

## Fiscal Policy in a DSGE Model of a Resource-Rich Emerging Economy: The Nigerian Experience

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*This paper examines the role of fiscal policy in driving macroeconomic dynamics in a resource-rich emerging economy like Nigeria. Specifically, the paper investigates the macroeconomic implications of fiscal policy using a small open economy dynamic stochastic general equilibrium model that features oil in the fiscal rule. The model is estimated via Bayesian methods using data covering the period 2010Q1-2021Q1. The results show that the feedback coefficient of output in the fiscal rules is mainly negative, indicating a counter-cyclical fiscal stance. Also, increased oil revenue leads to a rise in government consumption, investment and transfer payments. Further evidence indicates that government spending and transfer payments rose in response to increased debt. We also show that fiscal shocks are highly persistent and that government spending on consumption and investment, tax instruments and transfer are expansionary.*

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### 1. Introduction

A Resource-Rich Emerging Economy (RREE) is characterized in general by the following: existence of one or more natural resources in large amount, attractive markets, high growth rate, liberalization policy in trade and investments. In the recent times, the global economy, the RREE and the Nigerian economy being a subset, have witnessed serious economic problems due to internal and external shocks. Of particular importance is the COVID-19 pandemic of 2020-2021 that altered the monetary and fiscal policy dynamics of these economies. During the aforementioned period, fiscal policy instruments were targeted at the welfare enhancement of the citizenry

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in the form of palliatives to support the productive sector and extension of moratorium for various states in the country and other fiscal measures. As the economy was breathing a sigh of relief, the Russian-Ukraine war broke out causing another wave of supply-chain disruptions and volatilities in the price of crude oil. The latter had devastating consequences on fiscal policy measures of the RREE.

According to Iklaga (2021), the Nigerian economy is heavily dependent on revenues from oil exports, which makes it vulnerable to oil price fluctuations. In 2022, oil and gas accounted for about 80.0 percent of total government revenues and 90.0 percent of the country's total exports. The proven crude oil reserve is estimated at 37.05 billion barrels. However, production output is below the OPEC allocation of about 2.5 million barrels of crude daily (OPEC Annual Statistical Bulletin 2022). This is aggravated by incident of oil theft and pipeline vandalism. As a Small Open Economy (SOE), Nigeria remains a 'price-taker' and hence cannot influence international oil price decisions. Consequently, the mono-product nature of exports and fiscal revenue in the economy makes macroeconomic outcomes susceptible to the vagaries of oil prices (Iklaga, 2021).

The vulnerability of the economy to oil shocks could have precipitated the poor macroeconomic performance of the economy in addition to low savings rate and boom-bust cycles prevalent between 2016 and 2020. The frequency of business cycle fluctuations in the economy is aggravated by several exogenous factors including soaring public debt, supply-chain disruptions, rising geopolitical tensions and foreign direct investment (FDI) fragmentation (IMF, 2012; Oladunni, 2019; Sayadi and Khosroshahi, 2020 and Ahn *et al.*, 2022). The domestic drivers may include capital scarcity; government dominance in the economy; public service inefficiency in the economy and prospects of economic diversification. These fiscal policy in Nigeria result into socio-economic headwinds requiring comprehensive fiscal measures. In view of the these underlining domestic and global economic challenges, the increasing role of fiscal policy becomes evident. Hence, the research questions for this study include the following: What are the macroeconomic effects of fiscal shocks in Nigeria? What are the effects of oil-based fiscal-rules for Nigeria? To what extent do fiscal multipliers affect fiscal operations in Nigeria? Consequently, the objectives are

as follow: to examine the transmission mechanism through which fiscal shocks impact the Nigerian economy, investigate the role of oil-based fiscal policy in Nigeria, and analyze fiscal multipliers on consumption tax in the country.

The study considers different fiscal operations and their implications for macroeconomic stability and debt sustainability, the implications of improvements in public sector efficiency, and the options and implications of different fiscal adjustment strategies mainly aggravated by uncertainties in the global and domestic economies (Chuku, 2017). The study presents the business cycle statistics as well as the stylized facts with a view to account for the unique structural characteristics of resource-rich emerging economies within the framework of a structurally consistent dynamic stochastic general equilibrium (DSGE) model.

After this introduction, Section 2 presents a brief literature review. Section 3 highlights stylized facts of the Nigerian economy. Section 4 deals with the methodology, while Sections 5 and 6 discusses the findings and concludes the paper, respectively.

## **2. Literature Review**

Several theoretical and methodological studies have attempted to examine the macroeconomic effects of fiscal policy. These studies have employed both reduced-form econometric approach and the structural macro-econometric models such as Vector Autoregressive (VAR), Structural VAR (SVAR), and Markov Switching models. However, these methodological approaches are largely atheoretical and susceptible to the Lucas' Critique. As a result, some authors have adopted the use of general equilibrium methods, in particular, the dynamic stochastic general equilibrium (DSGE) models. The DSGE model is premised on micro-foundations that are theoretically sound and relevant for policy analysis.

