Article:

Wadud, Z, Dey, HS, Kabir, MA et al. (1 more author) (2011) Modeling and forecasting natural gas demand in Bangladesh. Energy Policy, 39 (11). 7372 - 7380. ISSN 0301-4215

https://doi.org/10.1016/j.enpol.2011.08.066

Paper:
Wadud, Z, Dey, HS, Kabir, MA and Khan, SI (2011) *Modeling and forecasting natural gas demand in Bangladesh.* Energy Policy, 39 (11). 7372 - 7380.

http://dx.doi.org/10.1016/j.enpol.2011.08.066

Modeling and Forecasting Natural Gas Demand in Bangladesh

Zia Wadud, Bangladesh University of Engineering and Technology, ziawadud@yahoo.com

Himadri S Dey, University of Notre Dame

Md. Ashfanoor Kabir, Bangladesh University of Engineering and Technology

Shahidul I Khan, Bangladesh University of Engineering and Technology

journal version available at:

http://www.sciencedirect.com/science/article/pii/S0301421511006872

Modeling and Forecasting Natural Gas Demand in Bangladesh

Abstract

Natural gas is the major indigenous source of energy in Bangladesh and accounts for almost one-half of all primary energy used in the country. Per capita and total energy use in Bangladesh is still very small, and it is important to understand how energy, and natural gas, demand will evolve in the future. We develop a dynamic econometric model to understand the natural gas demand in Bangladesh, both in the national level, and also for a few sub-sectors. Our demand model shows large long run income elasticity – around 1.5 – for aggregate demand for natural gas. Forecasts into the future also show a larger demand in the future than predicted by various national and multilateral organizations. Even then, it is possible that our forecasts could still be at the lower end of the future energy demand. Price response was statistically not different from zero, indicating that prices are possibly too low and that there is a large suppressed demand for natural gas in the country.

Key words

Natural gas, energy demand model, forecasting, demand elasticity

Modeling and Forecasting Natural Gas Demand in Bangladesh

1. Introduction

Bangladesh is a small but densely populated country in South Asia, with approximately 150 million people living on a land area just under 144,000 square kilometers. Although Bangladesh ranks among the top third of the countries in terms of total GDP, it is among the poorest countries in the world according to per capita income. In 2009, the GDP per capita was only USD 551 (World Bank 2010) and a large share (49.6%, United Nations Development Programme, UNDP 2010) of the population lives below the poverty line. The share of people living under extreme poverty (living under $1.25 PPP a day) is also very high, at 40% (UNDP 2010). Despite the current status, Bangladesh has been enjoying significant economic growth for the past decade, with a real GDP growth rate of around 6% during the past 5 years (Asian Development Bank, ADB 2009). The economic growth has been accompanied by growing energy demand as well. As in any other countries in the world, the energy sector plays a critical role in the socio-economic development of Bangladesh yet the country faces an acute energy shortage. Availability of adequate, reliable and uninterrupted energy supply is one of the most important bottlenecks for further development of the country. And, in order to plan future energy supply, it is therefore important for policymakers to know the demand for energy in future. Since natural gas is the only indigenous source of commercial energy in the country (ignoring little coal deposits), it is important to understand how natural gas demand will evolve in future in response to and in spurring the rapid economic growth.

Energy demand models for energy forecasting can be useful to the government in order to plan future capacity development and investments in the natural gas sector. However, the existing energy demand projections in the country are mostly old-fashioned with trend extrapolation the major procedure for energy forecasting. This paper aims to improve upon the natural gas demand models for Bangladesh and its different sectors of the economy using dynamic econometric techniques and use the model for forecasting national demand until 2025. To our knowledge, this is also first paper to utilize a dynamic econometric technique to model and forecast natural gas demand in Bangladesh. Although the paper focuses primarily on Bangladesh, the appeal of such energy demand models, which uses small time series information but sophisticated dynamic modeling technique, is much larger - especially for the developing countries.

The paper is organized as follows. Section 2 discusses the energy situation of Bangladesh including the importance of gas in the energy mix. Section 3 describes the energy demand model along with the results. Section 4 discusses the results and concludes.

2. Energy Scenario in Bangladesh

Total energy consumption in Bangladesh in 2008 was 0.87 Quadrillion BTU, which is only 0.18% of world consumption (US Energy Information Administration, USEIA 2010). Considering the large population, per capita consumption is even smaller, at a mere 5.67 million BTU, which is among the lowest in the world (world average 73.6 million BTU, USEIA 2010). Only 42% of the households have access to grid electricity, the supply of which is unreliable because of lack of generation capacity as well as unreliable primary energy feed to the generation plants. As a result, frequent rationing of electricity by the providers during the summer months are a common phenomenon.

Natural gas, biomass, and petroleum are the major contributors to the total primary energy consumption in Bangladesh. Biomass is still the principal source of energy for the rural population and comprised almost one-thirds of the total primary energy consumption. Natural gas has the largest share (almost half) of all primary energy consumption, which is possible because of its local availability. Imported petroleum constitutes almost one-fifths of the total consumption, whereas coal and hydro (and recently some solar as solar PV) contribute less than 1%. Fig. 1 presents the distribution of primary energy sources in use in Bangladesh in 2005.

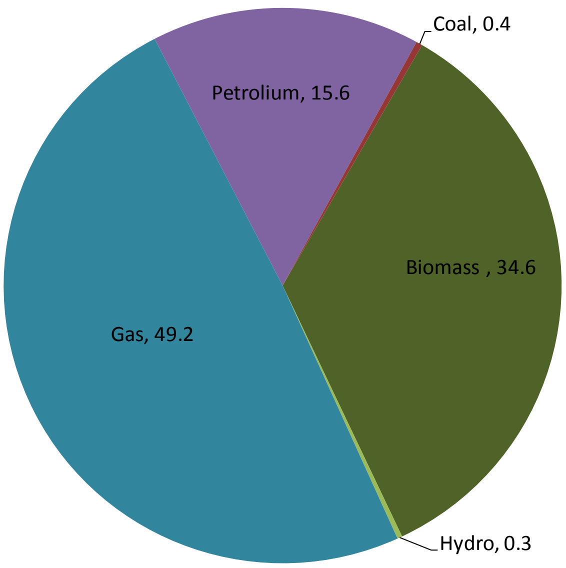

Fig. 1 Percentage share of the primary energy sources in Bangladesh in 2005 (Data: National Energy Policy-NEP, Ministry of Power, Energy and Mineral Resources 2008)

Not considering a negligible amount of petroleum production within the country, all of the petroleum demand is met by imports. Most of this petroleum is used in the transportation sector although the importance of petroleum in this sector has been decreasing since the government policy of encouraging compressed natural gas (CNG) as a transportation fuel. However, still a major share of all petroleum consumption in the country is by the transport sector. Around 10% of the electricity in 2006-2007 came from diesel and furnace oil (Bangladesh Power Development Board 2007). Lack of reliable gas supply recently has also forced some entrepreneurs to use diesel based generators for power. In the agriculture sector, diesel is heavily used for driving irrigation water pumps, while in rural areas with no electricity kerosene is still used for lighting. In 1996, around 65% of all households in Bangladesh used kerosene for lighting (Bangladesh Bureau of Statistics, BBS 2009), although the number is currently believed to be smaller.

