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Oil Price Fluctuations and it Impact on Economic Growth: A Dsge Approach

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Abstract
Ghana is poised to be one of the fastest growing economies in Sub-Saharan Africa because of its emerging oil and gas industry. Ghana's discovery of oil in commercial quantities in 2007 and its commencement of production in 2010 are expected to have an impact on the economy. To investigate these, we estimated a dynamic stochastic general equilibrium (DSGE) model based on the features of the Ghanaian Economy. We then examined the persistent effects of world oil price and monetary policy shocks (money supply-interest rate induced) on economic growth in Ghana. We realized that, a shock on interest rate leads to a sharp fall in prices which reflects the impact of the decrease in interest rate on the marginal cost. There is a paradoxical effect of a negative interest rate on total money supply. We also showed that a positive output shock has the same effect on consumption, investment, prices and wages as in the case of interest rate shock.
Keywords: DSGE model, Ghana, Interest rate, Output, Oil Price.

1. Introduction

The recent uses of DSGE models have earned a great deal of attention from researchers and policy makers in recent years. These models treat oil price fluctuations as exogenous supply disturbances that are unrelated to any economic fundamentals. Rotemberg and Woodford (1996) and Finn (2000), assessed the impact of oil supply shocks on the US economy. Leduc and Sill (2004) and Medina and Soto (2005), examined the role of monetary policy as a transmission channel for oil shocks. In an experiment by Jacquinot et al. (2009) and Nakov &

Pescatori (2010a), they showed that different types of oil shocks engender distinct monetary policy reactions. A number of studies have also employed Bayesian estimation techniques to identify the sources of oil price shocks and to analyze its economic effects (Nakov and Pescatori, 2010b; Balke et al., 2010; Bodenstein and Guerrieri, 2011; Forni et al., 2012).
Some recent studies have also examined the effects of oil price changes on the macro economy of developing (countries). Raguindin and Reyes (2005) examined the effects of oil price shocks on the Philippine economy over the period of 1981 to 2003. Their impulse response functions for the symmetric transformation of oil price shocks showed that an oil price shock leads to a prolonged reduction in the real GDP of the Philippines. Conversely, in their asymmetric VAR model, oil price decreases plays a greater role in each variable's fluctuations than oil price increases. El-Anashasy (2006) investigated the effects of oil price shocks on Venezuela's economic performance over 1950 to 2001 by employing a general to specific modeling (VAR and VECM). He found two long run relations consistent with economic growth and fiscal balance. Furthermore, he found that this relationship is important not only for the long run performance but also for short-term fluctuations. Olomola and Adejumo (2006) examined the effects of oil price shocks on output, inflation, real exchange rate and money supply in Nigeria using quarterly data from 1970 to 2003. Using VAR methodology they found that oil price shocks do not have any substantial effect on output and inflation. Oil price shocks significantly determine the real exchange rate and significantly affect the money supply in the long run.
In this research, we find the relationship between world Oil price shocks and economic growth of the Ghanaian economy. For a newly oil producing country like Ghana, such price shocks have its own effects, which could either be negative or positive. The global experience shows that the exploitation of oil or other natural resources have not always produced the economic boom and development that was expected. This calls for a research in the domain of the Ghanaian economy to calibrate the effects of these fluctuations. This will enable economic policy makers and analyst as well as researcher to come up with relevant and prudent economic reforms and policies to transform oil resources into long-term growth and development.
Studies that investigated the effect of oil-price shocks on output used VAR models to decompose the direct effects of an oil-price shock on output and other variables, from those generated by the endogenous monetary policy response (Hamilton, 1983; Bernanke, Gertler and Watson, 1997). However, lack of structural interpretation of the reduced-form coefficients of these types of model makes it very hard to straighten out the contribution of monetary policy, and to evaluate alternative monetary policy regimes.
Using a multi-sector dynamic stochastic general equilibrium (DSGE) model that explicitly includes oil price shocks (through monetary policy shock) allows us to better understand the mechanisms through which oil-price shocks affect inflation, output and the endogenous response of monetary policy. Moreover, this methodological approach allows policy makers to overcome the Lucas Critique of using macro-econometric model to predict the behavior of an economy. Hence the use of this approach to calibrate and analyze the short to long-term impact of oil price windfalls through monetary policy responses in low-income countries (LICs) particularly the Ghanaian economy. The model stems from a structure which captures the main mechanisms and policy issues of interest in low-income countries. It features a learning-by-doing mechanism that creates an externality associated with the production of traded goods and captures the notion that real exchange rate appreciation may harm productivity growth in the traded sector; a role for public capital in production, so that government

spending can raise output directly and potentially crowd in private investment; and less-than-full conversion of public investment into useful public capital. The model also allows for separate and possibly uncoordinated fiscal spending and reserve accumulation responses to oil revenue surges, permitting a variety of policy combinations.

2. The Ghanaian economy and its Oil Industry

2.1. Ghana's Economic Activities since Independence

Since the independence the Ghanaian economy has been exhibiting a changed economic outlook, with improving growth reflecting both strong economic fundamentals and a positive response to them from the private sector. Despite the oil and mineral wealth now being exploited, agriculture remains a mainstay of the economy, accounting for more than one-third of GDP and about 55% of formal employment. Ghana's primary cash crop is cocoa, which typically provides about one-third of all export revenues. Other products include timber, coconuts and other palm products, shea nuts, and coffee. With donor support, Ghana also has established a successful program of nontraditional agricultural products for export including pineapples, cashews, and peppers. Cassava, yams, plantains, corn, rice, peanuts, millet, and sorghum are basic foodstuffs grown for local consumption. In addition to domestic produce, fresh vegetables are also imported from Burkina Faso.

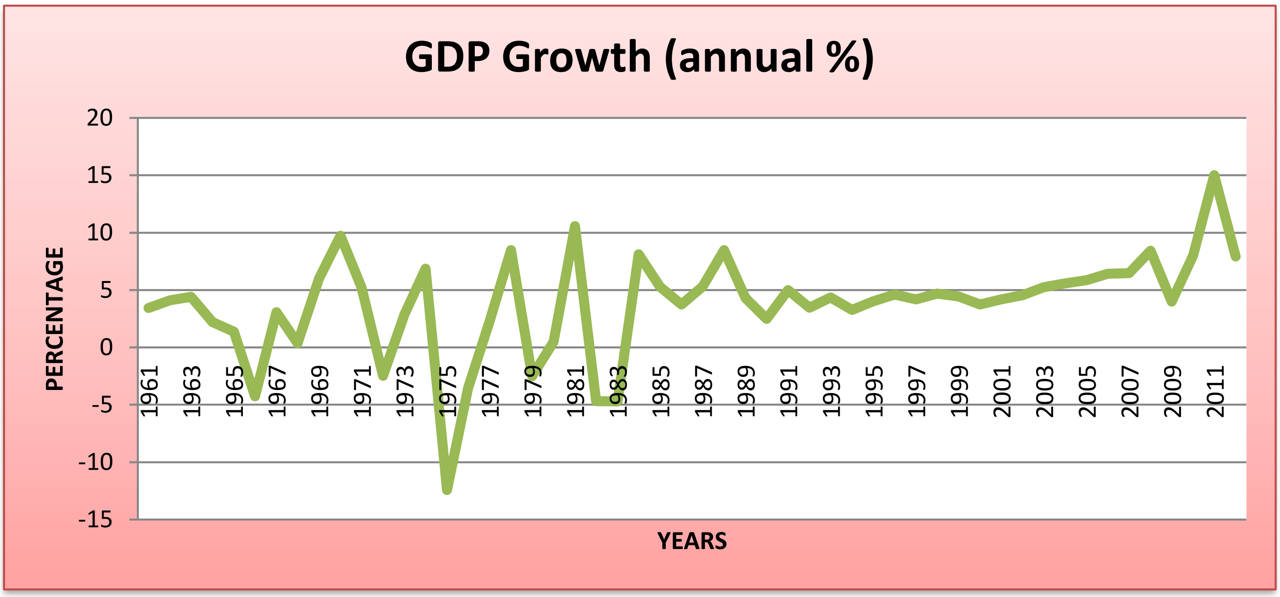

Figure 1: Ghana's Annual GDP Growth 1961-2012

Ghana's industrial base is relatively advanced compared to many other African countries. However, additional scope exists for value-added processing of agricultural products. Industries, including mining, manufacturing, construction and electricity, accounts for about 30% of GDP. With higher commodity prices, gold, cocoa, and oil are the top three export revenue earning sectors for Ghana.

