Energy Shocks and the Real Business Cycle Model in Bangladesh

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Abstract: Energy shocks are often identified as a source of macroeconomic fluctuations since it affects economic growth as well as business cycle. This paper presents a Real Business Cycle (RBC) model with energy for Bangladesh economy in the spirit of Dynamic Stochastic General Equilibrium (DSGE) analysis. Calibrating and estimating the RBC model, this paper examines how the fluctuations of key economic variables such as investment, consumption and output are explained by two policy shocks namely: technology and energy price shocks. The model's ability to describe the dynamic structure of the Bangladesh economy is analysed by means of Impulse Response Functions (IRFs). The results reveal that the exogenous shock's impacts on endogenous variables are in the right direction. The main finding of this paper is that energy price shocks are not a major factor for business cycle fluctuation in Bangladesh economy which seems to be driven mainly by the productivity shock.

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1. Introduction

Energy is a vital instrument for economy as it is used in some form almost in every activity. Consequently, analyzing interactions of the energy sector and the overall economy has been the subject of much interest among the researchers. The conventional wisdom is that even though energy does not make up a significant fraction of GDP, it plays a crucial role in economy since without energy nothing would be produced. The role of energy is important too on the consumer's side since many types of household products, especially durables are completely energy dependent (Tan, 2012). Bangladesh also considers energy as a prerequisite for her technological, societal and economic growth. In fact, given the pace of economic development in many countries and the increasing world population, the concern about energy keeps growing.

Economic theory has long struggled in attempting to explain the energy-macroeconomic relationship. Researchers investigated the theoretical relationship between the use of energy and economic growth through different possible channels. In the neoclassical growth models, energy is simply considered as an intermediate input of production (Tsani, 2010). Proponents of this view focus on the possibility of technological change and substitution of other physical inputs for energy to use existing energy resources efficiently, and to generate renewable energy resources that are not subject to binding supply constraints (Solow, 1974, 1997; Stiglitz, 1974). The advocates of this theory support the 'neutrality hypotheses'. These hypotheses imply that energy would not have any negative effect on economic growth. Thus, the government can simultaneously adopt the energy conservation and economic growth policies (Bartleet and Gounder, 2010).

In contrast, the ecological economic theory states that energy consumption is a limiting factor to economic growth (Stern, 2000, 2004, 2011). They consider energy as the prime source of value because other factors of production such as labor and capital cannot perform without energy (Belloumi, 2009). The advocates of this theory highlights the so-called 'growth hypothesis'. They advise that any shock to energy supply will ultimately have an inverse effect on economic growth. Consequently, they stand against the energy conservation policies.

Apart from the extensive empirical literature examining energy-economic activity, there is another kind of literature, which has analysed the energy shocks on economic variables using Real Business Cycle (RBC) models. The case for incorporating energy shocks into the RBC models has been made credibly by McCallum (1989). The RBC theory assumes that exogenous technological shocks identified through Solow residual, are the main source of aggregate fluctuations in the economy which has often been criticized (de Miguel et al, 2003). However, one of the identifiable sources of shocks that have claimed the attention of many economists is energy price shocks which, according to some researchers, is equivalent to adverse technology shocks and thus, induce significant contractions in economic activity. In fact, using US data (1953-1984), Hall (1988, 1990) finds that a standard measure of technology, the Solow residual, systematically tends to fall whenever energy price increases.

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 RBC model with energy for Bangladesh economy to investigate the interactions between energy and overall economy.

In light of these limitations, this paper presents a standard RBC model with energy in the spirit of DSGE model 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 The main goals of this paper is about the investigation and validation of the basic RBC model with regard to its performance in terms of the common RBC properties and to see how important technology shocks are to the basic RBC model, once the model is extended to allow for energy shocks. In other words, we would like to explore to what extent movements in energy prices can help to explain business cycle fluctuations in Bangladesh. We attempt to calibrate the RBC model to explain the quantitative business cycle properties of macroeconomic variables in Bangladesh economy. Then we examine how the fluctuations of key economic variables such as investment, 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 Impulse Response Functions (IRFs) which yield useful qualitative and quantitative information.

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

2. The Model

This research attempts to construct a simple DSGE model by extending Kydland and Prescott's (1982) analysis of a RBC model to understand the business cycle fluctuations in Bangladesh caused by energy shocks in addition to productivity shocks.

Energy is explicitly modeled in the household's utility function where the representative household derives utility from the consumption of energy oriented goods, non-energy oriented goods and from their leisure. Each household's endowment of time is normalized to 1 so that leisure is equal to (1-l) where l represents the number of working hours.

