The Dynamics of Electricity Consumption, Energy Use and GDP in Bangladesh

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Abstract
The aim of this paper is to investigate the relationship between electricity consumption, energy use and GDP in Bangladesh, using annual data covering the period from 1980 to 2014. The bounds testing (ARDL) approach reveal that electricity consumptions have significant and positive long run impact on GDP and vice versa. The results of the estimated ARDL-ECM models indicate that long-run causality is directing from electricity consumptions and energy use to GDP, and GDP and energy use to electricity consumptions. Thus, in the long run, we find evidence of the feedback hypothesis suggesting the interdependent relationship between electricity consumption and economic growth in which causation runs in both directions and serve as complements. Finally, this study also explores that the relationship among the variables is insignificant in the short-run. Thus, the empirical results of this study might provide a better enthusiastic to the policymakers of Bangladesh to execute the Power System Master Plan (PSMP) 2016 to become a high-income country by 2041.

Keywords: *Electricity Consumption*, *GDP*, Unit Root, *Bounds Test.*

JEL Classification: C32, O47, Q43.

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Introduction

Energy is one of the essential basics of modern-day life and it correspondingly performs a significant role in economic development of a country. In all economies, households and companies have extensive demand for electricity and energy. The demand of energy of a country is boosted by industrialization, extensive urbanization, population growth, rising standard of living and even the modernization of the agricultural sector (Masuduzzaman, 2012). The impact of energy consumption on economic growth has drawn the attention of economists since late 1970s. In an early work in this topic, Kraft and Kraft (1978) find the evidence of a unidirectional causal relationship from GNP to energy consumption in the United States. Mulugeta et al. (2010) advocate the growth hypothesis that energy consumption as an input in the process of production is directly or indirectly important for growth activities, harmonization of capital and labor.

During the recent 15 years, the average economic growth rate has been approached to 6% per annum. Nominal GDP has been increased from Taka 50 billion to Taka 15,136 billion from fiscal year 1972-73 to 2014-15 (Hasan et al., 2016). Bangladesh is still a lower-middle income country as per capita income stands at around $1500. According to the Seventh Five-Year Plan formulated by the government of Bangladesh, the average GDP growth rate from 2016 to 2020 is expected to reach 7.4%. If the economic growth as projected is achieved accompanying with energy sector development, Bangladesh will become a member of the upper-middle income economies in the 2020s. The need for energy grows exponentially as the economy prospers due to growing industrialization and urbanization. Persistent supply of energy is an important infrastructural prerequisite that drives economic growth. Bangladesh, while performing remarkably till date to meet surging energy needs, still has a long way to go to be self-sufficient in this sector. According to the United States Energy Association (USEA), the energy supply deficiency in Bangladesh this year stands at 19 percent (Ahmed, 2016). Furthermore, power outages are still common in Bangladesh leading to losses of about two to three percent of the country's GDP (The World Bank, 2016). The energy sector in Bangladesh covers a wide range of products such as electricity, petroleum products, natural gas, coal, biomass, solar and other renewable sources. But, the policy-makers have been given more attention on electricity as it is the most widely used form of energy. The aggregate generation of electricity has increased at a rate of around seven and half per cent since independence from Pakistan in 1971. The generation of power is less than the demand in Bangladesh over the years. This load-shedding creates problems of far reaching consequences in the socio-economic development. The population's access to electricity increased from the FY2010 baseline of 48% to 72% in