The country's largest source of foreign exchange is remittances from workers abroad. Ghana's post-independence economic story has been a difficult one, but over the last 20 years, political stability and economic growth has been the long-term trend. Ghana is on track to meet several of the Millennium Development goals, including halving extreme poverty by 2015. Real GDP growth averaged 4% in the mid-1980s and has increased to about 6% over the past decade. Inflation declined after a rapid increase in 2009 (Globalegde, 2013). The macroeconomy remains under pressure from large fiscal and trade deficits.

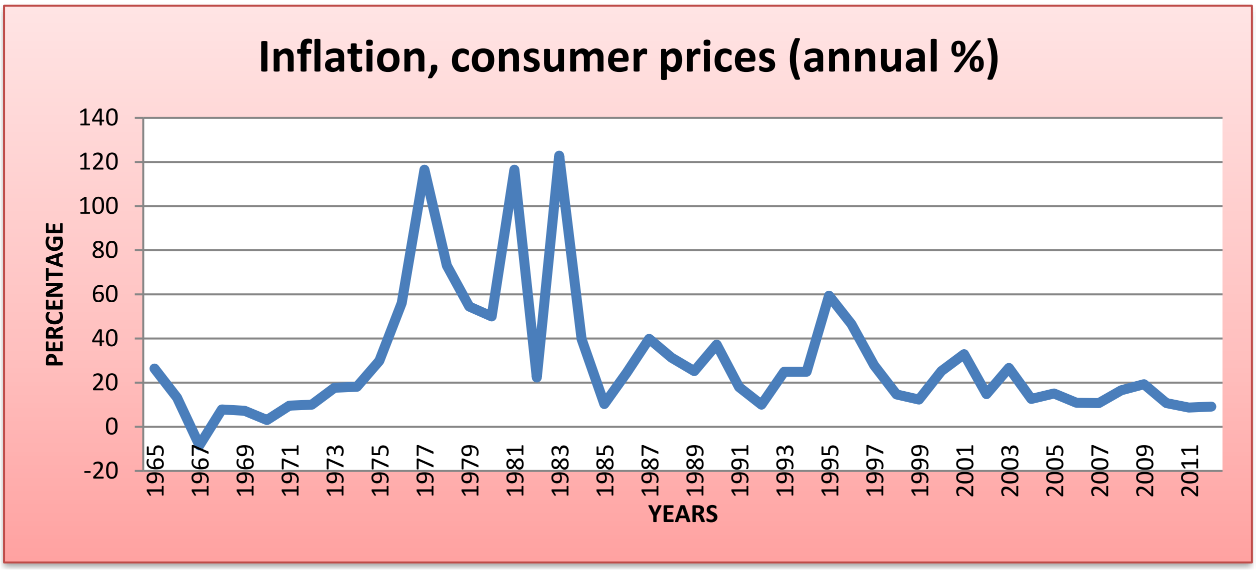

Figure 2: Ghana's Annual Inflation Rate From 1965-2012

2.2. The Ghanaian Oil Industry

In 2007, there was a major oil discovery off the coast of Ghana. The Jubilee Field, began production of oil and gas in December 2010, and is now producing approximately 85,000 barrels per day. This discovery has led to significant international commercial interest in Ghana. Some industry experts believe that within 5 years, Ghana is likely to be the third-largest producer of oil in West Africa. Timber and marine resources are important but declining resources.

Oil discovery can be a blessing and it can also be a curse for the citizens of societies in which the discoveries occur. This proposition is a truism that depends to a large extent on how the resource is extracted and how the revenues accruing from the discovery are shared and used for the benefit of the people in the society. The extraction, revenue sharing and utilization process can have positive or negative socio-economic consequences for the people and the nation. However, the positive effects can be accentuated while the negative effects can be mitigated if there is a conscious effort by the country to ensure that the method of production and the management of the resources take due cognizance of the peculiar nature and character of the oil and gas industry. Oil and gas resources are depleted over time and are non-renewable. This requires that policy makers are very strategic and future oriented in the decisions relating to extraction, revenue sharing and revenue utilization. Second, the resource is very scarce and of high intrinsic value; as a result it commands high returns to national treasury and can overshadow the resource mobilization efforts in traditional sectors of the economy. The attractiveness of the oil and gas industry, due to the associated high returns, can entice a large number of citizens away from traditional sectors.

The amount of oil expected in the Jubilee field, published by Ghanaian newspapers, vary between 1 and 2 billion barrels of crude oil. One barrel is 158,987 litres. In the report of the Ghana National Petroleum Company (GNPC) published in 2008, states that 800 million barrels of oil is the total field amount, with an upside potential of 3 billion barrels of oil *(GNPC, 2008)*. The International Monetary Fund (IMF) and the World Bank assumed in their base cases

2008/2009 a recoverable amount of 490/500 million barrels of oil [mmbo] *(World Bank, 2009)*.

The field operator, Tullow Oil, reveals on the companies' website that there are at least 500 mmbo through a most likely 700 mmbo to an upside of 1,000 mmbo recoverable reserves. As shown in the Table 1 below, the production amount depends on the number of drilled wells. The injection wells are especially important, as they maintain the field pressure. It is estimated that the field contains an additional 1.2 trillion cubic feet of gas, which are approximately 162 million barrels of oil equivalent *(Tullow Oil, 2010)*.

Table 1: Field Output during Different Phases.

ASSUMED FIELD RESERVES	PHASE ONE 17 WELLS ('000 barrels)	PHASE ONE(A) 5-8 ADDITIONAL WELLS ('000 barrels)	PHASE ONE(B) 10-20 ADDITIONAL WELLS ('000 barrels)	TOTAL RECOVERABLE FIELD RESERVES ('000 barrels)
Low estimates	250000	60000	160000	470000
Mid estimates	370000	100000	205000	675000
High estimates	590000	215000	260000	1065000

Tullow Oil, (2010)

In March 2009, the Tweneboa-1 (other oil field) exploration drilling discovered a field, containing up to 1.4 billion barrels of oil equivalent (bboe). The Owo-1 drilling tested the field structure and reported positively at the end of July 2010.The so called Tweneboa field seems to be of similar size to the Jubilee field and is the second major finding in Ghana. The other findings, including the Odum field were only minor amounts. But large parts of the Ghanaian sea have not been explored yet *(Tullow Oil, 2011)*.

The exploration of Ghana's newfound petroleum resources will undoubtedly have an important impact on the Ghanaian economy. The oil production based on the jubilee fields is expected to increase from 106,900 barrels per day in 2011 to 120,500 barrels per day in 2015 before declining continuously from 2016. Expected government revenue will alongside increase from one billion US dollars (US$1.0 billion) in 2011 to one billion, eight hundred million (US$1.8 billion) in 2016 before declining as shown in Table 2. Reliance on the Jubilee oil field alone will imply that after five years of production, Ghana may be a net importer. It is expected that other fields (wells) will come on stream to avert recourse to net importer position.

Table 2: Projections of Oil Output, Gross Revenue and Government Revenues from Jubilee Oil Fields for Ghana

Years	Expected Output (000 bpd)	Gross Revenue (US$ million)	Capital and Operating Costs (US$ million)	Government Revenue (US$ million)	Effective Government share (%)
2008	-	-	397.8	-	-
2009	-	-	1094.5	-	-
2010	-	-	1094.5	-	-
2011	106.9	2925.0	1108.9	899.7	30.77

2012	120.5	3300.0	1268.3	1010.8	30.64
2013	120.5	3300.0	350.3	1083.0	32.82
2014	120.5	3300.0	350.3	1483.8	44.97
2015	120.5	3300.0	350.3	1796.3	54.42
2016	101.4	2775.0	327.0	1804.1	65.00
2017	89.0	2437.5	312.1	1,587.4	65.11
2018	79.5	2174.9	300.4	1,400.4	64.37
2019	69.9	1912.4	288.8	1,213.3	63.43
2020	61.6	1687.4	278.8	1,053.0	62.40
2021	56.1	1536.8	272.1	945.7	61.56
2022	50.7	1387.6	265.5	839.4	60.46
2023	46.6	1275.1	260.5	759.3	59.52
2024	43.8	1200.1	257.2	705.8	58.83
2025	41.1	1125.1	253.9	652.4	57.95
2026	38.4	1050.1	250.6	599.0	57.04
2027	35.6	975.1	247.2	545.5	55.99
2028	34.3	937.6	245.6	518.8	55.35
2029	32.9	900.1	243.9	492.1	54.66
TOTAL	**1369.8**	**37499.8**	**9819.5**	**19,389.8**	**51.70**

World Bank Report (2009) & Thomas (2011)

3. Methodology

This study employs the DSGE model developed by Christiano et al (2001, 2005). Oil price shocks macro-dynamic models used in this paper is particularly suitable for constructing plausible macroeconomic scenarios following an increase in oil revenues in a low income country like Ghana. The model distinguishes between the short-to-medium terms effects versus the medium-to-long term effects of an increase in oil revenues through oil price increases.

