Charles Darwin University

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A Case Study of China

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Energy Consumption and GDP Nexus In Bangladesh

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Energy Consumption and GDP Nexus In Bangladesh

1. Introduction

In the past two decades, Bangladesh has achieved significant economic growth. Rapid economic growth together with an increasing population has resulted in a notable increase in energy consumption in the country (Islam and Khan 2016). The relationship between economic growth and energy consumption has received significant attention in the economic growth literature (see, for example, Mozumdera and Marathe 2007). This is because while energy is an impetus for economic growth, excessive energy consumption is also detrimental to environmental sustainability (Jafari et al. 2012). Due to various country-specific socio-economic characteristics and differences in various policy frameworks countries are adhering to, there is no consensus on the relationship between energy consumption and economic growth in the literature (Mozumdera and Marathe 2007; Ozturk and Acaravci 2011). In this context a revisit on the interrelationship between energy consumption and other economic activities in Bangladesh is timely.

Natural gas is the main energy source of Bangladesh and the power generation sector is heavily dependent on that (Government of Bangladesh 2016). In recent years, there have been significant efforts by the government to reduce the dependence on fossil-fuel-based energy. As a result, arrangements have been made to build three nuclear power plants with a life span of 60 years by 2024. Additionally, by 2021, another coal power plant will be set up to meet the increasing demand for energy in the country (Islam and Khan 2017). Intending to promote renewable energy in the country, the government of Bangladesh established the Sustainable and Renewable Energy Development Authority (SREDA) in 2014. Among other initiatives, the solar home system program implemented by a state-owned institution, Infrastructure Development Company Limited (IDCOL) currently provides solar energy for about 11% of the total population of Bangladesh (IDCOL 2015).Currently, energy from renewable energy sources, such as solar, wind, and hydro energy and biomass contribute to only less than 2% of the total energy generation in the country (Islam and Khan 2016).

In addition to renewable energy, energy conservation is another area of great concern of the government of Bangladesh, as it is key to ensure sustainable development in the country. According to the energy efficiency and conservation master plan, the government of Bangladesh expects a 20% improvement in energy efficiency, which will reduce the electricity demand by 8GW compared to base value by 2030. This, in turn, will contribute to 2.3 trillion BDT worth reduction in fuel imports in the country (JICA 2015). Given that the country is focusing on energy conservation and rapid economic growth, while tackling other socio-economic challenges, it is important to revisit the relationship between energy consumption and other key economic indicators in the country, such as GDP, capital formation and labour force.

To this end, using data for the period 1990-2014, this chapter aims at testing several hypotheses on the causal relationship between energy consumption and economic growth (measured by GDP), capital formation and labour. These include, whether (a) GDP causes energy consumption, (b) capital formation increase the demand for energy consumption, (c) labour force level impacts on the energy consumption, (d) energy consumption causes economic growth, (e) energy consumption increases capital formation, and (f) energy consumption affects the level of the Bangladesh labour force.

This chapter is organized as follows. Section 2 presents a brief review of existing literature on the causality between energy consumption and GDP. The methodology adopted for the empirical analysis is given in Section 3. Section 4 presents preliminary data analysis, while Section 5 presents estimation results and discussion. Section 6 provides concluding remarks.

2. Review of Literature

There is a significant body of empirical literature on the relationship between energy consumption and economic growth based on data from various countries. These findings could be broadly divided into four groups; (a) growth hypothesis, (b) conservation hypothesis, (c) feedback hypothesis, and (d) neutrality hypothesis (Ozturk and Acaravci 2011). Ozturk and Acaravci (2011) and Soytas and Sari (2003) noted that the empirical findings of the relationship between energy and economic growth depends on the model specification, econometric techniques used and the country characteristics. Below we discuss the empirical literature with respect to the above four hypotheses.

The growth hypothesis implies the presence of unidirectional causality running from energy consumption to economic growth. For example, evidence for growth hypothesis was found in a number of studies; in India (Masih and Masih 1996; Asafu-Adjaye 2000), Indonesia (Asafu-Adjaye 2000), Turkey, France Germany and Japan (Soytas and Sari 2003), China (Wolde-Rufael 2004), Taiwan (Yang 2000), and Korea and Philippines (Yu and Choi 1985). In this case, as energy consumption plays a vital role in economic growth, any disruption to energy supply can have an adverse impact on the economy.

The conservation hypothesis suggests that there is a unidirectional causality running from economic growth to energy consumption. Many studies found support for the conservation hypothesis. For example, Abosedra and Baghestani (1989) found support in the US, Aqeel and Butt (2001)in Pakistan, Cheng and Lai (1997) in Taiwan, Cheng (1999) in India, Jumbe (2004) in Malawi, Maish and Maish (1996) in Indonesia, and Soytas and Sari (2003) in Italy and Korea. Mozumdera and Marathe (2007) found similar results in Bangladesh between 1971 and 1999. The presence of the conservation hypothesis implies that energy conservation policies could be implemented with limited or no adverse impact on the economy.