Biomass is primarily used in rural areas to meet the energy needs for cooking. The traditional biomass sources include agricultural residue (rice husks, rice and jute stalks, sugarcane bagasse etc.), animal waste (mainly dried form, but some biogas plants, too), scrub wood, and fire wood (Miah et al. 2010). Although there are attempts by NGOs to improve the quality of biomass energy availability to the poor through solid briquettes or biogas plants, majority of the biomass sources are collected informally. These renewable biomass resources are considered to have significant potential to meet the energy demand, especially in the rural areas (Hossain & Badr 2005, Islam et al. 2006), and the absolute consumption of biomass based energy has been slowly increasing over the years (NEP 2008). However, the share of biomass in total primary energy consumption has been consistently decreasing in the country as it moves up the energy ladder. It is estimated that biomass constituted around 54% of all primary energy consumption in Bangladesh in 1994, which has reduced to around 35% in just over a decade in 2005 (NEP 2008). The share is still higher than most developing countries, where around one-fourths of primary energy consumption is generally from the biomass (Bhattacharyya and Timilsina 2009).

The coal sector of Bangladesh is quite underdeveloped. There is only one coal based power plant in Bangladesh which produced around 5% of total electricity in 2006-2007. Rest of the coal is used primarily by the brick fields.

Among the renewable energy sources, hydropower currently represents less than 5% of total installed electricity generation capacity. Since the country is a flat one, opportunities for installing further hydropower plants is negligible, although some micro-hydro plants could find niche areas of application (Islam et al. 2006, Islam et al. 2007). Solar Photovoltaics (PV) have gained some popularity in rural areas without electricity. Despite their higher prices, solar PVs were made affordable by the microcredit opportunities. Bangladesh currently has 12 MW installed capacity in solar electricity, although it represents a negligible share of total primary energy consumption (National Renewable Energy Policy, Ministry of Power, Energy and Mineral Resources 2008). Solar power does have the potential to have a significant market share in the future because of the availability of sunlight and further reduction in costs.

3. Role of Natural Gas

Natural gas is the major indigenous source of commercial energy supply in Bangladesh (National Energy Policy 2008). Electricity generation in Bangladesh is almost entirely dependent on natural gas, with almost four-fifths of the generated electricity coming from natural gas based plants in 2007 (Fig. 2). Note that the use of natural gas for electricity generation makes Bangladesh's electricity relatively clean in terms of greenhouse gas emissions.

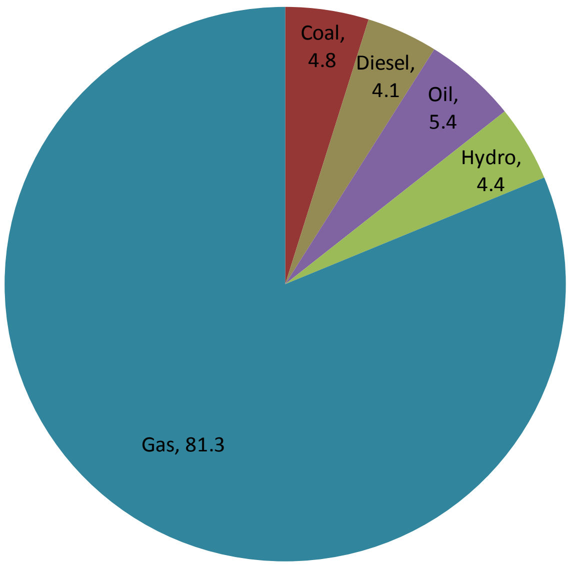

Fig. 2 Percentage share of fuels used for power generation in 2006-07 (Data: Bangladesh Power Development Board 2007)

In addition to electricity generation, natural gas is used in a number of other end-use sectors in Bangladesh. Gas is used in the industries primarily as a source of power, heating in the boilers and in some cases as raw materials. Especially in the fertilizer sector, natural gas is a major raw material. Fertilizer industries are a major natural gas consumer with 18% of all natural gas for consumption in the country in 2006. Natural gas was also used in the brick fields to fire the bricks and in tea production heating and drying. Residential use of natural gas is primarily for cooking in the households with gas connections. Transportation sector has recently been experiencing a rapid growth in gas demand. This is a direct result of government policy to encourage the conversion of motor vehicles to run on compressed natural gas (CNG). Despite the growth, the current consumption in the transportation sector is only a small share of total consumption. Natural gas usage by industries and households for captive power has also been increasing recently because of a lack of availability and reliability of grid electricity supply.

Since natural gas is the principal indigenous source of primary energy in the country, it is not surprising that its consumption has been increasing over the years. Spurred by the economic growth (and spurring economic growth) natural gas consumption has tripled over the last fifteen years (Fig. 3). The pattern of gas consumption also changed over these years. The share of fertilizer production sector, which was the largest consumer in the 1980s (43% in 1981), has been ever decreasing (18% in 2006), primarily because there were no new fertilizer factories in the country in the last decade (and a few chronically shut down for maintenance) but also because other sectors became more dominant (Fig 4). The absolute consumption, however, was increasing until the mid 1990s after which increase in gas consumption by the fertilizer sector was very small.

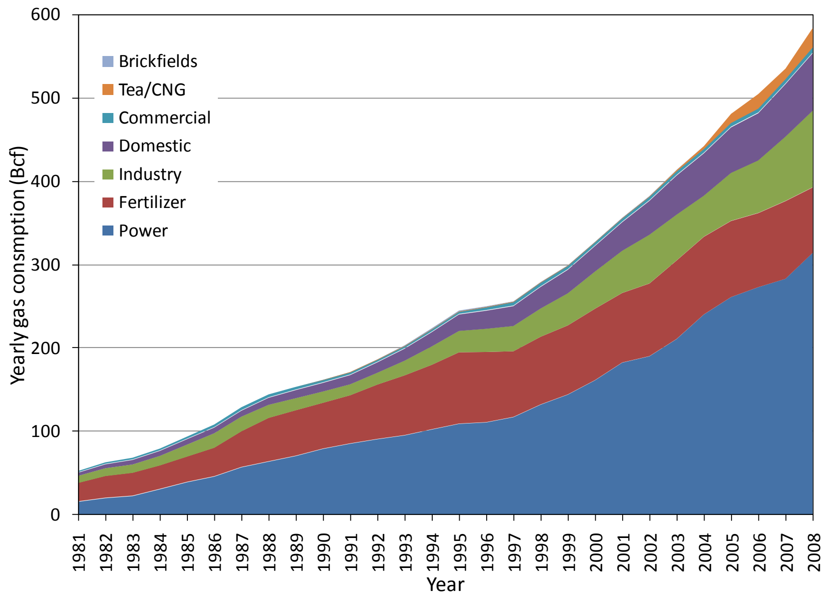

Fig. 3 Total and sector-wise natural gas consumption during 1981-2008 (Data: Petrobangla 2009)

On the other hand, power generation underwent a rapid growth, especially after 1995 and demand for natural gas from this sector generally drives the national demand for gas (Fig. 3). Natural gas consumption for electricity generation increased almost 16-folds between 1981 and 2006. At present, electricity generation consumes more than half of all natural gas consumption in the country, up from around one-thirds in 1981.

