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7

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Fahmida Khatun
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CMI CHR. MICHELSEN INSTITUTE

CENTRE FOR POLICY DIALOGUE (CPD)
B A N G L A D E S H
a civil society think tank

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Abstract

This study presents a discussion on the current energy and power situation of Bangladesh, and examines the causal relationship between foreign direct investment (FDI) in the energy and power sector and economic growth of the country. Causality analysis by using data for the period 1972-2010 reveals that there are robust positive and unidirectional short-run causal relationships running from FDI to energy use and from energy use to GDP growth. Results also confirm a causal relationship for the energy use equation in the long-run. Considering the resource and technology requirements for the development of the energy and power sector, FDI should be encouraged in this sector that could help achieve the targeted GDP growth in Bangladesh.

Contents

List of Tables and Figure

Tables

Figures

Acronyms

ADF	Augmented Dickey-Fuller
ADP	Annual Development Programme
AIC	Akaike Info Criterion
ARDL	Autoregressive Distributed Lag
BAPEX	Bangladesh Petroleum Exploration and Production Company Limited
BERC	Bangladesh Energy Regulatory Commission
BPDB	Bangladesh Power Development Board
bcf	Billion Cubic Feet
CBM	Coal Bed Methane
ECM	Error Correction Model
EDI	Energy Development Index
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GNP	Gross National Product
GoB	Government of Bangladesh
HDI	Human Development Index
IEA	International Energy Association
IPP	Independent Power Producer
km	Kilometre
MMT	Million Metric Ton
MW	Mega Watt
MoU	Memorandum of Understanding
mmcfd	Million Cubic Feet Per Day
PP	Philips-Perron
PPP	Public-Private Partnership
PSMP	Power Sector Master Plan
QRPP	Quick Rental Power Plant
REB	Rural Electrification Board
SAARC	South Asian Association for Regional Cooperation
SFYP	Sixth Five Year Plan
tcf	Trillion Cubic Feet
UCG	Underground Coal Gasification
USD	United States Dollar
VECM	Vector Error Correction Model
WDI	World Development Indicators

1. INTRODUCTION

The integration of developing and least developed countries with the global economy increased sharply in the 1990s with change in their economic policies and lowering of barriers to trade and investment. Foreign direct investment (FDI) is expected to benefit poor countries such as Bangladesh in a number of ways. Firstly, it supplements domestic investment which is low due to lack of resources in these countries. Secondly, FDI is expected to generate employment, transfer, increase domestic competition and bring other positive externalities such as transfer of good practices. Bangladesh offers attractive investment opportunities to foreign investors and has adopted policies to attract FDI into the country. In fact Bangladesh seems to offer one of the most liberal FDI regimes in South Asia.

Energy and power sector is one of those sectors in Bangladesh for which FDI has been encouraged through various policy supports as large investment is required to meet the energy demands of the country. CPD (2010) estimated that the average electricity generation has to increase by 12.5 to 14.5 per cent per year to achieve a growth of 8 per cent as targeted for FY2014-15 in the Sixth Five Year Plan (SFYP) (GoB 2011). The Government of Bangladesh (GoB) has to allocate its limited resources among several competing priorities including the social sectors. Thus the major source of investment for the energy and power sector is the private sector, both domestic and foreign. The extraction of natural gas and local coal and the installation of power plants in the country require large-scale investments. Given the capital intensive nature of the energy and power sector and the technological requirements for the sector, the inflow of FDI has been encouraged by the government through various supportive policies. However, FDI inflow to Bangladesh has not been satisfactory. Lack of good governance, corruption, political instability and turbulence, bureaucratic inertia, and poor law and order situation have been identified as major reasons for less attractive investment climate in the country.

How far the government policies have been useful to bring in adequate FDI in the energy and power sector, and to what extent such investments have contributed to the economic growth of the country are issues to be investigated in order to take an objective view on FDI in the sector. In the context of Bangladesh, very few empirical studies are available which delve into the relationship between FDI in the energy and power sector and economic growth. Most studies looked into the relationship between the overall FDI and economic growth of the country. This paper analyses the trend of FDI flow towards the energy and power sector in Bangladesh, and examines the responsiveness of economic growth to FDI in this sector by estimating an econometric analysis based on long-term data gathered from various official sources. It also discusses issues on governance in the energy and power sector which may influence the flow of FDI in this sector, and suggests policy recommendations for the development of the sector through higher investment.

The paper is organised in the following manner. Following the introduction, Section 2 presents a review of literature on the relationship between energy FDI and economic growth in South Asia. The outlook of the energy and power sector is presented in Section 3. The section describes the capacity and reserves of the energy and power sector in Bangladesh. Various plans and policies on the sector and resource flow towards the development of the sector and resources allocated for the sector through both government channel and FDI are also

discussed in this section. The contribution of FDI in the energy and power sector towards economic growth in Bangladesh is examined in Section 4. Data and methodology for causality analysis and empirical results of econometric analyses are presented in this section. Finally, the paper concludes in Section 5 by presenting a few policy recommendations for the development of the sector based on the findings of the study.

2. FDI, ENERGY AND ECONOMIC GROWTH: EMPIRICAL EVIDENCE IN SOUTH ASIA

2.1 FDI and Economic Growth

In economic literature, discussions on FDI are centred around two major theories; these are modernisation and dependency theories. In the modernisation theory FDI is considered to promote economic growth on the assumption that growth requires capital investment (Adams 2009). In recent times, the importance of FDI has been tagged with a number of other necessary conditions. Hence the new growth theories emphasised the role of technology transfer through FDI since poor countries suffer from lack of necessary infrastructure, developed and open financial markets, socio-economic and political stability (Calvo and Sanchez-Robles 2002; Adams 2009). It has also been argued that FDI could bring along organisational and managerial skills, marketing know-how and market access opportunities (Balasubramanyam *et al*. 1996; Kumar and Pradhan 2002; Adams 2009). FDI can also contribute to capital accumulation and increase total factor productivity (Nath 2005).

On the other hand, dependency theories suggest that FDI is not always a blessing. According to these theories, dependency on foreign investment could produce negative impact on growth and income distribution since FDI creates monopolies in the industrial sector that leads to underutilisation of domestic resources (Bornschier and Chase-Dunn 1985; Adams 2009). The economy may also be controlled by foreigners instead of being developed on its own (Amin 1974). Thus, the multiplier effect of FDI can be weak and may lead to stagnant growth in recipient countries (Adams 2009).

As is the case with the theoretical view, empirical results on the role of FDI in promoting economic growth of poor countries have been mixed as well. Findings of those studies on the relationship between FDI and economic growth vary across countries depending on their domestic trade policies and the level of infrastructure, including the level of education of the labour force. A few studies also conclude that FDI can exert a positive and significant impact only when there is technology transfer, while the others found that FDI do not have any positive impact on economic growth. The heterogeneity of the effect of FDI on growth has been mentioned by many, which in turn call for host country-specific studies in this area. Some of the studies that look into the relationship between FDI and economic growth along the lines discussed above include Zhang (2001), Balasubramanyam *et al*. (1996), Campos and Kinoshita (2002), Carkovic and Levine (2005), Akinlo (2004), Ayanwale (2007), Hermes and Lensink (2003), Fry (1993), Agosin and Mayer (2000), Sylwester (2005), Elias (1990), De Mello (1997), Nair-Reichert and Weinhold (2001), and Choe (2003).

Studies on the relationship between FDI in the energy sector and economic growth are almost non-existent. Most studies focus on the impact of FDI on economic development of

countries. Several studies seek to examine the FDI-growth nexus in South Asian countries to test the causality and investigate short-run and long-run relationships. In most cases, the association is found to be positive, but the direction, apparently, is found to be ambiguous. Srinivasan *et al*. (2011) for example, showed the existence of long-run relationship between FDI and gross domestic product (GDP) for Bangladesh, India, Pakistan, Sri Lanka and Nepal. While the causality depicts two way directions for all except India; in case of India, it is rather a one way relationship running from GDP to FDI.

Agrawal (2004) explored the economic impact of FDI in South Asia by undertaking time-series, cross-section analysis of panel data from five South Asian countries, namely India, Pakistan, Bangladesh, Sri Lanka and Nepal. His findings on the relationship between these two variables vary during various time periods. For example, the impact of FDI inflows on GDP growth rate is negative prior to the 1980, slightly positive for the 1980s, and strongly positive over the late 1980s and 1990s. Kundan and Qingliang (2010) indicate that FDI had a positive impact on economic growth in Nepal. Using the Granger Causality test, Unit Root test and Co-integration test with data for the period 1980-2006, their results show that there exists a long-term relationship between the variable and direction of causality runs from FDI to GDP growth rate.

