Bangladesh Journal of Political Economy

Vol. 31, No. 1, June 2015, pp. 369-395
Bangladesh Economic Association
(ISSN 2227-3182)

Impact of Gas Price Hikes on Bangladesh Economy: A Dynamic Stochastic General Equilibrium Analysis

SAKIB BIN AMIN*

Abstract *A great deal of energy literature has highlighted the fact that energy price shocks can significantly affect the economy by upsetting consumption spending in different sectors.However, the existing literature on Dynamic Stochastic General Equilibrium (DSGE) model mainly uses energy on the aggregate production side only. This paper constructs a DSGE model with energy which is calibrated for Bangladesh economy to analyze the role of Gas price shock on her economy and to investigate the robustness of the existing findings.Our model incudes household consumption of energy along with non-energy oriented consumption and service consumption in the utility function in addition to energy use at the firm level in industry and service sector. This model further includes endogenous electricity generating production function where electricity is produced locally using Natural Gas.One of the main assumptions of this model is that all the economic agents rely on energy either for household energy consumption of for production of various goods. Consequently, the model allows the analysis how the effects of Gas price changes are transmitted in the Bangladesh economy. Simulation results indicate that gas price shocks has negative impact on household consumption, sectoral production and therefore on household welfare in Bangladesh.*

1. Introduction

The effects of energy price changes on economic activity have been widely studied in last two decades. In principle, an increase of energy prices tends to

* Senior Lecturer (On Study Leave), North South University, Dhaka, Bangladesh, Email:sakibamin@yahoo.com

reduce the level of economic activity, given its implications on the evaluation of important macroeconomic variables (Miguel, Manzano and Moreno, 2005). The overall intuition concerning energy is that even though it does not make up a significant fraction of the value of production inputs, or of GDP, the role of energy in production is however central, since without energy nothing would be produced. The role of energy is also important for the consumers as many kinds of household products are energy dependent.

Recently, Dynamic Stochastic General Equilibrium (DSGE) model has become a standard research instrument in investigating economic fluctuations. In modern macroeconomics, the economy is described as a Dynamic General Equilibrium (DGE) system that reflects the collective decisions of rational individuals over a range of variables that relate to both the present and the future (Wickens, 2008). These individual decisions are then synchronized through the markets system to produce the macro economy. The main advantage of DSGE analysis is that one could isolate the impacts of different exogenous shocks and explain some policy related experiments. For example, Kim and Loungani (1992) examined the impact of energy price's volatility in the variability of output and supported the views of macroeconomists who downplay the impact of energy shocks on the economy. Recently, Dhawan and Jeske (2007) extended Kim and Loungani's model to include a distinction between investment in consumer durables and capital goods, as well as energy use by the households and revealed that energy price shocks are not a major source for economic fluctuations. Consequently, productivity shocks continue to be the driving force behind output fluctuations.

Rotemberg and Woodford (1996) argued for an imperfect competition so as to supplement the negative impact of oil price increases to match their empirical estimations. Finn (2000), however, countered that impact of negative energy price on economy could also be explained if one augment with variable utilization and variable depreciation of productive capital. Miguel, Manzano and Moreno (2005) showed that oil price shocks could account for a significant percentage of GDP fluctuations in many European countries. Tan (2012) also confirmed that negative role of energy price on the economy which has multiple sectors where energy is exogenously produced.Alves and Pereira (2006) survey the literature on dynamic computational models with a focus on energy studies and reports their special features to identify and analyze the main areas of investigation in general equilibrium models applied to the environment and energy and to systematize and classify the most recent existing bibliography in a survey (from the last ten years), since there are many surveys on previous literature already listed in Bhattacharya (1996).

The measure of growth in the developing countries like Bangladesh is synonymous with the level of energy usage as it is used in some form almost in every activity. Bangladesh also considers energy as a pre requisite for her technological, societal and economic growth.The term “Energy” in this paper is used mainly to represent Electricity. The market for electricity includes households, agriculture, industries, and transport. In Bangladesh, about 60 percent of the population currently has access to electricity. The remaining 40 percent represents the market yet to be brought under the national grid. The present generation capacity of 8005 MW cannot be realized to its fullest due to the events of forced outage, maintenance activities and particularly fuel constraints i.e. gas supply shortage.Households and industry are the two biggest consumers of electricity. The domestic sector accounts for 45 per cent of retail sales while the industry sector consumes around 35 per cent of the total. According to BPDB the per capita electricity of Bangladesh now is at 292 KWH/capita as of December 2012.

Generating and supplying enough electricity for demand remains an unresolved challenge for Bangladesh.Significant efforts aimed at adding new generation capacities characterized the power sector of Bangladesh in recent years.The addition in installed capacity is not reflected in terms of proportional increase in power generation. There are many factors that contribute to the difference between the installed capacity and the maximum available generation (derated capacity). For example, some plants may remain out of operation for maintenance, rehabilitation and overhauling, and the capacity of some plants may be derated due to aging. However, the shortage of natural gas, which is the major fuel used for electricity generation, is the most important factor for low-capacity utilization in Bangladesh. Although the fuel mixes for electricity generation has reshaped since 2008, still the share of gas to generate electricity represents 64.5 percent in 2013. In 2010, due to shortage of gas supply approximately 500-800 MW electricity could not be produced. This is obvious that any adverse shock on gas price could have been a large negative impact on Bangladesh economy.

The common features in all of the models in the existing literature are that energy prices are taken as exogenous stochastic process and energy is considered in the production function. However, the importance of energy in the household’s utility function remains unattended. As far as we have been concerned, no researcher has calibrated a DSGE model with natural gas as energy for Bangladesh economy to investigate the interactions between energy price shock and overall economy.

In light of these limitations, this paper presents a standard DSGE model with energy for the Bangladesh economy which has become a standard tool in quantitative economics. The basic building blocks of the model are standard in the literature.Our dynamic model incorporates households, production sector, government sector and an energy sector. In addition we distinguish the production sector between industrial and service production sector; household consumption in between energy consumption, non-energy consumption and service consumption.

The main goal of this paper is to explore to what extent movements in gas prices can affect Bangladesh economy. We first calibrate parameters using data from Bangladesh and solve the model for steady state conditions. Then we examine how the fluctuations of key economic variables are explained by the exogenous shocks by means of Impulse Response Functions (IRFs) which yield useful qualitative and quantitative information. Our results reveal thatgas price shocks has negative impact on household consumption, sectoral production and therefore on household welfare in Bangladesh.

The paper is organized as follows. The dynamic general equilibrium model is presented in section 2; calibration and estimation of the parameters are discussed in section 3. The results are analyzed in the section 4. Finally, in the last section, we present the conclusions.

2. The Model

The model considered in this paper is a Dynamic Stochastic General Equilibrium (DSGE) model of a small closed economy populated by a large number of infinite lived households. There are four sectors in the economy- the production sector, the household sector, the energy sector and the government sector. The energy firm uses gas to generate electricity. All four sectors are interconnected through competitive market equilibrium conditions and all markets are assumed to clear. However, government needs to intervene in the market and fix the electricity price faced by the public electricity generating company to clear the energy market. Economic agents are price takers in all markets and are assumed to have perfect foresight. Shocks in the price of gas and technology across the sectors are main sources of fluctuation in the economy. The basic structure of the model in terms of technology is similar in its set up to Kim and Loungani (1992). Energy enters in the model as consumption good for households and as a productive input for firms in the form of electricity. The main differences of this model are the presence of two different production sectors and endogenous electricity generating firm which has not been experimented in the literature till now. We now turn to the discussion of the details of the model which are presented in Table 1.