The feedback hypothesis implies that there is bidirectional causality between energy consumption and economic growth. Evidence for feedback hypothesis was found in Japan (Erol and Yu 1988), Canada (Ghali and El-Sakka 2004), Taiwan (Hwang and Gum 1991), South Korea (Glasure 2002; Oh and Lee 2004), and Argentina (Soytas and Sari 2003). Some studies have found that there is no causal relationship between energy and economic growth, supporting the neutrality hypothesis. See, for example, Fatai et al. (2002) in New Zealand, Maish and Maish (1996) in Malaysia, Singapore and Philippines, Stern (1993),Yu and Hwang (1984), and Yu and Jin (1992) in the US.

The next section presents the methodology and research hypotheses established based on the literature review.

3. Methodology

Since this chapter aims to analyse the nexus between energy consumption and GDP, we consider Vector Error Correction Models (VECM) under the Autoregressive Distributed Lag (ARDL) framework. One of the advantages in using the ARDL model approach is that we can estimate the long-run and short-run relationships simultaneously.

Following Lee (2005) and Odhiambo (2010) we include the variables; energy consumption (in kg of oil equivalent per-capita, E), per-capita GDP (PCGDP, constant LCU), per-capita gross capital formation (PCGCF, constant LCU) and total labour force – people age 15 and above, which include those who are currently employed and those who are unemployed but seeking work (L) to investigate the long-run relationship between energy consumption and GDP. We consider the following four linear functional relationships between the above four variables (all in log-form):

Energy

$$\ln E_t = \delta_0 + \delta_1 \ln PCGDP_t + \delta_2 \ln PCGCF_t + \delta_3 \ln L_t + e_t \qquad (1)$$

In Equation (1), we would expect $\delta_1$and δ_2 to be positive as more energy is required to enhance GDP and GCF through increased domestic production and δ_3 to be negative as if labour and energy are substitutes (Murry and Nan 1990), increased labour force may reduce the need for energy.

GDP

$$\ln PCGDP_t = \delta_0 + \delta_1 \ln E_t + \delta_2 \ln PCGCF_t + \delta_3 \ln L_t + e_t \qquad (2)$$

In Equation (2), we would expect $\delta_1$and δ_2 to be positive, as additional energy and GCF are expected to increase the level of GDP and, δ_3 can be expected to be either positive or negative as up to a certain point an increase in labour would increase GDP at an increasing rate and then starts to decline.

Gross Capital Formation

$$\ln PCGCF_t = \delta_0 + \delta_1 \ln E_t + \delta_2 \ln PCGDP_t + \delta_3 \ln L_t + e_t \qquad (3)$$

In equation (3), we would expect δ_1, δ_2 and δ_3, all to be positive as increase in energy consumption, GDP and labour would tend to increase the requirement for GCF.

Labour

$$\ln L_t = \delta_0 + \delta_1 \ln E_t + \delta_2 \ln PCGDP_t + \delta_3 \ln PCGCF_t + e_t \qquad (4)$$

In equation (4) we would expect $\delta_1$to be negative, as an increase in energy consumption would decrease the demand for labour, and δ_2 andδ_3 to have positive signs, as increased GDP and capital both would increase the demand for labour.

By estimating long-run equations (1) - (4) above, we test the following 6 hypotheses. Using Equation (1),

H_1: Conservation hypothesis (unidirectional causality running from GDP to energy)

H_2: Capital increases energy consumption

H_3: Labour reduces energy consumption

Using Equation (2),

H_4: Growth hypothesis (unidirectional causality running from energy to GDP)

Using Equation (3),

H_5: Energy consumption increases capital formation

Using Equation (4),

H_6: Energy consumption reduces the demand for labour

The ARDL(*p*, *q*, *r*, *s*) formulas corresponding to long-run relationships (1) - (4) can be written as

$$\Delta(\ln E_t) = \beta_0 + \beta_1 \ln PCGDP_t + \beta_2 \ln PCGCF_t + \beta_3 \ln L_t + \sum_{j=1}^{p} \gamma_{1j}\, \Delta(\ln E_{t-j}) + \sum_{j=0}^{q} \gamma_{2j}\, \Delta(\ln PCGDP_{t-j}) + \sum_{j=0}^{r} \gamma_{3j}\, \Delta\left(\ln PCGCF_{t-j}\right) + \sum_{j=0}^{s} \gamma_{4j}\, \Delta(\ln L_{t-j}) + u_t \quad (5)$$

$$\Delta(\ln PCGDP_t) = \beta_0 + \beta_1 \ln E_t + \beta_2 \ln PCGCF_t + \beta_3 \ln L_t + \sum_{j=1}^{p} \gamma_{1j}\, \Delta(\ln PCGDP_{t-j}) + \sum_{j=0}^{q} \gamma_{2j}\, \Delta(\ln E_{t-j}) + \sum_{j=0}^{r} \gamma_{3j}\, \Delta\left(\ln PCGCF_{t-j}\right) + \sum_{j=0}^{s} \gamma_{4j}\, \Delta(\ln L_{t-j}) + u_t \quad (6)$$