The utility function is assumed to be perfect separable among the components. The utility function is represented by the following equations:

(1) $V(c_t, 1-l_t, e_t) = U(c_t) + \theta(1-l_t) + \Phi(e_t)$[1]

Utility function exhibits the commonly assumed properties like $v_c>0$, $v_{cc}<0$, $\lim_{c\to 0} = \infty$ and $\lim_{c\to\infty} = 0$. That means, additional consumption and leisure increases utility but does so at a diminishing rate.

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

(2) $F(k_t, l_t, g_t) = AK_t^{\alpha} l_t^{\gamma} g_t^{1-\alpha-\gamma}$

[1] We use the functional form assumptions that $U(c_t)=\ln C_t$, $\theta(1-l_t) = \omega \ln(1-l_t)$ and $\Phi(e_t)= \zeta \ln e_t$

Where α and γ is the fraction of aggregate output that goes to the capital input and labor input respectively, and $1-\alpha-\gamma$ is the fraction that goes to the energy input. That means, all the economic agents rely on energy either for household's consumption or for production of various goods. Additionally, energy price is modeled as an exogenous random process in addition to productivity shock.

The law of motion of the stochastic productivity shock A is assumed to be: $A_t = \rho A_{t-1} + u_t$; $u_t \sim (0, \sigma^2)$ as like Tan (2012).

As in a neoclassical growth model, capital stock depreciates at the rate δ and households invest a fraction of income in capital stock in each period. So, capital accumulates according to law of motion:

(3) $K_{t+1} = (1-\delta)K_t + I_t$ with $0 < \delta < 1$

The price of energy used in the economy, p, is exogenously given and follows AR (1) process:

$P_t = \Psi P_{t-1} + v_t$ where v_t is i.i.d 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:

(4) $Y_t = C_t + I_t + P_t(e_t + g_t)$

The objective of the social planner is to maximize the utility of the representative households subject to feasibility, i.e.

$$\text{Max V} \sum_{t=0}^{\infty} {}^{t}[\text{U (c)} + {}^{-}(1-\text{l}) + ¤ \text{ (e)}]$$

s.t.

$Y_t = C_t + I_t + P_t(e_t + g_t)$

$K_{t+1} = (1-\delta)K_t + I_t$

$Y_t = AK_t^{\alpha} l_t^{\gamma} g_t^{1-\alpha-\gamma}$

$A_t = \rho A_{t-1} + u_t$ and $P_t = \Psi P_{t-1} + v_t$

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

(5) $$L = \sum_{t=0}^{\infty} {}^{t}[\text{U (c)} + {}^{-}(1-\text{l}) + ¤ \text{ (e)}] + \lambda_t [AK_t^{\alpha} l_t^{\gamma} g_t^{1-\alpha-\gamma} + (1-\delta)K_t - C_t - P_t(e_t + g_t)]$$

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

The subsequent Euler equations are as follows:

(6) $\beta\, (C_t/C_{t+1})\, [A\alpha K_{t+1}^{\alpha-1} l_{t+1}^{\gamma} g_{t+1}^{1-\alpha-\gamma} + (1-\delta)] = 1$

(7) $\omega\, C_t/1-l_t = AK_t^{\alpha} \gamma\, l_t^{\gamma} g_t^{1-\alpha-\gamma}$

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.

Additionally, after eliminating the Lagrange multiplier the equilibrium condition is described by the following system of difference equations that fully characterizes the cyclical properties of the model economies.

(8) $\omega C_t/e_t = P_t$

(9) $AK_t^{\alpha} l_t^{\gamma} (1-\alpha-\gamma)\, g_t^{-(\alpha+\gamma)} = P_t$

(10) $C_t + K_{t+1} + P_t(e_t+g_t) = (1-\delta) K_t + AK_t^{\alpha} l_t^{\gamma} g_t^{1-\alpha-\gamma}$

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

(12) $A_t = \rho A_{t-1} + u_t$

(13) $P_t = \Psi P_{t-1} + v_t$

3. Calibration

In this section, we discuss the calibration of different parameters of the model. There are 10 parameters in total with 6 structural and 4 shock 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 listed in table 1:

Table 1: Parameters of the Economy

β, discount factor	0.88
α, capital share of output in the production function	0.31
γ, labor share of output in the production function	0.65
δ, depreciation rate	0.025
ρ, persistence coefficient of productivity shock	0.95
ψ, persistence coefficient of energy shock	0.95
σ, standard error of productivity shock	0.01
τ, standard error of productivity shock	0.01
ω, Household's preference on leisure	2.01
ζ, Household's preference on energy consumption	0.33

We have generally adopted three approaches in terms of calibrating parameters for our RBC model. Some of the parameters, for which estimation remained an issue due to lack of reliable and detailed data, are picked from existing RBC/DSGE literature for developing and developed countries (Choudhary and Pasha, 2013). Due to data constraints, all parameters in our model are calibrated for annual frequency. 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 (BBS).