The Production Sector

There are three production sectors in the model: a service sector and an industrial sector where final goods are being produced using electricity as an additional productive input which is produced in the third sector, the energy sector. Final output in each sector is produced with a Cobb Douglas (CD) technology, exhibiting constant returns to scale in the inputs-labour, capital and electricity in the industry and service sector.

The representative firm use labour (l), capital (k) and electricity (e) to produce the final good of the respective sector. The production technology of the firms is described by a CD function with constant returns to scale:

$$F_i \quad l_{i,t}, k_{i,t}, e_{i,t} \quad A_t^i l_{i,t}^{\alpha_i} k_{H,t}^{\psi_i} j_t^{1-\alpha_i-\psi_i}$$

Where, i= respective sectors, j= electricity used by respective sectors. Alpha, α is the labour share, Psi, Ψ represents the capital share. The share of electricity is defined by (1- α- Ψ)

All the firms except Government operate under perfect competition maximizes profits as following:

$$\text{Max } \pi_{i,t} = P^i . A_t^i l_{i,t}^{\alpha_i} k_{H,t}^{\psi_i} j_t^{1-\alpha_i-\psi_i} - rk_i - wl_i - v^j . j$$

Where w is the wage rate, r is the interest rate and v is the market price of electricity. The price of the final good is normalized to one, thus v^j can be considered as the relative electricity price.

From firm's maximization problem, we obtain the following equilibrium conditions which state that the marginal productivity of labour, capital and electricity are equal to the wage, the interest rate and the electricity price respectively.

$$W_t = \frac{\partial F(l_t k_t, e_t)}{\partial l_t}$$

$$r_t = \frac{\partial F(l_t k_t, e_t)}{\partial k_t}$$

$$F_i$$

Wage and interest rate are assumed to be equalized across all the sectors. Firms will make zero profit in each period t due to the constant returns to scale assumption, in other words, π_t = o for all t.

On the other hand, Government faces the following cost minimization function:

$$c_G = wl_G + rk_G + v^m.m_{G,t} - P^G.A_t^G l_{G,t}^{\alpha_G} k_{G,t}^{\psi_G} m_{G,t}^{1-\alpha_G-\psi_G}$$

The Household

In the model economy there are an infinite number of identical households and the representative household maximizes the expected value of future utility. The household gets utility from consuming three types of consumption goods: electricity oriented goods (e), non-electricity oriented goods (c) and service goods. The household uses the following aggregator function to combine these three types of consumption into Consumption Aggregator:

$$c_t^A = X_t^\gamma\left(\theta c_t^\rho + (1-\theta)e_t^\rho\right)^{\frac{1-\gamma}{\rho}}$$

Where θ ε (0, 1) and. $\rho \leq 1$ With this aggregation function, the elasticity of substitution between c and e is $\frac{1}{1-\rho}$ and θ is the share of non-electricity oriented consumption in the household aggregator. The elasticity of substitution between services and the composite of energy and non-electricity consumption is one in our model. The parameter γ represents the share of service consumption in the consumption aggregator. This is similar to the aggregator function used by Dhawan and Jeske (2007), who include consumption of nondurables and services excluding energy, the flow of services from the stock of durables goods and energy goods. So, we write the period t utility function as follows:

$$U(c_t^A, l_t) = \varphi \log c_t^A + (1-\varphi)\log(1-l_t)$$

Where θ ε (0, 1). This log-utility specification is the same as in Kim and Loungani (1992). Notice that household's endowment of time is normalized to 1 so that leisure is equal to 1-l.

The momentary utility function is assumed to have the usual properties of monotonicity and quasi concavity. The household has three primary sources of income: 1) the income derived from selling capital stock, 2) Labour income and 3) The lump sum transfer payment ъ, it receives from the government. Capital and labour income are taxed at the rates τ^k *and* τ^l respectively.

The representative household also accumulates capital according to the law of motion:

$$k_{t+1} = (1-\delta)k_t + I_t$$

Where δ is the depreciate rate and I is the investment. Thus, the representative household maximizes expected utility subject to the following resource constraint:

$$\text{Max E} \sum_{t=0}^{\infty} \beta^t \varphi \log\left[X_t^{\gamma}\left(\theta c_t^{\rho} + (1-\theta)e_t^{\rho}\right)^{\frac{1-\gamma}{\rho}}\right] + (1-\varphi)\log(1-l_t)$$

Subject to

$$k_{t+1} + c_t + nX_t + q_t^e.e_t = (1-\tau^l)wl_t + ъ + (1-\tau^k)rk_t + (1-\delta)k_t$$

Where β^t is the discount factor.

The Lagrangian constrained for the household can be defined as follows:

$$L = \sum_{t=0}^{\infty} \beta^t[(\varphi \log\left[X_t^{\gamma}\left(\theta c_t^{\rho} + (1-\theta)e_t^{\rho}\right)^{\frac{1-\gamma}{\rho}}\right]) + (1-\varphi)\log(1-l_t)] - \lambda_t[k_{t+1} + c_t + nX_t + q_t^e.e_t - (1-\tau^l)wl_t - ъ - (1-\tau^k)rk_t - (1-\delta)k_t$$

Where λ_t is the Lagrange multiplier and the function is maximized with respect to c_t, k_{t+1}, e_t, l_t, X_t and λ_t.

The subsequent Euler equations are as follows:

The Euler equation interprets that the marginal disutility of reducing consumption in current period should be equal to the discounted utility from future consumption. The Euler equation in relation to leisure interprets that the disutility from additional working hour should be compensated by an increase in utility due to producing extra output.

$$\frac{c_{t+1}}{c_t} = \beta[(1-\tau^k)r_{t+1} + (1-\delta)]\frac{1 + (\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}.q_t^{e\frac{\rho}{\rho-1}}}{1 + (\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}.q_{t+1}^{e\frac{\rho}{\rho-1}}}$$

$$\frac{c_t}{1-l_t} = \frac{\varphi(1-\gamma)}{(1-\varphi)}.\frac{1}{1 + (\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}(q_t^e)^{\frac{\rho}{\rho-1}}}.w(1-\tau^l)$$

The Government

The government earns revenue from taxing labour income, capital income and selling electricity to the national grid. On the expenditure sides, the government purchases labour, capital and make a lump sum transfer to households. Capital taxes in the model are raised on asset returns of household and not on capital stock in the production sector as mentioned by Glomm and Ravikumar (1997, 1998). The government, like any other entity in the economy, must satisfy a budget constraint.

$$\tau^l.w.l + \tau^k.r.k + P^G A_t^G l_{G,t}^{\alpha_G} k_{G,t}^{\psi_G} m_{G,t}^{1-\alpha_G-\psi_G} - rk_G - wl_G - ъ = b$$

The IEA defines subsidy that lower the price consumers pay for oil products, natural gas, coal or electricity generated with one of those fuels. In this paper, we assume that government has to provide subsidy as it purchases electricity from the electricity producers at a high price and distributes it at a low price among the consumers. So, the total subsidy is:

$$b = P^G A_t^G l_{G,t}^{\alpha_G} k_{G,t}^{\psi_G} m_{G,t}^{1-\alpha_G-\psi_G} - q^e.e - q^s.s - q^g.g$$

The Energy Sector

Energy enters in our model as consumption good for households in the form of electricity, as a production of input for industrial and service sectors. Additionally, there is one electricity generating firm owned by government in the economy. This firm produces and supplies the entire demand of electricity by using natural gas.

