i> (0)	<i>I</i> (1)	<i>I</i> (0)	<i>I</i> (1)	
k=2	4.948	6.028	3.478	4.335	2.845	3.623
k=3	4.428	5.816	3.164	4.194	2.618	3.532

Notes: Narayan (2005), Case II: Unrestricted intercept and no trend, *** indicates the hypotheses are rejected at 1% level, k means lag in the estimated models

Given the existence of cointegration implies the existence of causality at least one direction. Hence, we perform the Johansen vector error correction based causality test (explained in the section Granger causality in the VECM framework). Our results show strong evidence that energy consumption granger cause economic growth in the long run. The results are consistent with the findings (from the similar developing countries) of Mashi and Mashi (1996) in India, Mashi and Mashi (1998) in Thailand, Srilanka; Wolde-Rufael (2005) in Algeria, Cameroon, Congo DR, Egypt, Morocco, Nigeria; Mahadevan and Asafu-Adjaye (2007) in India, Thailand. However, the evidence also show that there is a uni-directional causality running from energy consumption to economic growth also in the short run. This results strongly support that the Bangladesh economy highly dependent on energy consumption. The results also show that there is a feedback causality relationship between the electricity consumption and the economic growth in the long run but no causality exist in the short run. The causality relationship between electricity consumption and the economic growth is different from the

existing analysis of Mozumder (2007), however. The similar results found by Chen, Kuo and Chen (2007) in Hongkong; Odhiambo (2009) in South Africa; Squail (2007) in Iran, Nigeria, Wolde Rufael (2006) in Egypt, Morocco; Yoo (2005) in Korea; Yoo (2006) in Malaysia, Singapore; Yuan, Kang, Zhao, and Hu, (2008) in China. The evidence of causality between energy consumption and economic growth; electricity consumption and economic growth in Bangladesh consistently imply that, efficient use of energy and energy development policy will have strong positive effect on economic growth.

Table 4: Likelihood ratio test results

Models	Long run causality (LR test)		Causality decision
	$H_0: \alpha_1 = 0$ vs $H_1: \alpha_1 \neq 0$	$H_0: \alpha_2 = 0$ vs $H_1: \alpha_2 \neq 0$	
Y versus EN	28.464*** (0.000)	1.901 (0.168)	Y ← EN
Y versus EL	24.858*** (0.000)	14.780*** (0.000)	Y ↔ EL
Y versus CO2	15.022*** (0.000)	0.0342 (0.853)	Y ← CO2
EN versus CO2	7.143*** (0.007)	0.353 (0.552)	En ← CO2

Notes: parentheses indicate the probability level; ← indicates unidirectional causality and ↔ indicates bi-directional causality

When we examined the relationship between economic growth and CO2 emissions, we found that causality runs from the later to the former both in the short run and the long run (Table 4 and 5). The similar results found by Ang. (2007) for Malaysia. The result is conflicting to the EKC hypothesis, however. The EKC studies by Friedl and Getzner, (2003); Cannas *et al.*, (2003), de Bruyn and Opschoor, (1997) have failed to yield unanimous results in a line of EKC. Dinda and Coondoo (2006) also found the mixed results. Our results can be consistent in a way that environmental degradation might bring a negative externality to the economy through human health which in turn causing to the productivity. Most interesting result we found that energy consumption granger causes CO2 emissions in the short run but it just a opposite in the long run. That is an increase in energy consumption might bring about an increase in Co2 emissions.

Table 5: Short run causality test from Johansen VECM model

Models	χ^2 -stat	Decision	Models	χ^2 -stat	Decision
Y versus EN			Y versus EL		
ΔY	5.330* (0.0696)	Y←EN	ΔY	1.8403 (0.398)	Y«≠»EL
ΔEN	1.3359 (0.513)		ΔEL	0.3107 (0.856)	
Y versus CO2			EN versus CO2		
ΔY	15.975*** (0.001)	Y←CO2	ΔEN	1.598 (0.449)	CO2←EN
$\Delta CO2$	2.688 (0.442)		$\Delta CO2$	8.018** (0.018)	

Notes: Parentheses indicates the probability level; ← indicates unidirectional causality and «≠» indicates no causality

4. Conclusions

Applying bi-variate Johansen cointegration and vector error correction model, the paper investigated the dynamic linkage between energy consumption and economic growth; electricity consumption and economic growth; CO2 emissions and economic growth; and energy consumption and CO2 emissions for Bangladesh. To complement the Johansen cointegration, we also estimated ARDL model for bound test for cointegration to results robustness. There are some clear policy implications from our results. The result, of dynamic linkage between energy consumption and economic growth significantly reject the neo-classical assumption that energy use is neutral to economic growth. We can conclude that Bangladesh is an energy dependent country and shocks to energy supply would have a negative impact to the economic spurs. When we analysed more disaggregated level, using electricity consumption as a proxy for energy, we found the feedback effect as well. So, sufficient supply of electricity is required to promote the development and to increase the productivity of the labour, capital and other factors of production.

The results of the environmental degradation and the economic growth imply that former might bring a negative externality to the later through human health disaster which in turn can

cause to the poor productivity. This is consistent with the experiences of many developing countries, however. Therefore, the policy makers have to make strategic plans so that the environmental quality is not persistently decline which will have negative externality to output growth.

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