Studies using the New Keynesian DSGE models featuring fiscal policy initially assumed the existence of Ricardian equivalence, that is, a passive or neutral role for fiscal policy. In these models, there is lump sum taxation and the government faces an inter-temporal solvency condition (Leeper, 1991; Leeper & Leith, 2015; Sims, 1994; Bianchi and Ilut, 2016). A later variant of the New Keynesian DSGE model gave an explicit role to fiscal policy, which sets a policy rule and introduced non-

Ricardian fiscal effects by assuming the existence of rule of thumb households. The inclusion of rule of thumb agents engenders the non-neutral effect of fiscal policy on the economy (Gali *et al.*, 2007; Algozhina, 2012 and Rossi, 2014).

From an empirical angle, studies that have examined the effect of fiscal shocks on the macroeconomy focused on whether fiscal policy has an expansionary or contractionary effect. However, there are contrasting evidences. While some authors found that fiscal policy has expansionary macroeconomic effects (Gali *et al.*, 2005; Ratto, Roeger, and Veld, 2006; Furceri and Mourougane, 2010; Babecký *et al.*, 2018), the result from other studies showed that shocks to fiscal variables can have contractionary impact. From the DSGE literature, several reasons account for the mixed evidence including the introduction of non-Ricardian households, wage and price rigidity, degree of openness, use of lump-sum or distortionary taxes among others (Gali, *et al.* 2007; Tiakyi and Leon-Gonzalez, 2019; Varthalitis, 2019).

Cavalcanti and Vereda (2015) calibrated a DSGE model featuring a heterogeneous household sector with wage and price rigidity to the Brazilian economy. The authors found that fiscal shocks under several fiscal rules had mostly positive macroeconomic effect. Babecky *et al.*, (2018) estimated both DSGE and DSGE-VAR models to investigate the effect of disaggregated fiscal shocks on the Czechoslovakia economy. The results from the study showed that positive shocks to government spending and government investment had expansionary effects on the Czech economy. In terms of African economies, Takyil and Leon-Gonzalez (2019) estimated a New-Keynesian DSGE model for the Ghanaian economy to analyze the effects of government spending, consumption tax, and income tax shocks. The model featured both Ricardian and non-Ricardian households. They found mixed effect of fiscal shocks on the economy. That is, government spending had expansionary effect on non-Ricardian households but negative impact on the Ricardian consumers. Kemp and Hollander (2020) estimated a New Keynesian open-economy DSGE model for South Africa with heterogeneous households and distortionary taxes. Results from the study showed that government spending and investment shocks were expansionary while consumption and investment tax shocks were contractionary. The findings of Djinkpo (2019) also showed that fiscal shocks can have debt-stabilizing effect on the Gambian economy.

In the case of resource-rich economies, Gonzalez *et al.*, (2014) calibrated a DSGE model featuring both Ricardian and non-Ricardian households, wage and price rigidity and a fiscal authority financing its spending partly with oil revenue. The authors found that a positive fiscal spending shock has expansionary impact on output and consumption in Colombia.

Omotosho (2021) estimated a DSGE model for Nigeria, and found that a positive government spending shock has increasing effect on consumption in the presence of non-Ricardian consumers.

### **3. Some Stylized Facts of the Nigerian Economy**

In this section, we examine the behaviour of some of the main fiscal and non-fiscal variables of the Nigerian economy with a view to comparing their stylised facts with the prediction generated by our model. How do these fiscal variables relate to the business cycles in Nigeria? Thus, the business cycle stylized facts for Nigeria are presented in Table 1. It is based on the computation of the following business cycle statistics: volatility; relative volatility; contemporaneous correlation; direction of co-movements; autocorrelation and phase shift to establish cyclical behaviour of the economy. The procedures are well documented in Agenor, *et al.* (2000) and Alege (2012). The methodology used was the a-theoretical statistical approach based on a univariate detrending procedure to isolate the cyclical behaviour from the aggregate Nigerian macroeconomic data. The stylised facts are compared with those of Nigeria's major trade partners, in particular, the European Union (EU) and U.S.A. The results are based on the Hodrick-Prescott (HP) filter procedure.

The Table contains results for three categories of variables: Non-fiscal, Fiscal and foreign variables. The real GDP is volatile at 1109.15. The volatility is the standard deviation of the filtered cyclical component of the GDP. It is much higher in EU and USA than in Nigeria. Private consumption (CON), private investment (INV) and money supply (MS) are more volatile than the real GDP while other non-fiscal variables are less volatile such as Inflation (INF) and nominal interest rate (R). Consumption is much more volatile than real GDP. According to Neumeyer and Perri (2005) consumption is relatively more volatile than output in developing economies.