In case of Pakistan, it is found that FDI has an impact on output in the long-run (Khan and Khan 2011). Using the framework of Granger causality and Panel Co-integration for Pakistan over the period 1981-2008, the authors have established an empirical relationship between industry-specific FDI and output. The study found bidirectional relationship in the short-run, but unidirectional relationship in the long-run from GDP to FDI. However, the impact of FDI on economic growth varies across sectors – FDI causes growth in the primary and services sectors, while growth causes FDI in the manufacturing sector.

Shimul *et al.* (2009) examined the long-run relationship between FDI and economic growth in Bangladesh using time series data of 1973-2007. Two time series econometric approaches such as bound testing Autoregressive Distributed Lag (ARDL) Model and Engle Granger two step procedures were applied in the study. Their findings concluded that FDI and GDP were not co-integrated. Moreover, using Granger Causality test they showed that the FDI and openness were not significantly causing the GDP per capita both in the short and long-run.

2.2 Energy and Economic Growth

The mainstream neoclassical theory of economic growth does not pay much attention to energy resources (Stern 2004). The theory of production and growth considered energy as an intermediate input. The basic model for economic growth suggested by Solow (1956) does not include resources at all. Ecological economists emphasised the need for energy as a fundamental factor for economic production. Cleveland *et al*. (1984) argue that energy availability drives economic growth as opposed to economic growth resulting in increased energy use (Ockwell 2008). Stern (1997) considers energy as an essential factor of production since all production involves transformation or movement of matter for which energy is required. In the 80s and 90s several views existed on the potential linkages between energy and economic growth which had been tested empirically. For example analysts such as Kraft and Kraft (1978), Akarca and Long (1980), Yu and Hwang

(1984), Jorgenson (1984), Yu and Choi (1985), Hall *et al*. (1986), Erol and Yu (1988), Yu *et al*. (1988), Ammah-Tagoe (1990), Abosedra and Baghestani (1989), Hwang *et al*. (1991), Yu and Jin (1992), Stern (1993), Kaufmann (1994), and Cheng and Lai (1997) undertook empirical investigations to see whether there is any causal relationship between energy and economic growth.

In case of FDI in the energy sector and economic growth, studies have tried to establish their relationships through examining the linkage between energy consumption and economic growth. Lau *et al.* (2011) empirically examined the direction of causality and sign (in the panel sense) between energy consumption and real GDP for 17 Asian countries. These countries include Bangladesh, Bhutan, Brunei, China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Maldives, Nepal, Pakistan, Philippines, Singapore, Sri Lanka and Thailand. The Panel Co-integration results reveal a long-run equilibrium relationship between energy consumption and GDP. This indicates that an increase in GDP would lead to a greater use of energy. They establish that in the long-run, energy consumption is a result of economic activity. The Granger causality test also shows that in the short-run there is a unidirectional causal relationship running from energy consumption to GDP in case of these countries. This means that in the short-run, energy consumption leads to economic growth. This is due to the fact that these 17 Asian countries have energy-dependent economies.

Pradhan (2010) investigated the nexus between oil and electricity consumption and economic growth in the five countries of the South Asian Association for Regional Cooperation (SAARC) over the period 1970-2006. Using Co-integration and Error Correction Model (ECM), the paper finds a unidirectional short-run and long-run causality from oil consumption to economic growth in Bangladesh and Nepal, a unidirectional short-run and long-run causality from electricity consumption to economic growth in Pakistan and Sri Lanka, a unidirectional short-run and long-run causality from economic growth to oil consumption in India and Sri Lanka, and a unidirectional causality from economic growth to electricity consumption in India and Nepal. The study finds bidirectional causality between electricity consumption and economic growth in Bangladesh, and between oil consumption and economic growth in Pakistan.

Noor and Siddiqi (2010) examined the causal link between energy use and economic growth for five South Asian countries over the period 1971-2006. To explore the short and long-run impacts, various econometric techniques such as Panel Co-integration, ECM and FMOLS are applied in the study. In the short-run there exists unidirectional causality from per capita GDP to per capita energy consumption. They estimate that in the long-run one per cent increase in per capita energy consumption tend to decrease 0.13 per cent per capita GDP. Their findings indicate that short and long-run relationship pattern between energy consumption and growth indicates that energy shortage in South Asian countries is the consequence of increased energy use, coupled with insufficient energy supply.

Dhungel (2008) examined the causal relationship between per capita consumption of coal, electricity, oil and total commercial energy and the per capita real GDP in Nepal. Using a Co-integration and Vector Error Correction Model (VECM) he finds that the increase in real GDP indicates a higher demand for a large quantity of commercial energy such as coal, oil and electricity. Empirical findings of this study indicate that there is a unidirectional causality

running from coal, oil and commercial energy consumption to per capita real GDP, whereas a unidirectional causality running from per capita real GDP to per capita electricity consumption is found. Aqeel and Butt (2001) used Co-integration and Granger tests to study the causal relationship between energy consumption and economic growth in Pakistan. Their findings show unidirectional causality running from economic growth to petroleum consumption and causality running from economic growth to gas consumption. They also found unidirectional causality running from electricity consumption to economic growth. The causality between energy consumption to GDP in India, Indonesia, the Philippines and Thailand was examined by Fatai *et al*. (2002). They used both Granger and Toda-Yamamoto methodologies to assess the causality between energy consumption and economic growth over the period 1960-1999 in these countries. It was found that Granger causality was running from GDP to energy consumption in Australia and New Zealand. The causal association among energy consumption and income in case of the four Asian developing countries was investigated by Adjaye (2000). The study found unidirectional causality from energy consumption to income in India and Indonesia and bidirectional causality in the case of Thailand and the Philippines.

Cheng (1999) estimated Granger causality between energy consumption and economic growth for the period 1952-1995 by using Co-integration and ECMs. He found that the Granger causality was running from gross national product (GNP) to energy consumption in India. Masih and Masih (1996) considered six Asian economies namely India, Indonesia, Malaysia, Pakistan, the Philippines and Singapore to examine the temporal causality between energy consumption and income. Applying a Vector Error Correction, their findings show that energy consumption was causing income in India, income was causing energy consumption in Indonesia, and that a bidirectional causality existed in Pakistan. For the other three countries (Malaysia, Philippines and Singapore), they used an Ordinary Vector Autoregressive model. In case of these countries, no causality between energy consumption and income was revealed.

For Bangladesh, Alam and Mian (2006) explored the similar causal relationships between FDI and long-term economic growth. Kabir (2007) also investigated about FDI and sustainable growth of Bangladesh, and found that inflows of foreign investment can expand economic production and growth. It is economic growth that attracts FDI. Tanin *et al.* (2010) examined the relationship between FDI and GDP in the context of Bangladesh using time series data during 1970-2006 time periods. They find that economic growth attracts FDI. By using Co-integration techniques, Hye and Mashkoor (2010) attempted to determine relationship between energy consumption and economic growth in Bangladesh. The causality test undertaken in the study confirms bidirectional causality in the long-run. The estimated coefficients demonstrate that both economic growth and energy consumption impact each other positively. Using panel data from 88 countries including Bangladesh, India, Pakistan and Sri Lanka to examine the relationship between per capita GDP and per capita energy consumption. Sinha (2009) found a two-way (bidirectional) short-term and long-term relationship between energy consumption (demand) and per capita GDP. Ahamad and Islam (2011) and Paul and Uddin (2011) also found similar findings for Bangladesh. Mozumder and Marathe (2007) found that per capita GDP growth causes per capita energy consumption in Bangladesh. They applied a VECM to explore the dynamic Granger causality.

Table 1: Relationship of Economic Growth with FDI and Energy Consumption in South Asian Countries: Selected Empirical Evidences

Country	Author(s)	Series	Study Period	Major Findings
FDI and Economic Growth				
Bangladesh	Shimul *et al*. (2009)	FDI, GDP	1973-2007	No relationship
Bangladesh	Tanin *et al.* (2010)	FDI, GDP	1970-2006	FDI influences economic growth
India	Mehta (2009)	FDI, GDP	1991-2009	Long-run relationship between GDP growth and FDI
Nepal	Kundan and Qingliang (2010)	FDI, GDP	1980-2006	FDI affects GDP growth positively
Pakistan	Khan and Khan (2011)	FDI, Output	1981-2008	Positive effect of FDI on output. One (two) way in the long (short)-run from GDP to FDI
South Asia[a]	Srinivasan (2012)	FDI, GDP	1970-2007	Long-run bi (uni)-directional relationship between FDI and GDP in all countries (India)
Sri Lanka	Athukorala (2003)	FDI, GDP	1959-2002	Not significant relationship
Energy Consumption and Economic Growth				
Bangladesh	Ahamad and Islam (2011)	GDP, ELC	1971-2008	BD: EC causes EG and vice versa
Bangladesh	Paul and Uddin (2011)	GDP, ENC	1971-2010	NC: ENC does not cause GDP
Bhutan	Lau *et at*. (2011)	GDP, ENC	1980-2006	UD: ENC increases GDP
India	Adjaye (2000)	GDP, ENC	1973-1995	UD: ENC causes GDP
India	Ghosh (2002)	GDP, ENC	1950-1997	BD: EC causes EG and vice versa
Nepal	Dhungel (2008)	GDP, ENC	1980-2004	UD: ENC causes GDP
Pakistan	Aqeel and Butt (2001)	GDP, ENC	1955-1996	UD: GDP causes ENC
Pakistan	Masih and Masih (1996)	GDP, ENC	1955-1990	BD: EC causes EG and vice versa
Sri Lanka	Hossain and Saeki (2011)	GDP, ENC	1971-2007	NC: No causation
Sri Lanka	Morimoto and Hope (2004)	GDP, ENC	1960-1998	BD: EC causes EG and vice-versa

Source: Various sources.

