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Research Paper

Technological Shocks Mechanism On Macroeconomic Variables: A Dynamic Stochastic General Equilibrium Approach.

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ABSTRACT:- *As Ghana assumes a position of oil producer and middle-income country, it must learn to effectively deal with the related pressures from shocks. We analyze the effects of productivity shocks on Ghana's total output using the multi-sector dynamic stochastic general equilibrium (DSGE) model. It was actualized that a productivity shock results in a temporary shrinkage in the final goods sectors due to the reallocation of labour from the final and intermediate goods sectors. We demonstrated that technological shock induces an initial fall in marginal cost of production but later rises to reach equilibrium.*

Keywords:- *DSGE models, Economic growth, Technological shocks*

I. INTRODUCTION

Technology is an essential factor for development process. A technological shock may either affect productivity negatively or positively. Previous studies [1-8] have shown that an aggregate technology improvement is often consequential on total output of an economy, consumption and hours worked. Canova, López-Salido and Michelacci [9] analyzed the effects of neutral and investment-specific technology shocks on hours worked and unemployment. They characterized the response of unemployment in terms of job separation and job finding rates and found out that job separation rates mainly account for the impact response of unemployment while job finding rates for movements along its adjustment path. In 2008, Canova, López-Salido and Michelacci [10] analyzed the effects of neutral and investment-specific technology shocks on hours and output. Their study revealed hours robustly fall in response to neutral shocks and robustly increase in response to investment specific shocks.

For a newly oil producing country like Ghana, this shock can cause considerable mixed feelings. These issues call for this research to calibrate the influx of technological shock and its effects on the economic growth of the Ghanaian economy. The study applies a multi-sector dynamic stochastic general equilibrium (DSGE) model. 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.

II. METHODOLOGY

This section focuses on the DSGE model developed in Christiano et al [11, 12]. It displays the problem solved by firms and households, as well as the behaviour of financial intermediaries and the monetary and fiscal authorities. The model has structural features that are relevant in low-income countries, and as such it is ideally suited to look at the case of Ghana.

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The Consumer Problem

There is a continuum of households, indexed by $j \in (0,1)$. The j^{th} household makes a sequence of decisions during each period. First, it makes its consumption decision, its capital accumulation decision, and it decides how many units of capital services to supply. Second, it purchases securities whose payoffs are contingent upon whether it can re-optimize its wage decision. Third, it sets its wage rate after finding out whether it can re-optimize or not. Fourth, it receives a lump-sum transfer from the monetary authority. Finally, it 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.

Since the uncertainty faced by the household over whether it can re-optimize its wage is idiosyncratic in nature, households work different amounts and earn different wage rates. So, in principle, they are also heterogeneous with respect to consumption and asset holdings. A straightforward extension of arguments in Erceg, Henderson and Levin [13] establish that the existence of state contingent securities ensures that, in equilibrium, households are homogeneous with respect to consumption and asset holdings. Reflecting this result, the notation assumes that households are homogeneous with respect to consumption and asset holdings but heterogeneous with respect to the wage rate that they earn and hours worked. The preferences of the j^{th} household are given by:

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

where, E_{t-1}^{j} is the expectation operator, conditional on aggregate and household j idiosyncratic information up to, 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:

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

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:

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

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

$$k_t = u_t \bar{k}_t \tag{4}$$

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 utilization decisions 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 $a(u_t)\bar{k}_t$ denotes the cost, in units of consumption goods, of setting the utilization rate to u_t.

The Wage Decision

As in Erceg, Henderson and Levin [13], it is 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:

$$L_t = \left[\int_0^1 h_{jt}^{\frac{1}{\lambda_w}} dj \right]^{\lambda_w} \tag{5}$$

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

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

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

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

The household takes L_t and W_t as given. They also set their wage rate according to a variant of the mechanism used to model price setting by firms. In each period, a household 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:

$$W_{jt} = \pi_{t-1} W_{j,t-1} . \tag{8}$$

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:

$$Y_t = \left[\int_0^1 Y_{jt}^{\frac{1}{\lambda_f}} dj \right]^{\lambda_f} \tag{9}$$

where $1 \le \lambda_f < \infty$ 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

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

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:

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

Intermediate Good Firms

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

$$Y_{jt} = \begin{cases} k_{jt}^{\alpha} L_{jt}^{1-\alpha} - \phi & \text{if } k_{jt}^{\alpha} L_{jt}^{1-\alpha} \ge \phi \\ 0 & \text{otherwise} \end{cases} \tag{12}$$

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:

$$s_t = \frac{\partial S_t(Y)}{\partial Y}, \text{ where } S_t(Y) = \min_{(k,l)}\left\{r_t^k k + w_t R_t l,\, Y \text{ given by equation } (12)\right\} \quad \textbf{(13)}$$

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 [14]. This model has been widely used to characterize price-setting frictions. A useful feature of the model is that it can be solved without explicitly tracking the distribution of prices across firms. 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. 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

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

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, μ_{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 $\left(\xi_p\right)^l$, in which case $P_{j,t+l} = \tilde{P}_t X_{tl.}$. The presence of $\left(\xi_p\right)^l$ 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.