Similar to the production function used by Kim and Loungani (1992), we employ a Cobb Douglas production function for the electricity generating firm in this model. The electricity generating firm transforms the three factor inputs- labour, capital and natural gas into electricity according to the following specification:

$$G = A_t^G l_{G,t}^{\alpha_G} k_{G,t}^{\psi_G} m_{G,t}^{1-\alpha_G-\psi_G}$$

Labour and capital's distributive share is given by the parameter α_c and. $(1-\alpha_c-\psi_c)$ represents the share of natural gas in production aggregation. A certain amount of electricity is lost (χ) while transmitting by the distribution companies to the end consumers. So, equilibrium in electricity market:

$$e + s + g = A_t^G l_{G,t}^{\alpha_G} k_{G,t}^{\psi_G} m_{G,t}^{1-\alpha_G-\psi_G} - x(G)$$

The Competitive Equilibrium

The equilibrium of the economy is a sequence of prices $\{\pi_t\} = \{q_t, p_t, v_t, r_t, w_t\}$ and quantities $\{\phi\} = \{c_t, l_t, k_t, e_t, g_t, s_t, x_t, y_t\}$ such that:

1. Given a sequence of prices $\{\pi_t\} = \{q_t, p_t, v_t, r_t, w_t\}$ and taxe τ^l *and* τ^k $\{c_t, l_t, e_t, x_t\}$ is a solution to the representative households' problem;
2. Given a sequence of prices $\{\pi_t\} = \{q_t, p_t, v_t, r_t\}$ $\{k_t, g_t, s_t, y_t\}$ is a solution to the representative firm;
3. Given a sequence of quantities $\{\phi\}$, $\{\pi_t\}$ clears the market;
4. The economy wide budget constraint holds;
5. Energy market clears implies energy consumed should be equal to energy supplied.

Model Shocks

The basic model is driven by three different shocks: energy price shocks and productivity shocks affects the Industrial output and energy output energy generating firms.

Just as Cooley and Prescott (1995), the stochastic productivity shocks across sectors are assumed to be:

$\ln v_t^m = \Omega^m + \omega \ln v_{t-1}^m + \kappa_t$ (Gas Price Shocks)

$\ln A_t^Y = \Omega^Y + \mu^Y \ln A_{t-1}^Y + \eta_t^y$ (Technology Shocks in Industrial Sector)

$\ln A_t^G = \Omega^G + \mu^G \ln A_{t-1}^G + \eta_t^G$ (Technology Shocks in Government Sector)

3. Dataset, Parameter Specification and Calibration

To find a numerical solution, model calibration is necessary. Hence, the model is calibrated following Kydland and Prescott (1982). The model is implemented numerically using detailed data and parameter sets. The dataset is reported in Table 2 and reflects the variable values in 2011-2012. The data needed to calibrate the economy comes from Bangladesh Bureau of Statistics (BBS), Bangladesh Economics Review (BER), World Development Indicator (WDI), Bangladesh Labour Force Survey, Bangladesh Power Development Board, Bangladesh Petroleum Corporation, Summit Power Limited, and Bangladesh Tax Handbook.

Parameter values are reported in Table 3 and are specified in different ways. Wherever possible, parameter values are taken from the available data sources. This is the case, for example, consumer price of electricity, producer price of electricity, market price of electricity, fraction of system loss in electricity and the different effective tax rates.

In some cases, the parameters are chosen freely from the literature in that sense they are not implied by the steady state restrictions. This is the case, for example, the discount rate, the inter-temporal elasticity of substitution, the elasticity of substitution and the persistent coefficient of the different shocks. Although free, these parameters have to be carefully chosen since their values affect the value of the remaining calibration parameters. Accordingly, they were chosen either using central values or using available data as guidance. The remaining parameters are obtained by calibration in a way that the real picture of the economy is extrapolated as the steady state trajectory.

There are 25 parameters in total with 13structural, 6 shock related parameters and 6 policy related parameters in our model. Structural parameters can be categorized into utility and production function related parameters. It is important to have a good understanding of rationale behind picking different parameter values in order to properly evaluate the fit of the model. Let us briefly describe our procedure for selecting parameter values used in the paper.

First of all, we discuss parameters related to production. Alpha (α), Psi (ψ) and depreciation (δ) are the main parameters related to production. Since the model has two different sectors namely industry and service sector and one electricity generating firm, we need to calculate different alpha for each sector. Following Roberts and Fagernas (2004) we set the labor distributive share of industrial sector, α_Y equals to 0.2 using the following first order condition: $w = \alpha_Y . \frac{Y}{l_{Y,t}}$. The labour distributive share in the service sector, α_X can be calculated using the first order conditions and considering share of labour in service sector from data and calculating the ratios of $\frac{w}{Y}$ and $\frac{nX}{Y}$ as follows:

$$\frac{\omega_1^x}{\omega l} = \frac{nX}{Y} \alpha_X \frac{1}{\frac{\omega 1}{y}}$$

Given $\frac{\omega_1^x}{\omega l} = 0.719460501$; =1.658839316 and $\frac{\omega 1}{y} = 0.722841226$, we can estimate α_X equals to 0.313505778.

The share of capital used in industrial and service production, ψ_y and ψ_x can be calculated by employing the first order conditions with respect to capital and Constant Returns to Scale assumptions.

$$\psi_Y = \frac{rk_{Y,t}}{p^Y Y} = 0.760373942$$

$$\psi_X = \frac{rk_{X,t}}{n.X} = 0.660656913$$

However, the labor and capital distributive share in Government sector, PDB, α_c and ψ_c can be found using the following two first order conditions where α_c equals to 0.058408751 and ψ_c equals to 0.72464444369.

$$v^m . \alpha_G . m_{G,t} = (1 - \alpha_G - \psi_G) . l_G . w$$

$$r . (1 - \alpha_G - \psi_G) . k_{G,t} = \psi_G . m_{G,t} . v^m$$

Depreciation rate is usually very low in the developing countries. So, depreciation rate delta has been set at 0.025 implying that the overall depreciation rate in Bangladesh is 2.5 percent annually. This value is equally realistic form the perspective of the developing countries. Prescott (1986) and Kydland and Prescott (1991) also measure the value of δ to be 0.025.

Now, we discuss parameters related to household utility. Given the value of q^e, ρ, and the ratio of $\frac{e}{c}$ calculated from data, we can obtain θ (equals to 0. 0.911090619), the share of non-energy consumption in household aggregator using the following

Euler equation:

$$\frac{e_t}{c_t} = (q_t^e.\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}$$

Given the ratio, $\frac{nX}{c}$ q^e, ρ and θ, the share of service aggregator γ (equals to 0.0.811011097), can be calculated using the following Euler equation:

$$\frac{c_t}{nX_t} = \frac{1-\gamma}{\gamma}.\frac{1}{1+(\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}(q_t^e)^{\frac{\rho}{\rho-1}}}$$

φ reflects the share of energy consumption and non-energy consumption goods in the household's utility function and its value is calculated 0.607675927 as follows:

The intra-temporal efficiency condition (the labour-leisure) trade off implies that the marginal rate of substitution between labour and consumption must equal the marginal product of labour. That means,

$$\frac{U_l}{U_c} = F_l$$

$$\frac{c_t}{1-l_t} = \frac{\varphi(1-\gamma)}{(1-\varphi)}.\frac{1}{1+(\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}(q_t^e)^{\frac{\rho}{\rho-1}}}.w(1-\tau^l)$$

$$\geqslant \frac{(1-\varphi)}{\varphi} =.\frac{(1-\gamma).\theta.(1-l_t).\frac{wl}{Y}.\frac{(1-\tau^l)}{l}.\frac{Y}{c}}{\theta+(1-\theta)(\frac{e_t}{c_t})^{\rho}}$$

Certain standard parameters are calibrated following standard literature. To begin with, since the length of a period in the model is taken to be one year, β, the discount factor, is set to 0.96 which is quite standard in DSGE literature. This implies a real interest rate of 7.6 percent. The capital and labour income tax rates τ^k and τ^l as 0.15 and 0.10 as mentioned in Bangladesh Tax Handbook 2012. Next, the household consumer price of electricity, q^e ,the industry consumer price of electricity,$q^g$and the service consumer price of electricity, q^S is chosen as 4.93 Taka/Kwh, 6.95 Taka/Kwh and 9.00 Taka/Kwh respectively from Bangladesh Power Development Board (BPDB). The selling price of electricity by PDB (P^G) is calibrated using the country data which is equals to 2.307534701. The model assumes that Government fixes the selling price of electricity to clear the electricity market.