Note: [a]Bangladesh, India, Maldives, Nepal, Pakistan and Sri Lanka.
In 'Series' column: ENC: Energy consumption; ELC: Electricity consumption.
In 'Major Findings' column: UD: Unidirectional; BD: Bidirectional; NC: No causation.

The above literature review (summarised in Table 1) indicates that FDI is not an unmixed blessing and there is no consensus on the dynamic effects of FDI on growth. Some studies argue that the impact of FDI on growth varies across countries and relatively open economies have statistically significant results. On the other hand, some studies show that the direction of causality between FDI and growth depends on trade policies of recipient countries. Only a few studies explored the possibility of a bidirectional link between FDI and economic growth. The causal relationship between energy consumption and economic growth is found to be both unidirectional and bidirectional running from energy consumption to economic growth.

3. OVERVIEW OF THE ENERGY AND POWER SECTOR

3.1 Current Use and Capacity

Given the growth target of the country as spelt out in the SFYP of Bangladesh, the consumption of energy and power is not on track. The per capita energy use in Bangladesh

is the lowest among the South Asian countries (Table 2). Bangladesh ranked lower position in the Energy Development Index (EDI)[1] prepared by the International Energy Agency (IEA), and was only ahead of Nepal in South Asia in 2011. Though most of the South Asian countries have doubled their per capita energy use during 1972-2007, the growth of GDP per capita varies across countries during the period (Table 3).

Table 2: Key Economic and Energy Indicators of Selected South Asian Countries

Indicator	Bangladesh	Bhutan	India	Nepal	Pakistan
Population (million) in 2010	148.69	0.73	1170.94	29.96	173.59
GDP per capita (USD) in 2010	674.93	2088.43	1474.98	438.19	1018.87
Growth rate of GDP in 2010	6.07	7.44	8.81	4.55	4.14
Human Development Index (HDI) in 2011	146	141	134	157	145
Access to electricity (% of population) in 2009	41.0		66.3	43.6	62.4
Electric power consumption (kWh per capita) in 2009	252	-	571	91	449
Energy use (kg of oil equivalent per capita) in 2009	201	-	560	338	502
GDP per unit of energy use (constant 2005 PPP USD per kg of oil equivalent) in 2009	7.05	11.25	5.12	3.09	4.70
Energy imports, net (% of energy use) in 2009	16.09	-	25.65	11.43	24.16
Energy intensity in 2008	12577.30	61078.79	18824.70	8157.46	19851.94

Source: WDI (2011); IEA (2012).

Table 3: Trends of Energy Use and GDP Growth in Selected SAARC Countries

Year	Energy Use per Capita (Kg of Oil Equivalent)						GDP per Capita (Constant 2000 USD)					
	BGD	BHU	IND	NPL	PAK	LKA	BGD	BHU	IND	NPL	PAK	LKA
1972	80.52	-	278.89	301.88	271.08	314.10	210.33	-	206.67	141.68	271.24	331.71
1975	85.10	-	289.18	301.36	286.28	300.55	210.77	-	220.32	141.78	284.78	368.74
1980	92.95	-	301.82	302.97	301.01	303.53	226.21	-	229.26	141.21	330.25	436.05
1985	96.61	-	335.60	300.44	341.62	312.01	238.28	312.30	264.79	159.20	399.99	518.04
1990	110.14	-	374.52	303.02	397.21	322.32	254.88	473.40	318.41	176.71	465.38	573.92
1995	124.11	-	413.33	310.53	438.58	329.03	285.25	619.50	371.81	201.02	514.82	706.49
2000	132.02	-	450.21	331.86	457.44	444.97	334.57	762.30	452.97	224.88	535.58	872.67
2005	156.06	-	487.95	335.36	484.08	457.65	400.70	962.40	588.99	237.64	605.74	1008.68
2006	158.46	-	505.46	336.80	493.70	456.80	420.83	1001.70	637.08	241.70	629.53	1074.12
2007	163.29	-	528.91	337.76	512.15	463.97	441.38	1177.70	685.55	245.13	651.20	1140.02

Source: WDI (2011).
Note: BGD: Bangladesh; BHU: Bhutan; IND: India, NPL: Nepal; PAK: Pakistan; LKA: Sri Lanka.

[1]Energy Development Index used by the International Energy Agency measures the role of energy in human development. In 2011, Bangladesh ranked 44 among 66 countries in the EDI, whereas the positions of India, Pakistan, Sri Lanka and Nepal were 34, 38, 39 and 53 respectively. For details, see: www.iea.org/weo/development_index.asp

In Bangladesh, natural gas is the major source of primary energy, supplying about three-fourths (75 per cent) of the commercial energy demand. Total extractable gas reserve (proven and probable) in 24 gas-producing fields of the country is estimated to be 16.44 trillion cubic feet (tcf) as of June 2012 (Table 4). With increased demand for energy, proven gas reserve is depleting fast, and is not enough to run existing and new gas-based power plants of the country. At the present rate of consumption, the current proven reserve of gas will be exhausted by 2020. Currently, demand for gas is more than 2,500 million cubic feet per day (mmcfd), while the average rate of extraction is around 2,100 mmcfd, indicating a severe supply shortage. If the present gas production of 2 billion cubic feet (bcf) per day remains unchanged, the daily shortage will increase further. According to the projections of Bangladesh Petroleum Exploration and Production Company Limited (BAPEX), total annual demand for gas will be 1,061.5 bcf (2.9 bcf per day), 1,222.4 bcf (3.35 bcf per day) and 1,335 bcf (3.66 bcf per day) in FY2012-13, FY2013-14 and FY2014-15 respectively. Therefore, exploration of new onshore and offshore gas fields is essential to meet the future energy demand.

Table 4: Gas and Coal Resource Endowments for Power Sector (as of June 2012)

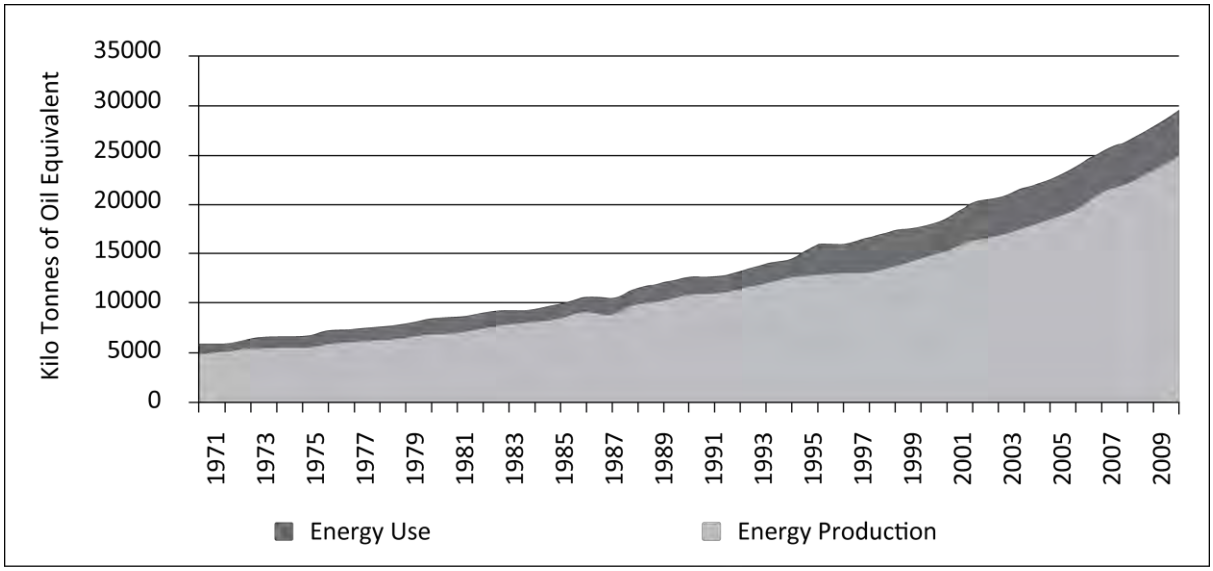
Gas Reserve and Supply Scenario		**Coal Reserve Scenario**	
Description	**Status**	**Location(Exportation year)**	**Reserve**
Total number of gas fields	24	Barapukuria (1985)	390 MMT
Number of gas fields in production	19	Khalaspur (1995)	685 MMT
Total reserve of extractable gas (proven and probable)	26.84 tcf	Phulbari (1997)	572 MMT
Total reserve remaining after usage	16.44 tcf	Jamalganj (1965)	1053 MMT
Daily exploration	2156 mcf	Dighipara (1995)	600 MMT
Daily demand	2500+ mcf		
Daily supply shortage	344+ mcf		

Source: GoB (2012).