3.1. The Consumer Problem

There is a continuum of households, indexed by $j \in (0,1)$. The j^{th} household makes an order of decisions during each period. It makes its consumption decision, its capital accumulation decision, and it decides how many units of capital services to supply. It purchases securities whose payoffs are contingent upon whether it can re-optimize its wage decision, it sets its wage rate after finding out whether it can re-optimize or not, it receives a lump-sum transfer from the monetary authority and decides how much of its financial assets to hold in the form of deposits with a financial intermediary and how much to hold in the form of cash. The preferences of the j^{th} household are given by, (Christiano et al 2001, 2005):

$$E_{t-1}^{j}\sum_{i=1}^{n}\beta^{l-t}\left[u\left(c_{t+l}-bc_{t+l-1}\right)-z\left(h_{j,t+l}\right)+v\left(q_{t+l}\right)\right]. \quad \textbf{(1)}$$

where, E_{t-1}^{j} is the expectation operator, conditional on aggregate and household j idiosyncratic information, and including, time $t-1$; c_t denotes consumption at time t; h_{jt}

denotes hours of work at time t; $q_t \equiv Q_t/P_t$ denotes real cash balances; Q_t denotes nominal cash balances. When $b>0$, equation **(1)** allows for habit formation in consumption preferences.
The household's asset evolution equation (budget constraint) is given by:

$$M_{t+1} = R_t\left[M_t - Q_t + \left(\mu_t + 1\right)M_t^a\right] + A_{j,t} + Q_t + W_{j,t}h_{j,t} + R_t^k u_t \bar{k}_t \\ + D_t - P_t\left(i_t + c_t + a\left(u_t\right)\bar{k}_t\right) \quad \textbf{(2)}$$

where, M_t is the household's beginning of period t stock of money and $W_{j,t}h_{j,t}$ is time t labour income. Additionally, $\bar{k}_t$, D_t and $A_{j,t}$ denote, respectively, the physical stock of capital, firm profits and the net cash inflow from participating in state-contingent securities at time t. The variable μ_t represents the gross growth rate of the economy-wide per capita stock of money, M_t^a. The quantity $\left(\mu_t + 1\right)M_t^a$ is a lump-sum payment made to households by the monetary authority. The quantity $M_t - P_t q_t + \left(\mu_t + 1\right)M_t^a$ is deposited by the household with a financial intermediary where it earns the gross nominal rate of interest, R_t. The remaining parts of equation **(2)**, aside from $P_t c_t$ pertain to the stock of installed capital, which is assumed to be owned by the household. The household's stock of physical capital $\bar{k}_t$ evolves according to:

$$\bar{k}_{t+1} = \left(1-\delta\right)\bar{k}_t + F\left(i_t, i_{t-1}\right) \quad \textbf{(3)}$$

where, δ denotes the physical rate of depreciation and i_t denotes purchases of investment goods at time t. The function, F, summarizes the technology that transforms current and past investment into installed capital for use in the following period. The properties of F is discussed as follows:
Capital services, k_t are related to the physical stock of capital by

$$k_t = u_t \bar{k}_t \quad \textbf{(4)}$$

where, u_t denotes the utilization rate of capital, which is assumed to be set by the household. This assumption that households make the capital accumulation and a utilization decision is a matter of convenience. At the cost of a more complicated notation, an alternative decentralization scheme in which firms make these decisions could be work with. From equation **(2)** $R_t^k u_t \bar{k}_t$ represents the household's earnings from supplying capital services. The increasing, convex function $a\left(u_t\right)\bar{k}_t$ denotes the cost, in units of consumption goods, of setting the utilization rate to u_t.

3.2. The Wage Decision

Erceg, Henderson and Levin (2000), assumed that the household is a monopoly supplier of a differentiated labour service, $h_{j,t}$. It sells this service to a representative, competitive firm that transforms it into an aggregate labour input, L_t, using the following technology:

$$L_t = \left[\int_0^1 h_{jt}^{\frac{1}{\lambda_w}} dj\right]^{\lambda_w} \quad \textbf{(5)}$$

The demand curve for h_{jt} is given by:

$$h_{jt} = \left(\frac{W_t}{W_{jt}} \right)^{\frac{\lambda_w}{\lambda_w - 1}} L_t, 1 \leq \lambda_w < \infty \quad \textbf{(6)}$$

where, W_t is the aggregate wage rate, that is, the price of L_t, W_t is related to W_{jt} through the relationship:

$$W_t = \left[\int_0^1 (W_{jt})^{\frac{1}{1-\lambda_w}} dj \right]^{1-\lambda_w} \quad \textbf{(7)}$$

Household takes L_t and W_t as given and faces a constant probability, $1-\xi_w$, of being able to re-optimize its nominal wage. The ability to re-optimize is independent across households and time. If a household cannot re-optimize its wage at time t, it sets W_{jt} according to:

$$W_{jt} = \pi_{t-1} W_{j,t-1} \ . \quad \textbf{(8)}$$

3.3. Final Good Firms

At time t, a final consumption good, Y_t, is produced by a perfectly competitive, representative firm. The firm produces the final good by combining a continuum of intermediate goods, indexed by $j \in (0,1)$, using the technology:

$$Y_t = \left[\int_0^1 Y_{jt}^{\frac{1}{\lambda_f}} dj \right]^{\lambda_f} \quad \textbf{(9)}$$

where $1 \leq \lambda_f < \infty$ and Y_{jt} denotes the time t input of intermediate good j.

The firm takes its output price, P_t and its input prices, P_{jt}, as given and beyond its control. Profit maximization implies the Euler equation

$$\left(\frac{P_t}{P_{jt}} \right)^{\frac{\lambda_f}{\lambda_f - 1}} = \frac{Y_{jt}}{Y_t}. \quad \textbf{(10)}$$

By integrating equation **(10)** and imposing equation **(9),** the following relationship between the price of the final good and the price of the intermediate good is obtained:

$$P_t = \left[\int_0^1 P_{jt}^{\frac{1}{1-\lambda_f}} dj \right]^{1-\lambda_f} \quad \textbf{(11)}$$

3.4. Intermediate Good Firms

Intermediate good $j \in (0,1)$ is produced by a monopolist who uses the following technology:

$$Y_{jt} = \begin{cases} k_{jt}^{\alpha} L_{jt}^{1-\alpha} - \phi & \text{if } k_{jt}^{\alpha} L_{jt}^{1-\alpha} \geq \phi \\ 0 & \text{otherwise} \end{cases} \quad \textbf{(12)}$$

where $0 < \alpha < 1$ and L_{jt} and k_{jt} denote time t labour and capital services used to produce the j^{th} intermediate good. Also $\phi > 0$ denotes the fixed cost of production. The assumption of entry and exit into the production of intermediate good j are ruled out.

Intermediate firms rent capital and labour in perfectly competitive factor markets. Profits are distributed to households at the end of each time period. Let R_t^k and W_t denote the nominal rental rate on capital services and the wage rate, respectively. Workers must be paid in advance of production. As a result, the j^{th} firm must borrow its wage bill, $W_t L_{jt},$ from the financial intermediary at the beginning of the period. Repayment occurs at the end of time period t at the gross interest rate, R_t. The firm's real marginal cost is:

$$s_t = \frac{\partial S_t(Y)}{\partial Y}, \text{ where } S_t(Y) = \min_{(k,l)} \left\{ r_t^k k + w_t R_t l,\ Y \text{ given by equation } (12) \right\}$$

(13)

where $r_t^k = \frac{R_t^k}{P_t}$ and $w_t = \frac{W_t}{P_t}$. Given the functional forms, marginal cost is given as:

$$s_t = \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha} \left(r_t^k\right)^{\alpha} \left(w_t R_t\right)^{1-\alpha} \quad \textbf{(14)}$$

Apart from fixed costs, the firm's time *t* profits are:

$$\left(\frac{P_{jt}}{P_t} - s_t\right) P_t Y_{jt}, \quad \textbf{(15)}$$

where P_{jt} is firm $j's$ price.