In Table 1, the relative volatility of consumption is very high at about 7.5079. As noted by Pereira (2019), that feature is typically related to credit constraints, in which some families are “rule-of-thumb” consumers who simply spend their current incomes at each point in time. The data also show that Inflation (INF) is contemporaneously negatively correlated with the GDP. However, EXP, IMP, CON, INV, MS and EXC are strongly contemporaneously correlated; R is weakly contemporaneously correlated with the GDP while INF is contemporaneously uncorrelated with the cycle. Further, private consumption, CON and other non-fiscal variables, in terms of co-movements are pro-cyclical which is consistent with theoretical predictions and international standards.

In addition, incorporating the phase shift allows us to detect if the variables could be good prediction of the expected evolution of the GDP. In the case of the Nigerian data, inflation, INF, INV, R, MS and EXC are leading the cycle while EXP, IMP and CON are lagging.

In the case of fiscal variables, the following are the inference from the business cycle statistics: all the variables are highly volatile and the relative volatility is very high. The contemporaneous correlations indicate that the variables are strongly contemporaneously correlated. GBY and GDT are countercyclical to the cycle while the other variables, GIV, GoE, OR, NOR GTR, DSE and D, are pro-cyclical. Finally, OR and GDT are lagging the cycle while the other variables are leading the cycle. This conforms with the expectation that fiscal variables should be leading index to the GDP.

Another feature of the Nigerian economic cycle reported in Table 1 is its high persistence coefficient, which is measured by the autocorrelation coefficients of the variables. The output autocorrelation is around 0.9 and even slightly above unit at about 1.03, 1.02, 1.06, 1.03 and 1.04 for GoE, GBY, GTR, DSE and D, respectively. This is an indication that over time past value of the variables are positively perfectly correlated with the present value. That means that output and other macroeconomic variables in the Nigerian economy are highly dependent upon their previous levels.

**Table 1: Business Cycle Statistics**

Non-Fiscal Variables	$\sigma_x(\%)$	$\sigma_x/\sigma_y$	$\rho_{xy}$	Co-movement	$x_t x_{t-1}$	Phase Shift
GDP	1109.15				0.99	
EXP	33.33913	0.0301	0.415185	Pro-cyclical	0.98	Lagging
IMP	103.8834	0.0937	0.874515	Pro-cyclical	0.97	Lagging
INF	3.017808	0.0027	-0.12164	Countercyclical	0.92	Leading
CON	8327.339	7.5079	0.965824	Pro-cyclical	0.98	Lagging
INV	5483.188	4.9436	0.980952	Pro-cyclical	0.92	Leading
R	1.5032	0.0014	0.20969	Pro-cyclical	0.94	Leading
MS	12068.74	10.8811	0.930004	Pro-cyclical	1.01	Leading
EXC	83.4360	0.0752	0.782443	Pro-cyclical	1.04	Leading
Fiscal Variables						
GIV	552.167	0.4978	0.773498	Pro-cyclical	1.03	Leading
GoE	2965.21	2.6734	0.886283	Pro-cyclical	1.03	Leading
GBY	116.2753	0.1048	-0.88117	Countercyclical	1.02	Leading
OR	1921.796	1.7327	0.528926	Pro-cyclical	0.99	Lagging
NOR	1535.329	1.3842	0.929404	Pro-cyclical	0.97	Leading
GTR	223.5499	0.2016	0.857649	Pro-cyclical	1.06	Leading
DSE	1010.493	0.9111	0.750655	Pro-cyclical	1.03	Leading
D	4065.777	3.6657	0.888326	Pro-cyclical	1.04	Leading
GDT	11661.32	10.5137	-0.34976	Countercyclical	0.96	Lagging
Foreign Variables						
$GDP^*_{EU}$	9604.845				1.00	
$INF^*_{EU}$	1.021385	0.0001	-0.489109	Countercyclical	0.95	Lagging
$R^*_{EU}$	1.171713	0.0001	-0.859781	Countercyclical	0.98	Leading
$GDP^*_{US}$	18901.06				1.00	
$INF^*_{US}$	0.952595	0.0001		Countercyclical	0.95	Leading
$R^*_{US}$	1.165761	0.0001	-0.35749	Countercyclical	0.91	Lagging

Note: GDP is real GDP; EXP is real export; IMP is real import; INV is investment; CON is private consumption; R is interest rate; MS is money supply; EXC is exchange rate; INF is inflation rate; GBY is government bond yield; GIV is public investment; OR is oil revenue; NOR is non-oil revenue; GoE is government expenditure; GDT is government debt; GTR is government transfer; D is government bond; GDS is government debt service;  $GDP^*_{EU}$ : Real GDP in EU,  $INF^*_{EU}$ :inflation in EU,  $R^*_{EU}$ : Interest rate in EU,  $GDP^*_{US}$ :Real GDP of US, Inflation in US,  $R^*_{US}$ : Interest rate in US,  $\sigma_x$ : Volatility,  $\frac{\sigma_x}{\sigma_y}$ :Relative volatility,  $x_t x_{t-1}$ : Autocorrelation and  $\rho_{xy}$ : Contemporaneous Correlation.

