Energy Price Shocks in Dynamic Stochastic General Equilibrium: The Case of Bangladesh[1*]

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Abstract. We investigate the role of energy price shocks on business cycle fluctuations in Bangladesh. In doing so, we calibrate a Dynamic Stochastic General Equilibrium (DSGE) model, allowing for both energy consumption by households and as an input in production. We find that qualitatively temporary energy price shocks and technology shocks produce similar impulse response functions, as well as similar (quantitatively) auto-correlations in aggregate quantities. The variance in aggregate quantities are better explained by technology shocks than by energy price shocks, suggesting that technology shocks are more important source of fluctuations in Bangladesh.

Аннотация. Мы исследуем влияние колебаний цен на электроэнергию на флуктуации бизнес-цикла на примере Бангладеш. В этом исследовании мы калибрируем динамическую стохастическую модель общего равновесия (DSGE-модель), учитывающую бытовое и промышленное потребление электроэнергии. Мы пришли к выводу, что временные колебания цен на электроэнергию и колебания производительности приводят к схожим ответным реакциям, а также к количественно схожим автокорреляциям суммарного количества. Расхождение в суммарных количествах лучше объясняются технологическими колебаниями, чем колебаниями цен на электроэнергию. Это приводит к выводу, что технологические колебания являются более важным источником флуктуаций бизнес-цикла в Бангладеш.

Key words: Energy price shocks, business cycles, dynamic stochastic general equilibrium.

1. INTRODUCTION

Standard Dynamic Stochastic General Equilibrium (DSGE) models typically assume that exogenous technology shocks identified through the Solow residual are the main sources of aggregate fluctuations in the economy. This concept has often been criticised as in De Miguel *et al*. (2003). They argue that there is a lack of discussion on the nature of technology shocks, which are unobservable, and based on the idea that they are just the result of the convergence of other kinds of factors that are not specified in the model. One of the identifiable sources of shocks that have claimed the attention of many economists is energy price shocks which, according to some researchers, being equivalent to adverse technology shocks can induce significant contractions in economic activity. In fact, using US data, Hall (1988) finds that a standard measure of technology, the Solow residual, systematically tends to fall whenever energy price increases. The case for incorporating energy price shocks into the DSGE models has subsequently been made credibly by McCallum (1989).

Authors such as Kim and Loungani (1992), Finn (2000), Rotemberg and Woodford (1998), Dhawan and Jeske (2007), De Miguel *et al*., (2003, 2005), Tan (2012) investigate the effect of energy price shocks on the variation of output using the DSGE framework. Most of the authors find that such energy price shocks offer very little help in explaining the US business cycle, therefore supporting the views of macroeconomists who downplay the impact of energy price shocks on

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the economy. For instance, Tobin (1980) has argued that the share of energy in US GDP is so small that it would require implausible parameter values to generate strong aggregate impacts from energy price shocks.

Although the above researchers investigated the theoretical relationship between energy and macroeconomy through different possible channels, upon closer analysis, two common characteristics can be seen for most of the aforementioned models. Firstly, energy is considered primarily in the production function, overshadowing its importance in the household's utility function. Secondly, all the models are found to be calibrated to reflect the scenarios of developed countries, mainly US economy leaving open the question of whether energy price shocks can explain macroeconomic fluctuations in developing countries.

This papers aim at filling the above gaps in the literature by providing a framework to analyse the relative impact of energy price shocks and technology shocks for Bangladesh. To the best of our knowledge, there is yet no record of an energy augmented DSGE model which has been calibrated for developing economy to investigate the interactions between energy and the overall economy. Differently from the above models on energy price shocks, we include energy both in the utility and production function, to recognise the importance of energy for household's welfare, which is particularly relevant for developing countries (Jamasb, 2006). Our model therefore constitutes a useful benchmark framework to address the behaviour of different macroeconomic variables for policy analysis in developing countries.