Finally, the market price of gas is considered as 0.7755 Taka/Kwh which is taken from Summit Power Limited Company.

Due to unavailability of the data of working hours, we set l=0.33 with an assumption that people work about one-third of their time endowment which is widely accepted value for RBC/DSGE analysis. For example, l is set equal to 0.30, consistent with the time-allocation measurements of Ghez and Becker (1975) for the US economy. In this chapter, the household's utility function follows a general CES form, meaning that it cannot be used to model an elasticity of substitution of exactly 1. Following Dhawan and Jeske (2007) the CES parameter of the household's utility function, ρ, is set at -0.11(1-(1/0.90)), which is negative and indicates that energy and non-energy consumption are somewhat complementary.

Owing to the unavailability of data, following King, Plosser and Rebelo (1988), we set the persistence of our three exogenous shocks equals to 0.95 and standard deviation of the shocks equals to 0.01. Using different series, empirical literature get a range of estimates for persistence 0.85-0.95 and standard deviation 0.0095-0.01.We assume that technology and energy shocks follows a mean zero AR (1) process in its natural log, with an iid disturbance.

4. Solution Algorithm

We use the stochastic perturbation method (log linearization around the deterministic steady state) put forward by Collard and Julliard (2001) to approximate the dynamics of our model economy. From the first order conditions in Table 4, we derive twenty three conditions guiding the dynamic behaviour of twenty nine endogenous variables plus three equations for the shocks. Since DSGE literature calibrates not only the parameter values but also the fundamental steady state variables (which Dynare consider as initial values), we do follow the same procedure. The calculated steady state values are listed in Table 5. However, Dynare can solve models without setting up the steady state and by guessing initial values for the endogenous variables. In the same fashion, the DSGE model can be solved recursively with using initial value and showed the Steady State (SS) results (Levine and Yang, 2012). To solve the models to generate a first order approximation for the policy function (See Adjemian et al, 2011 and Collard and Julliard, 2011 for the methodological details) and to conduct stochastic simulations, we run the program Dynare version 4.4.3- a pre-processor and a collection of Matlab routines. These routines linearize the system around its deterministic steady state and perform a second order Taylor approximation.

5. Results

To evaluate the performance of our model, i) we will compare steady state ratios from the models with their empirical counterpart and ii) analyze the impulse response function of different shocks. Our model shows that most of the relevant variable ratios are fairly close to the actual data. The model does a good job at matching the model generated ratios to the actual variable ratios as showed in data.

After considering the steady state ratios for our model with their empirical counterparts, finally we take a brief look at the impulse response functions generated in response to the productivity and energy price shocks.

Table 6: Ratios of Economic Variables of Bangladesh Data and Models in the Steady State

Economic Ratios	Data	Model
$\frac{c}{Y}$	0.337915857	0.349212
$\frac{e}{Y}$	0.009866408825	0.009866408825
$\frac{wl}{Y}$	0.722841226	0.7228419
$\frac{wl^Y}{Y}$	0.2	0.200000277
$\frac{g}{e}$	0.577879074	0.577878884
$\frac{s}{e}$	0.482669648	0.482669988
$\frac{i^Y}{I}$	0.2766859345	0.27668606
$\frac{i^X}{I}$	0.719460501	0.719460606
$\frac{v^m m^G}{wl^G}$	3.71428727	3.714263685
$\frac{rk^G}{v^m m^G}$	3.340192542	3.340205875
$\frac{wl^X}{nX}$	0.313505778	0.313505738
$\frac{rk^X}{nX}$	0.660656913	0.660655086
$\frac{q^s s}{nX}$	0.025837309	0.025837299
$\frac{q^g g}{Y}$	0.039626058	0.003962605

Transmission Mechanisms of Gas Price Shocks

In this section, we describe the dynamic mechanism in which Gas price shock is propagated. The shock is equal in size to the standard deviation of the normalized price. Figure 1shows the response of the different endogenous variables of the model in presence of such shock.

When there is an increase in relative gas price, non-energy consumption, energy consumption and service consumption decreases by 0.1 percent, 3 percent and 0.25 percent respectively. Electricity generation is also affected because of high gas price as the generating firm use natural gas to produce electricity and it is decreased by 8 percent. Since the amount of government transfer also decreases, household increases the labor supply to overcome the negative income effect, which lowers the wage rate in the economy. The amount of electricity used in industrial and service sector is also reduced by 2 percent and 1.5 percent respectively. Because of the complementarity effects, the reduction in the use of electricity in production further decreases the amount of capital and the amount of labor by a small margin. The decrease in the productive inputs is translated into an industrial output decrease of 0.4 percent which would imply a negative correlation between industrial output and gas prices.

Transmission Mechanisms of Productivity Shocks

In this paper, two types of productivity shocks is considered both for industry and energy generating firms which has more or less similar impact on the economy. An increase in technology makes capital more productive in the future, since future technology is expected to be higher (as the coefficient is close to 1), the social planner responds optimally by immediately building up the capital stock by 500 percent and 5 percent respectively. However, a technology shock in industry seems to have some adverse effect on service consumption.Overall, the IRF of consumption displays a hump shape as is already documented in literature. Both the industrial production and the energy production are increased as a result of productivity shock along with their usage of electricity. It is also revealed that productivity shock in industry has some positive influences over the factor prices. Figure 2 and 3shows the response of the different endogenous variables of the model in presence of productivity shock.

The behavior of impulse response functions for the endogenous variables are very similar to their response to an exogenous technology and energy price shock. The only difference is their magnitude of effect and the technology shocks have more strong impact on the variables than the energy shocks.

6. Conclusions

In this paper, we have analyzed the effects of gas price shocks on different key macroeconomic variables and on welfare in the context of a small economy where natural gas is locally produced such as is the case of the Bangladesh economy. The model used for this analysis is based on the standard dynamic stochastic general equilibrium modelwhere energy is included both in the utility and production function. Energy price shock is explicitly introduced in our model in addition to the productivity shocks. The model is calibrated for Bangladesh economy to analyze the role of Gas price shock on her economy and to investigate the robustness of the existing findings.

First of all, our investigation shows that the simulated model is able to replicate most of the ratios of macroeconomic variables on average in Bangladesh. The main conclusion from our work is that higher gas price would hinder the economic progress in Bangladesh by upsetting the economic variables and would have negative welfare effect. So, higher energy price would limit the progress of economic activities in Bangladesh.

However, the model is still rather stylized. It abstracts from many of the channels through which energy prices may affect the macro economy. Firstly, many of the studies that derive strong impacts of energy on real variables do so by assuming some rigidity in the response of wages and (non-energy) prices to the energy price. Secondly, it abstracts from the presence of fiscal and monetary authorities as well as market incompetitiveness. Thirdly, the model represents a closed economy.