Further, when the Oil Revenue, OR, is tested for correlation with both fiscal and non-fiscal variables, it was found that OR is strongly correlated with all the variables except DSE, GBY and R which are weakly correlated. However, OR is weakly correlated with EXC. This is contrary to expectation as higher oil revenue will strengthen foreign exchange market and thus, the value of the exchange rate.

With respect to the foreign variables considered in this section, the study found that GDP, INF and R in EU and in US are more volatile than in Nigeria. Similarly, the relative volatility in both regions are very low. In terms of the direction of comovement, INF, R is countercyclical in both regions as expected. Thus, comparing these findings to that of Nigeria where it was found that INF is countercyclical while R is pro-cyclical. Further, GDP, INF, R in both regions are highly persistent just as the case in Nigeria. In addition, INF in EU is lagging while it is leading in US. Finally, R in EU is leading while it is lagging in the US.

In summary, the following stylized facts are established for the fiscal variables: (1) all the variables are volatile; (2) their relative volatility is also high; (3) these variables are contemporaneously correlated with the cycle; (4) seven of these variables are pro-cyclical while the remaining two are countercyclical; (5) six of the variables are leading while two of them are lagging the cycle; and (6) the persistence of the variables measured by the autocorrelation coefficient is high across all the fiscal variables, over the cycle.

It follows that policy makers at the CBN and the fiscal authority, must be sensitive to business cycle fluctuations in her major trade partners when responding to business cycles in the Nigerian economy. Hence, the business cycle statistics established in this section will be compared with the predictions of the model developed in Section 4.

#### **4. Methodology**

To study fiscal operations in Nigeria, we propose an open economy New Keynesian DSGE Model that follows the standard structure and has several advantages including the following: behaviour of agents today affects the future environment, micro-foundation, monopolistic competition, short-run non-neutrality of monetary



policy, ability to capture and treat stochastic shocks as well as nominal rigidities. It is general because it incorporates all markets in the economy. Hence, the objectives of the paper, as stated earlier, are to examine the fiscal transmission mechanism through which fiscal shocks affect the Nigerian economy, (2) investigate the role of fiscal-based policy in Nigeria and (3) analyze fiscal multipliers on tax spending instruments in Nigeria.

#### **4.1 The Economic Environment**

The DSGE model adopted in this study draws from the works of Medina and Soto (2005), Allegret and Benkhodja (2015), and Omotoso (2021). It comprises five agents: households, firms, the central bank, the government, and the rest of the world, who form model-consistent expectations based on available information. It also includes the market clearing conditions as well as the exogenous processes. The infinitely-lived household decides how many units of goods to consume and labour to supply to maximize lifetime utility subject to a budget constraint. It is assumed that there are two types of households, the Ricardian and non-Ricardian.

Unlike the Ricardian, the non-Ricardian household is liquidity-constrained and lacks access to the financial market (Torres, 2015). A large amount of non-Ricardian consumers implies that fiscal policy is not passive as proposed in the models with Ricardian equivalence (Rossi, 2014). The household also forms habits in their consumption. This means that utility is time non-separable, depending on consumption in the previous period. The household sector is also assumed to supply labour to firms in a perfectly competitive labour market.

The model economy consists of non-oil and oil-producing firms. In the production sector, there are the final-good producers and the intermediate-goods producers. The final-good producer operates under a perfectly-competitive market and can re-optimize their prices. The final good producer aggregates the goods of the intermediate firms using the Dixit-Stiglitz (1977) framework. The intermediate-goods producers are in monopolistic competition and are price-setters. Firms in the domestic economy produce goods for domestic consumption and exports. There are also foreign firms that produce imported goods. Following the Calvo (1983) sticky price setting, a fraction of the intermediate-goods firms are allowed to re-set their prices.

The third agent is a monetary authority that implements monetary policy by following a Taylor-type rule to set its policy rate. It is also posited that Nigeria is a small open economy linked to foreign economies, which is the Rest of the World. As a small open economy, the size of the Nigerian economy is tiny and lacks a significant influence on the Rest of the World. Finally, there are some exogenous shock processes.

The fiscal authority makes fiscal policy decisions and satisfies its budget constraint. It purchases goods and services from firms, issues bonds, collects lump-sum taxes, and makes transfer payments to keep a balanced budget. Its spending is also derived partly from oil revenue. Secondly, in this study, the government commits to fiscal rules in spending and taxes. Finally, it is assumed there are adjustment costs on investment and that the economy is hit by both real and nominal shocks.

## 4.2 The Model

In what follows, the study presents the relevant agents and relevant equations of the small open economy, Dynamic Stochastic General Equilibrium model (SOE-DSGE). Each agent is considered to derive its optimization conditions. The abridged model entails:

### 4.2.1 Household

There is a continuum of infinitely lived households that make consumption and labour supply decisions. Households comprise two types, where the fraction  $\mu$  is Ricardian households and the other fraction  $(1 - \mu)$  are non-Ricardian households.