Assuming firms set prices according to a variant of the mechanism spelled out in Calvo (1983). In each period, a firm faces a constant probability, $1-\xi_p$, of being able to re-optimize its nominal price. The ability to re-optimize its price is independent across firms and time. If a firm can re-optimize its price, it does so before the realization of the time t growth rate of money. Firms that cannot re-optimize their price simply index to lagged inflation:

$$P_{jt} = \pi_{t-1} P_{j,t-1} \quad \textbf{(16)}$$

where, $\pi_t = P_t / P_{t-1}$. This price-setting rule is referred to as lagged inflation indexation.

Letting $\tilde{P}_t$ denote the value of P_{jt} set by a firm that can re-optimize at time t. This notation does not allow $\tilde{P}_t$ to depend on j. This is done in anticipation of the well-known result that, in models like this, all firms who can re-optimize their price at time t choose the same price (Rotemberg and Woodford, 1996). The firm chooses $\tilde{P}_t$ to maximize:

$$E_{t-1} \sum_{l=0}^{\infty} \left(\beta \xi_p\right)^l v_{t+l} \left[\tilde{P}_t X_{tl} - s_{t+l} P_{t+l}\right] Y_{j,t+l}, \quad \textbf{(17)}$$

subject to equations **(10)** and **(14)** and

$$X_{tl} = \begin{cases} \pi_t \text{ x } \pi_{t+l} \text{ x } \dots\dots\dots \text{ x } \pi_{t+l-1} & \text{for } l \geq 1 \\ 1 & l = 0 \end{cases} \quad \textbf{(18)}$$

In equation **(17),** v_t is the marginal value of a dollar to the household, which is treated as exogenous by the firm. Later, it will be shown that the value of a dollar, in utility terms, is constant across households. Also E_{t-1} denotes the expectations operator conditioned on lagged growth rates of money, $\mu_{t-l},\ l \geq 1$. This specification of the information set captures the assumption that the firm chooses $\tilde{P}_t$ before the realization of the time t growth rate of money. To understand equation **(17),** one should note that $\tilde{P}_t$ influences firm $j's$ profits only as long as it cannot re-optimize its price. The probability that this happens for l periods is $(\xi_p)^l$, in which case $P_{j,t+l} = \tilde{P}_t X_{tl.}$. The presence of $(\xi_p)^l$ in equation **(17)** has the effect of isolating future realizations of idiosyncratic uncertainty in which $\tilde{P}_t$ continues to affect the firm's profits.

3.5. Monetary and Fiscal Policy

The monetary policy is assumed to be given by:

$$\mu_t = \mu + \theta_0 \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + ... \quad \textbf{(19)}$$

where μ denotes the mean growth rate of money and θ_j is the response of $E_t \mu_{t+j}$ to a time t monetary policy shock. We assume that the government has access to lump sum taxes and pursues a Ricardian fiscal policy. Under this type of policy, the details of tax policy have no impact on inflation and other aggregate economic variables. As a result, there is no need to specify the details of the fiscal policy.

3.6. Loan Market Clearing, Final Goods Clearing and Equilibrium

Financial intermediaries receive $M_t - Q_t$ from households and a transfer, $(\mu_t - 1)M_t$ from the monetary authority. The notation here reflects the equilibrium condition, $M_t^a = M_t$. Financial intermediaries lend all of their money to intermediate good firms, which use the funds to pay for L_t. Loan market clearing requires:

$$W_t L_t = \mu_t M_t - Q_t \quad \textbf{(20)}$$

The aggregate resource constraint is given as:

$$c_t + i_t + a(u_t) \leq Y_t \quad \textbf{(21)}$$

3.7. Functional Form Assumptions

Given the functions characterizing utility as:

$$\begin{aligned} u(.) &= \log(.) \\ z(.) &= \psi_0 (.)^2 \quad . \\ v(.) &= \psi_q \frac{(.)^{1-\delta_q}}{1-\delta_q} \end{aligned} \quad \textbf{(22)}$$

In addition, investment adjustment costs are given by:

$$F(i_t, i_{t-1}) = \left[1 - S\left(\frac{i_t}{i_{t-1}}\right)\right] i_t \quad \textbf{(23)}$$

The function S is restricted to satisfy the following properties: $S(1) = S^{'}(1) = 0,$ and $\chi \equiv S^{"}(1) > 0$. It is easy to verify that the steady state of the model does not depend on the adjustment cost parameter, χ. Of course, the dynamics of the model are influenced by χ. Given the solution procedure, no other features of the S function need to be specified for the analysis. Two restrictions are imposed on capital utilisation function $a(u_t)$. Firstly, in the steady state u_t is required to be $u_t = 1$. Secondly, a is also required to be $a(1) = 0$. Under this assumptions, the steady state of the model is independent of $\delta_a = \frac{a''(1)}{a'(1)}$. The dynamics do depend on δ_a.

4. Calibration, Results and Discussion

The analyses of the model rely on calibrated numerical simulations using dynare. The micro-founded nature of the model makes some parameters being chosen based on microeconomic evidence, such as the efficiency of investment; otherwise, their values are chosen in line with literature. Other parameters also depend on steady-state ratios that can be determined from national income accounts, public and private sector balance sheets and input-output matrices, or can be informed by more-or-less structural macro-econometric estimates. The calibration of some of the parameters is essence for the policy experiments. One of which is of particular interest is λ_w, the elasticity of substitution between labour supplied to different sectors. The year 2008 is chosen to represent the steady state since the oil production year in Ghana is 2010 and parameters are calibrated to match ratios of this year.

4.1. Parameter Calibration

The model parameters are partitioned into three groups. The first group is composed of $\beta, \phi, \alpha, \delta, \psi_o, \psi_q, \lambda_w$ and μ. The parameter $\beta = 0.9951$ was set to imply a steady state annualized real interest rate of 8 percent. The parameter $\alpha = 0.7$ was also set to imply a standard value in the literature. The parameter $\delta = 0.015$ was set to be in line with Bu (2004). It is roughly equal to the estimate reported in Christiano and Eichenbaum (1992). The parameter, ϕ is set to guarantee that profits are zero in steady state. This value is consistent with Hall (1988), and Rotemberg and Woodford (1996), who argue that economic profits are close to zero on average. Although there are well known problems with the measurement of profits, setting profit at zero is a reasonable benchmark.

The parameter ψ_o was chosen to imply a steady state value of L equal to unity. Similarly, the parameter ψ_q was set to ensure $Q/M = 0.44$ in steady state. This value is equal to the ratio of $M1$ to $M2$ at the beginning of our sample period. The rationale for using this ratio is that $M1$ is a measure of money used for transactions, while $M2$ is a broader monetary aggregate. Re-estimation was done to calibrate ψ_q to different steady state values of Q/M. The primary impact on the model parameter estimates was to change the estimate of σ_q. The impulse response functions were relatively unaffected by different values of σ_q. The parameter μ was set to 1.017, which equals the post-war quarterly average gross growth rate of $M2$. From the assumed parameter values, the steady state velocity of money is given by:

$$\frac{PY}{M} = (\mu - q)(1-\alpha)\frac{\beta}{\mu} = 0.36$$

This ratio is slightly below the average value, 0.44, of $M2$ velocity in literatures. The parameter, λ_w, is set to 1 which is in line with Horvath (2000). This gives a result which is robust to perturbations in this parameter. This means that holding fixed the other parameter values at their benchmark values reported below, the impulse response functions implied by the model are insensitive to different values of λ_w. The specification of $z(.)$ implies a Frisch labour supply elasticity equal to unity. This elasticity is low by comparison with the values assumed in the real business cycle literature. For instance, the Frisch elasticity implicit in the 'divisible labour' model in Christiano and Eichenbaum (1992) is roughly 2.5 percent. However, it is well within the range of point estimates reported in the labour literature (Rotemberg and Woodford, 1999).