FY2015. The per capita electricity generation also increased from 220 kWh to 371 kWh (Bangladesh Economic Review, 2016). Although total installed capacity of Bangladesh Power Development Board (BPDB) is 15,379 MW, the maximum demand served during peak hours is 9,212 MW in April 18, 2017 (BPDB, 2017). According to the BPDB, the daily average power demand is around 8,500MW now, more than 60 percent of which comes from cheap and clean natural gas. The supply of gas, oil, hydro and coal-based power and imported power in total is close to the demand in recent times. As a result, load-shedding has reduced substantially but still this sector is struggling to supply quality electricity to its customers. Power sector is also struggling with increasing per unit supply cost due to increasing oil based electricity generation. While almost all urban areas have electricity, only 70 percent of rural households have access to it. System loss has also been decreased at 13.55 percent in FY2015-16 which was 27.97 percent in FY2001-02 (Bangladesh Economic Review, 2016). The scenario indicates that system is facing rolling blackouts in hot summer days due to some bottlenecks exists in transmission and distribution system. Natural gas accounts for about three quarters of primary energy supplies with the remainder coming from imported fuels and coal. Since the discovery of natural gas first in Bangladesh in the year 1955, until today 26 gas fields have been discovered in this country. Total initial recoverable proven and probable gas reserve of 26 fields has been estimated to be at 27.12 TCF. Up to December, 2015 as much as 13.52 TCF gas was produced, leaving only 13.60 TCF of recoverable gas. Currently, demand for gas in the country has already surpassed 3,200 million cubic feet per day (MMSCFD) whereas the average supply of gas is around 2,740 MMSCFD, leaving a shortfall of about 500 MMSCFD (Petrobangla, 2015). In order to supplement indigenous natural gas, Bangladesh is supposed to import Liquefied Natural Gas (LNG) to bridge or minimize the demand-supply gap. Coal can be a major source of primary energy supply in Bangladesh in future. Five coal fields have been discovered with estimated reserve of more than 3 billion tones out of which Petrobangla has developed the first coal mine of the country at Barapukuria. But, the production of Barapukuria coal mines in 2015 was 0.68 million tons and did not reach 1 million tons as planned (Ministry of Power, Energy and Mineral Resources, 2016). Thus, domestic coal development will become more important than at present in future, because high quality coal is abundant in Bangladesh. Bangladesh's current oil annual demand is around 5 million tons, and the self-sufficiency rate is only 5%. Bangladesh has an aspiration to become a high-income country by 2041 and thus, the Power System Master Plan (PSMP) 2016, sponsored by Japan International Cooperation Agency (JICA), aims at assisting the Bangladesh in formulating an extensive energy and power development plan up to the year 2041, covering five key viewpoints: a) Enhancement of imported energy infrastructure and its flexible operation; b) Efficient development and utilization of domestic natural resources (gas and coal); c) Construction of a robust, high-quality power network; d) Maximization of green energy and promotion of its introduction; e) Improvement of human resources and mechanisms related to the stable supply of energy (Ministry of Power, Energy and Mineral Resources, 2016).

Hence, power and energy are the main driving forces of country's economy and prerequisite for development and therefore, analysis of the relationship among electricity consumption, energy use and GDP in the country is essential to the policy makers and consumers. Motivated by the importance of this subject and the above growth scenario of Bangladesh economy, this research is to investigate the dynamics of electricity consumption, energy use and GDP in Bangladesh using annual data covering the period from 1980 to 2014.

Brief literature review

In the literature regarding energy consumption and economic growth, four possible hypotheses have been underlined: the growth, conservation, feedback and neutrality hypotheses (Ozturk, 2010).

First, the growth hypothesis suggests that unidirectional causality runs from electricity consumption to economic growth, indicating that the economy is energy dependent. This hypothesis is supported by researches, such as, Masuduzzaman (2012), Ghali and El-Sakka (2004), Kouakou (2011), Javid et al. (2013), Ahamad and Islam (2011), Alam and Sarker (2010), Buysee at al. (2012) and Saeki and Hossain (2011). Masuduzzaman (2012) investigates the relationship between economic growth, electricity consumption and investment for Bangladesh through co-integration and causality analysis over the period 1981 to 2011. He comments that over time higher electricity consumption and investment in Bangladesh give rise to more economic growth. Ahamad and Islam (2011) reveal a short-run unidirectional causality running from per capita electricity consumption to per capita GDP in Bangladesh applying co-integration and VECM based Granger causality test for the period from 1971 to 2008. Alam and Sarker (2010) also claim that there exists short run causal relationship running from electricity generation to economic growth, while Buysee at al. (2012) explore that uni-directional causality exists from energy consumption to economic growth both in short and long run in Bangladesh. Saeki and Hossain (2011) also finds support in favor of growth hypothesis in case of Bangladesh.

Second, the conservation hypothesis suggests for unidirectional causality from economic growth to energy consumption implying that economic growth may lead to energy consumption. This hypothesis is supported by researches, such as, Baranzini and Mathys (2013), Saeki and Hossain (2011), Mozumder and Marathe (2007), Jamil and Ahmed (2010), Fatai et al. (2004) and Ameyaw et al. (2017). Saeki and Hossain (2011) find existence of unidirectional causality from economic growth to electricity consumption in India, Nepal and Pakistan, while Mozumder and Marathe (2007) find that there is unidirectional causality from GDP to electricity consumption for Bangladesh over the period from 1971 to 1999 employing Co-integration and Vector Error Correction Model (VECM).