First of all, we discuss 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. According to Bangladesh Household Income and Expenditure Survey (2010), the labor 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 Cobb-Douglas production function used in our model.

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 fairly realistic form the perspective of the developing countries. The capital output ratio in Bangladesh is borrowed from Rahman and Rahman (2002) who estimated that the trends in capital output ration in Bangladesh over the period of 1980/81 to 2000/01 is equal to 2.

Now, we discuss parameters related to household utility. Given, alpha, delta and capital-output ratio, the values of discount factor beta is obtained from equations 6 and 11 calculated in steady state

$$\beta=1/\alpha(y/k)+1-\delta$$

Our estimated value 0.88 is compatible with the other existing literature considered the value of discount factor, beta for annual frequency for developing countries. 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.

Omega reflects household's preference for leisure and its value is chosen from equations 7 and 8 once again calculated in the steady state which yields b=2.01. The value of 2.01 falls within the range as estimated in other existing literature reported by DiCecio and Nelson (2007).

$$\omega=\gamma\ (1-l)\ y/c.l$$

Similarly, the household's preference for energy consumption, Zeta, is also calculated from equation 8 which yields a value 0.33.

$$\zeta= p.e/c$$

Finally, following King, Plosser and Rebelo (1988), we set the persistence of our two exogenous shocks equals to 0.95 and standard deviation of the shocks equals to 0.01.

4. Results

After calibration, to evaluate the performance of the model, we will 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.

The 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 0.68 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 (in percentage form) by a large extent. The model generated result 4.8 percent is far away from the average long run investment output ratio of 20 percent.

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 source of fluctuations comes from the technology shock and energy price shock. The following table reports a selection of second moment properties for the HP filtered series corresponding to the Bangladesh data and the simulated economy respectively. 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.

Table 2: Actual and Predicted Moments				
	Data[1]	RBC Model		
Statistics	Estimate	Model 1 Productivity and Energy Shocks	Model 2 Productivity Shocks	Model 3 Energy Shocks
Standard Deviation				
y	0.005488	0.004570	0.004584	0.000181
i	0.003155	0.002239	0.002244	0.000087
c	0.007593	0.001737	0.001744	0.000070
e	0.002546	0.000929	0.000575	0.000729
Standard Deviation Relative to Output				
i	0.57	0.49	0.49	0.48
c	1.38	0.38	0.38	0.38
e	0.46	0.20	0.12	4.02
Correlation with Output(Y)				
i	0.9965	0.9631	0.9631	0.9634
c	0.9938	0.9654	0.9655	0.9688
e	0.9967	0.5547	0.9655	0.9996

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

Our model performs well to capture the actual volatility of output and investment when we consider both the productivity and energy shocks together and just the productivity shocks. However, considering only energy shocks we observe a very gloomy picture. Energy price shocks can account for only 3.29 percent of output volatility whereas productivity shocks can account for almost 83 .52 percent of output volatility in our model. Investment also follows more or less the same pattern like output. However, 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 consumption of non-energy goods when we just consider energy shocks. So, energy price shock is a less important source of aggregate fluctuations in Bangladesh economy.

Additionally, our RBC 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 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. 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 impulse response functions generated in response to the productivity and energy price shocks.

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 normalized price. Figure 2 shows the response of the different endogenous variables of the model in presence of such shock.

When there is an increase in relative energy price, both the amount of energy consumption and the amount of energy used in the production decreases by 8 percent and 1.5 percent respectively. Because of the complementarity effects, the reduction in the use of energy in production decreases the amount of capital by one percent and the amount of labor by 0.4 percent approximately. The decrease in the productive inputs is translated into an output decrease of 2 percent which would imply a negative correlation between output and energy prices. Finally, consumption exhibits a similar response to the output.

Transmission Mechanisms of Productivity Shocks:

An increase in technology makes capital more productive in the future, since future technology is expected to be higher (as rho is close to 1), the social planner responds optimally by immediately building up the capital stock by 40 percent. As a result of a positive technology shock, investment rises the most (60 percent) followed by output (50 percent). Investment reverts back to original pre-shock levels just after a few periods compared to other endogenous variables. The behavior of impulse response functions for the endogenous variables are very similar to their response to an exogenous technology and energy shock. The only difference is their magnitude of effect and the technology shocks have more strong impact on the variables than the energy shocks.