Monetary and Fiscal Policy

The monetary policy is assumed to be given by:

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

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.

Loan Market Clearing, Final Goods Clearing And Equilibrium

Financial intermediaries receive $M_t - Q_t$ from households and a transfer, $\left(\mu_t - 1\right) M_t$ 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:

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

The aggregate resource constraint is given as:

$$c_t + i_t + a\left(u_t\right) \le Y_t \qquad \textbf{(21)}$$

In this setting the research adopts a standard sequence-of-markets equilibrium concept. This strategy involves taking a linear approximation about the non-stochastic steady state of the economy [11,12]. In principle, the non-negativity constraint on intermediate good output in equation **(12)** is a problem for this approximation. It turns out that the constraint is not binding for the experiments that the research considers and so it is ignored. Finally, it is worth noting that since profits are stochastic, the fact that they are zero, on average, implies that they are often negative. As a consequence, the assumption that firms cannot exit is binding. Allowing for firm entry and exit dynamics would considerably complicate the analysis.

Functional Form Assumptions

Given the functions characterizing utility as:

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

.

In addition, investment adjustment costs are given by:

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

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. Given the solution procedure, there is no need to specify any other features of the function a.

Technological Mechanism

For proper understanding of the technological shock mechanism, our model does well in accounting for this by employing final good and intermediate good sectors in the economy. Exploration of oil has always come along with the movement of resources from one sector of the economy to the oil sector. Ghana's economy is dominated by the agricultural sector; which contributes larger amount to it GDP; therefore with the discovery of oil that sector is definitely going to be affected. Firstly there is going to be an investment in the agricultural sector to the newly founded oil sector. Secondly, labour is going to be moved from the other part of the economy to the oil sector. Since oil production forms part of the intermediate goods sector, the final goods sector is going to experience a shrinkage through labour movements which is normally referred as the "Dutch Disease". Our model account for this by shocking the production functions with a technological shock and calibrating to know how this affects the economy through equations 9-12. The multi-sector nature of the model allows this shock to impact on the other agents of the model.

III. ANALYSIS AND DISCUSSION

The parameters of the model are calibrated to suit the Ghanaian economy. The analyses of the model rely on calibrated numerical simulations with the use of 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 the literature and the national income accounts of the Ghanaian economy with the year 2008 as the base year.

The simulations showed a temporary shrinkage in the final goods sectors, which resulted from the reallocation of labour between the final and intermediate goods sectors. As such, this contraction is an equilibrium outcome. However, if the final goods sector is a special source of productivity growth, as it is sometimes argued in the literature on Dutch disease for reasons related to productivity advances being more likely in the manufacturing sector, then the shrinkage of the final goods sector could lead to a permanent or persistent loss in productivity. The last outcome is indeed undesirable. The latter effect is referred to as the effect as representing 'Dutch disease' effects. To give a special productivity enhancing role to the production sector, the model assumes that increases in the size of the tradable sector have an impact on overall productivity.

Table 1 Baseline Calibration and Parameters

Parameter	Value	Source/Method
b	0.5	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
α	0.7	Labor share of production (Standard value in literature)
δ	0.015	Capital depreciation rate [15]
ζ_p	30	Implies prices are sticky for 6 months on average
ζ_w	0.9	Calvo's parameter on wage
λ_f	12	Firms market power
ρ^{π}	1.5	Taylor rule inflation response (Standard in Literature)
ρ^{Y}	0.5	Monetary rule parameter on output
ρ^{R}	0.3514	Monetary rule parameter on lagged interest rate

The larger this sector is, the larger is multifactor productivity in the sector. When the production sector shrinks however, the overall productivity decreases too, thus leading to a potentially long-term negative impact on the growth rate of the economy. This is illustrated in figure 1. In the presence of such external shocks, the impact on output from higher public investment is smaller, and the contraction in the production sector more pronounced. While the effect on GDP might be smaller, it would be larger if less of the oil boom were used for public investment. Alternatively, the simulation above assumes a large substitutability of labour between sectors yielded a large and sustained decline in the tradable sector. Combining these two assumptions now leads to a more substantial Dutch disease effect, with output considerably below its trend. These output losses do not outweigh the benefits of the oil windfall, since overall GDP is still be above its levels.