Coal is the other locally available alternative energy resource for power generation. Total reserve of local coal is 3,300 million metric tonnes (MMT) in five coal mines, namely Barapukuria, Khalaspur, Phulbari, Jamalganj and Dighipara. Of the total reserve, about 492 MMT are recoverable. Total and recoverable reserves of coal are equivalent to 87 and 14 tcf of gas respectively. Given the estimated annual demand for coal (36 MMT) in Bangladesh, proven and total (proven and probable) coal reserves will be adequate only for the next 65 and 96 years respectively. Therefore, it is important for Bangladesh to make efficient use of its local coal reserves to minimise the risk of price hike of imported petroleum and to reduce high dependency on gas. The Power System Master Plan (PSMP) of Bangladesh has set various targets for improving the coal-based power supply. For example, the PSMP of 2010 has introduced a plan to generate electricity of 19,200 mega watts (MW) by 2030 by setting up 28 new coal-based power plants which will include both local and imported coal (GoB 2010). A huge amount of domestic and foreign investment is needed to carry out these initiatives. It has been estimated that about USD 70.5 billion is required to develop the facilities for generation, transmission and distribution of power needed to implement the plan (GoB 2010).

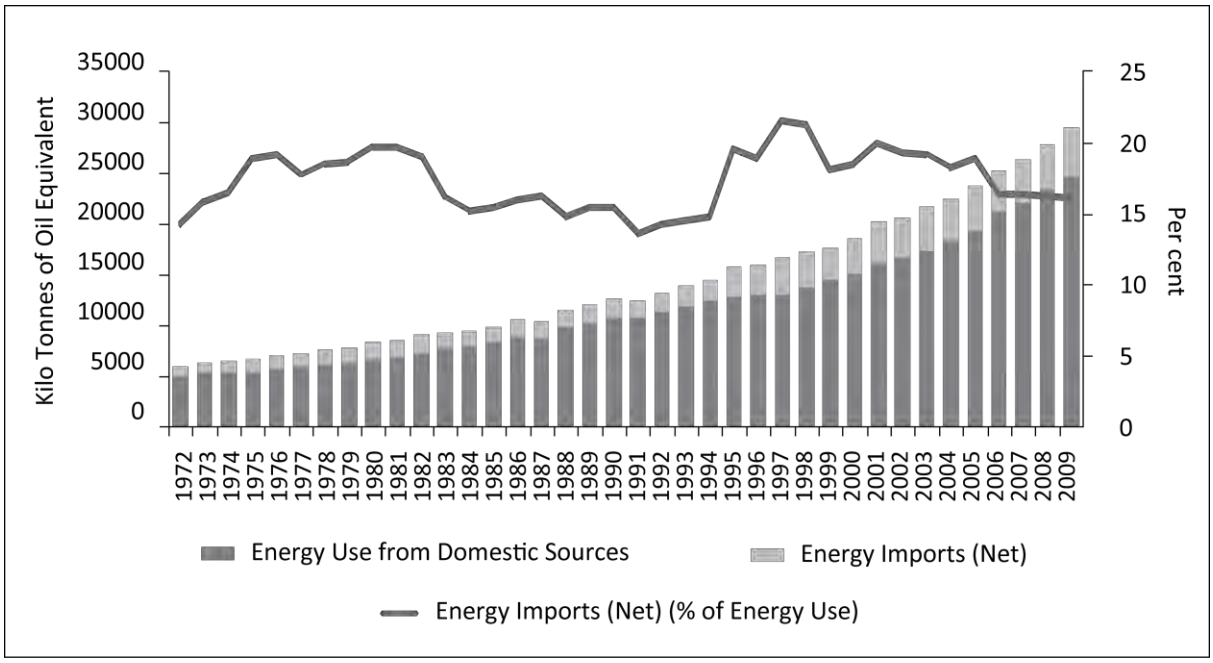
Total energy use has been doubled between 1994 (14,611.2 kilo tonnes of oil equivalent) and 2010 (29,599.33 kilo tonnes of oil equivalent) (WDI 2011). Increased energy use has led to higher imports of energy as domestic sources could not meet the demand. During 1971-2009, the average growth rate of energy import was 17.35 per cent. In 2008, total import of refined petroleum products amounted to 69.97 thousand barrels per day, that was twice the quantity of imports in 1998 (36.47 thousand barrels per day). Total import of coal in 2008 (881.85 thousand tonnes) was four times higher than that of 1998 (205.03 thousand tonnes) (IEA 2012). Figures 1 and 2 indicate the energy use, production and imports by Bangladesh.

Figure 1: Primary Energy Use and Energy Production in Bangladesh



Source: WDI (2011).

Figure 2: Energy Use from Domestic Sources and Energy Imports in Bangladesh



Source: WDI (2011).

According to the 2011 estimate of the Bangladesh Power Development Board (BPDB), total installed capacity of power generation in Bangladesh is 6,639 MW, which includes Independent Power Producers (IPPs) (1,330 MW), Small IPPs/Quick Rental Power Plants (QRPPs) (548 MW) and Rural Electrification Board (REB) (226 MW) (Table 5). However, the derated generation capacity was 5,271 MW in 2010, the maximum peak generation (actual) was 4,606 MW.[2] The distributional system loss, a perennial problem in Bangladesh is showing improvements in recent years. For example, in FY2010-11 distributional system loss came down to about 13.06 per cent from 35.79 per cent in FY1991-92.

Table 5: Installed Capacity and Actual Generation of Power Plants of the BPDB

Fuel	Installed Capacity FY2011		Derated Capacity FY2011		Target 2021*		Difference between Present and Targeted Installed Capacity (MW)
	MW	%	MW	%	MW	%	
Gas	5086	75.99	4651	76.74	5651	30.00	+565
Furnace oil	110	1.64	85	1.40	565	3.00	+455
Diesel	1017	15.20	905	14.91	-	-	-
Coal	250	3.74	200	3.30	9984	53.00	+9734
Hydro	230	3.44	220	3.63	188	1.00	-42
Nuclear	0	0.00	0	0.00	1884	10.00	+1884
Renewable	0	0.00	0	0.00	565	3.00	+565
Total	**6693**	**100.00**	**6061**	**100.00**	**18838**	**100.00**	**+12145**

Source: BPDB (2012); GoB (2010).
Note: *Outline Perspective Plan of Bangladesh 2010-2021.

During 2009-2011, the GoB signed a memorandum of understanding (MoU) with various local and international organisations to install 49 power plants with a generation capacity of 5,319 MW, of which three would be rental, 17 quick rentals, 11 IPPs and 18 were new initiatives by the government (Ahamad and Tanin 2013). Currently, 24 out of the proposed 49 power plants are in operation and contribute 1,944 MW to the national grid. The contribution of gas to installed capacity and actual power generation is the highest among all fuel sources as can be seen in Table 4. Coal, on the other hand contributes very little compared to gas even though domestic coal reserves are quite high (BPDB 2011).

The above overview reveals that though the use of energy has increased over time, it is still lower than the required rate for achieving the growth targets in the country. The source of primary energy is mainly dependent on natural gas, which at its current level of reserves, will not be able to meet the projected future demand unless new explorations are undertaken. The other source of primary energy is coal, which is mainly imported at present. In order to minimise the risk of price hike and reduce the burden of the government exchequer, domestic sources of coal should be explored through investing resources for coal development.

[2] Reasons for lower power generation during the peak hour include: i) maintenance, rehabilitation and overhauling of power plants; ii) aged power plants; and iii) shortage of gas supply (BPDB 2011).

3.2 Policy Regime of the Energy and Power Sector

The PSMP (2010) envisaged to be less dependent on any single primary energy resource by 2030. Therefore, it aims to adopt an energy mix which comprises of 25 per cent domestic coal, 20 per cent domestic natural gas, and 5 per cent national hydropower and renewable energy. In addition, actions will be taken to develop domestic gas exploration from offshore gas blocks. In doing so, the GoB will reevaluate domestic natural gas reserves, forecast the demand for natural gas, explore and develop domestic natural gas. Moreover, measures will be taken to finalise the 'Coal Policy', implement and evaluate pilot mining, forecast the demand for domestic coal, enhance training for mine engineers, and adopt Coal Bed Methane (CBM) and/or Underground Coal Gasification (UCG) technology.