In particular, we first calibrate our DSGE model to explain the quantitative properties of macroeconomic variables for the Bangladesh's economy. Then we examine how the fluctuations of key economic variables such as consumption and output are explained by the exogenous shocks. The model's ability to describe the dynamic structure of the Bangladesh economy is analysed by means of the Impulse Response Function (IRF) which yield useful qualitative and quantitative information.

Our results show that the basic DSGE model can replicate some of the main features of the Bangladesh economy for the period 1990–2010. In addition, we demonstrate that energy price shock is not the main explanatory factor of the macroeconomic fluctuations in Bangladesh. Consequently, we conclude that output fluctuations in Bangladesh are mainly driven by technology shock. Our results further reveal that the exogenous shock's impact on endogenous system variables are in the right direction.

The paper is organised as follows. The model is depicted in section 2 followed by a discussion on calibration of the parameters in section 3. Section 4 portrays the analysis of the results obtained and finally, in the last section, we present the conclusions.

2. THE MODEL

We assume a representative agent model where all economic agents are identical and act as both a household and a firm. Energy is explicitly modelled in the household's utility function where the representative household derives utility from the consumption of energy, from standard consumption, and from leisure. Following Finn (2000), we measure energy oriented goods as the sum of electricity, coal, natural gas and petroleum. Standard consumptions include all the durable and non-durable goods excluding energy goods. Each household's endowment of time is normalised to 1 so that leisure is equal to $(1-l)$ where l represents the number of working hours.

Household consumes a Constant Elasticity of Substitution (CES) aggregation of energy and standard consumption, and also derives utility from leisure. Thus for the household, in each period it decides on how much energy goods to consume (e_t), how much to consume of the standard consumption good (c_t) and how much time to devote to labour (l_t) in order to maximise its lifetime expected utility[2].

$$\max \mathrm{E}_0\left(\sum_{t=0}^{\infty}\beta^t u_t\right)$$

With a per-period utility function of the following form:

$$u_t = \varphi \ln[\theta c_t^{\rho} + (1-\theta)e_t^{\rho}]^{\frac{1}{\rho}} + (1-\varphi)\ln(1-l_t) \qquad (1)$$

The utility function exhibits the commonly assumed properties like $u_c > 0$, $u_{cc} > 0$, $\lim_{C\to 0} = \infty$ and $\lim_{C\to\infty} = 0$. That means, additional consumption and leisure increases utility but does so at a diminishing rate.

Here, φ represents the share of consumption in the household's utility where $\varphi \in (0, 1)$. θ is the share of standard consumption in the household's aggregator where $\theta \in (0, 1)$. With this aggregation function, the elasticity of substitution between energy and standard consumption is $\sigma = 1/1-\rho$. When $\rho = 0$ and $\sigma = 1$, the CES function becomes Cobb Douglas (CD) function. It is rational to choose $\rho < 0$, which implies that the goods are somewhat complementary.

[2] Due to the shocks, which follow a known probability distribution, future consumption, leisure, etc are uncertain, so we adopt expected utility as the objective function for the household.

Following Kim and Loungani (1992), the production technology of firm is described by a Cobb-Douglas production function, combining energy as an additional input along with capital and labour.

$$Y_t = A k_t^{\alpha} l_t^{\gamma} g_t^{1-\alpha-\gamma} \tag{2}$$

Where α and γ is the fraction of aggregate output that goes to the capital input (k_t) and labour input (l_t) respectively, and $1-\alpha-\gamma$ is the fraction that goes to the energy input (g_t). That means all the economic agents rely on energy either for household's consumption or for production of various goods. Furthermore, energy price is modelled as an exogenous random process in addition to technology shock.

Just as in Cooley and Prescott (1995), the stochastic technology A_t is assumed to follow:

$lnA_t = \omega \ln A_{t-1} + u_t$; where $u_t \sim N(0, \sigma^2)$.