Third, the neutrality hypothesis advocates the absence of a causal relationship between energy consumption and economic growth indicating that economic growth is autonomous from energy usage. Few studies supports the neutrality hypothesis. Using data of Albania, Belarus, Bulgaria, Estonia, Latvia, Lithuania, FYR Macedonia Moldova, Romania, Russia, Serbia and Ukraine over the period from 1990 to 2006, Acaravci and Ozturk (2010) finds no casusality between electricity consumption and economic growth. Some of the studies that also find evidence of neutrality hypothesis include the studies by Yu and Jin (1992) and Payne (2009) for the U.S. and Jobert and Karanfil (2007) for the Turkey.

Fourth, the feedback hypothesis give emphasis to the interdependent relationship between energy consumption and economic growth in which causation runs in both directions and may serve as complements. Some of the studies that find evidence of the feedback hypothesis include the following: Zhang and Yang (2012) and Zhou and Chau (2006) for China, Tang and Tan (2013) for Malaysia, Ahamad and Islam (2011) for Bangladesh and Yoo (2005) for South Korea.

Therefore, the above literature reveals that the results are inconclusive concerning the nature and direction of causality between energy and economic growth owing to the application of different econometric methodologies and different sample sizes. Moreover, the empirical results are very mixed and even vary for the same country and are not conclusive.

Methodology

Data and data sources

This study uses annual data of real GDP, electricity consumption (EC), and energy use (EU) over the period from 1980 to 2014. The data on real GDP (constant US dollar 2005 price) and energy use (kg of oil equivalent per capita) are collected from World Development Indicators, 2016 published by World Bank, while the data of electricity consumption (Billion Kwh) are collected from International Energy Statistics, 2016. All data series are transformed to natural logarithms. The rationale for considering log is that taking the natural logarithm of a series effectively linearizes the exponential trend (if any) in the time series data as the log function is the inverse of an exponential function (Asteriou and Price, 2007).

Unit root test

Two extensively used unit root test, namely Augmented Dickey Fuller (ADF) and Phillips-Peron (PP) test are employed to examine the stationarity of the time series. The ADF test is operated using the following equation:

$$\Delta Y_t = \alpha + \beta T + \gamma Y_{t-1} + \delta_i \sum_{i=1}^{m} \Delta Y_{t-i} + \varepsilon_t \quad (1)$$

where, α is a interecpt (constant), β is the coefficient of time trend T, γ and δ are the parameters where , $\gamma = \varrho$-1, ΔY is the first difference of Y series, m is the number of lagged first differenced term, and ε is the error term.

The PP test is performed using the following equation:

$$\Delta Y_t = \alpha + \beta T + \gamma Y_{t-1} + \varepsilon_t \quad (2)$$

where, α is a constant, β is the coefficient of time trend T, γ is the parameter and ε is the error term.

ARDL bounds test

The ARDL bounds testing procedure of cointegration are sequentially developed by Pesaran and Pesaran (1997), Pesaran and Shin (1999), and Pesaran, Shin and Smith (2001). Pesaran and Shin (1999) argue that ARDL bounds test method is relatively more efficient and performs better in small data sizes, while Johansen and Juselius cointegration model needs larger samples for the results to be valid. We employ the ARDL model as it provides robust results for small sample sizes as in the case in this study. We construct the long-run models as follows:

$$\mathbf{GDP_t = \alpha_1 + \beta_1 EC_t + \beta_2 EU_t + \varepsilon_{1t}} \quad (3)$$

$$EC_t = \alpha_1 + \beta_1 GDP_t + \beta_2 EU_t + \varepsilon_{1t} \quad (4)$$

$$EU_t = \alpha_1 + \beta_1 GDP_t + \beta_2 EC_t + \varepsilon_{1t} \quad (5)$$

where GDP is gross domestic product, EC is electricity consumption and EU is energy use. α_i are intercept terms, β_i are the coefficients and ε_i are the error terms.