As rationally priced and uninterrupted power supply to all by 2020 is an utmost priority of the GoB for sustainable socio-economic development, policy supports for investment are required to materialise the goal. In this regard, the GoB has estimated that a total investment of USD 17 billion, of which USD 10 billion will be derived from private investment to install the projected power plants by 2016. A total of USD 23 billion is also required to implement the energy sector Master Plan successfully by 2020. Moreover, the transmission line will be increased to 8,396 kilometres (km) and distribution line will be extended to 477,558 km as per the development plan by the year 2020. To facilitate the implementation of these plans, an amount of USD 7 billion has been planned as investment for the period during 2012-2020.

The GoB has formulated several policies (Table 6) to provide incentives to both domestic private and foreign investment in the country. The core objective of such policies is to strengthen the power sector by mobilising financial resources and create a competitive environment to encourage innovation. Foreign investors are granted a number of facilities and fiscal incentives, such as: (i) tax exemption on royalties, technical assistance fees and facilities for their repatriation; (ii) tax exemption on interest on foreign loans; (iii) tax exemption on capital gains from transfer of shares by the investing company; (iv) safeguards to protect foreign investors from double taxation stemming from the multiple bilateral agreements; (v) exemption from income tax for up to three years for expatriate personnel employed under the approved industry; (vi) remittance of up to 50 per cent of salary of foreigners employed in Bangladesh and facilities for repatriation of their savings and retirement benefits at the time of their departure; (vii) no restrictions on issuance of work granted to project-related foreign nationals and employees; and (viii) facilities for repatriation of invested capital, profits and dividends.[3]

Notwithstanding various policies, development of the energy and power sector of Bangladesh has remained an issue of great concern for decades. Commitments of successive governments to boost the energy and power sector, reflected through national policy documents were not translated into actions that kept the energy situation dire. Constraints to energy security in Bangladesh are multidimensional in nature, and can be categorised into five themes, namely economic, technical, legal and regulatory, political and social and environmental as shown in Table 7.

[3]For details: Private Sector Power Generation Policy of Bangladesh 1996, Government of Bangladesh (GoB).

Table 6: Policy Documents for the Energy and Power Sector Development of Bangladesh

Policy Document	Year
Private Sector Power Generation Policy *www.powercell.gov.bd/images/additional_images/PSEPGPB.pdf*	1996
Policy Guidelines for Small Power Plants in Private Sector *www.powerdivision.gov.bd/images/additional_images/SmallPowerPlantPolicy.pdf*	1998
Vision Statement and Policy Statement on Power Sector Reforms *www.powercell.gov.bd/images/additional_images/VSPSPSectorReform.pdf*	2000
Bangladesh Nuclear Power Action Plan in 2000	2000
Energy Regulatory Commission Act *www.powercell.gov.bd/images/additional_images/act.pdf*	2003
Bangladesh Private Sector Infrastructure Guideline *www.businesslaws.boi.gov.bd/components/com_eregistry/attach/Bangladesh%20Private%20Sector%20Infrastructure%20Guidelines%202004.pdf*	2004
National Energy Policy *www.picom.gov.bd/pdf/nationalenergy.pdf*	2004
Power Pricing Framework *www.powercell.gov.bd/images/additional_images/Power%20Pricing%20Framework.pdf*	2004
Power System Master Plan Update *www.powercell.gov.bd/images/additional_images/Power%20System%20Master%20Plan-2005.pdf*	2005
National Energy Policy (NEP) *www.powercell.gov.bd/images/additional_images /NE_20(update)-Policy.doc*	2006
Remote Area Power Supply System (RAPSS) Guidelines *www.powercell.gov.bd/images/additional_images/RAPSS.pdf*	2007
Renewable Energy Policy of Bangladesh *www.powercell.gov.bd/images/additional_images/REP_English.pdf*	2008
3-Year Road Map for Power Sector Reform (2008-2010) *www.powercell.gov.bd/images/additional_images/3-Year%20Road%20Map-_2008-2010_-final.pdf*	2008
Revised Policy Guideline for Small Power Plant (SPP) in Private Sector *www.powercell.gov.bd/images/additional_images/Small%20Power%20Plant%20Policy.pdf*	2008
Policy Guidelines for Enhancement of Private Participation in the Power Sector *www.powerdivision.gov.bd/images/additional_images/PPP_English.pdf*	2008
Invigorating Investment Initiative through Public-Private Partnership: A Position Paper *www.mof.gov.bd/en/budget/09_10/ppp/ppp_09_10_en.pdf*	2009
Policy and Strategy for Public-Private Partnership (PPP) *www.businesslaws.boi.gov.bd/components/com_eregistry/attach/PPP%20Plolicy%20and%20Guidelines.pdf*	2010
Outline Perspective Plan of Bangladesh 2010-2021 *www.indiaenvironmentportal.org.in/files/Final_Draft_OPP_2010-2021.pdf*	2010
Power System Master Plan *www.powerdivision.gov.bd/pdf/SUMMARYPSMP2010.pdf*	2010
National Industrial Policy *www.moip.gov.pk/Industrial_Policy_Implementation_6%200_May18_2011.pdf*	2011
Sixth Five Year Plan (FY2011-15) *www.plancomm.gov.bd/sixth_five_year_plan.asp*	2011
Power and Energy Sector Road Map: An Update *www.mof.gov.bd/en/budget/11_12/power/power_energy_en.pdf*	2011
Budget Speech FY2011-12 *www.mof.gov.bd/en/budget/11_12/budget_speech/speech_en.pdf*	2011
Power and Energy Sector Road Map: Second Update *www.mof.gov.bd/en/budget/12_13/power/power_energy_en.pdf*	2012

Source: Various Government documents.

Table 7: Constraints related to the Energy and Power Sector Development

Technical	Economic	Legal and Regulatory	Political and Social	Environmental
Construction of new power plants	Highly capital-intensive	Weak legal and regulatory (institutional) framework	Unstable political situation	Environmental clearance
Construction of transmission and distribution line	Lack of sufficient private investment	Undefined property rights and sharing at cross-border power trading	Lack of appropriate legislation to allow cross-border energy trade	Hazards resulting from gas/coal mining
Lack of appropriate technical, institutional and managerial skills	Absence of cost-reflective energy tariffs at retail level		Procrastination in decision making	
Poor maintenance of the existing power plants	Lack of PPP-based financing	Lack of leadership role of Bangladesh Energy Regulatory Commission (BERC)	Population density in the probable gas/coal field area	
Lacking in the proper utilisation of BAPEX	High dependence on oil import and gas-driven power plants		Social cost arising from accident	
	Poor physical infrastructure			
	Inadequate energy FDI			

Source: Adapted from various articles and policy briefs following Sovacool (2009).

One of the major obstacles responsible for the power shortage is the lack of adequate maintenance of existing power plants and institutional and managerial skills as revealed in Table 7. Poorly managed public-private partnership (PPP) and lack of local investment inhibit the development of the energy and power sector. Due to poor physical infrastructure and lack of political commitment, energy trade with neighbouring countries could not be materialised. Moreover, highly dense population of the country makes gas and coal exploration and production immensely difficult and costly. Procrastination in decision making for the approval of the finalised coal policy is deemed to be a major hindrance. An improper energy mix and high dependence on imported oil make the energy sector less cost-effective. Strengthening of the Bangladesh Energy Regulatory Commission (BERC) with appropriate legal and regulatory framework will be an effective step towards implementing the National Energy Policy (GoB 2006; GoB 2010).

The PSMP (2010) makes recommendations to address and resolve the following concerns relating to the business environment of the power sector by the GoB. These are: (i) developing a conducive environment that allows for a sufficient return relative to the risks of long-term investment; (ii) reducing risks involved in the recovery of investment; (iii) revising electricity and gas tariffs; (iv) strengthening the power purchasing entity of Bangladesh, the BPDB; (v) promoting the development of fuel and ensuring a stable supply

of fuel under a long-term contract; and (vi) establishing a transparent and efficient process in the government handling of private investment.

It is thus apparent from the above that the development of the energy and power sector requires removal of bottlenecks in various aspects that include technical, economic, regulatory, political and environmental. Recommendations have been made in the PSMP (2010) to address problems of the energy and power sector. However, implementation of these suggestions still remain unfulfilled.

3.3 Resources to the Energy and Power Sector

Domestic Resources

The GoB has gradually scaled up the budget allocation for the energy and power sector, indicating a stronger commitment from their part for improving the power situation of the country. Allocation for the energy and power sector in the National Budget for FY2013-14 is 5 per cent of the total budget and 15.6 per cent of the Annual Development Programme (ADP), indicating an increase over the years. For example, in FY2008-09 allocation for the fuel and electricity was 4.2 per cent of the total budget, while allocation for the power sector was 11.6 per cent of the Revised ADP of FY2008-09. It may however, be mentioned that a large part of the government resources goes as subsidy for the energy and power sector (Table 8).

Table 8: Trends of Domestic Resource Allocation for the Power Sector in Bangladesh

(Crore Tk.)