The capital stock depreciates at the rate δ (with $0 < \delta < 1$) and the household invests a fraction of income in the capital stock in each period. So, capital accumulates according to law of motion:

$$k_{t+1} = (1-\delta)k_t + i_t \tag{3}$$

The price of energy used in the economy, P_t, is exogenously given and follows AR (1) process: $lnP_t = \Psi \ln P_{t-1} + v_t$; where v_t is normally distributed with standard deviation τ and zero mean. As energy is consumed both by the consumers and the producers in this model, the economy's resource constraint for period t is given by:

$$Y_t = c_t + i_t + P_t(e_t + g_t) \tag{4}$$

The Lagrangian to the planning problem can be written as follows[3]:

$$L = \sum_{t=0}^{\infty} \beta^t \left(\varphi \log\, [\theta c_t^{\rho} + (1-\theta) e_t^{\rho}]^{\frac{1}{\rho}} + (1-\varphi)\log(1-l_t) \right) + \lambda_t [A k_t^{\alpha} l_t^{\gamma} g_t^{1-\alpha-\gamma} + (1-\delta)k_t - c_t - P_t\ (e_t + g_t)] \tag{5}$$

where λ_t is the Lagrange multiplier and the function is maximised with respect to c_t, k_{t+1}, e_t, l_t, g_t and λ_t.

The first-order conditions are:

$$\frac{c_{t+1}}{c_t} = \beta.[A\alpha\, K_{t+1}^{\alpha-1} l_{t+1}^{\gamma} g_{t+1}^{1-\alpha-\gamma} + (1-\delta)] \frac{1 + \left(\frac{\theta}{1-\theta}\right)^{\frac{1}{\rho-1}} .P_t^{\frac{\rho}{\rho-1}}}{1 + (\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}} .P_{t+1}^{\frac{\rho}{\rho-1}}} \tag{6}$$

$$\frac{c_t}{1-l_t} = \frac{\varphi}{1-\varphi} . \frac{1}{1 + (\frac{\theta}{1-\theta})^{\frac{1}{\rho-1}} .P_t^{\frac{\rho}{\rho-1}}} .[A\, K_t^{\alpha} \gamma\, l_t^{\gamma-1} g_t^{1-\alpha-\gamma}] \tag{7}$$

$$\frac{e_t}{c_t} = (P_t . \frac{\theta}{1-\theta})^{\frac{1}{\rho-1}} \tag{8}$$

$$P_t = A k_t^{\alpha} l_t^{\gamma} (1-\alpha-\gamma) g_t^{-(\alpha+\gamma)} \tag{9}$$

[3] Notice that we could equally well have formulated a competitive economy, where the household faces a budget constraint, taking prices as given, and a representative firm maximizing profits, also taking prices as given. The solution to the planning problem coincides with the competitive equilibrium, i.e. the First Welfare Theorem applies. For computational reasons we choose the planning formulation, as it yields fewer equations to solve.

$$c_t + k_{t+1} + P_t \ (e_t + g_t) = A k_t^{\alpha} l_t^{\gamma} g_t^{1-\alpha-\gamma} + (1-\delta) k_t \quad (10)$$

$$Y_t = A k_t^{\alpha} l_t^{\gamma} g_t^{1-\alpha-\gamma} \quad (11)$$

$$lnA_t = \omega lnA_{t-1} + u_t \quad (12)$$

$$lnP_t = \Psi \ln P_{t-1} + v_t \quad (13)$$

3. CALIBRATION

Before examining the model's performance to evaluate the empirical data, model calibration is required. In this section, we use the term calibration for the process by which researchers choose the parameters of their DSGE model from various sources. For example, Cooley and Prescott (1995) calibrate their model by choosing parameter values that are consistent with long run historical averages and microeconomic evidence. Dhawan and Jeske (2007) calibrate parameters to produce theoretical moments of model aggregates that reproduce, as best possible, the empirical moments obtained from the empirical data.