$$\Delta(\ln PCGCF_t) = \beta_0 + \beta_1 \ln E_t + \beta_2 \ln PCGDP_t + \beta_3 \ln L_t + \sum_{j=1}^{p} \gamma_{1j}\, \Delta(\ln PCGCF_{t-j}) + \sum_{j=0}^{q} \gamma_{2j}\, \Delta(\ln E_{t-j}) + \sum_{j=0}^{r} \gamma_{3j}\, \Delta\left(\ln PCGCF_{t-j}\right) + \sum_{j=0}^{s} \gamma_{4j}\, \Delta(\ln L_{t-j}) + u_t \quad (7)$$

$$\Delta(\ln L_t) = \beta_0 + \beta_1 \ln E_t + \beta_2 \ln PCGDP_t + \beta_3 \ln PCGCF_t + \sum_{j=1}^{p} \gamma_{1j}\, \Delta(\ln L_{t-j}) + \sum_{j=0}^{q} \gamma_{2j}\, \Delta(\ln E_{t-j}) + \sum_{j=0}^{r} \gamma_{3j}\, \Delta\left(\ln PCGDP_{t-j}\right) + \sum_{j=0}^{s} \gamma_{4j}\, \Delta(\ln PCGCF_{t-j}) + u_t \quad (8)$$

We determine the number of lags *p*, *q*, *r*, *s*, in each equation based on the AIC and SIC criteria.

The ARDL bounds test can be used to test the long-run (or the co-integrating) relationship between energy consumption, GDP, capital and labour based on a non-standard F-test by testing the null and the alternative hypotheses;

H_0: $\beta_1 = \beta_2 = \beta_3 = 0$ (no co-integration)

H_A: At least one of β_1 or $\beta_2$or $\beta_3 \neq 0$ (existence of co-integration).

We use the critical values provided in Pesaran et al. (2001). There are two sets of critical values; one based on the assumptions that all variables are I(0) and the other based on the assumptions that all variables are I(1). If the calculated F-statistic is above the I(1) critical value, the null hypothesis should be rejected and concluded that there is support for co-integration. If the calculated F-statistic is below the I(0) critical value, the null hypothesis should not be rejected and concluded that there is no support for co-integration. If the calculated F-statistic is between the I(0) critical value and the I(1) critical value, the test result is inconclusive.

There are two points worth noting in relation to the bounds test; (a) even though the bounds test approach does not generally require the order of the integration of all the variables to be I(0) or I(1), it does require that none of the variables in the model equation are of order I(2) or higher. To ensure that none of the variables are I(2) or higher, we perform the unit root tests; (b) if some or all of the variables in a regression model are non-stationary in their level form, then a least squares regression model with these variables may produce spurious results. As the bounds test results also reveal whether the variables; energy consumption, economic growth, capital, and labour are co-integrated, we can use the bounds test results to confirm whether the model estimation results are spurious. It is because, even if the variables in the regression model are integrated of order 1, that is I(1), if they are co-integrated, then the least squares estimation results would still be valid.

If co-integration exists between energy consumption, GDP, capital, and labour, then we can use an error correction (EC) model to estimate the speed of adjustment of the disequilibrium caused by previous period shocks that re-converges to the long-run equilibrium. The EC models which correspond to equations (5) - (8) can be written as

$$\Delta(\ln E_t) = \gamma_0 + + \sum_{j=1}^{p} \gamma_{1j} \Delta(\ln E_{t-j}) + \sum_{j=0}^{q} \gamma_{2j} \Delta(\ln PCGDP_{t-j}) + \sum_{j=0}^{r} \gamma_{3j} \Delta(\ln PCGCF_{t-j}) + \sum_{j=0}^{s} \gamma_{4j} \Delta(\ln L_{t-j}) + \mu EC_{t-1} + u_t \quad (9)$$

$$\Delta(\ln PCGDP_t) = \gamma_0 + \sum_{j=1}^{p} \gamma_{1j} \Delta(\ln PCGDP_{t-j}) + \sum_{j=0}^{q} \gamma_{2j} \Delta(\ln E_{t-j}) + \sum_{j=0}^{r} \gamma_{3j} \Delta(\ln PCGCF_{t-j}) + \sum_{j=0}^{s} \gamma_{4j} \Delta(\ln L_{t-j}) + \mu EC_{t-1} + u_t \quad (10)$$

$$\Delta(\ln PCGCF_t) = \gamma_0 + \sum_{j=1}^{p} \gamma_{1j} \Delta(\ln PCGCF_{t-j}) + \sum_{j=0}^{q} \gamma_{2j} \Delta(\ln E_{t-j}) + \sum_{j=0}^{r} \gamma_{3j} \Delta(\ln PCGDP_{t-j}) + \sum_{j=0}^{s} \gamma_{4j} \Delta(\ln L_{t-j}) + \mu EC_{t-1} + u_t \quad (11)$$