#### Ricardian households

These are optimizing households who can access funding from the financial market. The Ricardian consumer derives utility at time  $t$  from consuming a composite good,  $C_t$  and, and disutility from labor,  $N_t$ . The objective of the Ricardian household is to maximize the sum of discounted utility given by:

$$U = E_t \sum_{t=0}^{\infty} \beta^t \left[ \left( \frac{(C_{R,t} - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_{R,t}^{1+\varphi}}{1+\varphi} \right) \right] \quad (1)$$

subject to the nominal budget constraint in equation (2). The budget constraint depicts that on the revenue side, the household receives wages on labor supplied,  $W_t N_{R,t}$  and returns from capital investment,  $R_t^c K_t$ . They own businesses and receive profit from these ventures in the form of dividends,  $DV_t$ , they possess risk-free (domestic and foreign) financial instruments,  $D_t, D_t^*$  and receive government transfer payments,  $TP_t$ . It is also assumed that the individual household uses its total revenue to buy consumption goods,  $P_t C_{R,t}$ , investment goods,  $P_{i,t} I_{nc,t}$  and obtain financial assets,  $D_{t+1}, D_{t+1}^*$ . Households also pay consumption tax ( $\tau_{t,n}$ ) and income tax ( $\tau_{t,c}$ ). The budget constraint is therefore written as:

$$(1 + \tau_{t,c})P_t C_{R,t} + P_{i,t} I_{nc,t} + \frac{D_{t+1}}{R_t^c v_t} + \frac{\varepsilon_t D_{t+1}^*}{R_t^* v_t^*} \leq (1 - \tau_{t,n})W_t N_{R,t} + D_t + R_t^c K_t + \varepsilon_t D_t^* + TP_t + DV_t \quad (2)$$

where  $P_{i,t} I_{nc,t} = P_{cd,t} I_{cd,t} + P_{cf,t} I_{cf,t}$  represents the sum of domestic and foreign investment goods;  $R_t^c$  and  $R_t^*$  are the nominal rate of return on domestic and foreign bonds respectively while  $v_t$  and  $v_t^*$  are domestic and foreign risk premia which are assumed to be exogenous and evolve as AR(1) processes.

Capital accumulation is assumed to follow the process:

$$K_{t+1} = (1 - \delta) K_t + I_{nc,t} \left[ 1 - AC \left( \frac{I_{nc,t}}{I_{nc,t-1}} \right) \right] \quad (3)$$

Where parameter  $\delta$  denotes capital depreciation and AC represents adjustment cost on investment.

### Non-Ricardian households

These are liquidity-constrained consumers who can neither borrow nor own firms. The non-Ricardian household maximizes its utility function

$$U_{NR} = E_t \sum_{t=0}^{\infty} \beta^t \left[ \left( \frac{(C_{NR,t} - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_{NR,t}^{1+\varphi}}{1+\varphi} \right) \right] \quad (4)$$

subject to its budget constraint:

$$(1 + \tau_{t,c})P_t C_{NR,t} \leq (1 - \tau_{t,c})W_t N_{NR,t} + TP_t \quad (5)$$

The budget constraint postulates that the household receives only wages  $W_t N_{NR,t}$  and lump-sum transfer from the government  $TP_t$  and uses its income to buy consumption goods.

#### 4.2.2 Firms

The model economy consists of non-oil and oil-producing firms. In the production sector, there are the final-good producers and the intermediate-goods producers. The final good producer operates in a perfectly competitive market. The final good producer aggregates the goods of the intermediate firms using the Dixit-Stiglitz (1977) framework. The intermediate-goods producers are monopolistic competitive firms. Firms in the domestic economy produce goods for domestic consumption and exports. There are also foreign firms that produce imported goods. Following the Calvo (1983) sticky price setting, a fraction of the intermediate-goods firms is allowed to re-set price.

##### Domestic non-oil firms

###### (i) Final goods producer

Perfectly competitive firms aggregate final domestic goods ( $Y_t$ ) from intermediate goods using the Dixit-Stiglitz technology in equation (6):

$$Y_t = \left[ \int_0^1 Y_{t(j)}^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (6)$$

The demand for the intermediate domestic goods  $j$  in equation (8) is derived by maximizing profits subject to the bundling technology:

$$\max_{Y_{t(j)}} P_t \left[ \int_0^1 Y_{t(j)}^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 P_{t(j)} Y_{t(j)} dj \quad (7)$$

$$Y_{t(j)} = Y_t \left[ \frac{P_{t(j)}}{P_t} \right]^{-\varepsilon} \quad (8)$$

Where  $P_{t(j)}$  is the price of intermediate goods and  $P_t$  is the final goods price. In the same manner, goods for exports are aggregated as:

$$Y_t^* = \left[ \int_0^1 Y_{t(j)}^* \frac{\varepsilon-1}{\varepsilon} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (9)$$