However, we have generally adopted three approaches in terms of calibrating parameters for our DSGE model. Some of the parameters are picked from the existing DSGE literature for developing and developed countries (Choudhary and Pasha, 2013). Some of the parameter values are chosen by using steady state conditions of the model. Rest of the parameter values are directly considered from Bangladesh Bureau of Statistics (2015) and Bangladesh Household Income and Expenditure Survey (2015). Due to data constraints, all parameters in our model are calibrated for annual frequency.

There are 11 parameters in total with 7 structural and 4 shock related parameters in the model. Structural parameters can be categorised 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 listed in Table 1.

First of all, we discuss parameters related to production. Alpha (α), Gamma (γ) and Depreciation (δ) are the main parameters related to production. Following Rahman and Yusuf (2010), we set alpha equals to 0.31 which implies capital's share of national income in Bangladesh is slightly less than a third. This is fairly close to the computed aggregate capital share which is 0.36 as calculated by Tan (2012). However, the average of capital shares of other developing countries is around 0.45 as reported by Liu (2008). According to Bangladesh Household Income and Expenditure Survey (2010), the labour share of output in Bangladesh varies from 0.65 to 0.70. We decided to use a value of 0.65 to make it consistent with the CD production function used in our model. Finn (2000) also mentions that the measures of labour's output share range from 0.64 (Prescott, 1986) to 0.76 (Lucas, 1990).

Table 1. Parameters of the economy.

β, discount factor	0.88
α, capital share of output in the production function	0.31
γ, labour share of output in the production function	0.65
δ, depreciation rate	0.025
φ, the share of consumption in the household's utility	0.41
θ, the share of standard consumption	0.8
σ, the CES parameter of household's utility function	–0.11
ω, persistence coefficient of technology shock	0.95
Ψ, persistence coefficient of energy shock	0.95
ζ, standard error of technology shock	0.01
τ, standard error of energy shock	0.01

Source: Bangladesh Household Income and Expenditure Survey (2015), Bangladesh Bureau of Statistics (BBS, 2015).

Depreciation rate is usually very low in the developing countries. Thus, depreciation rate, δ has been set at 0.025 implying that the overall depreciation rate in Bangladesh is 2.5% annually. This value is equally realistic from the perspective of the developing country's economic condition (IMF, 2001 and Yisheng, 2006). The capital output ratio in Bangladesh is borrowed from Rahman and Rahman (2002) who estimated that the trend in capital output ratio in Bangladesh over the period of 1980/81 to 2000/01 is equal to 2.

Now, we discuss parameters related to household utility. Given, α, δ, capital-output ratio and considering the value of steady state level of price is $P = 1$ (mean zero in the log implies a mean of unity in the level), the value of discount factor beta, is obtained from equations (6) and (11) evaluated in steady state:

$$\beta = \frac{1}{\alpha \frac{Y}{k} + (1-\delta)}$$

Our estimated value 0.88 is less compatible with the value of discount factor used in other existing literature for developing countries at annual frequency. Ahmad *et al.*, (2012) estimate the long run discount factor for a group of developed and developing countries and find that the discount factor of most of the developing countries is relatively similar to that of developed countries. For example, they calculate the discount factor, β, equals to 0.94 for Philippines. As a robustness check, we have performed sensitivity analysis along three different discount parameters (β = 0.88, β = 0.96 and β = 0.99) and confirm that our results are robust to a wide range of possible β values (see Table 2). It is worth noting from Table 2 that the steady state value of *c* shows odd pattern with low β values. In principle, lower β value should imply a lower level of steady state consumption (as the household is more impatient). However, in this sensitivity analysis, we have also changed the value of δ which offset the changes observed in c for different β values. Thus, lower β value yields a higher value for c in our analysis. However, we have also run another sensitivity analysis keeping the value of δ to 0.025. Our results show that *c* is now smaller for lower β values.

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 a widely accepted value for 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.

Certain standard parameters are calibrated following standard literature. The share of standard consumption, θ, is set at 0.8. In this paper, 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. Here, it is set at 0.9 for the main analyses, and the CES parameter of the household's utility function, ρ, is therefore –0.11 (1- (1/0.9)), which is negative and indicates that energy and standard consumption are somewhat complementary.