$$\Delta(\ln L_t) = \gamma_0 + \sum_{j=1}^{p} \gamma_{1j} \Delta(\ln L_{t-j}) + \sum_{j=0}^{q} \gamma_{2j} \Delta(\ln E_{t-j}) + \sum_{j=0}^{r} \gamma_{3j} \Delta(\ln PCGDP_{t-j}) + \sum_{j=0}^{s} \gamma_{4j} \Delta(\ln PCGCF_{t-j}) + \mu EC_{t-1} + u_t \quad (12)$$

where EC_{t-1} is the error correction term derived from the long-run relationship (1) - (4) and for equations (9) - (12), respectively. The coefficients γ_{ij}'s measure the short-run dynamics associated with the long-run relationships and coefficient μ is the speed of adjustment that measures the long-run effect. Using the EC models (9) - (12), we can test two forms of Granger causality, namely (a) short-run causality by performing Wald test on the short-run γ_{ij} coefficients to identify whether individual independent variables have any causal relationship with the dependent variable; and (b) a long-run causality using a t-test on the EC coefficient, μ to identify whether independent variables collectively have any causal relationship with the dependent variable. Following Page (1954), we also test the stability of the EC model using cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ).

Figure 1

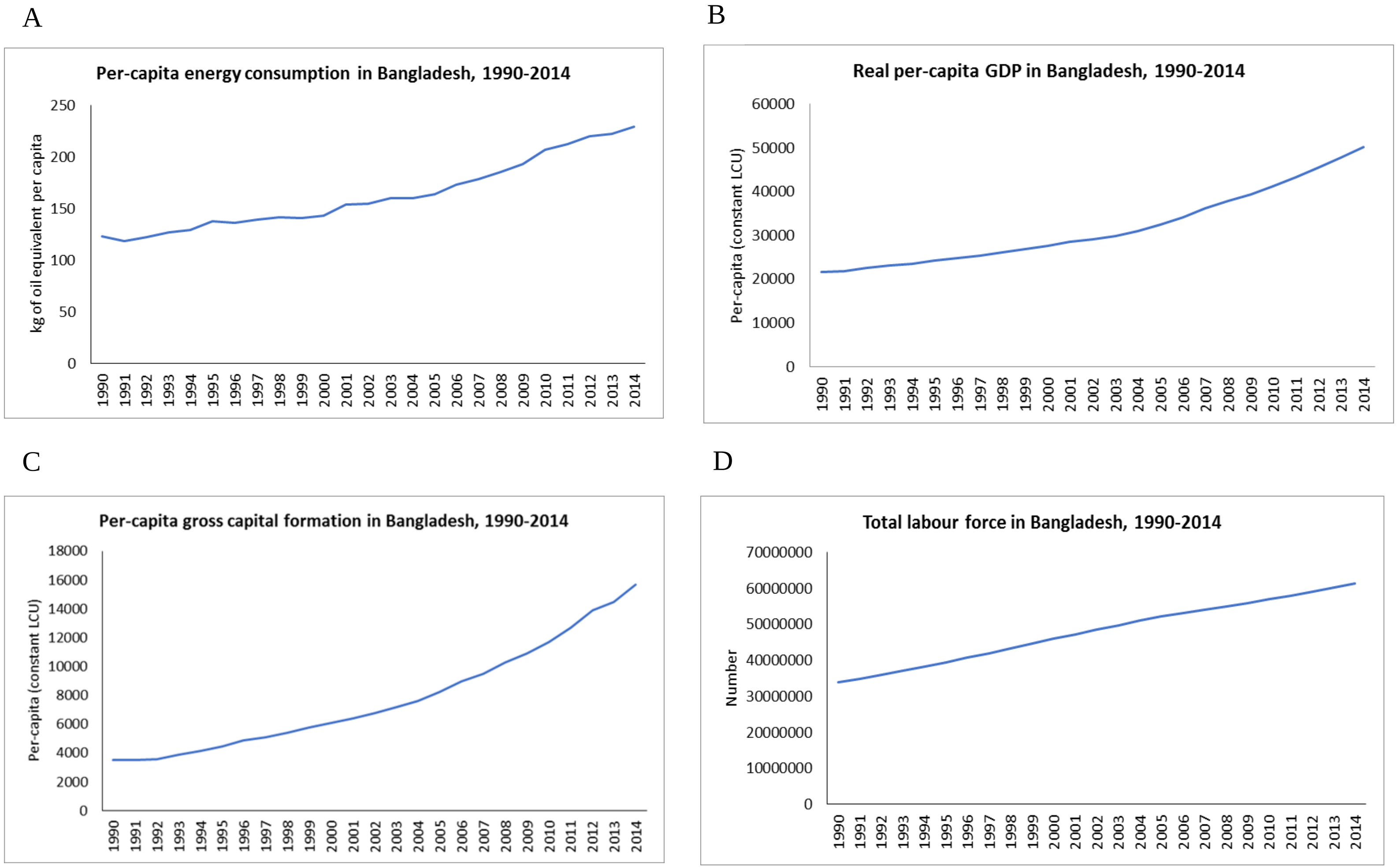

A
Per-capita energy consumption in Bangladesh, 1990-2014
kg of oil equivalent per capita
0
50
100
150
200
250
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
B
Real per-capita GDP in Bangladesh, 1990-2014
Per-capita (constant LCU)
0
10000
20000
30000
40000
50000
60000
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
C
Per-capita gross capital formation in Bangladesh, 1990-2014
Per-capita (constant LCU)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
D
Total labour force in Bangladesh, 1990-2014
Number
0
10000000
20000000
30000000
40000000
50000000
60000000
70000000
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