The monetary policy is characterised by equation **(19)**, where θ_i's are the impulse responses implied by an estimated VAR say:

$$\mu_t = \tau\left(I - A_1 L - .... - A_4 L^4\right)^{-1} c\varepsilon_t$$

Where, c is the last column of C, and $A_1,...,A_4,C$ are the estimated parameters of a VAR. In addition, τ is a row vector with zeros everywhere, except unity in the last element. The moving average parameter, θ_i, is the coefficient on L^i in the expansion of the polynomial to the right of the equality in the previous expression, for $i = 0,1....$. To incorporate this representation of monetary policy into the model, the procedure described by King and Watson (1996) is used. Christiano, Eichenbaum and Evans (1998) show that this representation is not statistically significantly different from the one generated by a first order auto-regression with coefficient roughly equal to 0.5.

The last group of the model is described as follows: $\gamma \equiv \left(\lambda_f, \xi_w, \xi_p, \sigma_q, \chi, b, \sigma_a\right)$. These parameters were estimated by minimizing a measure of the distance between the model and empirical impulse response functions. Let $\Psi(\gamma)$ denote the mapping from γ to the model impulse response functions, and letting $\hat{\Psi}$ denote the corresponding empirical estimates. The first 25 elements of each response function are included and those that are zero by assumption are excluded. Hence the estimator of γ is the solution to:

$$J = \min_{(\gamma)}\left(\hat{\Psi} - \Psi(\gamma)\right)' V^{-1}\left(\hat{\Psi} - \Psi(\gamma)\right). \quad \textbf{(24)}$$

Where, V is a diagonal matrix with the variances of the $\hat{\Psi}'s$ along the diagonal. The standard error for σ_a is driven towards zero because of the estimation procedure at which the algorithm breaks. As a result, that parameter is set to be $\sigma_a = 0.01$ and optimize the estimation criterion over the remaining elements in γ. The various parameter estimates imply that elasticity is 0.96, i.e., a one percentage point rise in the annualized rate of interest leads to a 0.96 percentage reduction in real balances. This elasticity is considerably smaller than standard estimates reported for static money demand equations. For example, the analogous number in Lucas (1988) is 8.0. The model found that the estimate of σ_q is driven primarily by the model's attempt to replicate the initial responses of the interest rate to a monetary policy shock. Consequently, the interest semi-elasticity is interpreted as pertaining to the short-run response of money demand. This elasticity is often estimated to be quite small (Christiano, Eichenbaum and Evans, 1998). The estimate of the habit parameter *b* is 0.65. This value is close to the point estimate of 0.7 reported in Boldrin, Christiano and Fisher (2001). Those authors argued that the ability of standard general equilibrium models to account for the equity premium and other asset market statistics is considerably enhanced by the presence of habit formation in preferences.

Table 3: Preference Parameters

Parameters	Value	Source/Method
b	0.65	Degree of habit persistence
β^t	0.9951	Matches real interest rates equal 8 percent
θ	12	Standard value in Literature
R	1.0086	Ensures nominal interest rate is zero at steady state
χ	0.01	Habit parameter 2 for experiment
ψ	1	Marginal disutility of hours
σ_q	0.9993	relates cash holding and the interest rate
η	1.5	Price elasticity of demand for differentiated goods

Finally, the estimated value of $\lambda_f = 12$ is close to the values used in the literature (Rotemberg and Woodford, 1996). Tables 3 - 5 summarize the parameter values. Government spending is particularly large in Ghana standing at around 37% of GDP in 2008. Most of this spending is on government consumption. The steady state inflation rate is set to 18% which is the average inflation rate for the year 2008. The parameters of the models are set so to meet these and other key variables of the Ghanaian economy. The benchmark simulation for both fiscal and monetary policy also assumes the following; based on current proven reserves, oil production is expected to be relatively high with peak production over the first 5 years.

Table 4: Technology Parameters

Parameters	Value	Source/Method
α	0.7	Standard value in literature
δ	0.015	In line with Bu (2004)
ζ_p	30	Implies prices are sticky for 6 months on average
ζ_w	0.9	Calvo's parameter on wage

λ_w	1	Households labour market power
λ_f	12	Firms market power

According to the World Bank report (2009) the government revenues from oil and gas could reach a cumulative amount of US 19 billion during the production period 2011–2029 from Table 2. Finally the value of the steady-state efficiency is based on work by Arestoff and Hurlin (2006).

Table 5: Policy Parameters

Parameters	Value	Source/Method
ρ^{π}	1.5	Standard in Literature
ρ^{Y}	0.5	Monetary rule parameter on output
ρ^{R}	0.3514	Monetary rule parameter on lagged interest rate

4.2 Oil Revenue and Monetary Policy Shock Mechanism

To understand the contemporaneous effect of a policy shock which is treated here as interest rate shock, it is useful to focus on the money market clearing condition, equation **(20),** and the household's first order condition, $v'(q_t)+\psi_t=\psi_t R_t$, where $q_t = Q_t/P_t$, also ψ_t is the marginal utility of p_t units of currency . Given the assumptions, the full amount of a policy shock-induced money injection must be absorbed by household cash holdings, Q_t. Firms do not wish to absorb any part of a cash infusion because $W_t L_t$ does not respond to a policy shock. The wage rate, W_t, is predetermined because the $W_{jt's}$ are predetermined by assumption. Employment L_t is predetermined because of the assumption that consumption, investment and capital utilization are predetermined. It follows from equation **(20)** that at period t money injection must be accompanied by an equal increase in Q_t. As oil revenues accrue directly to the government, the oil shock translates into higher government spending. Given that size of the government is already large in Ghana it is important to evaluate quantitatively the overall impact on the main macroeconomic aggregates and on price levels. The analyses follows that as government spends the oil revenue as it accrues, it results in an increase in aggregate demand leading to a sharp (but short-lived) spike in real GDP growth. This also results in a persistent effect on real GDP. Inflation increases moderately, which is accounted for by the increase in non-tradable inflation combined with a decrease in inflation in the tradable sector.

The model does well in accounting for the dynamic response of the Ghanaian economy to a monetary policy shock as result of oil revenue received and spent by the government. As it can be seen from Figure 3, there is a noticeable fall in inflation as soon as the shock hit the economy. This fall in prices reflects the impact of a decrease in interest rate on the marginal cost. The main impact is that inflation decreases more and there is a larger rise in output in the aftermath of the shock. Notice how the money stock rises to its peak level after the shock and is roughly goes back to where it started. The prolonged rise in the money stock doesn't essentially reflect the fall in the price level. At the same time, there is a prolonged increase in output that lasts even after the boom in the money supply is over. The shock also impact positively on total consumption and investments. As showed by Figure 3, there is a contemporaneous rise in both consumption and investment for about two to three years before both variables start to fall to attain stability.

With a negative interest rate shock the paradoxical effect on total money supply is an increase in its supply which is well accounted for by the model; but this on the other hand induces sharp rise in the growth of money. The increase in consumption as explained above can be accounted for as a result of the rise in real wage. One should notice that the magnitude of these aggregate-demand effects depends critically on the monetary policy reaction function. Moreover holding the monetary policy rule constant, higher inflation and the real appreciation are thus important parts of the required macroeconomic adjustment. Unlike the real appreciation however, an increase in inflation is not an inevitable part of the transmission mechanism but is a result of the aggregate-demand pressures that can arise from a rapid increase in spending and the monetary policy stance.

Alternately, the dynamic effects of a monetary shock on $R_t, C_t, I_t, Y_t, L_t, u_t$, productivity and profits can be explained as follows. The persistent fall in R_t reflects the high adjustment of Q_t/P_t relative to its high value in the period of the shock. In part, this high adjustment is due to the inertia in P_t. But it is also the case that households are slow to reduce their cash holdings from its high level in the impact period of the shock.