Component	FY2008-09	FY2009-10	FY2010-11	FY2011-12	FY2012-13
Development Budget of Power Division	2308.30	2102.20	5981.88	7185.80	8151.00
Subsidy	1007.00	994.00	4200.00	6000.00	6400.00
Total Public Expenditure	3315.30	3096.20	10181.90	13185.80	14551.00
Percentage of GDP	0.60	0.66	1.17	1.47	1.42
Percentage of Total Budget	4.20	4.50	7.10	8.18	7.72
Percentage of Total Development Budget	19.00	17.80	25.70	32.00	26.85

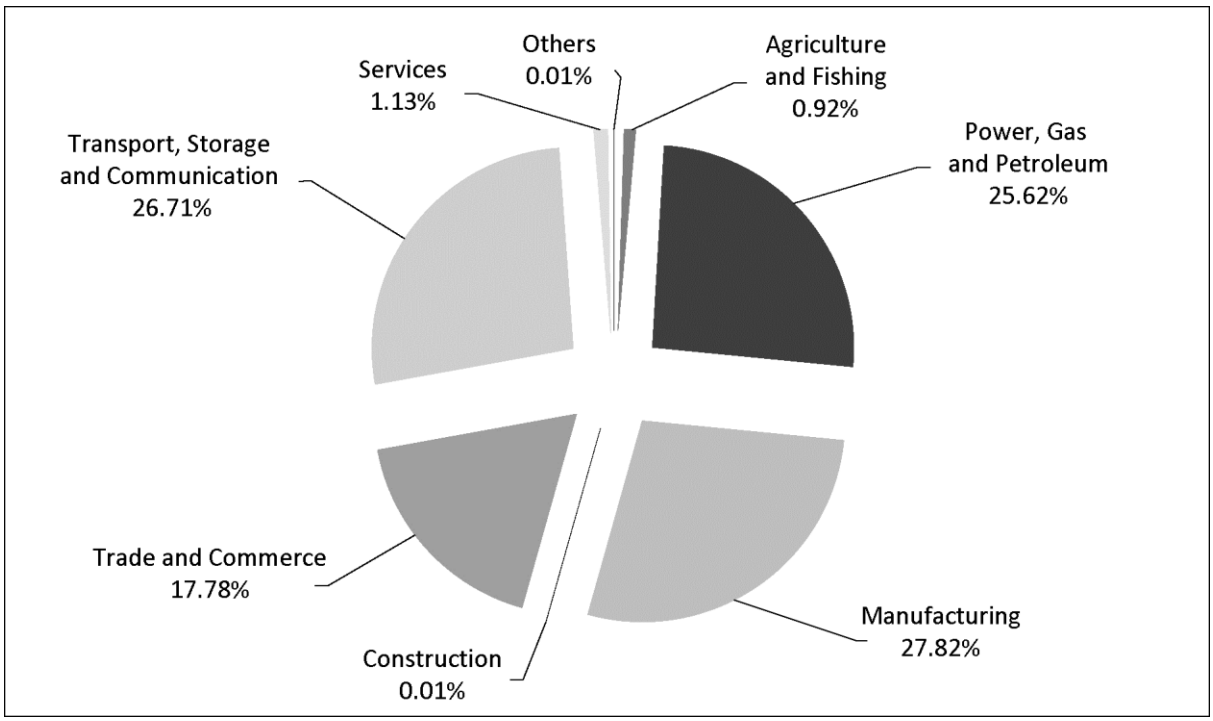
Source: GoB (2012).

The GoB intends to augment power generation to 11,457 MW by 2015 that requires an investment of USD 15 billion, of which USD 5 billion is supposed to be provided by the public sector (GoB 2011), and the rest will have to come as private investment. The lack of adequate public and private investment in oil, gas and electricity is also acknowledged in the SFYP (GoB 2011). In case of electricity production, the share of government is about 60 per cent in 2010, and it is expected that private sector will take the lead by 2016 (BPDB 2011).

Foreign Investment

The inflow of FDI increased significantly in Bangladesh during 2000-2008, specifically in the energy and power sector that had a positive impact on the overall infrastructure and capacity development of the country. During 1996-2010, the largest share of total FDI inflows went to the 'manufacturing' sector, followed by 'transport, storage and communication' and 'power, gas and petroleum', i.e. the energy sector (Figure 3). The highest flow of FDI was during the period between 1997 and 2001 and between 2005 and 2007. Since 2008 onwards, the FDI flow has, however been decreasing which appears to be a major concern for the development of the energy and power sector of Bangladesh.

Figure 3: Sectoral Share of FDI Inflow in Bangladesh: 1996-2010



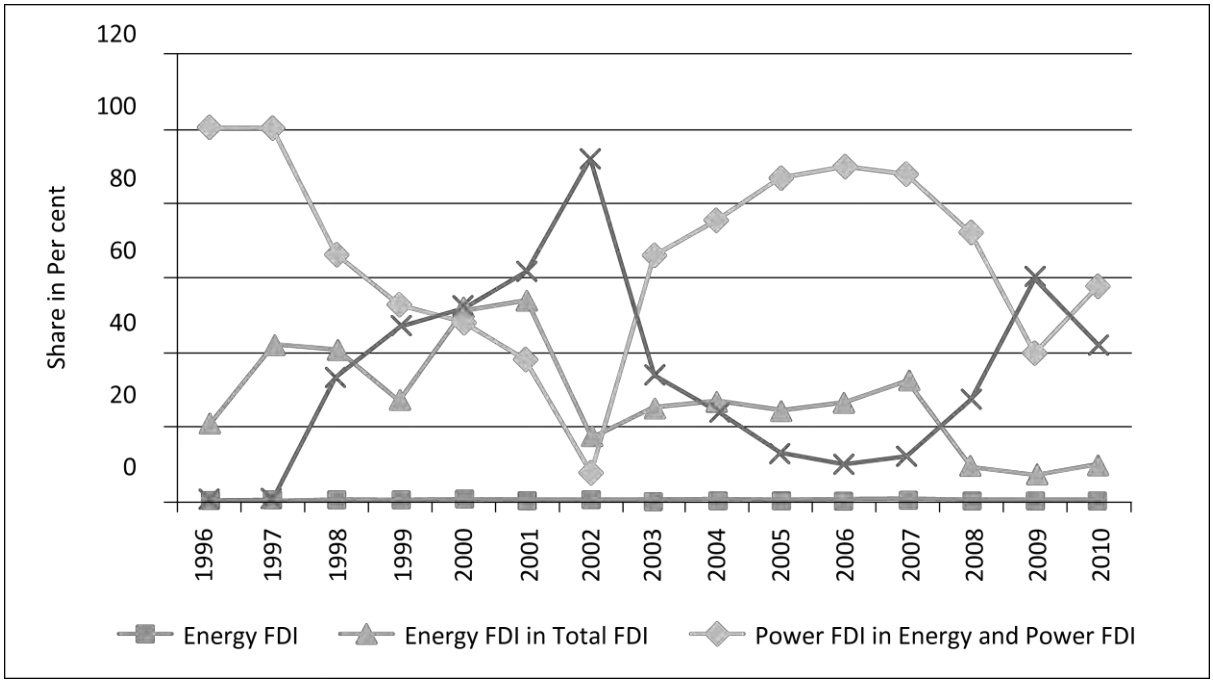
Source: Bangladesh Bank (2011).

Between 2008 and 2010, the share of FDI in the energy and power sector plummeted to approximately 10 per cent or lower from as high as 36 per cent in the last half of the 1990s and 30 per cent in the first half of the 2000s. Unlike the power sub-sector which underwent a stable yet low level of inflow, FDI flow towards gas and petroleum development had been erratic (Figure 4). Interestingly, during 1996-2010 the growth of FDI flow to the energy and power sector and the growth of GDP of Bangladesh followed similar trend (Figure 5). In this period, the average GDP growth rate was 5.66 per cent whereas FDI in energy sector was USD 149.87 million.