φ reflects the share of energy consumption and standard consumption goods in the household's utility function and its value is found to be 0.41 as follows:

For optimality, the labour-leisure trade off should be such that the marginal rate-of-substitution between leisure and consumption must equal the marginal product of labour (the implied normalised wage rate in the corresponding competitive equilibrium). That means,

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

Table 2. Sensitivity analysis for β.

Variables	β = 0.88 and δ = 0.025	β = 0.96 and δ = 0.12	β = 0.99 and δ = 0.14
k	0.712689	0.820228	0.963403
Y	0.370975	0.427755	0.466477
A	1	1	1
c	0.262911	0.242628	0.24319
l	0.331236	0.382276	0.402381
P	1	1	1
i	0.0178172	0.0984273	0.134876
e	0.0754072	0.0695897	0.069751
g	0.014839	0.0171102	0.0186591

$$\frac{\frac{1-\varphi}{1-l_t}}{\frac{\varphi}{\rho}\cdot\frac{\rho\theta c_t^{\rho-1}}{\theta c_t^{\rho}+(1-\theta)e_t^{\rho}}}=[A\,K_t^{\alpha}\gamma\,l_t^{\gamma-1}g_t^{1-\alpha-\gamma}]$$

$$\frac{\frac{1-\varphi}{1-l_t}}{\frac{\varphi}{\rho}\cdot\frac{\rho\theta c_t^{\rho-1}}{\theta c_t^{\rho}+(1-\theta)e_t^{\rho}}}=[\gamma\frac{Y}{l}]$$

$$\frac{1-\varphi}{\varphi}\cdot\frac{l}{1-l_t}\left[1+\frac{(1-\theta)}{\theta}(\frac{e_t}{c_t})^{\rho}\right]=\gamma\frac{Y}{l}$$

By using equation (8), we can calculate the steady state ratio of energy to standard consumption which yields a value of 0.28. Now, given the value of l, γ, θ and the ratio of $\frac{c}{y}$ and $\frac{e}{c}$, we can find the value of φ equals to 0.41.

Owing to the unavailability of data, following King, Plosser and Rebelo (1988), we set the persistence of our two exogenous shocks equal to 0.95 and standard deviation of the shocks equal to 0.01. Using different series, empirical literature gets a range of estimates for persistence 0.85–0.95 and standard deviation 0.0095–0.01.

We assume that the natural log of the technology variable and the energy price follow an AR (1) process, where the shocks are iid with zero mean and variances σ_u^2 and σ_v^2, respectively. Zero mean implies steady state levels $A = 1$ and $P = 1$.

4. RESULTS

After calibration, to evaluate the performance of our model, we compare steady state ratios from the models with their empirical counterpart. Furthermore, second order moments (such as standard deviation, contemporaneous correlation with output etc.) obtained from simulations will also be evaluated from our models and their fit with the actual data[4].

Our model shows that the relevant capital output ratio is equal to 1.92 which is fairly close to the actual data of 2 as explained in the previous section. Another important ratio of our model is the consumption-output ratio. The model does a good job at matching the model generated ratio of 0.70 to the actual consumption output ratio of 0.65–0.70 as showed in data. However, our model undershoots the value of investment output ratio by a large extent. The model-generated result 4.8% is far away from the average long run investment output ratio of 20%.

We would also like to verify the ability of the model to reproduce other empirical regularities of the Bangladesh business cycle. In order to do so, we proceed to the stochastic simulation of the model with the parameters obtained in the calibration section, where the sources of fluctuations come from the technology shock and energy price shock. Table 3 reports a selection of second moment properties for the HP filtered series corresponding to the Bangladesh data and the simulated economy respectively[5]. In other words, we would like to evaluate our model's performance by comparing the results with data. For this purpose, the following table reports some selected historical moments from data and their counterparts predicted by our models.