Gas usage in other industrial and commercial applications and domestic households has also been increasing. In absolute terms, consumption has increased in other industrial and commercial applications as well as in the households, although household consumption has increased more rapidly. Natural gas usage in households for cooking purpose in the major urban areas has increased from 7% of total gas consumption in 1981 to 11% in 2006. Also, as mentioned above, transportation and captive power production have been two rapidly rising end use sectors.

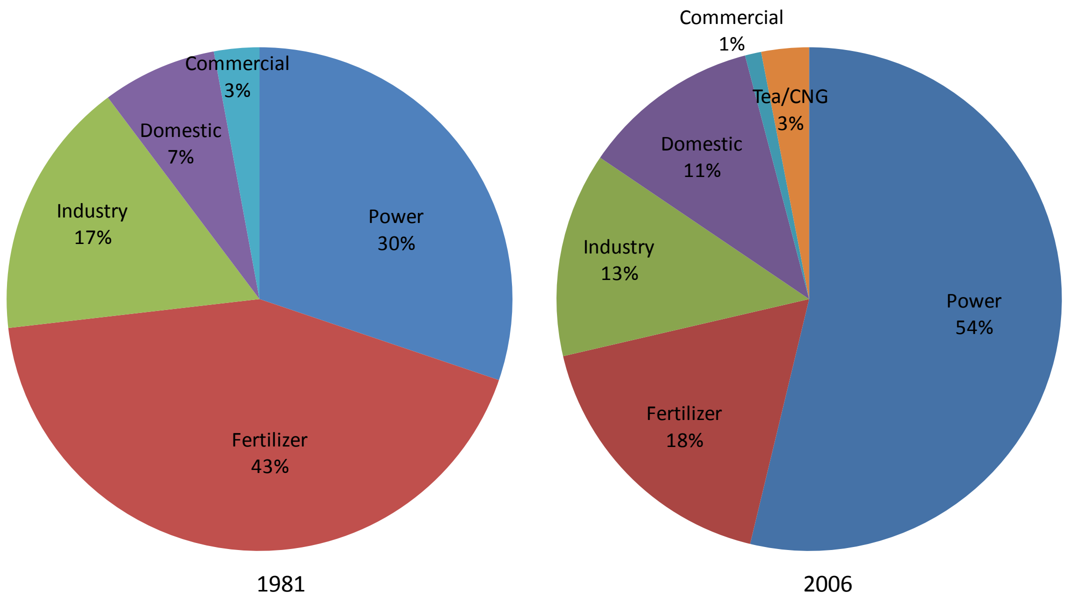

Fig. 4 Changes in gas usage pattern between 1981 and 2006 (Source: Petrobangla 2008).

4. Modeling Demand for Natural Gas

4.1 Energy Demand Models

Energy is a critical input to the growth of any economy and therefore energy demand modeling and forecasting has been a widely researched area among both academics and practitioners. These models can vary in their underlying modeling objectives, modeling philosophies, sophistication in modeling methods or requirements of data. Often, these factors can be related to each other, e.g. a sophisticated modeling method will most certainly require a larger dataset or lack of data may force the development of a simple model.

Bhattacharya and Timilsina (2009), Jebaraj and Iniyan (2006) and Urban et al (2007) recently reviewed the existing energy demand models for application in developing countries. Bhattacharyya and Timilsina (2009) identify four simple approaches – growth rate, elasticity based, specific consumption and energy intensity – for forecasting energy demand in developing countries. The advantages of these methods are minimal data and skills requirements, although the methods can be widely off the mark in practice. Among the relatively sophisticated models for energy demand, are trend models, econometric models, engineering economy models, hybrid models, system dynamics models, scenario approaches, input-output models and artificial neural network models, all of which we discuss briefly here.

Trend and econometric models generally use information at the aggregate level, and are also known as top-down models. A trend model finds a statistical relationship of energy demand with time using past information on energy demand. This is the most common method for forecasting energy demand by the practitioners in developing countries, including Bangladesh. On the other hand, econometric models are well grounded in economic theories and explain the energy demand in terms of the demand drivers and quantify their relative importance on demand (the functional relationship between demand and its drivers) through statistical or econometric methods. Correctly specified econometric demand models behave well for forecasting energy demand unless there is a fundamental shift in the structure of the economy. Models based on artificial neural networks have recently been used by Geem and Roper 2009 and Nasr et. al. 2003, among others. These models are similar to econometric models, but the functional relationships between energy demand and its drivers are determined using neural networks, and thus lack the theoretical foundations of economics.

Engineering-economy models (also known as end-use models or bottom up models) focus on the detailed accounting of energy use through engineering representation of the energy system. These models focus on different end uses of energy at a disaggregated level at the user ends (e.g. domestic appliances, vehicle fuel use etc.). End use models are excellent in capturing structural changes and technological developments (e.g. Bhattacharya and Timilsina 2009), yet they are data intensive, which renders them less useful in the context of developing countries. Input-output models are also disaggregated (but more aggregated than bottom-up models), sector-wise models, which rely on an array of relationships between different industrial segments of the economy (e.g. Liang et al. 2007). These models are again data intensive, and thus less suitable for a developing country like Bangladesh.

Scenario approaches rely on expert judgments on how future may evolve, and are the least technical of all models. Scenarios are also often an integral part of the end-use models which use various potential growth/technology diffusion scenarios in their representation of future energy systems (Bhattyacharya and Timilsina 2009). While data requirements can be minimal, there is a clear lack of theoretical underpinning in scenario building models. However, scenario approaches are still used for planning into distant future (Shell 2008).

Hybrid models combine two or more of the above models to overcome the limitations of one single model. For example, the engineering-economy models increasingly use econometric methods at a disaggregate level for forecast purposes. Similarly, econometric models can adopt sector-wise representation of the economy. Hybrid models have become widespread, especially in the developed countries, however, data requirements are generally larger than either of the parent models.

Among all these models to forecast energy demand, econometric models with reasonable time-series information on energy consumption and relevant demand drivers appear the most suitable for developing countries, primarily because of the unavailability of the relevant data in the developing countries in order to develop the more sophisticated models. While econometric demand models abound for different energy carriers such as electricity, petroleum, coal or total energy in a country, only a few studies model demand for natural gas for the whole country. Earlier studies in natural gas demand in the developed countries primarily focus on residential demand for gas, since natural gas was primarily used for domestic heating purposes (Bloch 1980). Recently few more demand studies appeared in academic literature, most notably in India (Parikh et al. 2007), but even those were for specific sectors (e.g. natural gas demand in the fertilizer sector). The focus on specific sectors of the economy is not unexpected, since in most countries, natural gas is only a small source in the energy mix and is generally used in specific sectors. However, Erdogdu (2010) is an exception, which attempted to forecast aggregate natural gas demand for Turkey, using an ARIMA model where gas demand is a function of demands in previous periods only.