Though the energy and power sector attracted more FDI than most other sectors, it experienced a fluctuating trend with steep decline after 2000. Despite high potential to attract foreign investment in the energy and power sector, FDI inflows are hindered by several factors such as institutional weakness, corruption, political instability, poor law and

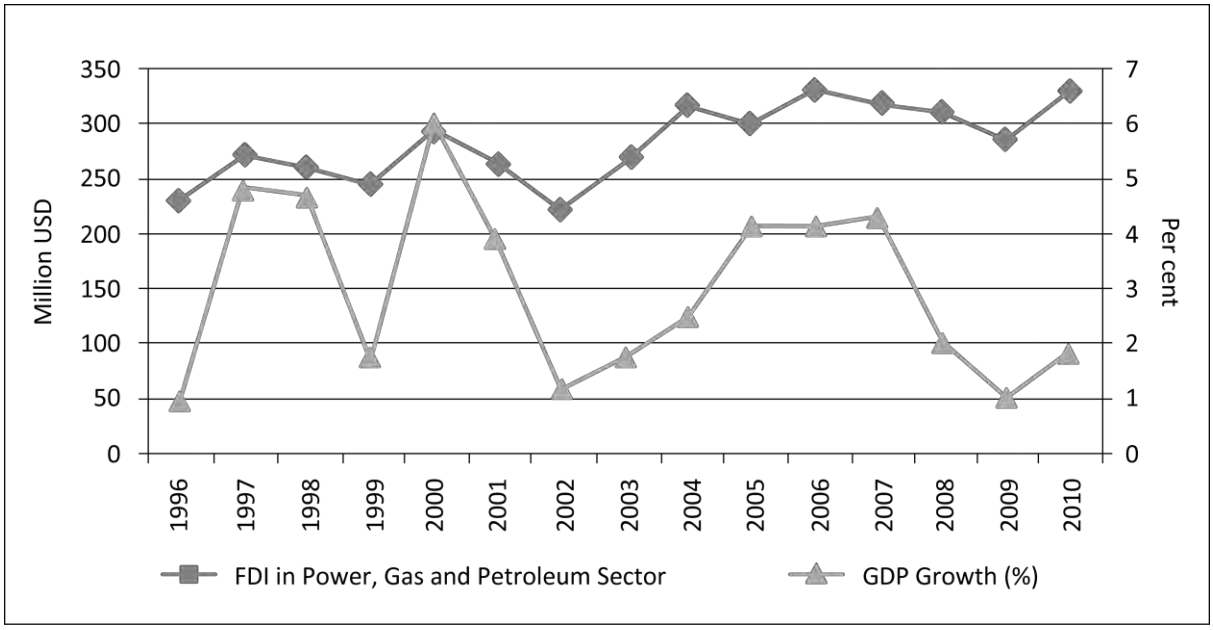
order situation and low labour productivity. If the growth rate of energy FDI follows the current trend, the growth potentials of the economy of Bangladesh cannot be captured.

Figure 4: Share of FDI in the Energy and Power Sector as % of GDP



Source: Bangladesh Bank (2011).

Figure 5: Trends of Energy and Power FDI and Economic Growth



Source: WDI (2011).

4. CAUSALITY BETWEEN FDI IN THE ENERGY AND POWER SECTOR AND ECONOMIC GROWTH IN BANGLADESH

Possible sources and directions of any causal relationship between economic growth, FDI and energy consumption in Bangladesh can be found by examining the Granger causality. This study employs the Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) unit root tests to identify the order of integration of the explanatory variables (series considered in the model). The Johansen Co-integration test is employed to examine the existence of a long-run equilibrium relationship between the series of the model. The sources and directions of the causal relationship between the model variables from the Vector Error Correction Model (VECM) specified Granger causality procedures are also explored in this study following the approach of Oh and Lee (2004) and Narayan and Singh (2007). This paper uses data for the period 1972-2010 from Bangladesh Bank (on FDI) and from the World Development Indicators (WDI) (on per capita energy consumption and per capita GDP) (WDI 2011).

For time series data, linear combinations of two or more non-stationary series may be stationary if it is integrated at same order, i.e. integrated in order one, I (1) or in order two I (2). If such a stationary combination exists, the series are considered to be co-integrated with long-run equilibrium relationships (Johansen and Juselius 1990). Incorporating these Co-integration properties, a VECM can test the Granger causality of the series. To do so, the VECM is specifically adopted to examine the Granger causality between per capita GDP (PCGDP), FDI inflow (FDII) and per capita energy consumption (PCEC) of Bangladesh. In this process, PCEC (FDII) Granger causes PCGDP if either: a) the estimated coefficients on lagged values of PCEC (FDII); or b) the estimated coefficient on lagged value of error term (ECT_{t-1}) from co-integrated regression is statistically significant. Likewise, PCGDP Granger causes PCEC (FDII), if either the estimated coefficients on lagged values of PCGDP or the estimated coefficient on lagged value of error term (ECT_{t-2}) from co-integrated regression is statistically significant (Narayan 2005).

The existence of Co-integration relationship indicates that there are long-run equilibrium relationships between model variables, and at least one causal relationship exists among the selected variables. But, it does not indicate the direction of the causal relationship. Moreover, the possibility of 'spurious correlation' may be found for the presence of Co-integration between model variables. In this way, the VECM can be employed to detect the sources and directions of the causal relationships. In this way, the VECM allows the possibility of distinguishing between long and short-run relationships for the variables. The study considers the following VECM for Granger causality equations:

$$\Delta PCGDP_t = \sum_{i=1}^{k11} \beta_{11i} \Delta PCGDP_{t-i} + \sum_{j=1}^{k12} \beta_{12j} \Delta PCEC_{t-j} + \sum_{l=1}^{k13} \beta_{13l} \Delta FDII_{t-l} + \beta_{13} ECT_{t-1} + u_{1t} + \beta_{10} \quad (1)$$

$$\Delta PCEC_t = \sum_{i=1}^{k21} \beta_{21i} \Delta PCEC_{t-i} + \sum_{j=1}^{k22} \beta_{22j} \Delta FDII_{t-j} + \sum_{l=1}^{k23} \beta_{23l} \Delta PCGDP_{t-l} + \beta_{23} ECT_{t-2} + u_{2t} + \beta_{20} \quad (2)$$

$$\Delta FDII_t = \sum_{i=1}^{k31} \beta_{31i} \Delta FDII_{t-i} + \sum_{j=1}^{k32} \beta_{32j} \Delta PCGDP_{t-j} + \sum_{l=1}^{k33} \beta_{33l} \Delta PCEC_{t-l} + \beta_{33} ECT_{t-3} + u_{3t} + \beta_{30} \quad (3)$$

In Equations (1), (2) and (3), PCGDP, PCEC and FDII represent per capita GDP, per capita energy consumption and FDI inflow in Bangladesh respectively. ΔPCGDP[4], ΔPCEC and ΔFDII are the differences in these variables that capture their short-run disturbances. *κ*s are the numbers of lags and ECT_{t-1}, ECT_{t-2} and ECT_{t-3} are the error correction terms[5] to capture the long-run effects. In addition, u_{1t}, u_{2t} and u_{3t} are the serially uncorrelated error terms which are derived from residuals of the estimated Co-integration and measure the magnitudes of the past disequilibria. ECTs are generally measured in the long-run. If three series are out of equilibrium, the dependent variable will adjust to reduce the equilibrium error. It refers to the speed of adjustment or correction from the deviation of the dependent variable that will adjust to minimise the long-run equilibrium error.

In Equations (1), (2) and (3), changes in the endogenous variable are caused not only by their lags, but also by the previous period's disequilibrium in level. In general, considering Equation (1), per capita GDP Granger causes per capita electricity consumption and/or FDI inflow in the short-run, if the estimated coefficients on lagged values of GDP are statistically significant. In contrast, if the lagged disequilibrium term is found to be significant, then the long-run causality can be confirmed by the Granger causality test.

Results of the VECM Specified Granger Causality Test

This section presents the empirical results derived from step-by-step estimation of Granger causality using VECM. The trend of three series for the model shows a fluctuating inflow of per capita FDI against an increasing per capita GDP in the country (Figure 6). Summary statistics of the model variable are presented in Table 9.

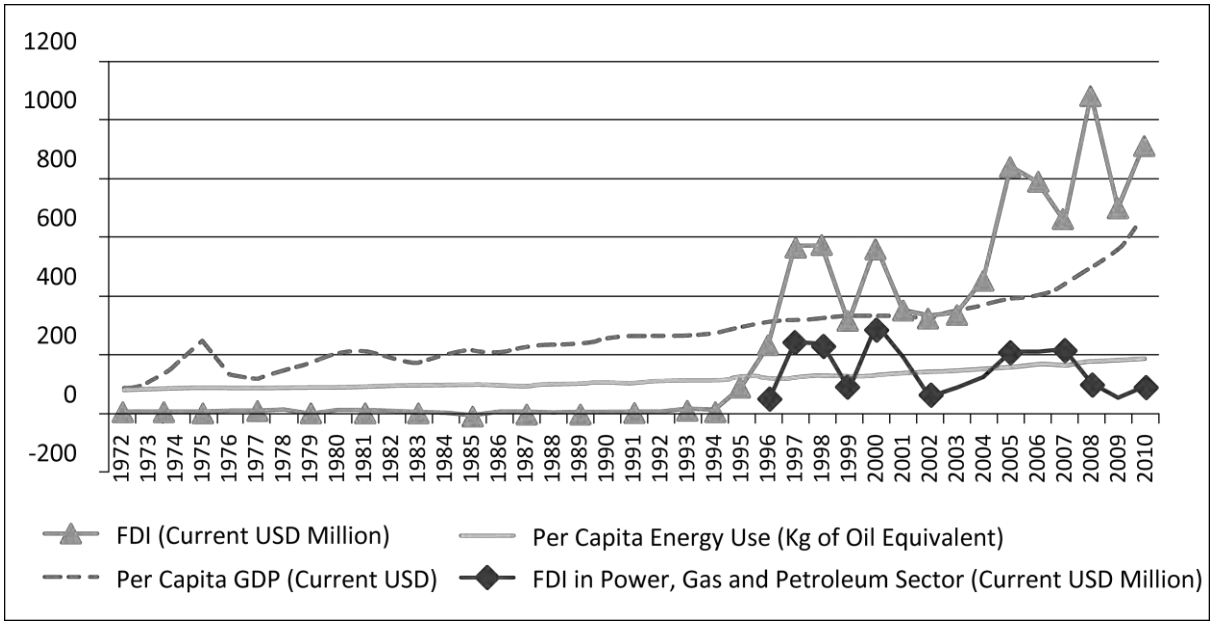
Results of the unit root test results for log of PCGDP, log of PCEC and log of FDII are presented in Table 10. The ADF and PP tests are performed to check the possible unit root. The decision on series stationarity is taken based on all the test statistics and respective probability (p) values. Based on the ADF test, all series are found to be non-stationary in level, but stationary in first difference (integrated of order one, I (1)). The PP test reveals the same. In sum, results from unit root tests explore that the model variables are non-stationary in level, but stationary in first difference, I (1).