Our model performs well to capture the actual volatility of output and investment when we consider both the technology and energy price shocks together as well as when we take into account the technology shocks alone. However, considering only energy price shocks is not sufficient. A shock to the energy sector or a policy pertaining to that sector should have significant impact on the rest of the economy. Yet, energy price shocks can account for only 3.29% of output volatility whereas technology shocks can account for almost 83.52% of output volatility in our model. Investment also follows more or less the same pattern as output. Moreover, the model does a poor job in replicating the variation of consumption of energy and non-energy goods. The situation is more severe in the standard consumption when we just consider energy price shocks. Therefore, energy price shocks are a less important source of aggregate fluctuations in Bangladesh economy. Our results reveal from the long run data that energy input is well substituted by other inputs (capital and labour) in the production function when there is any shock in energy price. In fact, the results indicate that there are some mechanisms by which macroeconomic variables could be stable in spite of a limited source of energy inputs as argued by Bartleet and Goulder (2010). Additionally, our DSGE model shows that the series are not strongly persistent and robust in the sense of having a large first order autocorrelation coefficient and matching the historical data. The highest persistent series is

[4] Dynare, a preprocessor and a collection of MATLAB routines is used in this paper to solve for the steady states, linearise the necessary conditions around steady states, compute the moments and calculate the impulse response paths once the necessary equations are transformed into Dynare codes (Griffoli, 2011).

[5] We have used HP filtering data to make it consistent with Dynare generated data as it gives HP filtering data. However, considering the fact that HP filtering data might give rise to spurious cycles as criticised in some literature, we have also checked with Baxter and King (BK) filtering process but that does not make any significant differences.

Table 3. Actual and predicted moments.

	Data*	DSGE Model		
Statistics	Estimate	Model 1 Technology and Energy Price Shocks	Model 2 Technology Shocks	Model 3 Energy Price Shocks
Standard Deviation				
Y	0.005488	0.004321	0.004335	0.000172
i	0.003155	0.002264	0.002270	0.000088
c	0.007593	0.001629	0.001637	0.000115
e	0.002546	0.000784	0.000470	0.000624
Standard Deviation Relative to Output				
i	0.57	0.49	0.52	0.51
c	1.38	0.38	0.38	0.67
e	0.46	0.18	0.11	3.62
Autocorrelation				
Y	0.823	0.4815	0.4845	0.4841
i	0.824	0.4406	0.4437	0.4437
c	0.821	0.5777	0.5811	0.5230
e	0.821	0.4879	0.5811	0.4731
Correlation with Output (Y)				
i	0.9965	0.9545	0.9545	0.9550
c	0.9938	0.9457	0.9470	0.9890
e	0.9967	0.5238	0.9470	0.9986

* The statistics are based on log-differenced and HP filtered for the period 1990–2010 to reflect the actual growth rates.

capital which is 0.74 whereas the autocorrelation of the remaining series are typically in the neighborhood of 0.45 compared to their empirical counterpart of a range around 0.82.[6] The policy and transition function reveals that the exogenous shock's impacts on endogenous variables are in the right direction. Lastly, the model captures the fact that most of the series are quite pro-cyclical with output.

After considering the steady state ratios and second order moments for our model with their empirical counterparts, finally we take a brief look at the IRF generated in response to the technology and energy price shocks.

4.1 TRANSMISSION MECHANISMS OF ENERGY PRICE SHOCKS

In this section, we describe the dynamic mechanism in which energy price shock is propagated. The shock is equal in size to the standard deviation of the normalised price. Figure 1 shows the response of the different endogenous variables of the model in presence to such a shock. When there is an increase in relative energy price (P), both the amount of energy consumption (e) and the amount of energy used (g) in the production decreases by 8% and 1.5% respectively. Because of the complementarity effects, the reduction in the use of energy in production decreases the amount of capital (k) by 1% and the amount of labour (l) by 0.5% approximately. The decrease in the productive inputs is translated into an output (Y) decrease of 2% which would imply a negative association between output (Y) and energy prices (P). Finally, consumption (c) exhibits a similar response to the output (Y).