4.2 Natural Gas Demand Models in Bangladesh

The case of Bangladesh is quite different from most other countries in the world since it is almost solely dependent on natural gas for all of its commercial energy needs. Despite the importance of natural gas, the demand models used to forecast gas demand into the future for planning purposes are fairly elementary in Bangladesh. Most of the studies follow simple trend extrapolation to generate gas demand for future years, while some utilize the even simpler growth rate approach. Wood Mackenzie (2005) estimated sector wise gas demands using econometric models where demand is a direct function of GDP only. Quader and Gomes (2002) project gas demand based on planned capacity expansion of fertilizer and power sector, and lack any theoretical underpinning of demand modeling. On the other hand, Uddin and Ahsan (2004) forecast peak energy (gas) demand for power sector only following a bottom-up approach.

Asaduzzaman and Billah (2008) attempts to develop an econometric model to explain natural gas consumption in four sectors (domestic, fertilizer, industry and power) in Bangladesh, however their model specification is not very useful for policy purposes. For example, their gas demand model for power sector involves a time trend and power demand as explanatory factors. Clearly, generated power cannot be an independent explanatory factor since power demand itself depends on other independent explanatory factors. Also, the relationship between natural gas demand and power production is dictated directly by the technology and an econometric estimation is possibly redundant.

4.3 Proposed Demand Model

Almost all of the natural gas models for Bangladesh, as mentioned above, fail to recognize that demand for energy, like any other normal good, can depend on many external drivers. These can include income of consumers, price of energy goods, environmental factors (e.g. temperature), technological breakthrough, policy changes, changes in the structure of the economy, population growth etc. Among these, income and price have long been identified as the most important parameters. The positive relationship between energy and GDP or income has been well documented in numerous energy studies (Cleveland et al. 2000, Brown et al. 2000, Ayres and Warr 2005, Ayres et al. 2007). The negative impact of price has also been well documented, especially in studies of petroleum demand in the transport sector (Gately and Huntington 2002, Graham and Glaister 2002, Wadud et al. 2010). Because of the lack of information on other demand drivers, energy demand studies in developing countries often use these two variables for explaining the changes in demand (e.g. Ibrahim and Hurst 1990). We also use these two variables in explaining natural gas demand in Bangladesh.

We have a few variations possible about using the gas demand and GDP variables. We can model aggregate gas demand with respect to aggregate GDP. We can also model total gas demand as a function of per capita GDP and population (and price, too). The other option is model per capita gas demand based on per capita GDP. Since aggregate demand is the most important for variable for policy makers for planning purposes, we focus on aggregate demand. We investigate both options of using total GDP and per capita GDP later to find our best model.

Several functional forms are possible for the demand model – linear, log-linear, semilog, translog etc. These functional forms define the mathematical relationship between the demand variables. Since log-linear Cobb-Douglas is the most used functional form for demand modeling, we follow the same one. In such models, the parameter estimates of the explanatory variables directly give the elasticities of demand with respect to those variables. These elasticities are assumed constant. Also, log-linear models better represent the non-linear nature of the variables (Kaboudan and Liu 2004). According to the Cobb-Douglas form, the natural gas demand is given by,

$$Gas = C\,(Price)^{\alpha}\,(GDP)^{\beta}\,[(Population)^{\gamma}] \qquad (1)$$

Taking logarithm of both sides, and considering the error term,

$$\ln Gas_t = \kappa + \alpha \ln Price_t + \beta \ln GDP_t + [\gamma \ln Population_t] + \varepsilon_t \qquad (2)$$

Where,	Gas	= Demand for natural gas at time t
	Price	= Real price of natural gas at time t
	GDP	= Real GDP at time t, expressed in aggregate or per capita basis
	[Population]	= Population at time t, if the variable is present in the model
	$\alpha, \beta, \gamma, \kappa$	= Parameters to be estimated
	ε	= Error term

Another improvement of our demand model over past ones is our specific treatment of the time series nature of the underlying data. Since our data is time series (and so was all previous studies), there is a possibility of serial correlation among the errors. It is also most likely that gas demand does not respond immediately to increases in GDP. This is because significant capital investment may be required to bring in additional supply to meet the demand. There is therefore a lag between demand and the explanatory variables, which cannot be captured by the static models. In order to account for the dynamic time dependent nature of natural gas demand, we use a dynamic model. We opt for a partial adjustment model (lagged dependent variable among the explanatory factors) because of its simplicity. The parameter estimates of a partial adjustment model also have useful interpretations of short-run and long-run elasticities. Our final model is thus:

$$\ln Gas_t = \kappa + \Sigma_i\, \mu_i \ln Gas_{t-i} + \alpha \ln Price_t + \beta \ln GDP_t + [\gamma \ln Population_t] + \varepsilon_t \qquad (3)$$

Where,	μ_i	= parameters to be estimated
	i	= Lag length

Eq. 3 can be consistently and efficiently estimated using the Ordinary Least Squares method. We estimate Eq. 3 for total gas consumption in the country and use those estimates to forecast total natural gas demand in Bangladesh for the next 15 years. In order to understand how natural gas consumption in different end-use sectors have changed over the years, and the relative impact of GDP and price on demand between the end-use sectors, we also attempt to model the demand for specific sectors. We believe sector-wise models could be useful for planning purposes of the individual sectors. The end use sectors we are interested in are the four largest ones in terms of present market share: power, industries, fertilizer and domestic.

5. Data

Time series data for all the relevant variables have been collected from different national and international sources. Yearly prices of natural gas for different sectors are available from Petrobangla's (2009) Annual Report. Natural gas prices in Bangladesh did not directly follow the international market prices, rather the government sets prices from time to time for different consuming sectors. Recently the government approved a pricing formula linked to international price of high sulfur fuel oil (HSFO), although the prices of gas from Petrobangla is still low (only 7% of HSFO, Moncarz and Abeygunawardena 2007). Since the price changes could occur at any time in the year (generally changing from the first day of a month), month weighted average selling price for the year for each end-use sector was used in this study. For average real price of natural gas in the country, sector wise consumption weighted price was computed. Fig. 5 presents the monthly nominal prices of gas for different end use sectors of the economy. Nominal prices were modified using the Consumer Price Index (CPI) to get the real price, which is used for estimation of the model.

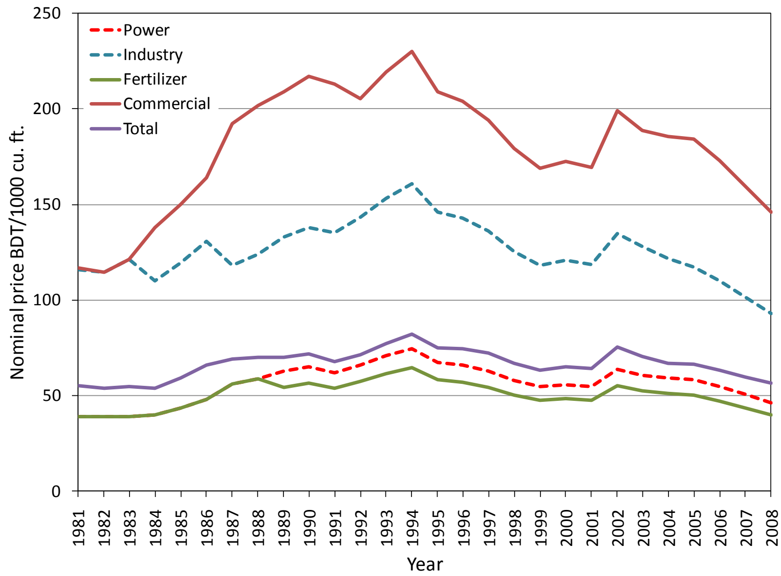

Fig. 5 Nominal prices of gas for different end use sectors and sale-weighted average during 1981-2008 (Data: Petrobangla 2009)

GDP and per capita GDP were used to proxy for per capita income and have been collected from World Development Indicators of the World Bank (2010). Nominal GDP was converted to GDP at year 2000 prices using the GDP deflator index. Information of consumption of natural gas in the different sectors of the economy is available at Petrobangla Annual Report (2009). Note that, although we have data until 2008 from Petrobangla (2009) we used data until 2004 for estimating the demand model for the power sector. This is because of the severe lack of investments in the power sector since then, which meant the power consumption and thus gas demand in that sector was significantly behind the actual demand after that period. For the model specifications with population, we collect the data from BBS (2009). Fig. 6 presents the nominal GDP, GDP per capita and population as time series.