For further research, it would be interesting to include pollution on our baseline model to do some comparative static to evaluate the dynamic effects of specific emission policy choices. We would also like to consider externality where it is assumed to enter household utility additively separable and furthermore assess the overall welfare effect of a reform. Finally, we would also intend to extend the model by explicitly modelling the energy market so that energy policy reforms and their impact on the overall economy can be accurately analysed.

References

1. Alves, MR., and Pereira, AM., 2006, "Survey of Applied General Equilibrium Models for Energy and Environmental Studies", Preliminary Versions.

2. Bhattacharyya, SC., 1996, "Applied General Equilibrium Models for Energy Studies: A Survey", Energy Economics 18, pp. 145-164.

3. Cooley, Thomas F., and Edward C. Prescott., 1995, "Economic Growth and Business Cycle", In Frontier of Business Cycle Research, Princeton, NJ.

4. De Miguel, C., Manzano, B., and Martín-Moreno, JM, 2005, "Oil Shocks and the Business Cycle in Europe", EEE 215.

5. Dhawan,R., and Jeske, K., 2007, " Energy Price Shocks and the Macroeconomy: The Role of Consumer Durables",mimeo, Federal Reserve Bank of Atlanta.

6. Dynare, version 4.4.3.

7. Finn, MG., 2000, "Perfect Competition and the Effects of Energy Price Increases on Economic Activity," Journal of Money, Credit and Banking 32, pp. 400-416.

8. Ghez, G., and Becker G., 1975, "The Allocation of Time and Goods over the Life Cycle", New York: Columbia University Press.

9. Glomm, G and Ravikumar, B., 1997, "Productive government expenditures and long-run growth", Journal of Economic Dynamics and Control 21(1), pp. 183-204.

10. Glomm, G and Ravikumar, B., 1997, "Flat-Rate Taxes, Government Spending on Education, and Growth", Review of Economic Dynamics 1(1), pp. 306-325.

11. Kim, IM., and Loungani, P., 1992, "The Role of Energy in Real Business Cycles," Journal of Monetary Economics 29, pp. 173-189.

12. King, R., Plosser, C., and Rebelo, S., 1988a, "Production, growth and business cycles, I: The basic neoclassical model", Journal of Monetary Economics 21, pp. 195-232.

13. King, R., Plosser, C., and Rebelo, S., 1988a, "Production, growth and business cycles, II: New Directions", Journal of Monetary Economics 21, pp. 309-342.

14. Kydland, F., and Prescott, E., 1982, "Time to build and aggregate fluctuations", Econometrica 50, pp. 1345-1371.

15. MATLAB, version 8.3.0.

16. Robers, J., and Fagernas, S., 2004, "Why is Bangladesh Outperforming Kenya? A Comparative Study of Growth and its Causes since the 1960s",ODI Strategic Policy Impact and Research Unit (SPIRU) Papers 5.

17. Rotemberg, JJ., and Woodford, M., 1996, "Imperfect Competition and the Effects of Energy Price Increases on Economic Activity," Journal of Money, Credit and Banking 28, pp. 549-577.

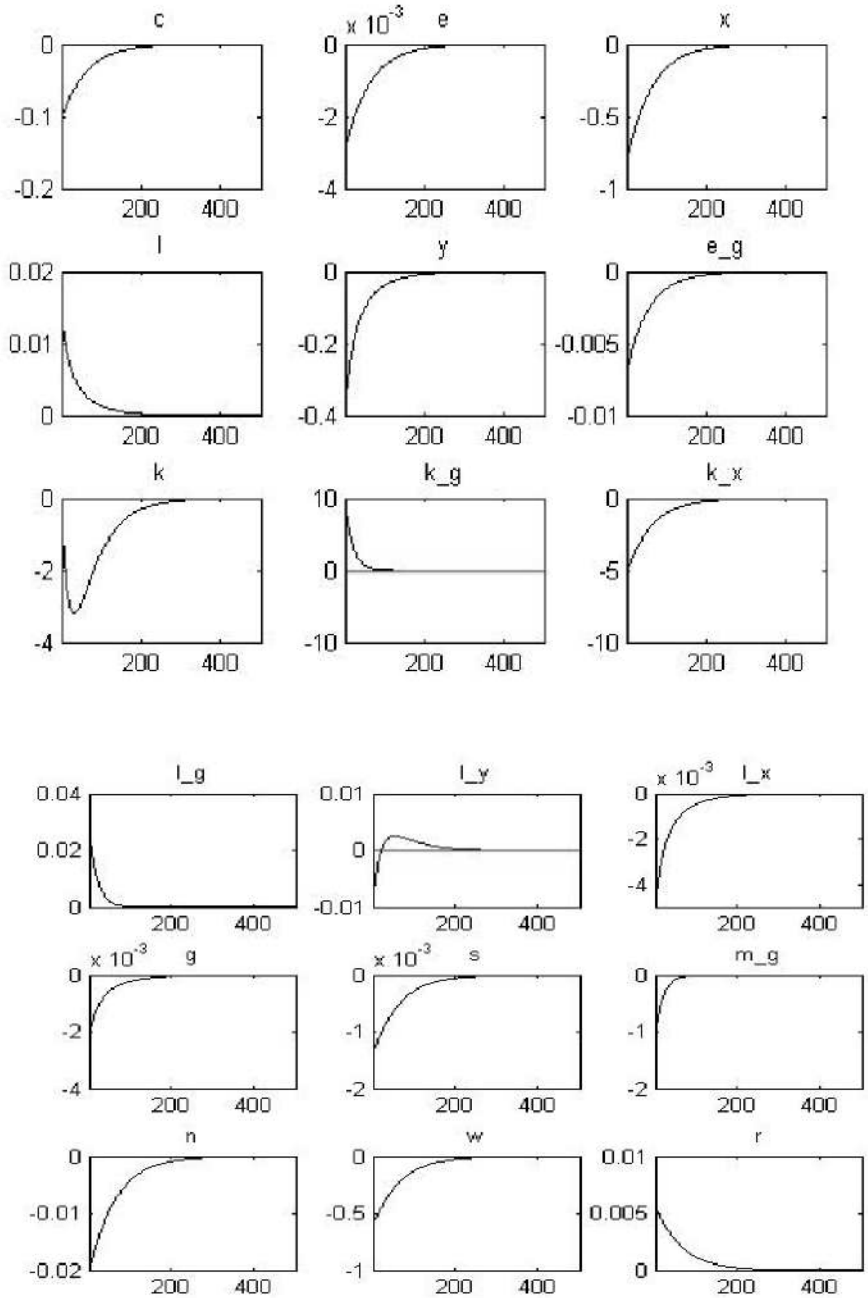
18. Stéphane Adjemian, Houtan Bastani, Michel Juillard, Frédéric Karamé, Ferhat Mihoubi, George Perendia, Johannes Pfeifer, Marco Ratto and Sébastien Villemot., 2011, "Dynare: Reference Manual, Version 4", Dynare Working Papers, 1, CEPREMAP.