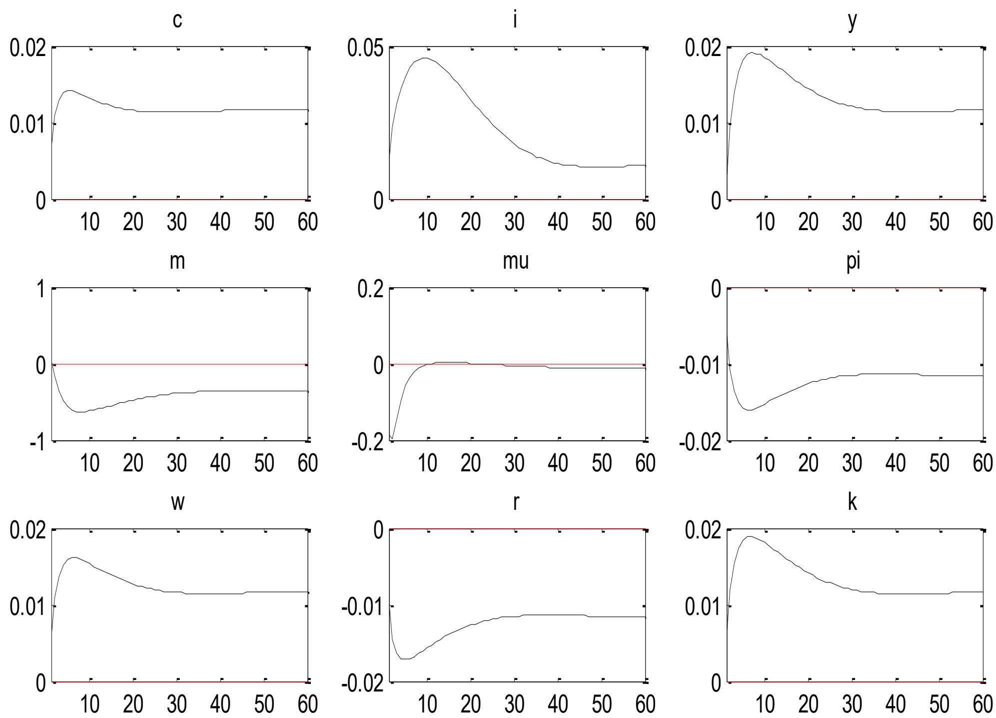

Figure 3: Variable Responses to Monetary Policy Shock

Consumption (c), Investment (i), Output (y), Money Supply (m), Money Growth Rate (mu), Inflation (pi), Real Wage (w), Nominal Interest Rate (r), Capital Service (k)

This response in Q_t reflects money market clearing, equation **(20)**, the inertial behaviour of W_t and the sharp rise in L_t after a policy shock. The sharp rise in hours worked occurs because household demand for goods increases, reflecting habit formation in preferences and second order adjustment costs in investment. These considerations provide intuition for the persistent rise in Q_t/P_t after an expansionary monetary policy shock. It then follows from equation **(27)** that R_t must be low for a prolonged period of time. The increase response in c_t and i_t implies that output, employment and capital utilization rates also increases. Finally, the increase in productivity reflects the effects of capital utilization, as well as the presence of the fixed cost in the production function, as shown in Figure 5. To understand the impact of the rise in Q_t on R_t; Now supposed that ψ_t is constant and P_t is predetermined, the increase in Q_t corresponds to a rise in real balances. Given the household's first order condition for cash balances, R_t must decrease to induce households to increase real cash balances, Q_t/P_t . In practice, ψ_t must decrease, but by only a relatively small amount.
Finally, since R_t falls and the firm's wage bill and revenues also rises by the shock, profits must increase as well. One cannot consider monetary shocks without inferring to the pros and cons of this shock on output. Eventually Figure 3 shows a fall in output; but what happens if there is a shock of output on the other variables. Figure 6 shows the effect of this output shock on the other variables. A positive shock to output have the same effect on consumption, investment, prices and wages as it occurred when there is an interest rate shock.

4.3 Effects of Price Shock to Macroeconomic Variables
The study again explore the responses that surfaces as a result of a surge in prices of goods and services. Whenever there is an increase in government spending, general price levels also increases. This is because the projected increase in oil revenues comes at the time where inflation remains high. Therefore Figure 4 depicts these responses to an inflation shocks. Let assume that an increase in inflation target comes as an initial surprise to economic agents in the model, so that the increase in inflation target implies a discretionary policy tightening and leads to a temporary reduction in aggregate-demand.
The decrease in the target is perceived as credible once inflation is reduced to its new target. In this scenario, the monetary policy tightening leads to lower GDP growth in the short run, with a more gradual increase in intermediate production and a similar real exchange rate appreciation. These results imply that a reduction in the inflation target is relatively costless. This is due to the fact that nominal rigidities are relatively small in the model, so that discretionary changes in monetary policy have a short-lived effect. Inflation expectations also adjust relatively quickly, which implies monetary policy credibility is relatively easy to acquire. For these reasons, these projections are optimistic, and should be therefore interpreted with cautions.

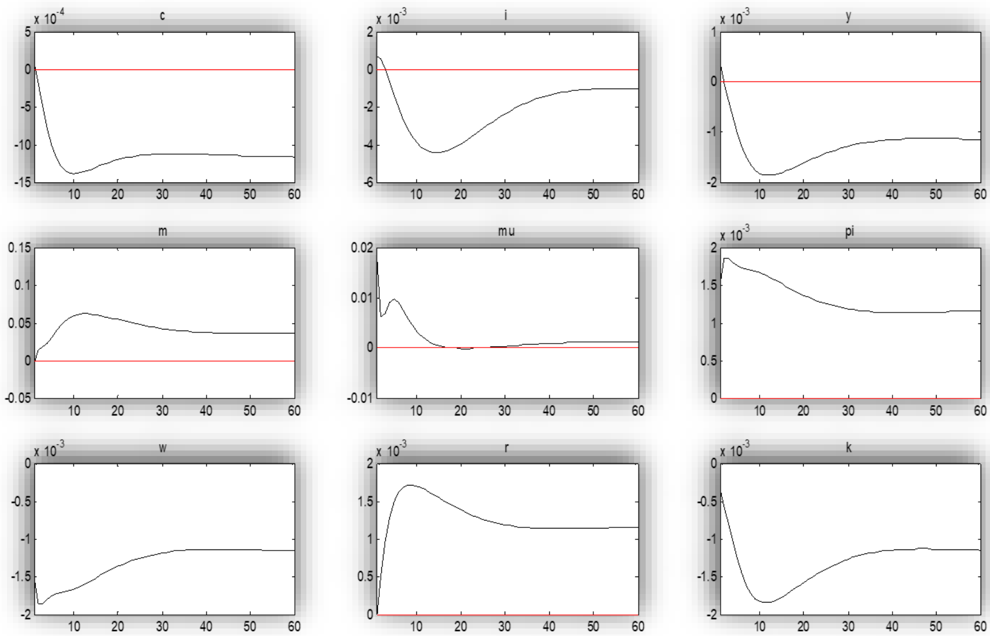

Figure 4: Effects of Price Shock
Consumption (c), Investment (i), Output (y), Money Supply (m), Money Growth Rate (mu), Inflation (pi), Real Wage (w), Nominal Interest Rate (r), Capital Service (k),

5. Conclusion

We examined the impact of structural shocks of oil prices on Ghanaian economy. As oil revenues accrue directly to the government, the oil shock translates into higher government spending. Given that size of the government is already large in Ghana, we quantitatively evaluated overall impact of this shocks on the main macroeconomic aggregates and on price levels. These simulations followed a DSGE model by Christiano et al (2001 & 2005). The model is suitable for the Ghanaian case with similar agents and oil shock macro-dynamics. The model was calibrated based on the micro-founded evidence and steady state ratios determined from national income accounts of Ghana. The benchmark simulation captured interest rate shock and this leads to a sharp rise in prices which reflects the impact of the increase in interest rate on the marginal cost. The effect is that inflation decease more and there is a larger rise in output. Money stock rises to its peak level after the shock and is roughly goes back to where it started. The prolonged rise in the money stock, essentially reflect the fall in the price level. The effect of the shock on total consumption and investments is positive; this increase in consumption and investment last for some time before both variables start to fall to attain stability. Here the model is able to accounts for the paradoxical effect of a negative interest rate on total money supply which is an increase in its supply. The model also shows that a positive output shock have the same effect on consumption, investment, prices and wages as it occurred when there is an interest rate shock.