Demand for the exportable goods  $j$ , equation (11) is derived by maximizing profits

(equation 10)

$$\max_{Y_{t(j)}^*} P_{t(j)}^* \left[ \int_0^1 Y_{t(j)}^{*\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 P_{t(j)}^* Y_{t(j)}^* dj \tag{10}$$

Subject to the bundling technology in equation (9)

$$Y_{t(j)}^* = Y_t^* \left[ \frac{P_{t(j)}^*}{P_t^*} \right]^{-\varepsilon} \tag{11}$$

**(ii) Intermediate goods producers**

It is assumed that there is a continuum of identical monopolistic competitive firms  $j \in [0, 1]$  that produce differentiated goods ( $Y_{t(j)}$ ) using a production technology with labor ( $N_{d,t(j)}$ ), capital ( $K_{d,t(j)}$ ) and oil ( $O_{m,t(j)}$ ) as inputs such that the production function is of the form:

$$Y_{d,t(j)} = A_t (N_{t(j)})^{\alpha_n} (K_{d,t(j)})^{\alpha_k} (O_{m,t(j)})^{\alpha_o} \tag{12}$$

The parameters  $\alpha_n$ ,  $\alpha_k$  and  $\alpha_o$  measures the response of aggregate output produced to labour, capital and oil inputs.  $\log A_t \equiv a_t$  evolves as a random-walk process such that  $a_t = \rho_a a_{t-1} + \varepsilon_t^a$  and  $\varepsilon_t^a$  is the total factor productivity shock.

Price Rigidity: The intermediate firms fix prices based on the Calvo (1983) price-setting mechanism. In this regard, at each period,  $1 - \theta$  fraction of the firms set prices optimally, while the other  $\theta$  fraction keeps their prices unchanged. The re-optimizing firms fix the optimal price,  $OP_t^*$ , by maximizing the nominal discounted profits of the representative firm subject to demand constraints as follows:

$$\text{Max} E_t \sum_{k=0}^{\infty} (\theta\beta)^k \left[ Y_{d,t(j)} (OP_{d,t}^* - P_{d,t+k} mc_{t+k}) \right] \tag{13}$$

Subject to the firm’s demand function for its intermediate good:

$$Y_{d,t+k(j)} = \left( \frac{P_{d,t(j)}}{P_{d,t}} \right)^{-\varepsilon} Y_{d,t+k} \tag{14}$$

**(iii) Imported goods**

Perfectly competitive firms produce final foreign goods ( $Y_{f,t}$ ) from an aggregation of intermediate goods using the Dixit-Stiglitz technology:

$$Y_{f,t} = \left[ \int_0^1 Y_{f,t(j)}^{\frac{\varepsilon_f - 1}{\varepsilon_f}} dj \right]^{\frac{\varepsilon_f}{\varepsilon_f - 1}} \quad (15)$$

Demand for the intermediate domestic goods  $j$  is derived by maximizing profits:

$$\max_{Y_{f,t(j)}} P_{f,t(j)} \left[ \int_0^1 Y_{f,t(j)}^{\frac{\varepsilon_f - 1}{\varepsilon_f}} dj \right]^{\frac{\varepsilon_f}{\varepsilon_f - 1}} - \int_0^1 P_{f,t(j)} Y_{f,t(j)} dj \quad (16)$$

Subject to equation (15)

$$Y_{f,t(j)} = Y_{f,t} \left[ \frac{P_{f,t(j)}}{P_{f,t}} \right]^{-\varepsilon_f} \quad (17)$$

Where  $P_{t(j)}$  is the price of intermediate goods and  $P_t$  is the final goods price. The optimal price setting for foreign goods is:

$$P_{f,t}^* = \frac{\varepsilon_f}{\varepsilon_f - 1} \frac{E_t \sum_{k=0}^{\infty} (\theta_f \beta)^k P_{f,t+k} Y_{f,t+k} mc_{t+k}}{E_t \sum_{k=0}^{\infty} (\theta_f \beta)^k Y_{f,t+k}} \quad (18)$$

For the  $\theta_f$  fraction of firms that keep their prices unchanged, the aggregate price for foreign goods ( $P_{f,t}$ ) evolves according to:

$$P_{f,t} = \left[ \theta_f P_{f,t-1}^{1-\varepsilon_f} + (1-\theta_f) (P_{f,t}^*)^{1-\varepsilon_f} \right]^{\frac{1}{1-\varepsilon_f}} \quad (19)$$

**Oil-Producing firms**

Oil firms are assumed to operate in a perfectly competitive crude oil market. Following Allegret and Benkhodja (2015), the oil firm employs capital and oil reserves to produce crude oil. Its production technology is defined as:

$$O_{d,t} = A_{o,t} K_{O,t}^{\alpha_o} R_{O,t}^{\theta_o} \quad (20)$$

Where  $A_{o,t}$  is the technology-specific shock to the oil sector which evolves according to an AR(1) process. The parameters  $\alpha_o$  and  $\theta_o$  measure the contributions of capital and oil reserves to the production of crude oil.