19. Tan, BH., 2012, "RBC model with endogenous energy production", School of Economics, Singapore Management University.

20. Wickens, M., 2008, "Macroeconomic Theory: A Dynamic General Equilibrium Approach", Princeton University Press.

Appendix

Figure 1: Relative Impulse Responses to an energy shocks



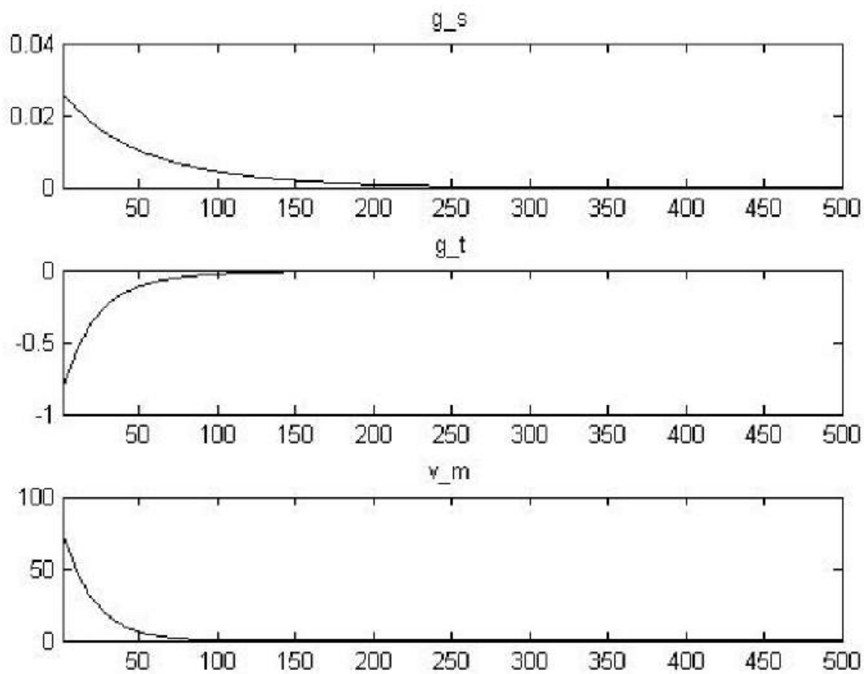
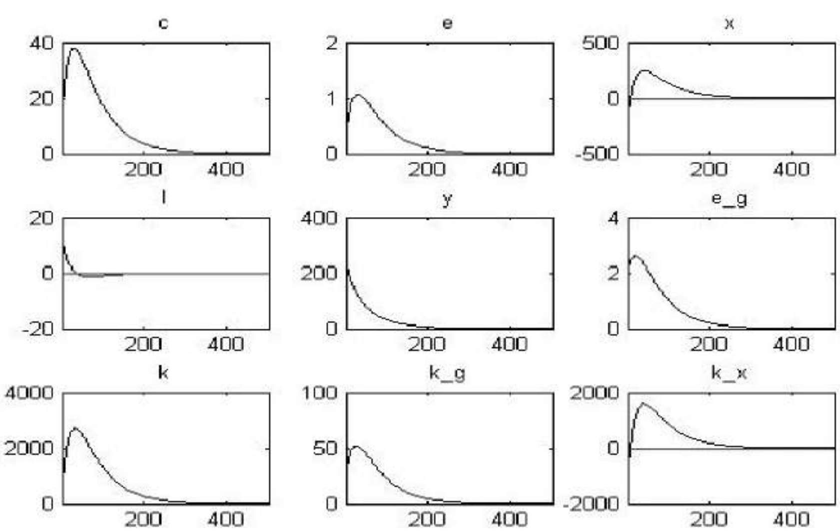


Figure 2: Relative Impulse Responses to a productivity shocks in Industry



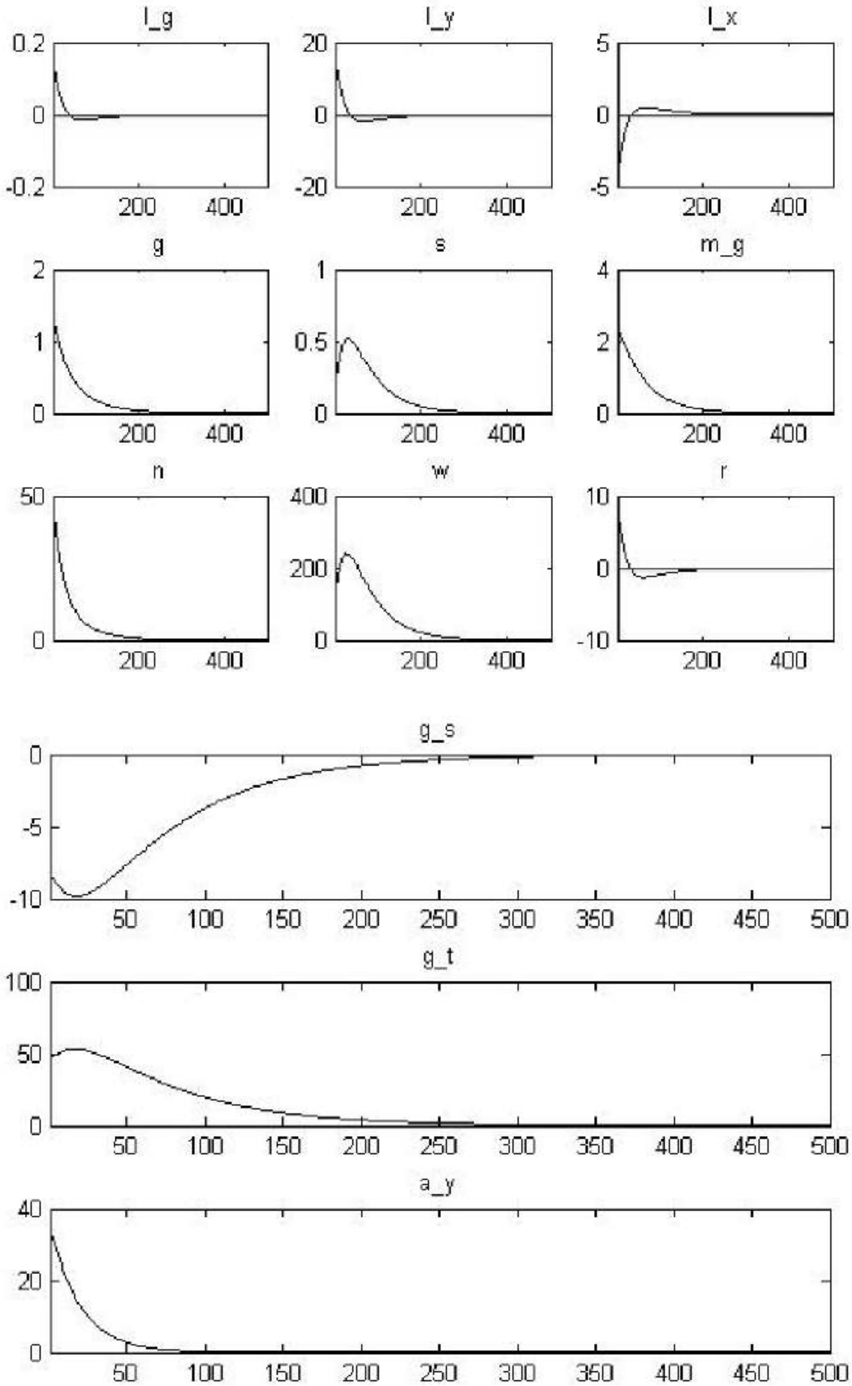
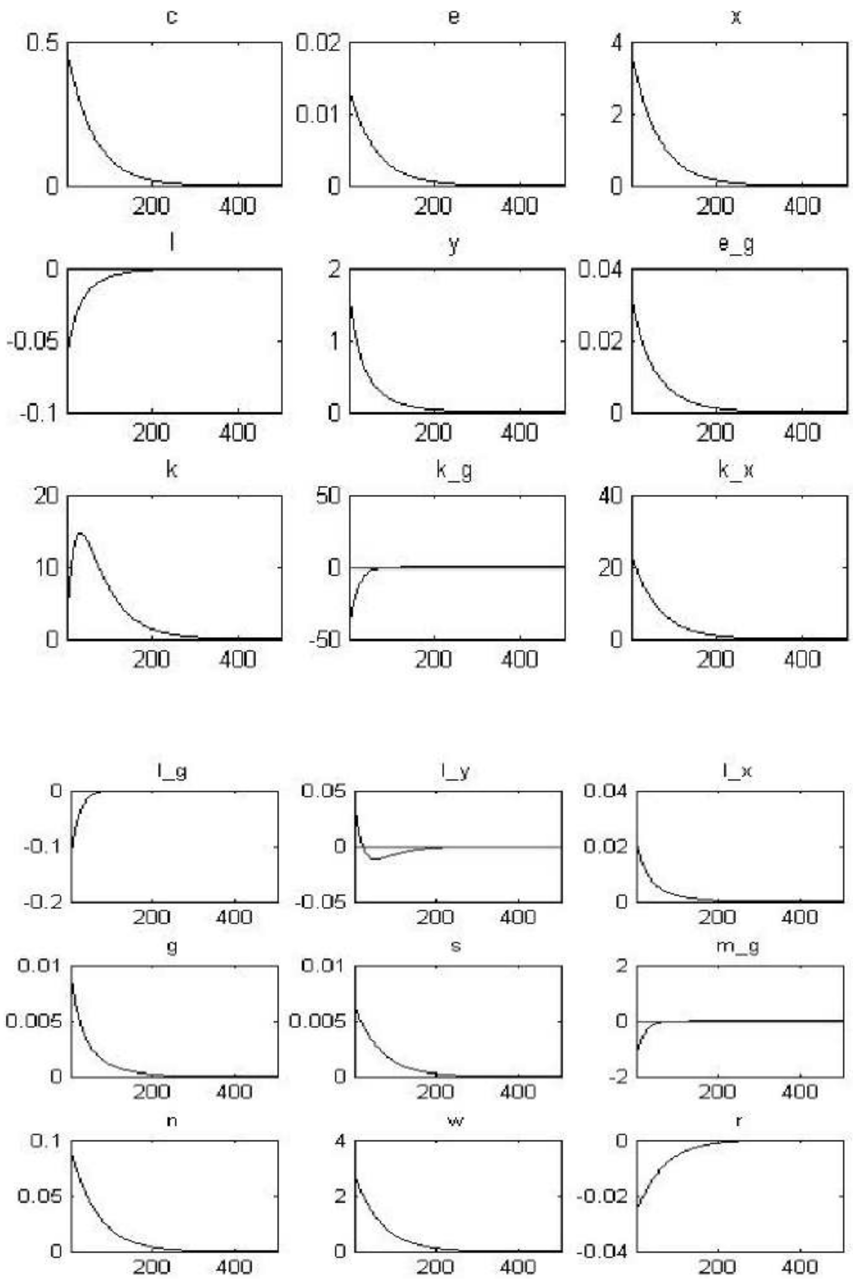