This paper uses Granger causality test over other alternative techniques, i.e. ARDL, because of the favourable unit root properties of the series. The subsequent section explores the long-run equilibrium relationship between the series using Johansen's maximum likelihood procedure, namely Johansen Co-integration test.

[4] Δ denotes first difference operator.

[5] It is called the error correction term, since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments.

Figure 6: Trends of Per Capita Energy Consumption and GDP and FDI Inflows (Total and Energy) in Bangladesh



Source: Bangladesh Bank (2011); WDI (2011).

Table 9: Summary Statistics of the Series

Variable	Observation	Mean	Min.	Max.	Std. Dev.	Skewness	Kurtosis
PCGDP	39	277.29	674.90	86.20	122.75	1.08	4.56
PCEC	39	117.62	185.70	80.50	29.90	0.76	2.47
FDI	39	229.06	1086.31	-8.01	323.15	1.13	2.97

Source: Authors' calculation.

Table 10: Results from the Unit Root Tests

Variable	Augmented Dickey Fuller (ADF)				Philips–Perron (PP)				Order of Integration
	Constant		Constant & Linear Trend		Constant		Constant & Linear Trend		
	Level	1st diff.	Level	1st diff.	Level	1st diff.	Level	1st diff.	
PCGDP	-1.462 (0.542)	-5.700 (0.000)	-4.522 (0.005)	-5.596 (0.000)	-1.329 (0.606)	-9.813 (0.000)	-4.431 (0.006)	-9.559 (0.000)	I (1)
PCEU	2.575 (1.000)	-8.040 (0.000)	-1.208 (0.895)	-9.211 (0.000)	4.333 (1.000)	-8.105 (0.000)	-0.630 (0.971)	-31.165 (0.000)	I (1)
FDII	-8.729 (0.000)	-	-3.081 (0.145)	-5.071 (0.006)	-1.470 (0.536)	-6.612 (0.000)	-2.341 (0.402)	-6.363 (0.000)	I (1)

Source: Authors' calculation.
Note: Respective probability (p) values are in parentheses.

To find out whether the three model variables are co-integrated, the paper employed the Johansen Co-integration test. In Table 11, trace statistics and maximum Eigen value statistics reveal that the three variables (PCGDP, PCEC and FDII) have at least one co-integrating relation or long-run equilibrium relationship at 1 per cent level. Determination of optimum lag length for Co-integration test is based on Akaike Info Criterion (AIC) through the VECM estimation.

Table 11: Results from the Johansen Co-Integration Tests

Hypothesised No. of Co-Integrating Equation (CE)	H_0:	H_1:	Eigen Value	Trace Test			Maximum Eigen Value Test		
				λ_{trace}	5% Critical Value	Prob.	$\lambda_{max.}$	5% Critical Value	Prob.
None*	r=0	r=1	0.629	35.556	29.797	0.010	29.716	21.132	0.002
At Most 1	$r\leq$1	r=2	0.119	5.840	15.495	0.714	3.791	14.265	0.881

Source: Authors' calculation.
Note: The 'r' denotes the number of co-integrating vectors. Trace test indicates 1 co-integrating equation(s) at the 0.05 level. Maximum Eigen value test indicates 1 co-integrating equation(s) at the 0.05 level. * denotes rejection of the hypothesis at 5 per cent level.

As the three considered model variables (PCGDP, PCEC and FDII) are co-integrated in the long-run, the VECM specified Granger causality test is employed to find out the sources of causation and directions of the causal relationships. The VECM contains the co-integrating relations to assess the long-run behaviour of the endogenous variables to congregate for their equilibrium with short-run speed of adjustment (Table 12).

Table 12: Results from the VECM Specified Granger Causality Tests

Dependent Variable	Sources of Causation				Short-run Relationship	Long-run Relationship
	Short-run *(chi-sq- statistics (prob.))*			Long-run *(t-statistics (prob.))*		
	ΔPCGDP	ΔPCEC	ΔFDII	ECT_{t-i}		
ΔPCGDP	-	2.507 (0.100)	0.251 (0.616)	-1.071 (-6.340)	EC causes GDP	No
ΔPCEC	0.191 (0.662)	-	3.942 (0.047)	-0.003 (-0.089)	FDI causes EC	Yes
ΔFDII	0.136 (0.712)	0.923 (0.337)	-	-0.666 (-0.437)	No causality	No

Source: Authors' calculation.
Note: a, b and c imply significance at 1 per cent, 5 per cent and 10 per cent level respectively; corresponding p-values are in parentheses.

Table 12 shows the test statistics including χ^2 Wald tests and t-tests. According to the short-run causality test statistics, there is evidence of positive short-run and a strong linear causal relation running from per capita energy consumption to per capita GDP (proxy of economic growth), which indicates past PCGDP helps to predict PCEC. The positive sign of this relation implies that an increase in PCGDP leads to an increase in PCEC. But, the reverse short-run causality does not exist. Additionally, FDI causes energy consumption in the short-run. Coefficients of the error correction term (ECT_{t-2}) are found to be significant in energy consumption equation (Equation 2), which indicates that given any deviation of per capita GDP and per capita EC from the long-run equilibrium relationship between ECT_{t-1} and ECT_{t-2} with EPC and GDP respectively, where both variables in the VECM would interact dynamically to restore the long-run equilibrium. The short-run results provide evidence in support of the proposition that economic activity is the result of energy consumption. That is, energy is an essential input to production. However, it found that economic growth is less dependent on energy consumption in the long-run.

5. CONCLUDING REMARKS

The present study examined the direction of the causal relationship between energy consumption and economic activity in Bangladesh. More specifically, the research explored the relationship between FDI, energy use and economic growth for Bangladesh using time series data for the period 1972-2010 and explores the short and long-run policy implications on energy demand, required FDI in energy sector and consequent economic growth. The Granger causality test has been deemed to be suitable for the study that used the Co-integration technique to find out that there is no co-integration between the variables concerned. The following results are derived from the causality test:

I. A positive and unidirectional causality running from per capita energy consumption to per capita GDP (PCEC => PCGDP) in the short-run;
II. A positive and unidirectional causality running from per capita FDI to per capita energy consumption (FDI => PCEC) in the short-run;
III. A positive and unidirectional causality running from per capita FDI to per capita GDP (FDI => PCGDP) in the long-run.

Empirical findings of the study lead to various policy implications for the energy and power sector of Bangladesh. *First,* the evidence of a positive and unidirectional causality running from per capita energy consumption to per capita GDP implies that reduction of energy consumption could lead to a fall in economic growth. In other words, higher energy consumption will imply higher GDP. Therefore, efforts should be made to increase the availability of higher per capita energy. Hence more inflow of FDI and more resource allocation from domestic sources for the energy and power sector are essential.

Second, increased inflow of FDI is found to have positive impact on per capita energy consumption implying that higher FDI leads to higher energy consumption. This is due to the possibility that when there is FDI flow into a country, economic activities are expected to increase, which in turn requires more energy. This underscores the need for higher FDI in the energy sector. Since liberal policy regime alone has been proved to be not a sufficient condition to attract FDI, policymakers have to focus on removing other barriers such as political instability, delay in decision making, inefficiency of human resources, corruption and lack of governance.

Third, since the economy is still underdeveloped, any effort to conserve energy should be made carefully so that it does not reduce energy consumption since the present study finds that there is causality between per capita energy consumption and per capita GDP. In the short-run, the implementation of energy conservation policies might lead to a negative impact on economic growth. However, given that Bangladesh is vulnerable to the impact of global warming it may pursue efforts towards environment-friendly and renewable energy use. Solar energy could be one of the ways not only for reduction of carbon emission, but also to protect the country from facing high energy prices in the international market. Bangladesh has to play an active role in bringing advanced technology and resources from the developed countries in this respect.

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