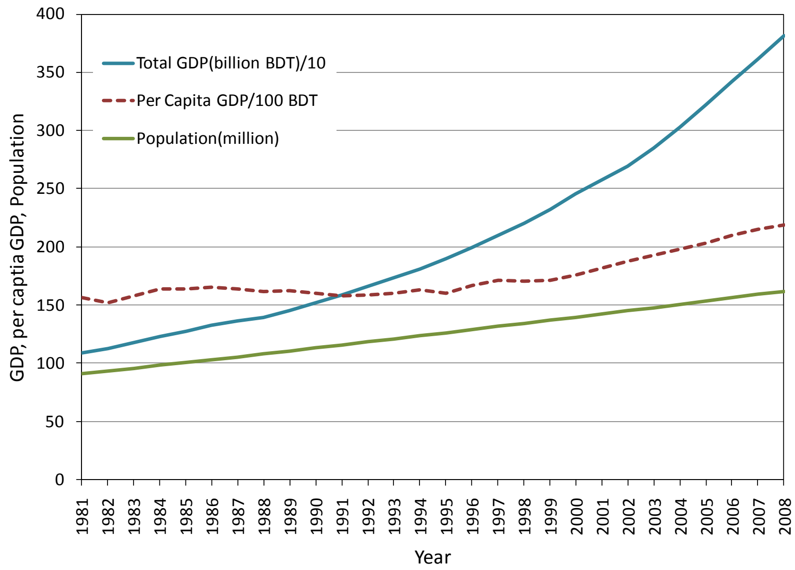

Fig. 6 Nominal GDP, per capita GDP and population during 1981-2008 (Data: BBS 2009)

6. Results

6.1 Specification of the Models

There are potentially two competing models for natural gas demand: one where the explanatory variables contain total GDP (Model A), and other where it contains per capita GDP and population (Model B). Obviously both these variants have other variables such price of gas and lagged consumption, as discussed above. In order to determine the best model, we focus on the model fit diagnostics such as R^2, adj. R^2 or Akaike Information Criteria (AIC). Omitted variables specification tests (RESET test, Ramsey 1969) and residual autocorrelation test (Durbin's h test, Gujarati 2003) also played an important role in discarding some models with high model-fit statistics. Although our primary objective is forecasting, we cannot use the ex-post prediction criterion tests since all of those tests require dividing the sample into half, which would have greatly reduced our already small sample size. On the other hand, the ex-ante prediction tests compare the predictive capability of the models with respect to a random walk or some other user defined values (Yaffee 2010), which we do not feel is appropriate in the current context.

All aggregate and power sector gas demand models with two lags of dependent variables in the specification (i.e. i=2 in Eq. 3) fails the omitted variable or serial autocorrelation tests. For these models, we can either reject the null hypothesis that the model specification has no omitted variables or reject that the model residuals are not serially correlated. However, for demand in the industrial sector, two lags perform well for both Models A and B.

For total gas demand, both the model specifications (Models A and B) perform well, i.e. there is no serial correlation or omitted variable bias. Model fit statistics for Models A and B are also similar (adj. R^2=0.998 for both, AIC -111.5 and -110.4, Table 1), with Model A marginally better than Model B using AIC. Both these models have a single lag of the dependent variable in the specification.

For industrial gas demand, single lag of the dependent variable is rejected due to serial correlation in the residuals for both Models A and B, although two lags work well for both. Once again, the adj. R^2 are identical (0.991, Table 1). AICs are also similar (-64.3 and -62.6), although Model A performs marginally better. As mentioned earlier, for power sector we use a smaller sample up to year 2004, with a single lag of the dependent variable. Model A passes the specification tests, while for Model B we find serial correlation among the residuals through Durbin's h test. However, the parameter estimates for Model A are a doubt, especially for the impact of GDP, encouraging us to search for a third alternate specification. We find that Model B, sans Population (we call it Model C) provides a marginally better model fit than either of Model A or B (AIC -75.5 vs. -71.7 and -73.9). Therefore we choose Model C as the preferred specification for natural gas consumption in the power sector.

For the fertilizer and domestic sectors, we could not find any model specification that fits the data well. This is not surprising since demand for fertilizer, and thus demand for gas in the fertilizer industry does not directly depend on GDP, rather depends on agricultural production. Although agricultural GDP increased during the period, and there was an increase in demand for fertilizers over the years, the government opted to import fertilizer instead of increasing local production capacity ever since production has peaked in the mid 1990s. Natural gas demand for fertilizer factories therefore remained stagnant. The demand for fertilizer sector is therefore directly linked with the government decision of whether to invest on new fertilizer factories or to import fertilizer, and thus difficult to model using a time-series econometric model. Therefore, even after using agricultural GDP as an explanatory variable, we could not estimate a plausible model that fits the data reasonably well.

Table 1. Parameter estimates and model diagnostics for gas demand (variables in logarithm, t-stats in parentheses)

	National demand		Power sector demand			Industry demand	
	Model A	Model B	Model A	Model B	Model C	Model A	Model B
Parameter estimates							
Total GDP	0.330** (2.44)	-	0.021 (-0.10)	-	-	0.750** (4.81)	-
Per capita GDP	-	0.276* (1.89)	-	0.574* (1.80)	0.575* (1.84)	-	0.760* (1.83)
Population	-	0.723 (1.64)	-	-0.267 (-0.57)	-	-	1.428** (3.86)
Price	0.148 (1.33)	0.133 (1.30)	-0.254 (-1.61)	-0.133 (-0.88)	-0.079 (-0.69)	-0.159 (-1.30)	-0.181 (-0.93)
Lag 1 of independent variable	0.775** (9.90)	0.739** (6.52)	0.989** (9.13)	0.972** (8.25)	0.910** (21.79)	1.340** (10.01)	1.330** (9.72)
Lag 2 of independent variable	-	-	-	-	-	-0.765** (-5.95)	-0.800** (-6.00)
Constant	-8.688** (-2.25)	-15.265* (-1.91)	1.774 (0.30)	0.163 (0.02)	-4.764 (-1.47)	-19.066** (-4.72)	-31.636** (-4.71)
Specification diagnostics							
Adj. R^2	0.998	0.998	0.995	0.996	0.996	0.991	0.991
AIC	-111.48	-110.41	-71.69	-73.86	-75.45	-64.25	-62.64
RESET test p-value (null: no omitted variable)	0.16	0.33	0.10	0.37	0.59	0.38	0.11
Durbin's h test p-value (null: no autocorrelation)	0.32	0.52	0.31	0.04	0.19	0.85	0.69
N	27	27	23	23	23	26	26

* statistically significant at 90% confidence, ** statistically significant at 95% confidence,

Domestic household sector offers difficulty during modeling. In Bangladesh, the gas price is fixed in the domestic sector based on the number of burners used in the household (gas is used for cooking only, there is no space heating requirements). Since it is a fixed cost that everyone (with a connection) has to pay, with no limit on usage, there is no rational reason for demand to change according to the price. Similarly changes in GDP or even household income have little impact on consumption, because income is not a constraint in consuming natural gas for household use, rather consumption is simply dictated by availability of gas pipeline in a city.