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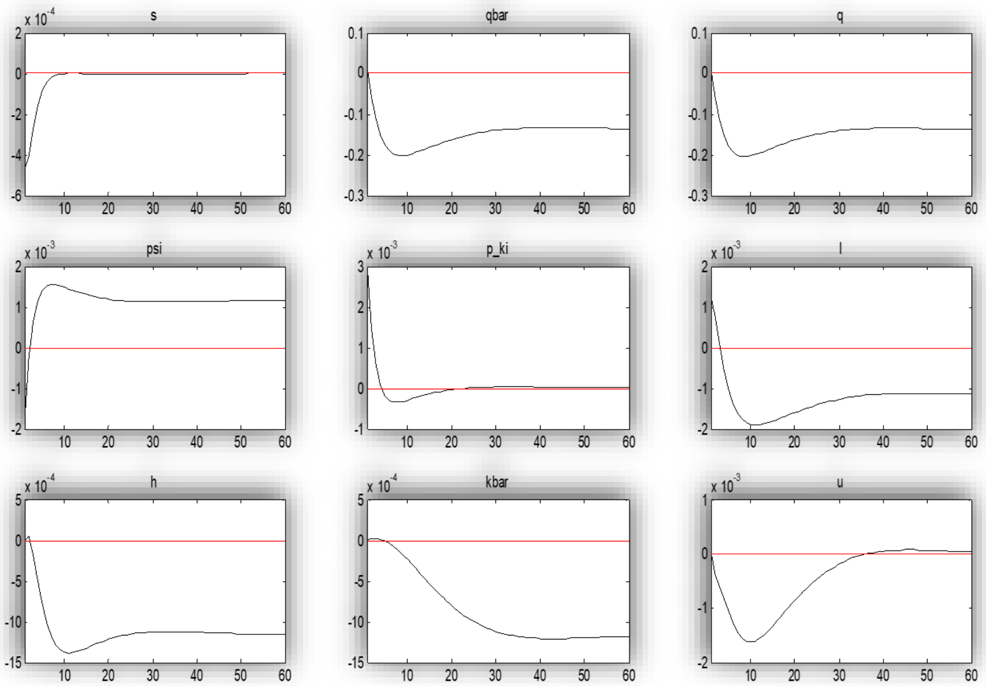

Figure 4b: Other Variable Responses to Price Shock
Real Marginal Cost (s), Real Transaction Money (qbar), MU of Consumption (q), Wage (psi), MP of Capital (p_ki), Labour (l), Habit (h), Capital Stock (kbar), Capital Utilisation (u)

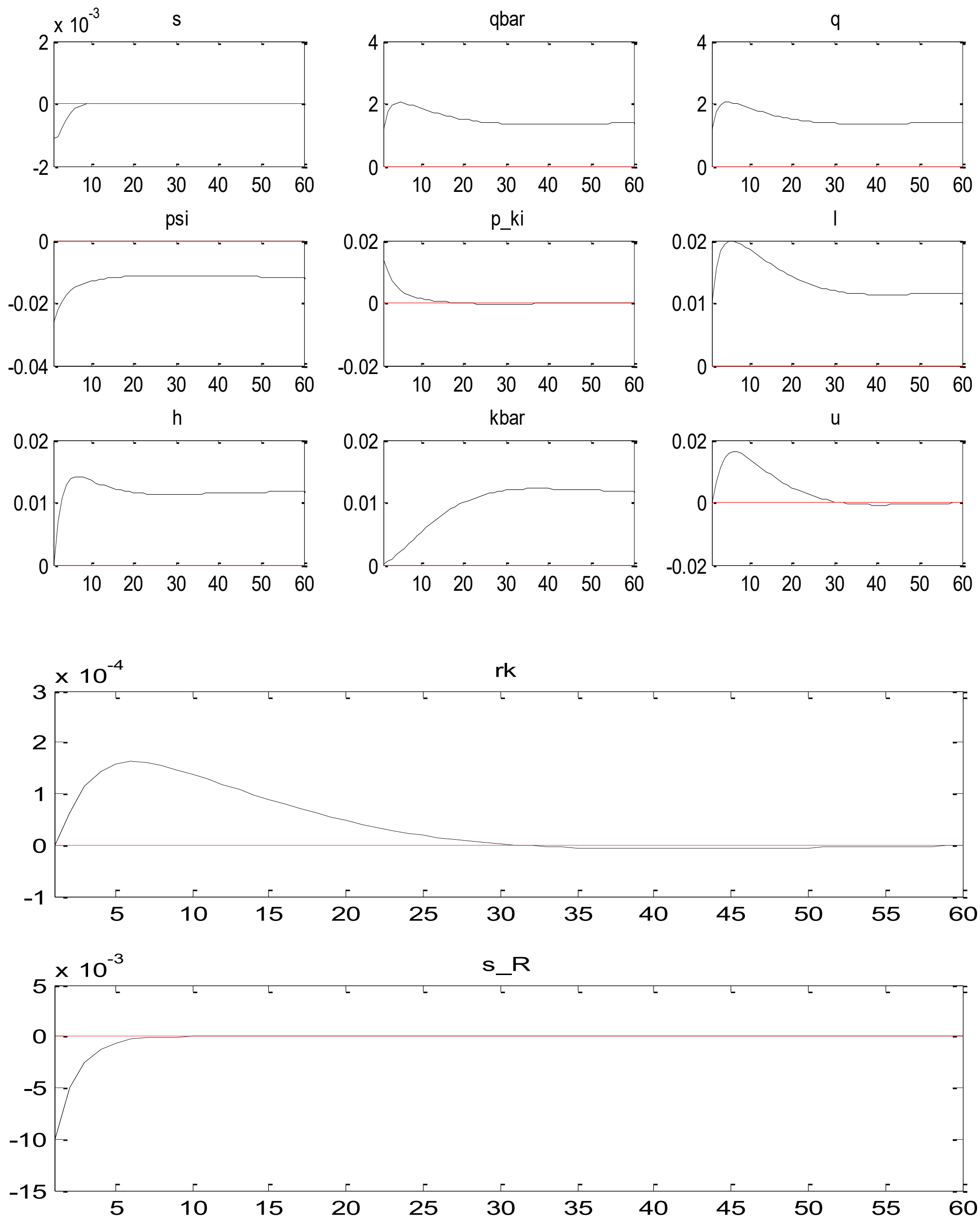

Figure 5: **Other Variable Responses to Interest Rate Shock**
Real Marginal Cost (s), Real Transaction Money (qbar), MU of Consumption (q), Wage (psi), MP of Capital (p_ki), Labour (l), Habit (h), Capital Stock (kbar), Capital Utilisation (u), return to capital (rk)