l_g
l_y
l_x
g
s
m_g
n
w
r
g_s
g_t
a_y

Figure 3: Relative Impulse Responses to a productivity shocks in Energy Firm



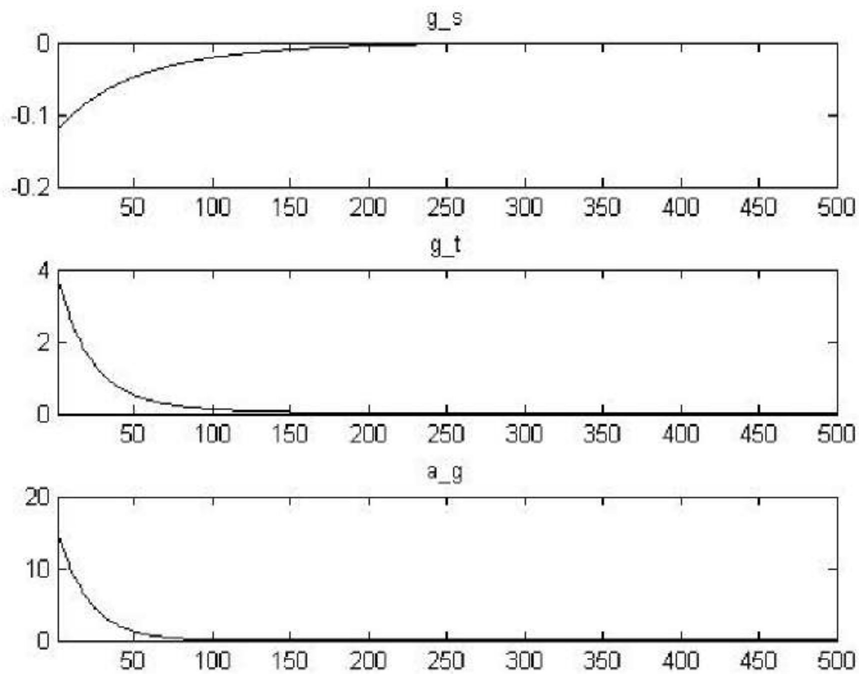

g_s
0
-0.1
-0.2
50 100 150 200 250 300 350 400 450 500
g_t
4
2
0
50 100 150 200 250 300 350 400 450 500
a_g
20
10
0
50 100 150 200 250 300 350 400 450 500

Table 1: The Dynamic General Equilibrium Model: The Model Structure

Household Utility Function:

$$\varphi \log\left[X_t^{\varsigma}\left(\theta c_t^{\rho} + (1-\theta)e_t^{\rho}\right)^{\frac{1-\gamma}{\rho}}\right] + (1-\varphi)\log(1-l_t)$$

Household Resource Constraint:

$$k_{t+1} + C_t + n.X_t + q_t^e.e_t = (1-\tau^l)wl_t + s + (1-\tau^k)rk_t + (1-\delta)k_t$$

Government Resource Constraint:

$$\tau^l.w.l + \tau^k.r.k + P^G A_t^G l_{G,t}^{\alpha_G} k_{G,t}^{\psi_G} m_{G,t}^{1-\alpha_G-\psi_G} - rk_G - wl_G - s = b$$

Economy wide Resource Constraint:

$$k_{t+1} = A_t^Y l_{Y,t}^{\alpha_Y} k_{Y,t}^{\psi_Y} g_t^{1-\alpha_Y-\psi_Y} - C_t + (1-\delta)k_t$$

Total Subsidy:

$$b = P^G A_t^G l_{G,t}^{\alpha_G} k_{G,t}^{\psi_G} m_{G,t}^{1-\alpha_G-\psi_G} - q^e.e - q^s.s - q^g.g$$

Production Functions:

G= $A_t^G l_{G,t}^{\alpha_G} k_{G,t}^{\psi_G} m_{G,t}^{1-\alpha_G-\psi_G}$ [PDB]

Y= $A_t^Y l_{Y,t}^{\alpha_Y} k_{Y,t}^{\psi_Y} g_t^{1-\alpha_Y-\psi_Y}$ [Industrial Sector]

X= $l_{X,t}^{\alpha_X} k_{X,t}^{\psi_X} s_t^{1-\alpha_X-\psi_X}$ [Service Sector]

Equilibrium in Electricity Markets:

e + s + g = $A_t^G l_{G,t}^{\alpha_G} k_{G,t}^{\psi_G} m_{G,t}^{1-\alpha_G-\psi_G} - x(G)$

Equilibrium in Labour Markets:

$$l = l_G + l_Y + l_X$$

Equilibrium in Capital Markets:

$$k = k_G + k_Y + k_X$$

Firms Profit Maximization Problem:

$\pi_Y = P^Y.A_t^Y l_{Y,t}^{\alpha_Y} k_{Y,t}^{\psi_Y} g_t^{1-\alpha_Y-\psi_Y} rk_Y - wl_Y - q^g.g$ [Industrial Sector]