Equation (3), (4) and (5) can be written in the following conditional error correction model (ECM) version of the ARDL in order to carry out the bounds testing procedure:

$$\Delta GDP_t = c_1 + \pi_1 GDP_{t-1} + \pi_2 EC_{t-1} + \pi_3 EU_{t-1} + \sum_{i=1}^{p} \theta_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \emptyset_i \Delta EC_{t-i} + \sum_{i=1}^{p} \delta_i \Delta EU_{t-i} + u_{1t} \quad (6)$$

$$\Delta EC_t = c_2 + \pi_1 EC_{t-1} + \pi_2 GDP_{t-1} + \pi_3 EU_{t-1} + \sum_{i=1}^{p} \theta_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \emptyset_i \Delta EC_{t-i} + \sum_{i=1}^{p} \delta_i \Delta EU_{t-i} + u_{1t} \quad (7)$$

$$\Delta EU_t = c_3 + \pi_1 EU_{t-1} + \pi_2 GDP_{t-1} + \pi_3 EC_{t-1} + \sum_{i=1}^{p} \theta_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \emptyset_i \Delta EC_{t-i} + \sum_{i=1}^{p} \delta_i \Delta EU_{t-i} + u_{1t} \quad (8)$$

where equation (6), (7) and (8) are termed as model 1, 2 and 3 respectively. The first parts of the above equations represent the long-run dynamics of the models and the second parts show the short-run relationship in which Δ signifies the first difference operator. c_i(i = 1, 2, 3) shows constants, π_i (i = 1..3) denotes coefficients on the lagged levels, θi, ϕ_i and δ_i,(i = 1…ϱ) denote coefficients on the lagged variables, and finally u_i(i = 1…3) stands for error terms. ϱ signifies the maximum lag length, which is decided by the Akaike Information Criterion (AIC). We estimate the equations (6) to (8) in order to test the long-run relationship where the null and alternative hypotheses are as follows: $H_0: \pi_1 = \pi_2 = \pi_3 = 0$ (No long run relationship); $H_1: \pi_1 \neq \pi_2 \neq \pi_3 \neq 0$ (Long run relationship exists). Then we will estimate the long- and short-run coefficients of the same equations only if we find a long-run relationship in the first step.

Empirical Findings

The results of ADF and PP tests (Table 1) show that all of the variables are nonstationary in levels. Results also show that all series are stationary in first differences with 1% significance level. Since none of the variables are I(2) and all of the variables are I(1), we can use the autoregressive distributed lag (ARDL) bound testing method to detect the presence of cointegration among the variables.

Table 1

ADF and PP unit root test results

Variables	ADF		PP	
	Intercept	Trend & Intercept	Intercept	Trend & Intercept
GDP	4.32 (1.00)	0.26 (0.99)	4.32 (1.00)	0.26 (0.99)
ΔGDP	-3.97* (0.00)	-4.33* (0.00)	-4.35* (0.00)	-9.60* (0.00)
EC	-1.25 (0.64)	-2.21 (0.47)	-2.41 (0.14)	-2.21 (0.47)
ΔEC	-7.14 (0.00)	-7.32 (0.00)	-4.56* (0.00)	-9.27* (0.00)
EU	2.29 (0.99)	-1.09 (0.92)	4.37 (1.00)	-1.19 (0.89)
ΔEU	-7.24* (0.00)	-8.31* (0.00)	-7.23* (0.00)	-20.49* (0.00)

Notes: First bracket shows P-values. * indicate stationary at 1% level using MacKinnon (1996) critical and P -values. The number of optimal lags for the ADF test is specified by AIC, that is minimized from the maximum 4 lags length. Automatic bandwidth for PP test is selected according to Newey-West using Bartlett kernel.

In order to estimate the parameters of equations we have to find the optimal lag length of the VAR model. The optimal lag length '4' is selected by the Akaike

Information Criterion (AIC). The AIC picks an ARDL (1, 1, 3) for the variables included in the model 1, while ARDL (3, 2, 4) and ARDL (1, 3, 0) for the model 2 and 3 respectively. Table 2 shows that the computed F- statistics for model 1 is 49.09 that is higher than the upper bound critical value of 5 at 1% level of significance. The computed F- statistics for model 2 is 4.83 that is higher than the upper bound critical value of 3.87 at 5% level of significance. The null hypothesis of no long run relationship between energy use, GDP and electricity consumption is accepted for model 3 when energy use is dependent variable. Therefore, the long-run relationship among the variables exist when GDP is dependent on energy use and electricity consumption, and electricity consumption is dependent on GDP and energy use.

Table 2

Results of ARDL bounds cointegration test

Model: Dependent Variable	Forcing Variables	F-Statistics	5% Critical Bounds		1% Critical Bounds		Remarks
			I(0)	I(1)	I(0)	I(1)	
1: GDP	EC and EU	49.09*	3.1	3.87	4.13	5	Present
2: EC	GDP and EU	4.83**	3.1	3.87	4.13	5	Present
3: EU	GDP and EC	2.77	3.1	3.87	4.13	5	Absent

Note: * and ** denote rejection of the null hypothesis at the 1% and 5% levels respectively.