Figure 1: Relative Impulse Responses to a productivity shocks

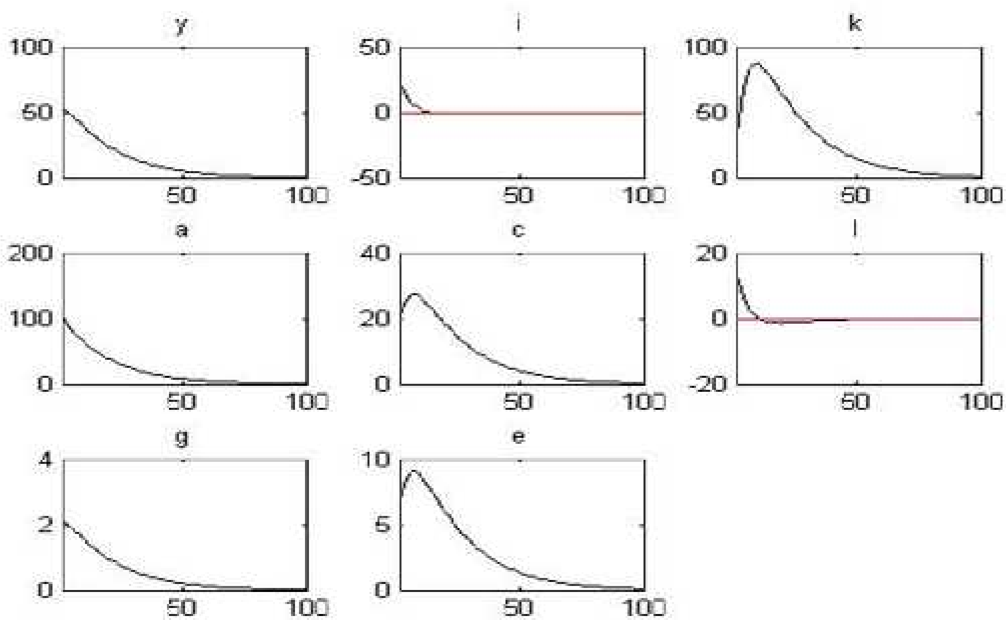
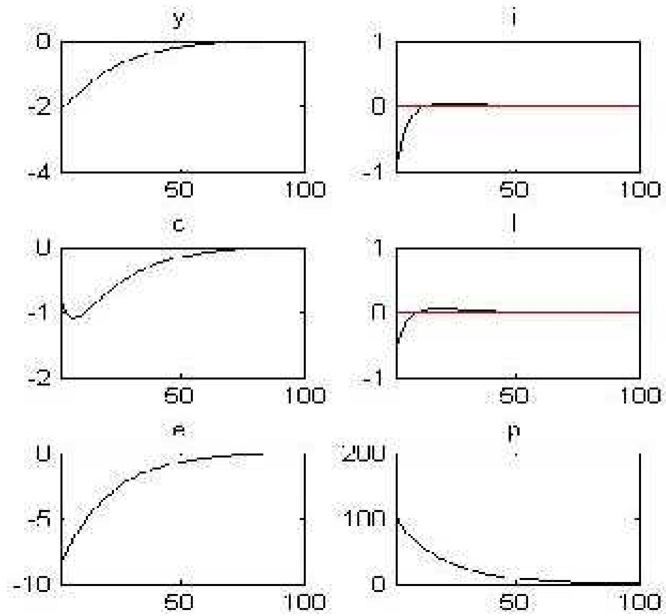


Figure 2: Relative Impulse Responses to an energy shocks



5. Conclusions

In the introduction to this paper we referred to McCallum's suggestion that RBC 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 function. Energy price shock is explicitly introduced in our model in addition to the productivity shocks. The model used in this paper is based on the standard Dynamic Stochastic General Equilibrium (DSGE) analysis which is a small first step in modelling energy price shocks in a RBC framework for Bangladesh economy. The main conclusion from our paper is that energy price shocks are not a major factor form business cycle fluctuation in Bangladesh economy. In fact, our results do some support to the views of macroeconomists who downplay the impact of energy shocks on the economy. Overall, the RBC model developed in this paper does a reasonable job in order to capture the direction of the variables which occur when faced the exogenous shocks. But, the model fails to replicate the exact strength of the movements in aggregate fluctuations 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.

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.

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