### 4.3 The Monetary Authority

The Central Bank implements monetary policy using an interest rate rule. The nominal interest rate ( $R_t$ ) is set based on a lagged interest rate ( $R_{t-1}$ ) and the inflation ( $\pi_t$ ), output ( $Y_t$ ) and exchange rate ( $e_t$ ).

$$\frac{R_t}{\bar{R}} = \left[ \frac{R_{t-1}}{\bar{R}} \right]^{\rho_R} \left[ \left( \frac{\pi_t}{\bar{\pi}} \right)^{v_\pi} \left( \frac{Y_t}{\bar{Y}} \right)^{v_Y} \left( \frac{e_t}{\bar{e}} \right)^{v_e} \right]^{1-\rho_R} \exp(\varepsilon_{r,t}) \tag{21}$$

where,  $\varepsilon_{r,t}$  denotes monetary policy shock;  $\rho_R$  is the degree of interest rate smoothing.  $v_\pi, v_Y, v_e$  shows the responsiveness of the nominal interest rate to changes in inflation, output, and exchange rate.  $\bar{R}, \bar{\pi}, \bar{Y}$ , and  $\bar{e}$  denote the steady state values of the respective variables.

### 4.4 The Fiscal Authority

The fiscal authority is bound by a balanced budget constraint. It earns revenue from bonds ( $D_t$ ), consumption tax ( $CTX_t$ ), income tax ( $ITX_t$ ), and oil revenue ( $OR_t$ ). The revenue is used to fund government expenditure on public goods ( $GC_t$ ) and public capital ( $GI_t$ ), interest payable on government debt ( $R_t D_{t+1}$ ), lump-sum transfers ( $TP_t$ ) and fuel subsidy payment. The government budget constraint is given as:

$$CTX_t + ITX_t + D_t + OR_t = p_{gc}GC_t + p_{gi}GI_t + R_{t-1}D_{t-1} + TP_t + FS_t \tag{22}$$

Following Omotoso (2021), the government is assumed to provide fuel subsidy. Fuel subsidy equals the difference between the final retail price paid by the domestic consumer and the supply cost of imported refined oil. The cost of supplying imported refined oil depends on the international price plus cost of logistics- transport and distribution.

Government imports refined oil  $O_{m,t}$  at the foreign price  $P_{om,t}^*$  which is sold to domestic consumers at a subsidized retail price  $P_{od,t}$  based on the pricing scheme.  $P_{od,t}$  depends on the landing price of the imported refined fuel  $P_{lo,t}$  such that:

$$P_{od,t} = P_{od,t-1}^{1-\vartheta} P_{lo,t}^{\vartheta} \quad (23)$$

Where  $P_{lo,t}$  is given by:

$$P_{lo,t} = \varepsilon_{i,t} \frac{P_{om,t}^*}{P_t^*} \Psi \quad (24)$$

$\Psi$  is the law of one price gap associated with imported fuel. It defines the market inefficiencies in domestic pricing of imported fuel.  $\vartheta$  is the parameter showing the pass-through of imported oil price to domestic fuel price. It determines the level of government fuel subsidy. When  $\vartheta = 1$ , it means that there is complete pass-through and no fuel subsidy regime exist and conversely, when  $\vartheta = 0$ .

Payment of fuel subsidy equals the difference between the subsidized retail price paid by the domestic consumer and the supply cost of imported refined oil. This is defined as:

$$FS_t = (P_{lo,t} - P_{od,t}) O_{m,t} \quad (25)$$

Fiscal rules allow government spending and lump-sum tax to respond to debt, output, and oil revenue. In equations (26) to (30), the rules governing government consumption, public investment, debt, and lump-sum taxes are explicitly defined in the log-linearized form:

$$\tilde{g}c_t = \rho_{gc} \tilde{g}c_{t-1} + (1 - \rho_{gc}) (\rho_{gy} \tilde{y}_t + v_{gd} \tilde{d}_t + v_{gor} \tilde{or}_t) + \varepsilon_t^{gc} \quad (26)$$

$$\tilde{g}i_t = \rho_{gi} \tilde{g}i_{t-1} + (1 - \rho_{gi}) (\rho_{gyi} \tilde{y}_t + v_{gdi} \tilde{d}_t + v_{gori} \tilde{or}_t) + \varepsilon_t^{gi} \quad (27)$$

$$\tilde{t}p_t = \rho_{tp} \tilde{t}p_{t-1} + (1 - \rho_{tp}) (\rho_{tpy} \tilde{y}_t + v_{tpd} \tilde{d}_t + v_{tpor} \tilde{or}_t) + \varepsilon_t^{tp} \quad (28)$$