Table 1: Summary Statistics

(1)	Energy (kg of oil equivalent per capita) (2)	PCGDP (constant LCU) (3)	PCGCF (constant LCU) (4)	Labour (number) (5)
1990	123	21653	3497	33853862
1995	138	24205	4443	39492646
2000	143	27645	6063	45978639
2005	164	32522	8254	52170458
2010	207	41138	11722	56913121
2014	229	50099	15697	61288304
Minimum	119	21653	3497	33853862
Mean	163	31771	7781	47928542
Maximum	229	50099	15697	61288304
Standard Deviation	34	8654	3710	8575662

Table 2: Stationarity test results for Bangladesh

		ADF test			PP test			KPSS		Conclusion
		Test stat	Critical Value (5%)	p-value	Test stat	Critical Value (5%)	p-value	Test stat	Critical Value (5%)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Energy	Level	-1.993	-3.603	0.577	-1.993	-3.603	0.577	0.179	0.146	Non-stationary
	First Diff	-5.711	-2.986	0.000*	-5.711	-2.986	0.000*	0.317	0.463*	Stationary, I(1)
PCGDP	Level	0.134	-3.603	0.999	0.041	-3.603	0.999	0.195	0.146	Non-stationary
	First Diff	-2.708	-2.986	0.087**	-2.667	-2.986	0.094**	0.618	0.739**	Stationary, I(1)[a]
PCGCF	Level	-3.353	-3.603	0.081	-3.353	-3.603	0.081	0.185	0.146	Non-stationary
	First Diff	-3.476	-2.986	0.018*	-3.380	-2.986	0.022*	0.399	0.463*	Stationary, I(1)
Labour	Level	-2.484	-2.998	0.132	-6.147	-2.992	0.000*	0.195	0.146	Non-stationary
	First Diff	-1.722	-1.956	0.080**	-1.512	-1.956	0.120	0.622	0.739**	Stationary, I(1)[a]

Note: ADF and PP tests: H_0: series is non-stationary, KPSS: H_0: series is stationary. * Significant at 5% level, ** Significant at 10% level.
[a] Stationary at 10% level.

4. Preliminary Data Analysis

The data for the four variables energy consumption (E), per-capita GDP (PCGDP), per capita gross fixed capital formation (PCGCF), and total labour force (L) for Bangladesh for the period of 1990-2014 were collected from the World Bank open data (World Bank 2019). Figure 1 presents the time-series plots of the data. Table 1 presents the values of the four variables for a number of selected years and the summary statistics. As can be seen, all four variables have gradually increased over time. Per-capita energy consumption, per-capita GDP, and the total labour force in Bangladesh have almost doubled over the last 25 years, while the per-capita gross capital formation has quadrupled. In the rest of the analysis of this chapter, we use all variables in natural logarithm form.

5. Estimation Results

As discussed in Section 3, to apply the ARDL bounds test on Models (9) - (12), we need to ensure that none of the variables in our models is integrated of order 2 (I(2)) or higher. In order to investigate that we performed the unit root tests. We present the unit root test results based on three commonly used unit root tests, namely, Augmented Dickey and Fuller (1979) (ADF) test, Phillips and Perron (1988) (PP) test and KPSS (Kwiatkowski et al. 1992) test. The first two tests, ADF and PP tests, test the null hypothesis H_0: series has a unit root (or equivalently the series is non-stationary), whereas the null hypothesis for the KPSS test is H_0: series has no unit roots (that is the series is stationary).

Table 2 presents the unit root test results based on the above three tests. As can be seen, all the variables are either stationary in the level form (I(0)) or the first differenced form (I(1)), and therefore, the ARDL bounds test approach can be applied for further analysis.

Table 3 presents the bounds test results for co-integration. As can be seen, all the calculated values of the F-test statistic are higher than the bounds test upper limit - I(1) critical value - at the 5% level of significance. This means that all the variables under consideration are co-integrated.

Table 3: ARDL bounds test results

ARDL Model	Null hypothesis	F-Test statistic	Critical values at 5% level of significance	
			I(0)	I(1)
(1)	(2)	(3)	(4)	(5)
ARDL (1, 2, 2, 1)	F (Energy/PCGDP, PCGCF, Labour)	6.39	2.45	3.63
ARDL (1, 0, 1, 2)	F (PCGDP/Energy, PCGCF, Labour)	19.73	3.27	4.31
ARDL (1, 3, 2, 0)	F (PCGCF/Energy, PCGDP, Labour)	4.26	3.38	4.23
ARDL (2, 0, 2, 0)	F (Labour/Energy, PCGDP, PCGCF)	5.00	3.27	4.31

Table 4: Presents the long-run estimation results (for models (1) - (4) and (9) - (12)) and diagnostic test results for serial correlation, heteroscedasticity, and normality. As can be seen, the results indicate that serial correlation is not an issue in any of the estimated models at 5% level of significance. Based on Breusch-Pagan-Godfrey (B-P-G) test, we do not reject the null hypothesis of no heteroscedasticity at the 5% level of significance, indicating that there is no issue of heteroscedasticity. Jarque-Bera (J-B) test results indicate that, generally, the normality assumption is satisfied at the 5% except PCGCF, which is significant at 1% level of significance. In addition, the Ramsay rest test results indicate that the null hypothesis that model specification is correct is not rejected at 5% and 1% (for PCGCF) level of significance.