4.2 TRANSMISSION MECHANISMS OF TECHNOLOGY SHOCKS

Dedola and Neri (2006) argue that in the standard DSGE model, technology shocks play an important role in accounting for output fluctuations. Our results

[6] The persistent of capital is not reported in the table as we mainly focus on consumption, investment and output in this table.

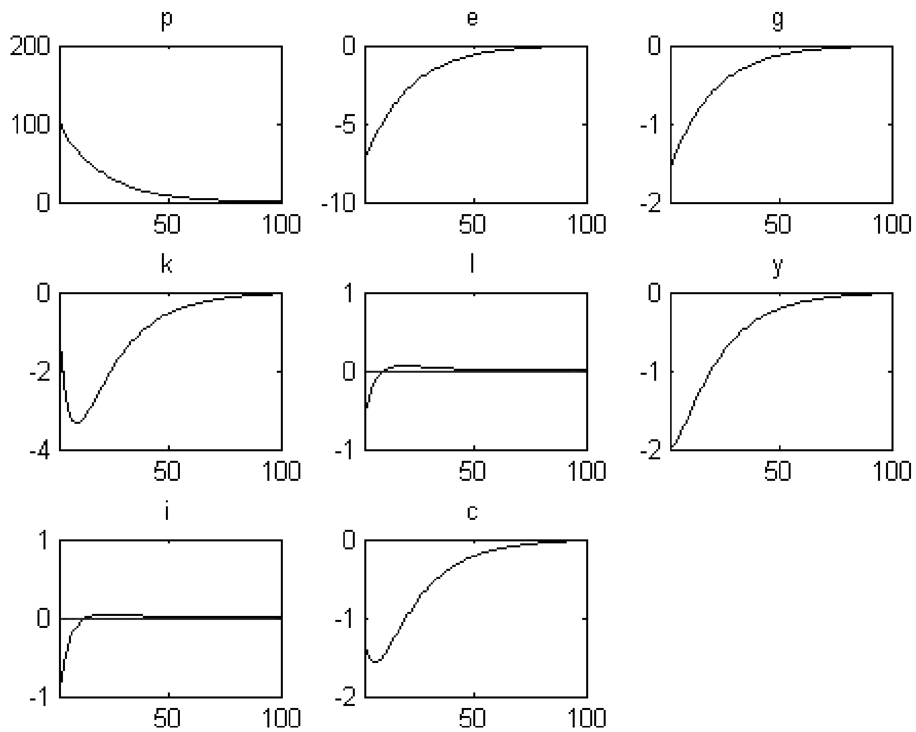

Figure 1. Impulse responses to an energy price shock.

reveal that the technology shock has stronger impact on the variables than the energy price shocks.

An increase in technology (*A*) makes capital more productive in the future. Since future technology is expected to be higher, the social planner responds optimally by immediately building up the capital stock (*k*) by 40%. As a result of a positive technology shock, investment (*i*) rises by 25% and output (*Y*) by 50%. The IRF of consumption (*c, e*) displays a hump shape as is already documented in the literature. Investment (*i*) reverts back to original pre-shock levels just after a few periods compared to other endogenous variables.

It is worth noting that the behaviours of IRF for the endogenous variables are opposite in directions to their response to an exogenous technology and energy price shock as the later shock acts as a negative technology shock. Finn (2000) also finds that an energy price shock can be considered as an adverse technology shock, since it causes capital (which embodies the technology) to produce at below capacity levels.

5. CONCLUSIONS

McCallum (1989) suggests that DSGE theory should explicitly model exogenous energy price changes. We made an attempt to implement this suggestion in the simplest possible way where energy is included both in the utility and production functions which constitute a novelty with respect to previous literature. Energy price shock is explicitly introduced in our model in addition to the technology shocks. In addition we contribute to the existing literature by modelling energy price shocks in a DSGE framework for a developing country, Bangladesh.