These technological shocks come up with the following scenarios: Firstly, Dutch disease effects do not necessarily need to be large. They depend on the extent to which the final goods sector shrinks, which in turn is a function of a number of parameters. For example, a limited substitutability of production factors between the final and intermediate goods sectors curbs the extent to which the first declines when an oil windfall occurs and therefore also contains the Dutch disease effects; the downside is that limited substitutability also implies large wage pressures, higher inflation, and a more pronounced real appreciation. Secondly, policy measures that boost the final goods sector limit the overall Dutch disease effects as well. In the simulation, investment spending will eventually lead to an increase in the size of the production sector, at that point Dutch disease effects might have disappeared. In fact, the same mechanism that yields Dutch disease effects when the sector shrinks generates positive productivity effects when the sector expands due to investment. Even if large Dutch disease effects occur, these do not necessarily outweigh the benefits from the oil windfall. Of course, the analysis here applies only one specific mechanism for simulating Dutch disease effects. Alternative mechanisms, for example, linking the size of the production sector to the productivity growth rate instead of the level, could yield much larger effects, in which case it would be more likely that Dutch disease effects outweigh oil windfall benefits.

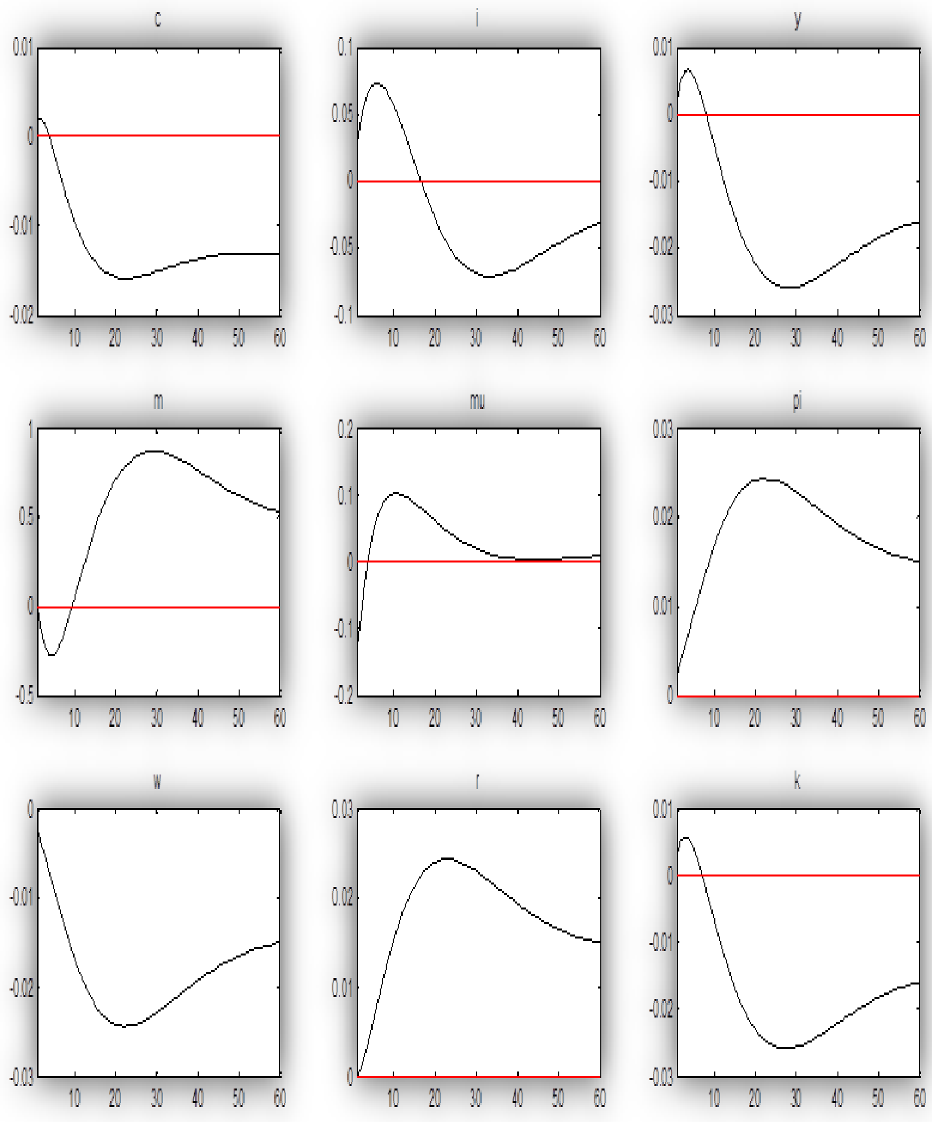

Figure 1 Variable Responses To Productivity Shock

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

These Dutch Disease effects are already prevalence in the Ghanaian economy. An economy which was moved by the agricultural sector has now seen a drastic increase in the service sector, moving agricultural sector to be the second largest contributor of the economy's gross domestic product.