6.2 Parameter and Elasticity Estimates

Table 1 already presents the parameter estimates for the valid models. Since the variables are in logarithms, the parameter estimates directly represents the short-run elasticities. Clearly, gas demand in the national level increases with an increase in income, whether expressed through total GDP or GDP per capita. We find that a 1% increase in GDP increases aggregate demand for natural gas by 0.33% in the short run and 1.47% in the long run for Model A. There are numerous studies in energy demand literature which suggested a positive relationship between GDP and energy demand, therefore our results are consistent with those in the literature.

The impact of price is statistically not different from zero, which is counter-intuitive. Economic theory dictates that the demand for a normal good has a negative correlation with price. We believe our price elasticity is statistically insignificant because of two reasons. Firstly, the price is already very low, therefore consumers are not sensitive to any changes around this very low level. Secondly, there is a large suppressed demand for energy in Bangladesh, which again implies that consumers are less concerned about the price and are more inclined to increase consumption. There is indeed a large suppressed demand in the country as evident from the denial of new gas pipeline connections for households for more than a year. Our demand model therefore represents a 'constrained' demand.

For Model B, we find that the parameter estimate for population is statistically not different from zero, even at a liberal 90% confidence level. This is possibly not surprising in the light of above discussion: there is already a large suppressed demand, therefore increases in population does not directly increase consumption or demand. Note also that population and per capita GDP are highly correlated (r=0.886), making multicollinearity a possibility and the results from Model B less reliable.

Power sector consumption of gas also increases with GDP, but the response is larger than total gas consumption. A 1% increase in GDP increases the gas consumption in the power sector by 0.58% in the short run and around 6.3% in the long run while the impact of price or population is statistically insignificant (Model C). The very high long run elasticity makes these results a suspect. Also, the close-to-unity parameter estimate for lagged power consumption raises concern about non-stationary nature of the data.[1]

Industrial sector also shows similar findings, with a short run income elasticity of 0.76 and long run elasticity of 1.76 for Model A. This indicates that the demand for natural gas in industrial

[1] Preliminary unit root tests marginally rejects the possibility of non-stationary data.

applications increases more than that for national aggregate demand. This is possibly because of the increasing importance of the industrial sector to the GDP. Once again, the impact of price is not significantly different from zero.

6.3 Forecast for Natural Gas Demand

Our primary objective is to forecast natural gas demand in Bangladesh until 2025. While our dynamic econometric model derives a relationship between GDP and natural gas demand, statistically speaking, the results show only an 'association' between the variables, and not a 'causality', i.e. we cannot tell from our results whether increases in energy demand increased GDP or increases in GDP increases energy demand. The direction of causality is important, since if GDP is dependent on natural gas demand, then our model should not be used for forecasting natural gas demand.

The direction of causality between energy consumption and output (GDP) is possibly one of the most researched areas in energy economics. As such, evidence of all four possible relationships (energy causes GDP, GDP causes energy demand, each causes the other, neither causes the other) is available in the literature. Instead of investigating the issue ourselves, we utilize existing literature to guide the direction of causality. Mazumder and Marathe (2007) reveals that output (GDP) fluctuations cause electricity demand fluctuations in Bangladesh. Recently, Paul and Uddin (2010) also reports that GDP drives energy demand in Bangladesh. These two findings indicate that our model, which is based on the assumption that GDP causes natural gas demand, is correct and can be used for forecasting.

In order to determine the forecast for natural gas demand in Bangladesh, we need to know the values of the independent variables into the future. We assume that there will be no changes in real prices of natural gas over the forecast period. Such an assumption can always be called into question, especially since there is an increasing likelihood that oil prices, and accordingly natural gas prices, can increase in the near future.[2] Our econometric modeling results, however, tell us that small changes in price are not likely to affect natural gas demand significantly.[3] Rising oil prices, however, can have significant impact on the GDP growth of the country and thus indirectly, but significantly, affect natural gas demand (which we consider later as a low growth scenario).

[2] Japan's increasing demand for LNG since the earthquake can also put pressure on natural gas prices.

[3] Note that for any large increases in price (or GDP), these types of econometric demand models may not be appropriate for forecasting.

Real GDP growth for year 2009 and 2010 were 5.9% and 5.5% respectively, whereas for year 2011, it is projected to be 6.3% (ADB 2010). We assume for the rest of the forecast period the real GDP growth rate will be 6.5% per year. Considering Bangladesh's economic performance in the years prior to global recession, and India and China's very high growth rates, a 6.5% real GDP growth rate appear entirely plausible. As a sensitivity study, we also run a forecast assuming the real GDP growth rate keeps on increasing by 0.1% every year from 2011, reaching 9% in 2017 and remaining at 9% since then. Although we call it a high-growth scenario, this is also perfectly plausible: many socio-economic studies in Bangladesh currently assume a real GDP growth rate as high as 8% as alternate scenarios (Bhattacharya and Deb 2006). In addition, the Government of Bangladesh has recently set a target of a GDP growth of 10% by 2017. We also model a low growth scenario (4.5% annually), which can result from a sustained period of a high oil prices in the international market, as mentioned earlier. Using our GDP growth rates and considering the dependence on lagged values we forecast natural gas demand for the whole country in Fig. 7 for Model A.

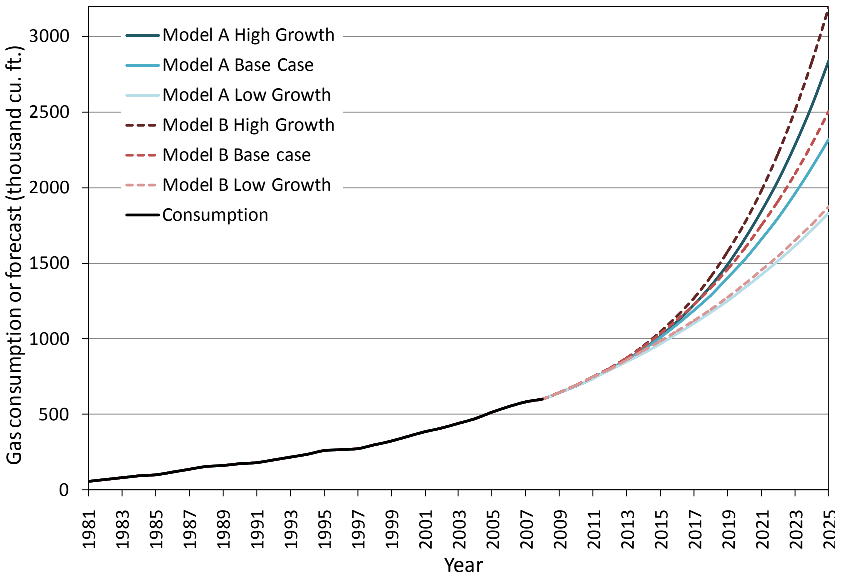

Fig 7. Forecast natural gas demand for two models A and B, using three growth scenarios.