Table 3 illustrates the long run coefficients of model 1 and model 2. All of the long-run coefficients of the ARDL models are significant at 1% significance level suggesting that electricity consumptions have a significant long run impact on GDP and vice versa. The ARDL results for model 1 (when GDP is a dependent variable) show that consumptions of electricity and energy use are positively related with GDP. The result implies that a 100% increase in electricity consumptions and energy use contributes to 31% and 107% increase in GDP respectively. The ARDL results for model 2 also show that GDP is positively related to electricity consumptions in Bangladesh.

Table 3

Long-run coefficients for ARDL (1, 1, 3): Model 1 and ARDL (3, 2, 4): Model 2

Model	Variable	Coefficient	P-value	Long-run Cointegration Equation
1: GDP	EC	0.31*	0.00	GDP = 18.89 + 0.31 EC + 1.07 EU
	EU	1.07*	0.00	
2: EC	GDP	4.28*	0.00	EC = -77.69 + 4.28 GDP – 5.17 EU
	EU	-5.17*	0.00	

Note: denotes the coefficients are significant at the 1% level.

The short-run dynamics along with the error correction term (ECT) results are reported in Table 4. The results of the estimated ARDL-ECM models clearly indicate that the coefficients of error correction terms of the model 1 and 2 are negative and statistically significant at the 1% level of significance. It suggests that the long-run causality is also directing from electricity consumptions and energy use to GDP, and GDP and energy use to electricity consumptions. The error correction term of model 1 is -0.21, which implies that GDP requires about five years to converge to equilibrium after being shocked. In contrast, the error correction term of model 2 is -0.41 which implies that 41% of the last year's disequilibrium is corrected this year by changes in electricity consumptions. But, the results also explore that the short-run impact of the variables for both model is insignificant.

Table 4

Error correction estimates

Variable	Coefficient	Std. Error	t-statistic	P-Value
Model 1				
D(EC)	0.01	0.02	0.71	0.49
D(EU)	-0.00	0.04	-0.18	0.86
D(EU(-1))	-0.15**	0.06	-2.53	0.02
D(EU(-2))	-0.12**	0.04	-2.72	0.01
CointEq(-1)	-0.21*	0.01	-14.86	0.00
Model 2				
D(EC(-1))	0.23	0.16	1.43	0.17
D(EC(-2))	0.50*	0.15	3.25	0.00
D(GDP)	1.35	1.01	1.35	0.19
D(GDP(-1))	-2.53*	0.93	-2.73	0.01
D(EU)	-0.54	0.29	-1.86	0.07
D(EU(-1))	0.61	0.47	1.30	0.21
D(EU(-2))	2.09*	0.45	4.64	0.00
D(EU(-3))	1.57*	0.39	3.94	0.00
CointEq(-1)	-0.41*	0.09	-4.73	0.00

Note: * and** denote significance at 1% and 5% levels respectively.

In order to verify the robustness of the models, diagnostic checking of the estimated models have been carried out in terms of conventional multivariate residual-based tests for serial correlation, normality and heteroscedasticity (Table 5). At 5% level of significance, the Lagrange Multiplier (LM) test for autocorrelation indicates the absence of autocorrelation and ARCH Chi-square test for heteroskedasticity indicates the absence of heteroskedasticity. The model also passes the Jarque- Bera normality test at 5 percent suggesting that the error is normally distributed in the models.

Table 5

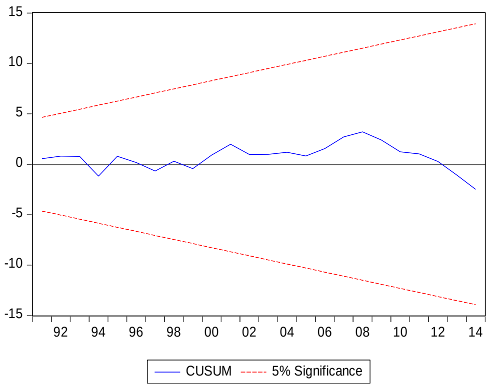
Results of diagnostic tests

Diagnostic Tests	Model 1		Model 2	
	Statistics	P-Value	Statistics	P-Value
Serial Correlation LM	$\chi^2 = 7.07$	0.13	$\chi^2 = 8.91$	0.06
ARCH Heteroskedasticity	$\chi^2 = 0.81$	0.94	$\chi^2 = 1.72$	0.78
Jarque-Bera Normality	1.49	0.47	2.66	0.26

Finally, cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of the recursive residuals (CUSUMSQ) tests are employed to test for parameter stability. Figure 1 and 2 plot the CUSUM and CUSUM of squares statistics for model 1 and 2 respectively. The plotted points for the CUSUM and CUSUMSQ statistics stay within the critical bounds of a 5% level of significance (except CUSUMSQ statistics for model 2). Thus, these statistics confirm the stability for all coefficients of the estimated equations.