The main conclusion from our paper is that energy price shocks are not a major factor for macroeconomic fluctuation in the Bangladesh economy and therefore, output fluctuations in Bangladesh are mainly driven by technology shock. This might be the case of the substitution possibility of energy with labour and capital in the production process as described by Dhawan and Jeske (2007). Besides, different measures of the underground economy of Bangladesh has pointed out that the informal economy had the size of 35% of the total official GDP, which is a large value and sufficient enough to distort any macroeconomic outcomes (Schneider, 2004).

Additionally, variance decomposition analysis shows that energy price shock contributes a very small percentage (3.29%) to variations in overall output, similar to results obtained in Tan (2012), Dhawan and Jeske (2007) and Kim and Loungani (1992). It is also not surprising that a choice of functional forms and parameterisation may affect model dynamics and also change the model's amplification and propagation mechanism (Kormilitsina, 2011). In fact, our results offer some support to the views of macroeconomists who downplay the impact of energy price shocks on the business cycle fluctuations (Dhawan and Jeske (2007). It is also worth noting

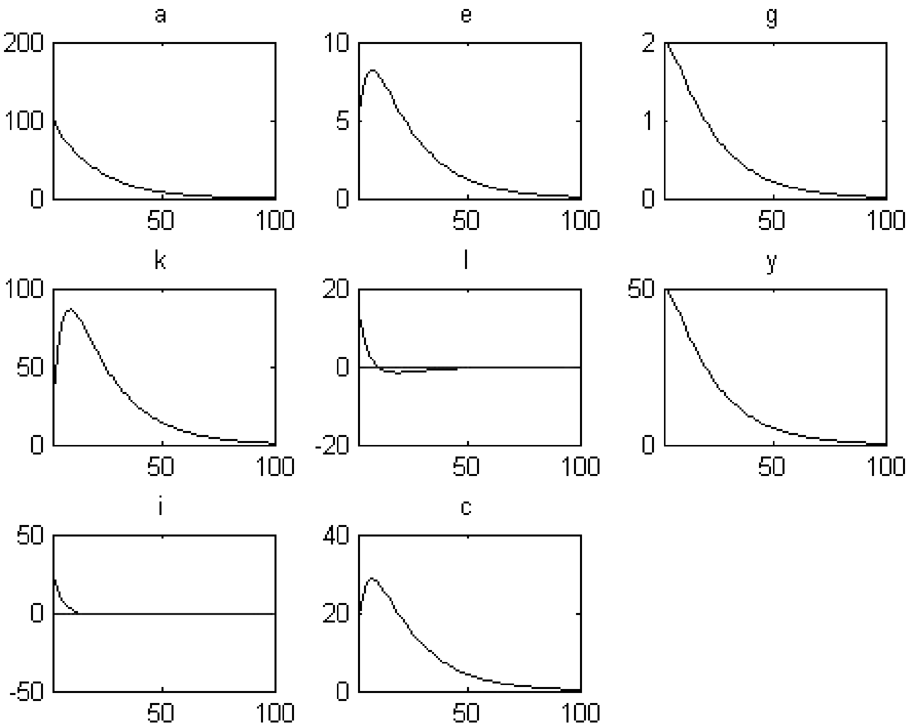

Figure 2. Impulse responses to a technology shock.

that when we scrutinise the IRF generated results in response to the exogenous energy price shocks, we may speculate an inverse relationship between different economic variables (like energy usage, productive inputs, consumption, output, etc.) and energy prices in Bangladesh economy. However, these relations are completely outweighed by the stronger positive impact of the exogenous technology shocks on the variables.

Our model could be generalised by introducing different types of households, firms, energy generating firms and a government sector to carefully analyse policy in developing countries. In fact, Jamasb (2006) argue that in most developing countries, electricity reform requires extensive restructuring of prices and subsidy arrangements. Therefore, our benchmark model could be extended by considering a detailed disaggregated electricity sector for a mixed economy where the government controls energy prices charged to households and firms, and enables the government to absorb the shocks. Consequences of energy price liberalisation can also be analysed.

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