$\pi_X = n.l_{X,t}^{\alpha_X} k_{X,t}^{\psi_X} s_t^{1-\alpha_X-\psi_X} - rk_X - wl_X - q^s.s$ [Service Sector]

Government cost maximization problem:

$$c_G = wl_G + rk_G + v^m.m_{G,t} - P^G.A_t^G l_{G,t}^{\alpha_G} k_{G,t}^{\psi_G} m_{G,t}^{1-\alpha_G-\psi_G}$$

Exogenous Shocks:

$\ln v_t^m = \Omega^m + \omega \ln m_{t-1}^m + \kappa_t$ (Gas Price Shocks)

$\ln A_t^Y = \Omega^Y + \mu^Y \ln A_{t-1}^Y + \eta_t^Y$ (Technology Shocks in Industrial Sector)

$\ln A_t^G = \Omega^G + \mu^G \ln A_{t-1}^G + \eta_t^G$ (Technology Shocks in Government Sector)

Table 2: The Dynamic General Equilibrium Model- The Basic Data Set

c, Consumption by Household	As percent of GDP	0.806
q^e.e, Electricity consumption by household	Sectoral Share of GDP (%)	1.45
Y, Industry, value added	(% of GDP)	29.81
GDP	Value	9,147,840,000,000 Taka
Y	Value	2,726,971,104,000 Taka
c/Y (Calculated)	Ratio	0.337915857
nX, Service, value added	(% of GDP)	49.45
nX/Y	Ratio	1.658839316
c/nX(Calculated)	Ratio	0.203706202
e/GDP	Ratio	0.002941176471
e/Y(Calculated)	Ratio	0.009866408825
e/c(Calculated)	Ratio	0.029197827
e, Domestic Electricity Consumption	Million Kilowatt Hours(Mkwh)	11627
g, Industrial Electricity Consumption	Million Kilowatt Hours(Mkwh)	6719
s, Service Electricity Consumption	Million Kilowatt Hours(Mkwh)	5612
l^Y, Labour Share of Industry	In Percentage	27.66859345%
l^X, Labour Share of Service	In Percentage	71.9460501%
l^e, Labour Share of Electricity	In Percentage	0.385356454%
q^e, consumer price of electricity faced by residential household	Taka/Kwh	4.93
q^S, electricity price faced by service sector	Taka/Kwh	9.00
q^g, electricity price faced by industry	Taka/Kwh	6.95
P^G, electricity price faced by Government (Calculated)	Taka/Kwh	2.307534701
V^m, market price of gas	Taka/Kwh	0.7755

Table 3: The Dynamic General Equilibrium Model- The Structural Parameters

1. β, discount factor	0.96(Borrowed)
2. φ, the share of electricity and non-electricity consumption in the household's utility	0.0.607675927 (Calculated)
3. θ, the share of non-energy consumption in household aggregator	0.0.911090619 (Calculated)
4. σ, the CES parameter of household's utility function	ρ=0.11(Borrowed)
5. γ, the share of service in the consumption aggregator	0.0.811011097 (Calculated)
6. α_G, labour distributive share in BPDB	0.058408751(Calculated)
7. α_Y, labour distributive share in industrial sector	0.2(Calculated)
8. α_X, labour distributive share in service/commercial sector	0.313410243 (Calculated)
9. Ψ_G, share of gas used in electricity production by BPDB	0.72464444369(Calculated)
10. Ψ_Y, share of electricity used in industrial production	0.760373942(Calculated)
11. Ψ_X, share of electricity used in commercial production	0.660656913(Calculated)
12. κ, fraction of system loss	0.12(Data)
13. ω, persistence coefficient of gas price shock	0.95(Borrowed)
14. μ^Y, persistent coefficient of TFP shock in industry	0.95(Borrowed)
15. μ^G, persistent coefficient of TFP shock in BPDB	0.95(Borrowed)
16. ζ, standard error of gas price shock	0.01(Borrowed)
17. ε^Y, standard error of TFP shock in industry	0.01(Borrowed)
18. ε^G, standard error of TFP shock in BPDB	0.01(Borrowed)
19. δ, depreciation rate	0.025(Borrowed)
20. τ^K, tax on capital	0.15(Data)
21. τ^l, tax on labour	0.10(Data)
22. q^e, consumer price of electricity faced by household	4.93(Data)
23. q^S, consumer price of electricity faced by service sector	9.00(Data)
24. q^g, consumer price of electricity faced by industry	6.95(Data)
25. P^G, electricity price faced by Government	2.307534701(Calculated)

Table 4: Euler Equations and First Order Conditions

$$1.\ \frac{c_{t+1}}{c_t} = \beta^{\gamma}[(1-\tau^k)r_{t+1} + (1-\delta)]\frac{1+(\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}.q_t^{e\,\frac{\rho}{\rho-1}}}{1+(\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}.q_{t+1}^{e\,\frac{\rho}{\rho-1}}}$$

$$2.\ \frac{c_t}{1-l_t} = \frac{\varphi(1-\gamma)}{(1-\varphi)}.\frac{1}{1+(\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}(q_t^e)^{\frac{\rho}{\rho-1}}}.w(1-\tau^l)$$

$$3.\ \frac{c_t}{nX_t} = \frac{1-\gamma}{\gamma}.\frac{1}{1+(\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}(q_t^e)^{\frac{\rho}{\rho-1}}}$$

$$4.\ \frac{g_t}{c_t} = (q_t^e.\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}}$$

$$5.\ w = \alpha_Y.\frac{Y}{l_{Yt}}$$

$$6.\ r = \psi_Y.\frac{Y}{k_{Yt}}$$

$$7.\ q^g = (1-\alpha_Y-\psi_Y)\frac{Y}{g_t}$$

$$8.\ w = \alpha_x.\frac{nX_t}{l_{xt}}$$

$$9.\ r = \psi_x.n.\frac{X}{k_{xt}}$$

$$10.\ q^e = (1-\alpha_x-\psi_x)\,n.\frac{X}{e_t}$$

$$11.\ v^m.\alpha_G.m_{Gt} = (1-\alpha_G-\psi_G).l_G.w$$

$$12.\ r.(1-\alpha_G-\psi_G).k_{Gt} = \psi_G.m_{Gt}.v^m$$

Table 5: The Dynamic General Equilibrium Model- The Steady State Values

1. c, non-electricity oriented goods by household	0.349212
2. e, electricity consumption by household	0.00986641
3. X, Total production in Service Sector	3.1686
3. Y, Total production in industry	1
4. G, electricity produced by government sector(BPDB)	0.0225891
5. K, total capital($K= K^G+K^Y+K^X$)	24.1084
6. K^G, capital used by BPDB(Government sector)	0.440619
7. K^X, capital used in commercial/service sector	13.973
14. l, total labour($l= l^G+l^Y+lX$)	0.33
17. l^G, labour used by BPDB(Government sector)	0.00127168
18. l^Y, labour used in industrial sector	0.0913064
19. l^X, labour used in commercial/service sector	0.237422
20. g, electricity consumption by industry	0.00570159
21. s, electricity consumption by service/commercial sector	0.00476222
24. m^G, gas used by BPDB in electricity production	0.0133413
25. n, price of commercial/service products	0.523525
26. w, price of labour	2.19043
27. r, price of capital	0.0784314
28. b, subsidy	-0.0834374
29. ъ, government transfer	0.449696
31. V^m, market price of gas	0.7755
32. A_t^Y, TFP shock in industrial sector	0.352114
33. A_t^G, TFP shock in government electricity generating firm(BPDB)	0.15406