For Model B, we require a population growth rate and per capita real GDP growth rate. We assume a population growth rate of 1.8%, in keeping with the past decade. We derive the per capita GDP growth rate such that total real GDP growth rates in the three scenarios remain the same as above. Forecast results are presented in Fig. 7.

The forecast national demand shows a very high growth, as is expected from the high income elasticity estimates earlier. This indicates that Bangladesh is currently at a state of development where energy demand will rise rapidly in the next decades. The pattern is consistent with the logistic growth (S-curve) hypothesis that energy demand increases slowly in the beginning, when income is low, it rises rapidly during the development stage, and then again increases slowly when the income is similar to those in the developed countries. Bangladesh has been growing rapidly for the past few years, and our results show that it has possibly reached the phase where energy demand grows more rapidly than before (the 'take-off' phase of an S-curve). This also indicates a possible structural shift in the economy and energy demand in the next decade.

6.4 Discussion and Comparison of Results

The long-run income elasticity of natural gas demand in Bangladesh is 1.47. This is on the higher side of the energy demand literature. Especially in the developed countries the income elasticity of energy demand seldom exceeds unity: Gately and Huntington (2002) found it to be around 0.55, while van Benthem and Romani (2009) report 0.61 to 0.65. However, in developing countries the income elasticity tends to be larger than those in the developed countries (van Benthem 2010, Gately and Huntington 2002). Akinlo (2008) also found income elasticity in some African countries to be larger than unity. Our results are therefore consistent with those in the literature.

In Fig. 8, we compare our national level forecast (Model A) with the forecasts from Wood Mackenzie (2005) and ADB (Moncarz and Abeygunawardena 2007). The ADB report uses the demand estimates from ECON (2004), who produces two forecasts: one for low growth scenario and another for high growth scenario. The demand projection methods were not available. Petrobangla uses the modified Wood Mackenzie forecasts, available until year 2020, as their official projections. We also compare the forecast values with a naïve linear trend extrapolation.

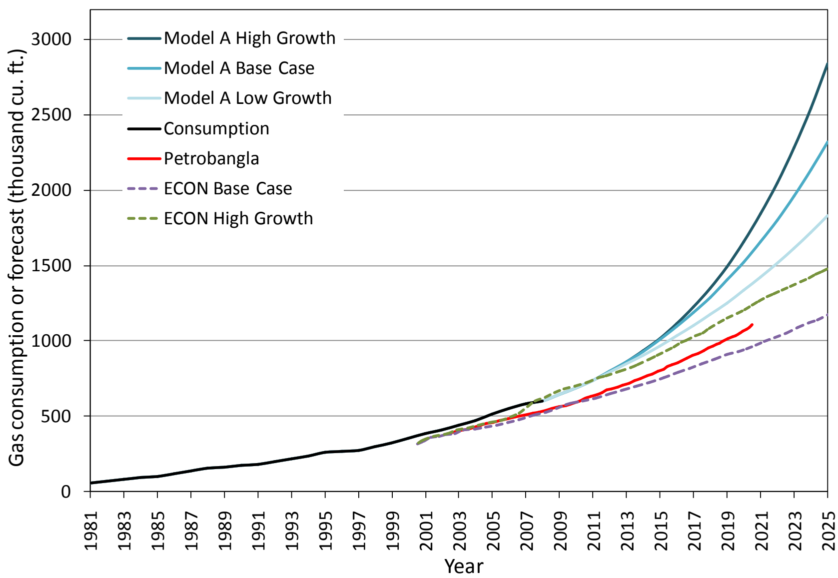

Fig 8. Comparison of natural gas demand forecast with forecast by other agencies

Results show that previous estimates are significantly smaller than our forecast demand for natural gas in Bangladesh in future. The Petrobangla/Wood Mackenzie (2005) estimate for year 2020 is smaller by around 30% from our base case predictions, and by 20% from our low growth case- the difference is even larger for the high growth case. The 'high growth' scenario of ADB/ECON come the closest to any of our year 2025 forecast, but it still is smaller by 36% from our base case projections. ADB/ECON low growth forecasts are smaller by 36% from our low growth projections of year 2025. Clearly, at a higher GDP growth rate scenario, the demand for natural gas will diverge even further from the previous predictions. The large divergence of our model results from previous forecasts is due to our specific attention to the dynamic aspect of the model (previous models are static), and larger but more plausible GDP growths assumptions. The large growth in energy demand also indicates a possible structural shift in the economy in the next decade, which was not captured in the previous models.

7. Summary and Policy Implications

Natural gas is the most important indigenous energy resource in Bangladesh. For development planning of the natural gas sector it is necessary to understand the evolution of gas demand in future. We used a dynamic econometric model to determine natural gas demand in Bangladesh, both in the national level and for two end-use sectors.

Our model allows us some interesting insight that can be useful to the policymakers. The statistically insignificant response of natural gas consumption with respect to changes in prices and population, both nationally and for individual sectors, indicate the reality of a large suppressed demand within the country. This indicates that our energy demand model and forecast results are not 'true' demand for natural gas, but represent only the lower bound of the demand. Actual demand will therefore continuously outstrip the forecast values. However, if the past investment and policy scenario continues, natural gas demand will possibly follow the forecast path in this study.

Price response was almost non-existent in our results, therefore, there is a significant opportunity for the policymakers to raise the prices with little deadweight welfare losses in a partial equilibrium framework.[4] At present, there is a severe lack of investment from the Government in the natural gas sector, which aggravates the energy supply crisis in Bangladesh. Increasing natural gas prices to reflect the prices of alternate fuels (which are higher) will not only reduce the distortions and

[4] Note that, there could still be large general equilibrium effects.

associated losses in the economy, but also generate potential revenue to encourage investment in the sector.

We found a rather large long run response in natural gas demand with respect to GDP/income. Using our econometric model, we also derive forecasts for natural gas consumption in Bangladesh. Our forecasts are significantly larger than the previous demand projections made by multinational agencies, but are more likely considering Bangladesh's high GDP growth rate in the next decade. The difference in the forecast demands can be important for future capacity expansion plans, and plans based on the low forecasts could hamper economic growth in future. It is therefore important for the policymakers to adopt advanced modeling tools to project future natural gas and energy demand in the country in order to ensure efficient allocation of resources in the energy sector.

References

Akinlo AE 2008. Energy Consumption and Economic Growth: Evidence from 11 Sub-Sahara African Countries. Energy Economics 30, 2391-2400

Asaduzzaman M and Billah AHMM 2008. Energy for the future, in Centre for Policy Dialogue, Emerging Issues in Bangladesh Economy: A Review of Bangladesh's Development 2005-2006, University Press Limited, Dhaka.