The long-run estimation results presented in Table 4 Column (2) for the energy equation (1) reveals that PCGDP and PCGCF have a positive and significant impact on energy consumption. For example, a 1% increase in per-capita GDP and per-capita gross capital formation increases energy consumption by 0.697%, and 0.103%, respectively. Therefore, we find support for the hypotheses H_1: conservation hypothesis (unidirectional causality running from GDP to energy) and H_2: capital increases energy consumption in Bangladesh in the long-run. Column 2 results also indicate that labour force has a negative and significant impact on energy consumption, supporting H_3: labour reduces energy consumption. The estimate of labour coefficient reveals that a 1% increase in total labour reduces energy consumption by 0.164%. Such a negative relationship between energy and labour is expected when labour and energy consumption are substitutes. Column (3) results for the PCGDP equation (2) reveal that none of the variables has a statistically significant impact on PCGDP. Since the energy coefficient is statistically insignificant, we have no support for the H_4: growth hypothesis (unidirectional causality running from energy to GDP) in the long-run.

Column (4) Table 4 results for PCGCF equation (3) indicate that all variables; energy consumption, per-capita GDP, and labour force positively contribute to the per-capita gross capital formation and this result is statistically significant. The estimates indicate that a 1% increase in energy consumption increases capital formation by 0.878%, a 1% increase in per-capita GDP increases capital formation by 1.398%, and a 1% increase in labour force increases capital formation by 2.851%. To this end, we find evidence to support H_5: energy consumption increases capital formation in Bangladesh. Column (5) results on labour equation (4) reveals that per-capita gross capital formation positively and significantly influences the labour force. The point estimate reveals that a 1% increase in the capital formation increases the total labour force by 0.633%. Column 5 results also indicate that energy consumption has a negative impact on the labour force, but it is not statistically significant. Although based on earlier results, we found that labour could act as a substitute to energy, it is also evident that energy does not necessarily have a significant adverse impact on labour force and hence the employment level in Bangladesh. This indicates that we do not find evidence to support H_6: energy consumption reduces demand for labour in Bangladesh. In summary, the long-run results indicate that there is a bidirectional causality between (energy, GCF) and (GCF, Labour) and a unidirectional causality from GDP to energy, labour to energy, and GDP to GCF.

All the EC coefficient estimates reported in Table 4 are in the range -1 to 0 as they should be and are all statistically significant. These EC estimates reveal that, in Bangladesh, short-run deviations in the long-run relationships models for energy, PCGDP, PCGCF, and labour are corrected within a year at a rate of 93.9%, 16.1%, 81.2% and 5.2%, respectively. All EC terms are statistically significant, and this indicates that there is a collective long-run causality from all the variables on the right-hand side towards the respective left-hand side variable in each model (1) – (4). As can be seen in Figures 5, 6, 7, and 8, in the majority of instances, the stability of the EC models can be confirmed using CUSUM and CUSUMQ.

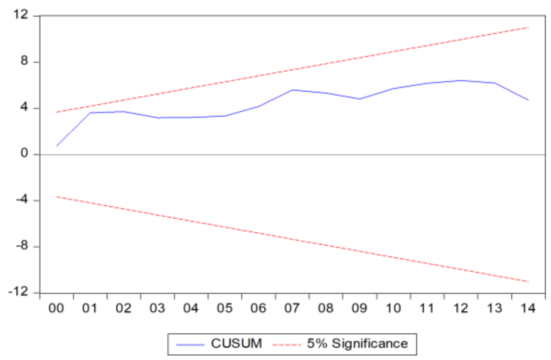
Table 5 presents the short-run Granger causality results. As can be seen, in the short run, there is bidirectional causality among (energy and GCF), (GDP and GCF) and (labour and GDP). The short-run causality test results also indicate that there is a unidirectional causality from GDP to energy. Similar results were observed earlier in the long-run relationship as well. This result provides evidence for the presence of conservation hypothesis (H_1: *unidirectional causality running from GDP to energy)* in Bangladesh. Our results with respect to H_1 is in line with Mozumder and Marathe (2007) on Bangladesh. On the other hand, we do not find any causal relationship running from energy to GDP in Bangladesh either in the short-run or long-run (see Table 4), and therefore, we find no evidence for the presence of growth hypothesis (*H_4: growth hypothesis, unidirectional causality running from energy to GDP)*. In addition, short-run causality test results also indicate a unidirectional causality running from labour to energy, which we also found in the long-run as well (see Table 4) in Bangladesh.