Figure 1

Plots of CUSUM and CUSUMSQ stability test for Model 1



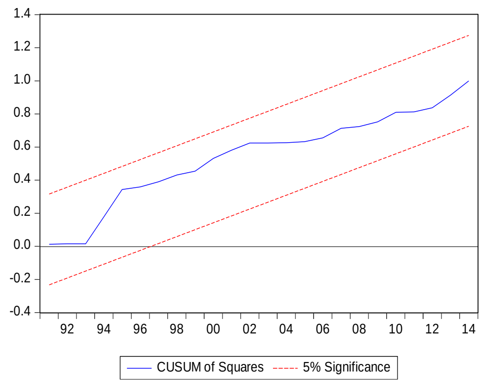
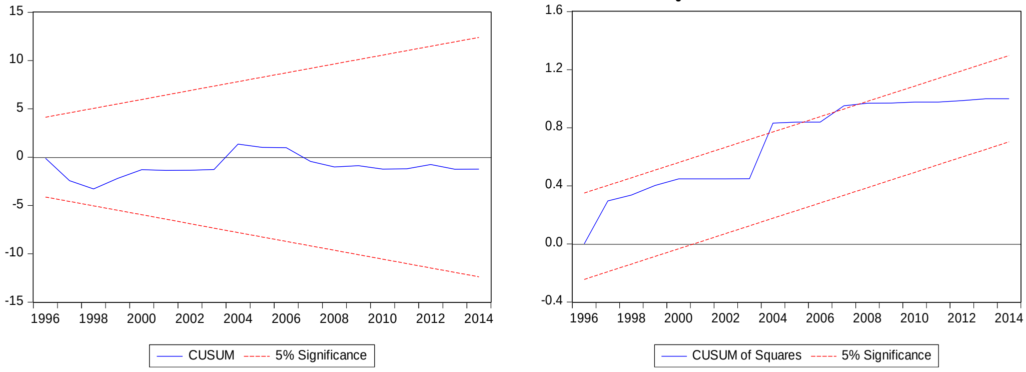


Figure 2

Plots of CUSUM and CUSUMSQ stability test for Model 2



Conclusion

Employing the bounds testing cointegration procedure and ARDL-error correction model, this paper investigates the long run and short run dynamics of electricity consumption, energy use and GDP in Bangladesh, using annual data covering the period 1980-2014. The bounds testing cointegration procedures reveal that the long-run relationship among the variables exist when GDP is dependent on energy use and electricity consumption, and electricity consumption is dependent on GDP and energy use. All of the long-run coefficients of the ARDL models are significant at 1% significance level suggesting that electricity consumptions have a significant long run impact on GDP and vice versa. The result implies that a 100% increase in electricity consumptions and energy use contributes to 31%, and 107% increase in GDP respectively. The result also explores that a 100% increase in GDP contributes to 428% increase in electricity consumptions. So, individually energy use is the most positive determinant of GDP in Bangladesh, while GDP is the most positive determinant of electricity consumptions. The results of the estimated ARDL-ECM models indicate that the coefficients of error correction terms of the models are negative and statistically significant at the 1% level of significance. It implies that the long-run causality is also directing from electricity consumptions and energy use to GDP, and GDP and energy use to electricity consumptions. The error correction term of model 1 is -0.21, that implies that GDP requires about five years to converge to equilibrium after being shocked. In contrast, the error correction term of model 2 is -0.41, that implies that 41% of the last year's disequilibrium is corrected this year by changes in electricity consumptions. At the end, we find that there is no short run significant relationship exist among the variables in Bangladesh.

We find support for the feedback hypothesis in long run and empirical studies, such as, Yoo (2005), Zhou and Chau (2006), Ahamad and Islam (2011), Zhang and Yang (2012) and Tang and Tan (2013). Future researchers can investigate the dynamics of energy use and economic growth using longer time series and other potential control variables. Finally, the empirical results of the present study might give a better enthusiastic to the policymakers of Bangladesh to execute the Power System Master Plan (PSMP) 2016.

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