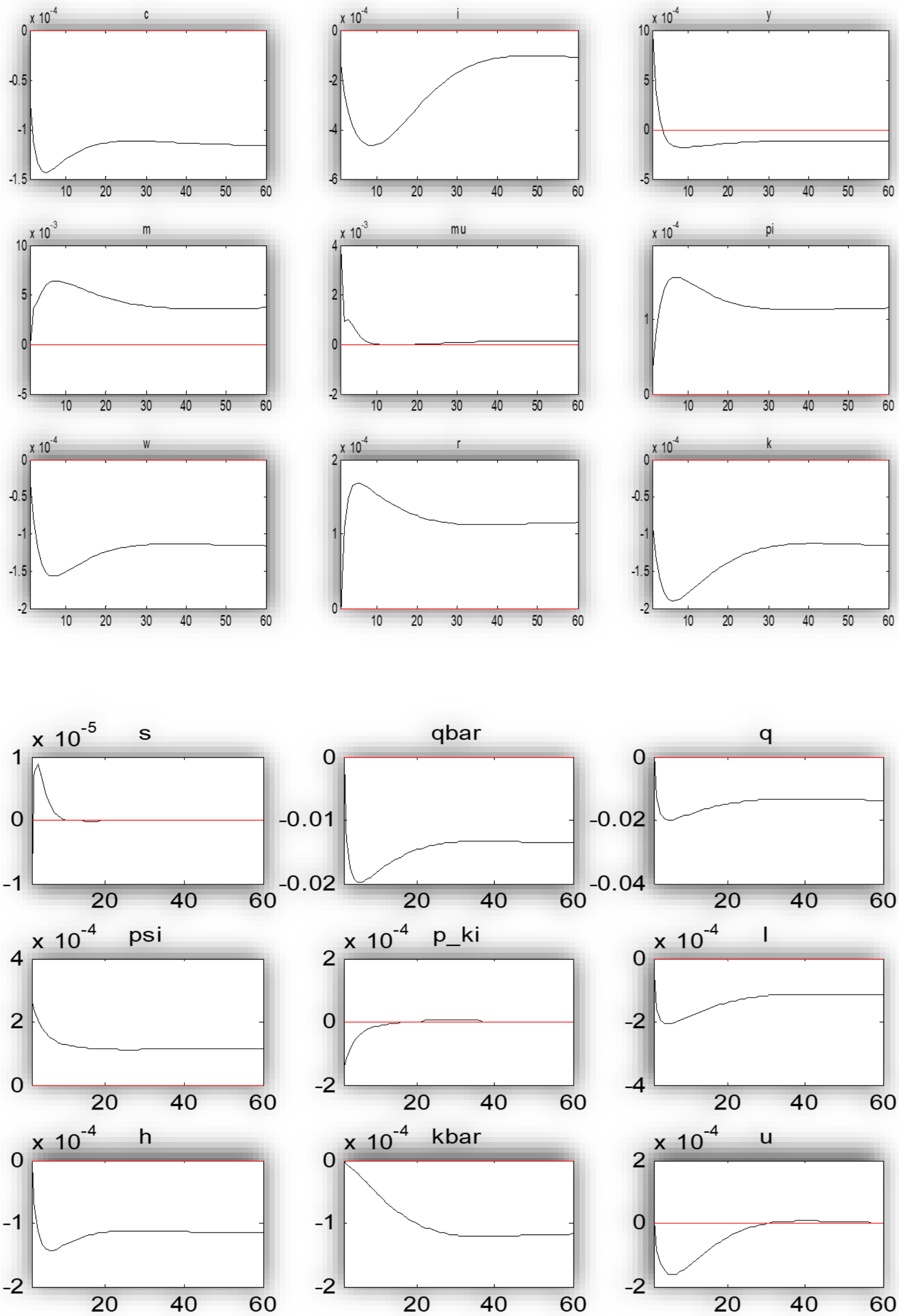

Figure 6: Variable Responses to Output Shock

Table 6: Moments of Stimulated Variables

VARIABLE	MEAN	STANDARD DEVIATION	VARIANCE	SKEWNESS	KURTOSIS
Consumption	0.232994	0.175580	0.030828	0.657955	-0.047037
Investment	0.232273	0.248524	0.061764	0.148490	-0.056003
Output	0.232913	0.180993	0.032758	0.585541	-0.071362
Money Supply	-7.459563	5.825118	33.931994	-0.574318	-0.074178

Money Growth Rate	-0.231297	0.371983	0.138371	-0.073960	-0.083001
Inflation	-0.232954	0.177532	0.031518	-0.630575	-0.057395
Real Wage	0.232954	0.177532	0.031518	0.630575	-0.057395
Nominal Interest Rate	-0.232909	0.178474	0.031853	-0.618265	-0.063374
Capital Service	0.232892	0.180797	0.032687	0.588146	-0.071014
Real Marginal Cost	0.000011	0.001910	0.000004	-0.081936	0.122806
Transaction Money (M1)	27.420279	21.011657	441.48973	0.618306	-0.063364
Real Transaction Money	27.653233	21.189051	448.97586	1.618422	-0.063311
MU of Consumption	-0.232859	0.178388	0.031822	-0.624171	-0.058263
Wage	-0.000000	0.000000	0.000000	0.402279	-1.448597
MP of Capital	-0.000146	0.021263	0.000452	0.124231	0.110012
Labour	0.232844	0.182105	0.033162	0.572453	-0.077269
Habit	0.233036	0.175535	0.030812	0.658469	-0.045816
Capital Stock	0.233265	0.173577	0.030129	0.693968	-0.007197
Capital Utilisation	-0.000337	0.056751	0.003221	0.121894	-0.042256
Return to Capital	-0.000003	0.000568	0.000000	0.121894	-0.042256

Table 7: Correlation of Simulated Variables

	C	I	Y	M	Mu	PI	W	R	K	S	Qbar	Q	Psi	Wbar	P_KI	L	H	Kbar	U	RK
C	1.00	0.83	0.99	-0.99	-0.51	-0.99	0.99	-0.99	0.99	-0.07	0.99	0.99	-0.99	0.31	0.09	0.99	0.99	0.98	0.19	0.19
I	0.83	1.00	0.89	-0.89	-0.49	-0.85	0.85	-0.86	0.88	-0.22	0.86	0.86	-0.84	0.33	0.31	0.89	0.83	0.71	0.67	0.67
Y	0.99	0.89	1.00	-0.99	-0.45	-0.99	0.99	-0.99	0.99	-0.07	0.99	0.99	-0.98	0.32	0.11	0.99	0.99	0.95	0.29	0.29
M	-0.99	-0.89	-0.99	1.00	0.46	0.99	-0.99	0.99	-0.99	0.03	-0.99	-0.99	0.98	-0.32	-0.08	-0.99	-0.99	-0.95	0.29	-0.29
Mu	-0.51	-0.49	-0.49	0.46	1.00	0.50	-0.50	0.54	-0.51	0.89	-0.54	-054	0.61	-0.20	-0.85	-0.54	-0.47	-0.39	0.30	-0.30
PI	-0	-0.	0.99	-0.	0.50	1.00	-1.	0.99	-0.	0.08	-0.99	-0.	0.99	-0.32	-0.10	-0.	-0.	-0.97	0.23	-0.

	99	85		99			00		99			99				99	99			23
W	0.99	0.85	0.99	-0.999	-0.54	-1.00	1.00	-0.999	0.99	-0.08	0.99	0.99	-0.999	0.32	0.10	0.99	0.99	0.97	0.23	0.23
R	-0.99	-0.86	-0.99	0.99	0.54	0.99	-0.99	1.00	-0.99	0.12	-1.00	-1.00	0.99	-0.32	-0.14	-0.99	-0.99	-0.96	0.25	-0.25
K	0.99	0.88	0.99	-0.999	-0.51	-0.99	0.99	-0.999	1.00	-0.10	0.99	0.99	-0.999	0.32	0.12	0.99	0.99	0.95	0.29	0.29
S	-0.07	-0.22	-0.07	0.04	0.89	0.08	-0.08	0.12	-0.10	1.00	-0.12	-0.12	0.20	-0.09	-0.97	-0.13	-0.03	0.07	-0.37	-0.37
Qbar	0.99	0.86	0.99	-0.999	-0.54	-0.99	0.99	-1.00	0.99	-0.12	1.00	1.00	-0.999	0.32	0.14	0.99	0.99	0.96	0.25	0.25
Q	0.99	0.86	0.99	-0.999	-0.54	-0.99	0.99	-1.00	0.99	-0.12	1.00	1.00	-0.999	0.32	0.14	0.99	0.99	0.96	0.25	0.25
Psi	-0.99	-0.84	-0.98	0.98	0.61	0.99	-0.99	0.99	-0.99	0.20	-0.99	-0.99	1.00	-0.32	-0.21	-0.99	-0.98	-0.95	-0.22	-0.22
Wbar	0.31	0.33	0.32	-0.32	-0.20	-0.32	0.32	-0.32	0.32	-0.09	0.32	0.32	-0.32	1.00	0.10	0.32	0.31	0.28	0.17	0.17
P_KI	0.09	0.31	0.11	-0.08	-0.85	-0.10	0.10	-0.14	0.13	-0.97	0.14	0.14	-0.21	0.10	1.00	0.17	0.04	-0.08	0.52	0.52
L	0.99	0.89	0.99	-0.999	-0.54	-0.99	0.99	-0.999	0.99	-0.13	0.99	0.99	-0.999	0.32	0.17	1.00	0.99	0.94	0.31	0.31
H	0.99	0.83	0.99	-0.999	-0.47	-0.99	0.99	-0.999	0.99	-0.03	0.99	0.99	-0.998	0.31	0.04	0.99	1.00	0.98	0.18	0.18

Kbar	0.98	0.71	0.95	-0.95	-0.39	-0.97	0.97	-0.96	0.95	0.071	0.96	0.96	-0.95	0.28	-0.08	0.94	0.98	1.00	0.02	-0.02
U	0.19	0.67	0.29	-0.30	-0.30	-0.23	0.23	-0.25	0.29	-0.37	0.25	0.25	-0.22	0.17	0.52	0.31	0.18	-0.02	1.00	1.00
Rk	0.19	0.67	0.29	-0.30	-0.30	-0.23	0.23	-0.25	0.29	-0.37	0.25	0.25	-0.22	0.17	0.52	0.31	0.18	-0.02	1.00	1.00