Additionally, this shock also induces a sharp (but short-lived) fall in the production sectors marginal cost and then after certain two years marginal cost begins to rise to attain equilibrium. This is accompanied by a contemporaneous rise in labour force for short period then after both labour and wage falls drastically before reaching equilibrium as shown in Figures 2.

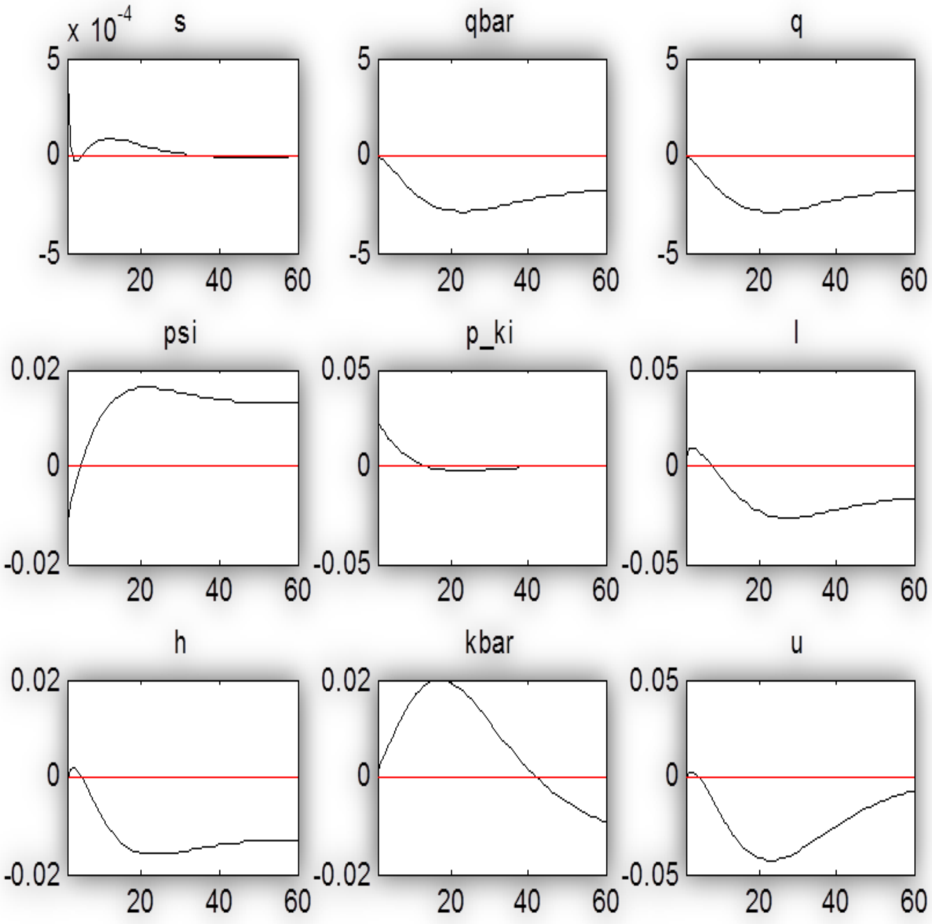

Figure 2: Other Variable Responses to Technological Shock

Real Marginal Cost (s), Real Transaction Money (qbar), MU of Consumption (q), marginal utility of consumption (psi), MP of Capital (p_ki), Labour (l), Habit (h), Capital Stock (kbar), Capital Utilisation (u)

IV. CONCLUSION

The study examined the impact of technological shocks of oil prices on the economic activities of Ghana. The model was calibrated based on the micro-founded evidence and steady state ratios determined from national income accounts of Ghana. It was actualized that a productivity shock which indicates a temporary shrinkage in the final goods sectors is as a result of the reallocation of labour from the final and intermediate goods sectors. This Dutch disease effect is accounted for as the model assumes that increases in the size of the tradable sector have an impact on overall productivity. When this sector shrinks, the overall productivity decreases too, thus leading to a potentially long-term negative impact on the growth rate of the economy. The research alternatively assumed a large substitutability of labour between sectors which yielded a large and sustained decline in the tradable sector. Combining these two assumptions led to a more substantial Dutch disease effect, with output considerably below its trend. These output losses do not outweigh the benefits of the oil windfall, since overall GDP will is still be above its levels.

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