Table 4: Long-run estimation results

Independent Variables (1)	Dependent variable: Energy (2)	PCGDP (3)	PCGCF (4)	Labour (5)
Constant		22.877** (0.087)		16.803* (0.000)
Trend			-0.080 (0.119)	
Energy		-0.290 (0.771)	0.878* (0.011)	-0.343 (0.207)
PCGDP	0.697* (0.000)		1.398* (0.013)	-0.262 (0.393)
PCGCF	0.103** (0.073)	1.127 (0.142)		0.633* (0.000)
Labour	-0.164* (0.001)	-1.169 (0.163)	2.851* (0.023)	
EC	-0.939* (0.000)	-0.161* (0.000)	-0.812* (0.000)	-0.052* (0.000)
Serial Correlation (B-G LM)	1.941 (0.183)	0.376 (0.693)	0.878 (0.448)	2.779 (0.100)
Heteroscedasticity (B-P-G)	0.837 (0.596)	1.342 (0.294)	0.759 (0.664)	0.776 (0.617)
Normality (J-B)	0.926 (0.629)	0.768 (0.681)	7.583[a] (0.023)	3.243 (0.198)
Ramsey Reset Test	0.699 (0.417)	0.554 (0.468)	8.518[a] (0.015)	3.302 (0.091)

Note: *p*-values are given in parenthesis. * Significant at the 5% level; ** significant at the 10% level. Breusch-Godfrey serial correlation LM (B-G LM) test H_0: No Serial correlation; Breusch-Pagan-Godfrey (B-P-G) Test H_0: No heteroscedasticity; Jarque-Bera (J-B) test H_0: Data is normally distributed; Ramsey Reset test H_0: The model is correctly specified. [a] Null hypothesis not rejected at the 1% level of significance.