Asian Development Bank 2009. Asian Development Bank and Bangladesh: Fact Sheet. Asian Development Board, Philippines

Asian Development Bank 2010. Asian Development Outlook 2010: Macroeconomic Management Beyond the Crisis. Asian Development Bank, Philippines

Ayres RU and Warr B 2005. Accounting for growth: the role of physical work. Structural Change and Economic Dynamics 16, 181-209

Ayres RU, Turton H and Casten T 2007. Energy efficiency, Sustainability and Economic Growth. Energy 32, 634–648.

Bangladesh Bureau of Statistics 2009. Statistical Yearbook of Bangladesh 2008. Bangladesh Bureau of Statistics, Agargaon

Bangladesh Power Development Board 2007. Annual Report 2006-07. Bangladesh Power Development Board, Dhaka

Bhattacharya D and Deb UK 2006. Bangladesh 2020: An Analysis of Growth Prospect and External Sector Behaviour. Paper No. 56, Centre for Policy Dialogue, Dhaka

Bhattacharyya SC and Timilsina GR 2009. Energy Demand Models for Policy Formulation: A Comparative Study of Energy Demand Models. Policy Research Working Paper 4866, The World Bank

Bloch FE 1980. Residential Demand for Natural Gas. Journal of Urban Economics 7, 371-383

Brown MA, Levine MD, Short W, 2000. Scenarios for a clean energy future. Inter laboratory Working Group on Energy-Efficient and Clean-Energy Technologies. Prepared for Office of Energy Efficiency and Renewable Energy, US Department of Energy. Available from /www.nrel.gov/docs/fy01osti/29379.pdfS

Cleveland C, Kaufmann RK and Stern DI 2000. Aggregation and the role of energy in the economy. Ecological Economics 32, 301–317.

ECON Analysis AS and de Besche A 2004. Bangladesh Optimal Gas Utilization Study (Phase ii). Norwegian Petroleum Directorate.

Erdogdu E 2009. Natural Gas Demand in Turkey. Applied Energy, Vol. 87, pp. 211-219.

Gately D and Huntington 2002. The Asymmetric Effects of Changes in Price and Income on Energy and Oil Demand. The Energy Journal 23(1), 19-55

Geem ZW and Roper WE 2009. Energy demand estimation of South Korea using artificial neural network. Energy Policy 37, 4049-4054.

Graham DJ and Glaister S 2002. The demand for automobile fuel: A survey of elasticities. Journal of Transport Economics and Policy 36 (1), 1-26.

Gujarati D N 2003. Basic Econometrics.4th edition, published by Mcgraw-Hill.

Hossain AK, Badr O 2007. Prospects of renewable energy utilization for electricity generation in Bangladesh. Renewable and Sustainable Energy Reviews 11, 1617-1649.

Ibrahim IB and Hurst C 1990. Estimating energy and oil demand functions. Energy Economics 13, 93-102.

Islam A K M S, Islam M, Rahman T 2006. Effective renewable energy activities in Bangladesh. Renewable Energy, Vol. 31, pp. 677-688

Islam M R, Islam M R, Beg M R A 2008. Renewable energy sources and technology practice in Bangladesh. Renewable and Sustainable Energy Reviews, Vol. 12, pp. 299-343.

Jebaraj S, Iniyan S 2006. A Review of Energy Models. Renewable and Sustainable Energy Reviews, Vol. 10, pp. 281-311.

Kaboudan MA and Liu QW 2004. Forecasting quarterly US demand for natural gas. Information Technology for Economics and Management 2(1), paper no. 4, available at: http://www.item.woiz.polsl.pl/issue2.1/journal2.1.htm

Liang QM, Fan Y and Wei YM 2007. Multi-Regional Input-Output Model for Regional Energy Requirements and CO_2 Emissions in China, Energy Policy 35(3), 1685-1700

Miah MD, Kabir RRMS, Koike M, Akther S, Shin MY 2010. Rural household energy consumption pattern in the disregarded villages of Bangladesh. Energy Policy, Vol. 38, pp. 997-1003.

Ministry of Power, Energy and Mineral Resources 2008. National Energy Policy, Draft report, Dhaka

Ministry of Power, Energy and Mineral Resources 2008. Renewable energy policy 2008. Power Division, Dhaka

Moncarz PD and Abeygunawardena P 2007. Bangladesh Gas Sector: Issues, Option and the Way Forward. Asian Development Bank, Philippines

Mozumder P and Marathe A 2007. Causality Relationship between Electricity Consumption and GDP in Bangladesh. Energy Policy 35, 395-402

Nasr GE, Badr EA and Joun C 2003. Backpropagation neural networks for modeling gasoline consumption. Energy Conversion and Management 44, 893-904

Parikh J, Purohit P and Maitra P 2007. Demand Projections of Petroleum Products and Natural Gas in India. Energy 32, 1825-1837

Paul BP and Uddin GS 2010. Energy and Output Dynamics in Bangladesh. Energy Economics (in press), doi: 10.1016/j.eneco.2010.11.011

Petrobangla 2008. Annual Report 2007. Bangladesh Oil, Gas and Mineral Corporation, Dhaka

Petrobangla 2009. Annual Report 2008. Bangladesh Oil, Gas and Mineral Corporation, Dhaka

Quader AKMA and Gomes E 2002. An Exploratory Review of Bangladesh Gas Sector: Latest Evidence and Areas of Further Research. Occasional Paper Series, Paper No. 17, Centre for Policy Dialogue, Bangladesh

Ramsey JB 1969. Tests for Specification Errors in Classical Linear Least-Squares Regression Analysis. Journal of the Royal Statistical Society, Series B (Methodological) 31(2), 350-371.

Shell 2008. Shell Energy Scenarios to 2050. Shell International BV, the Netherlands

Uddin M, Ahsan Q 2004. Expected status of natural gas in Bangladesh in meeting the electricity demand in the next twenty five years. 3rd International Conference on Electrical and Computer Engineering ICECE 2004, 28-30 December, Dhaka, Bangladesh.

United Nations Development Programme 2010. Human Development Report 2010: The Real Wealth of Nations, Pathways to Human Development, 20th Anniversary Edition. Palgrave

Urban F, Benders RMJ and Moll HC 2007. Modeling Energy Systems for Developing Countries, Energy Policy 35, 3473-3482

US Energy Information Administration 2010 [online]. Country Analysis Brief-Bangladesh. Available at www.eia.doe.gov

van Benthem A and Romani M 2009. Fuelling Growth: What Drives Energy Demand in Developing Countries? The Energy Journal 30(3), 91-114

Wadud Z, Graham DJ and Noland RB 2010. Gasoline Demand with Heterogeneity in Household Responses. The Energy Journal 31(1), 47-73

Wood Mackenzie 2005. Preparation of Gas Sector Master Plan Revised Interim Report.

World Bank 2010 [online]. World Development Indicators 2010. Available at http://data.worldbank.org/indicator

Yaffee RA 2010. Forecast Evaluation with Stata, United Kingdom Stata Users Group Conference, London