Figure 5: CUSUM and CUSUM of Squares for Energy



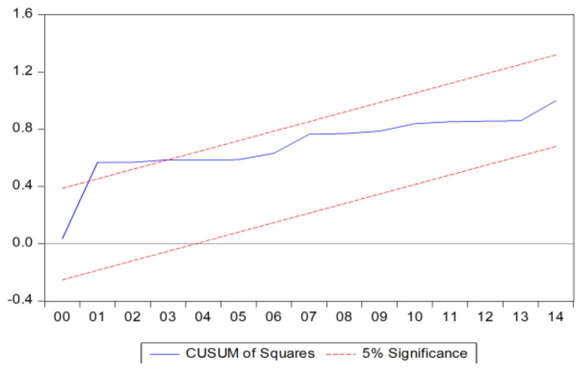


Figure 6: CUSUM and CUSUM of Squares for per-capita GDP

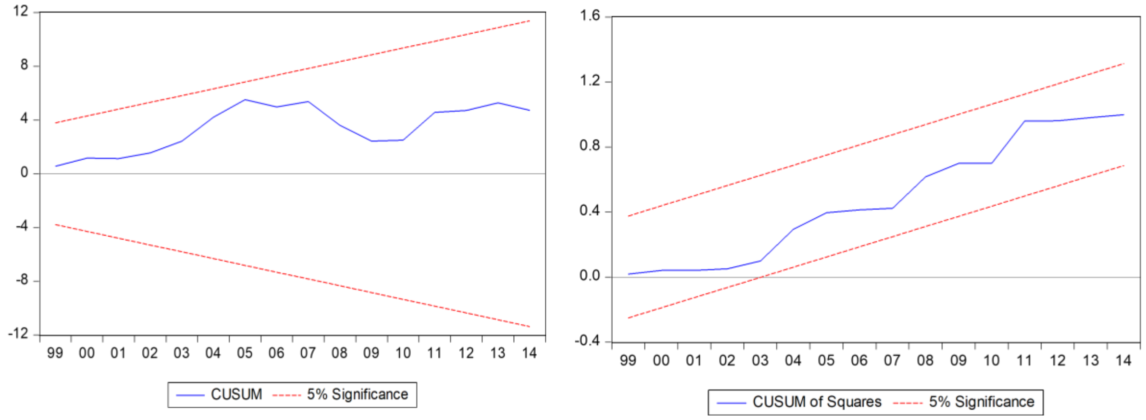


Figure 7: CUSUM and CUSUM of Squares for per-capita GCF

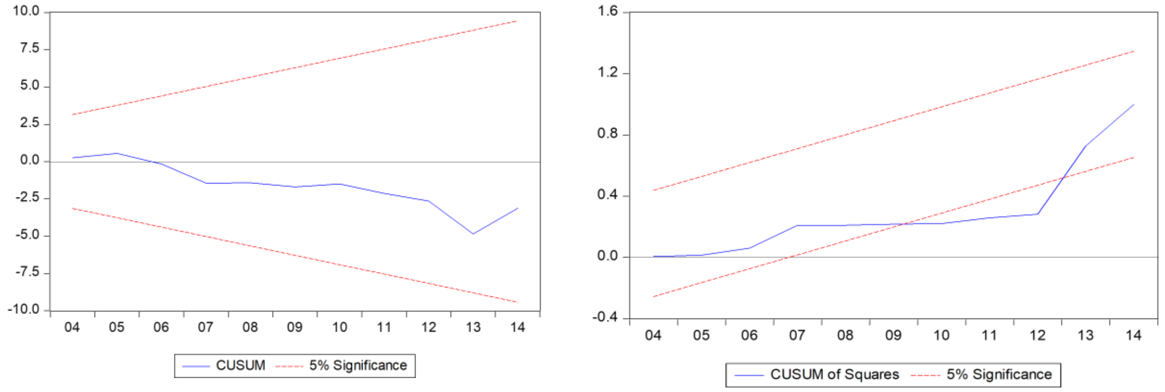


Figure 8: CUSUM and CUSUM of Squares for labour

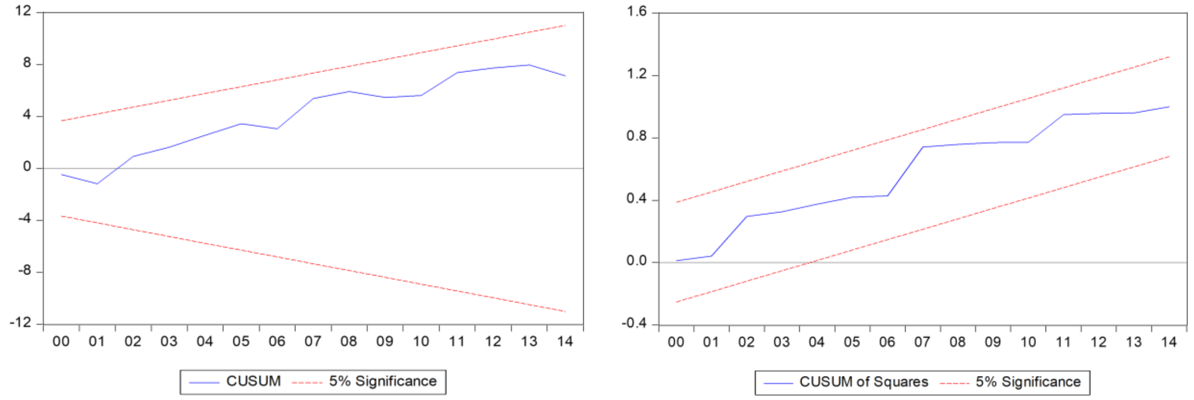


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Table 5: Results for the Granger causality test

Dependent Variable	Short-run results χ^2 Statistics				Short run Granger causality test conclusion
(1)	D(Energy) (2)	D(PCGDP) (3)	D(PCGCF) (4)	D(Labour) (5)	EC (6)
D(Energy)		23.082* (0.000)	19.144* (0.000)	10.056* (0.007)	PCGDP→ E GCF → E L → E
D(PCGDP)	0.953 (0.621)		10.314* (0.006)	17.245* (0.000)	GCF → PCGDP L→ GDP
D(PCGCF)	7.897* (0.019)	12.404* (0.002)		6.619* (0.037)	E → GCF PCGDP → GCF L → GCF
D(Labour)	0.234 (0.889)	6.353* (0.042)	3.190 (0.203)		PCGDP→L

Note: p-values are given in parenthesis. * Significant at the 5% level.

6. Conclusions and Policy Implications

There is a growing interest in promoting renewable energy consumption and adopting energy conservation policies in Bangladesh. However, as it is widely accepted that energy consumption plays a significant role in economic growth, an in-depth analysis of energy and GDP nexus in Bangladesh, using the most recent data, is timely.

This chapter, using data for the period 1990-2014, tested six hypotheses on the short-run and long-run causal relationship between energy consumption and economic growth (measured by GDP), capital formation and labour; (1) the conservation hypothesis (unidirectional causality running from GDP to energy), (2) capital increases energy consumption, (3) labour reduces energy consumption, (4) growth hypothesis (unidirectional causality running from energy to GDP), (5) energy consumption increases capital formation, and (6) energy consumption reduces the demand for labour.

Our results revealed a unidirectional causality running from GDP to energy in the short-run as well as long-run, supporting the conservation hypothesis in Bangladesh. Results also revealed that capital increases energy consumption, labour reduces energy consumption, and energy consumption increases capital formation in the long-run. Nevertheless, no unidirectional causal relationship was found running from energy to GDP in the short-run or long-run, suggesting that the growth hypothesis is not valid in Bangladesh. Furthermore, we found no evidence that energy consumption reduces the demand for labour. Overall, our findings imply that Bangladesh can adapt energy conservation policies either in the short-run or long-run with limited or no adverse impact on GDP and labour force.[1]

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[1] In this study, due to data unavailability, we have used data only for the period 1990-2014 (25 observations). When using the results from this study, this data size limitation should be kept in mind. However, the diagnostic tests we have performed on the estimation results gives assurance that the results are of reasonably good quality.

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