$$\tilde{\tau}_{c,t} = \rho_{\tau c} \tilde{\tau}_{c,t-1} + (1 - \rho_{\tau c}) (\rho_{\tau cy} \tilde{y}_t + v_{\tau cd} \tilde{d}_t) + \varepsilon_t^{\tau c} \quad (29)$$



$$\tilde{\tau}_{n,t} = \rho_{\tau n} \tilde{\tau}_{n,t-1} + (1 - \rho_{\tau n}) (\varrho_{\tau n} \tilde{y}_t + \nu_{\tau n} \tilde{d}_t) + \varepsilon_t^{\tau n}, \tag{30}$$

where  $\rho_{gc}, \rho_{gi}, \rho_{lx}, \rho_d, \rho_{\tau c}$  and  $\rho_{\tau n}$  are AR(1) parameters measuring persistence in government spending, government investment, transfer payment, debt, consumption tax, and labour income tax, while  $\rho_{gy}, \rho_{gyi}, \varrho_{tpy}, \varrho_{\tau c}, \varrho_{\tau n}$  measures the fiscal cyclicalities that is, the response of government expenditure, government investment, transfer payment, consumption tax and income tax to output;  $\nu_{gd}, \nu_{gdi}, \nu_{tpd}, \nu_{gor}, \nu_{gori}$  and  $\nu_{ort}$  are fiscal policy coefficients for debt and oil revenue.  $\nu_{\tau c} \tilde{d}_t$  and  $\nu_{\tau n} \tilde{d}_t$  are responses of consumption tax and income tax to debt.

Government derives oil revenue from crude oil exports  $O_{d,t}$  at the international oil price  $P_{o,t}^*$  and from royalty  $\tau_{o,t}$  derived from the quantity of crude oil produced by oil firms.

$$OR_t = \varepsilon_{i,t} O_{d,t} (P_{o,t}^* + \tau_{o,t}) \tag{31}$$

#### 4.5 Open Economy Features

The open economy relationship between the terms of trade, the real exchange, international risk sharing, and uncovered interest parity are derived.

##### 4.5.1 The Law of One Price (LOP) gap

It is assumed that there is a complete asset market, with zero arbitrage in the international market. The law of one price holds such that:

$$\Psi_t = \frac{e_t P_t^*}{P_{f,t}} \tag{32}$$

Where,  $e_t$  is the nominal exchange rate,  $P_t^*$  is the world price index and  $P_{F,t}$  is the domestic price of imported goods.

##### 4.5.2 Real Exchange Rate

The real exchange rate is defined as the ratio of the world price index to that of domestic price, which is:

$$Q_t = \frac{e_t P_t^*}{P_{d,t}} \quad (33)$$

Where,  $Q_t$  is the real exchange rate,  $e_t$  is the nominal exchange rate,  $P_t^*$  denotes the world price index and  $P_{d,t}$  is the domestic price index.

#### 4.5.3 International Risk Sharing

There is equal risk-sharing between domestic and foreign households since domestic ( $P_t$ ) and foreign ( $P_t^*$ ) bond prices are assumed to be the same. Since domestic ( $C_{R,t}$ ) and foreign households ( $C_t^*$ ) share similar preferences, the first-order condition for the domestic Euler consumption equation is given as:

$$Q_{t,t+1} = \beta \left( \frac{C_{R,t+1} - hC_{R,t}}{C_{R,t} - hC_{R,t-1}} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \quad (34)$$

This also holds for consumers in foreign economies such that:

$$Q_{t,t+1} = \beta \left( \left( \frac{C_{t+1}^* - hC_{t+1}^*}{C_t^* - hC_{t-1}^*} \right)^{-\sigma} \right)^{-\sigma} \frac{P_t^*}{P_{t+1}^*} \frac{\varepsilon_t}{\varepsilon_{t+1}} \quad (35)$$

Combining equations (34) and (35) with the definition of the real exchange rate yields equation (36) based on Gali and Monacelli (2005):

$$C_{R,t} = K C_t^* Q_t^{\frac{1}{\sigma}} \quad (36)$$

Log-linearizing equation (36) produces:

$$\tilde{c}_{R,t} = \tilde{c}_t^* + \frac{1}{\sigma} \tilde{q}_t \quad (37)$$

Since Gali and Monacelli (2005) show that the relation between the real exchange rate ( $q_t$ ) and terms of trade ( $s_t$ ) is  $q_t = (1 - \alpha) s_t$ , then equation (37) becomes:

$$\tilde{c}_{R,t} = \tilde{c}_t^* + \frac{1 - \alpha}{\sigma} \tilde{s}_t \quad (38)$$

Since consumers are assumed to form habits ( $h$ ) on their consumption and with world market-clearing condition  $y_t^* = c_t^*$ , this becomes:

$$\tilde{c}_{R,t} - h\tilde{c}_{R,t-1} = \tilde{y}_t^* - h\tilde{y}_{t-1}^* + \frac{(1-h)(1-\alpha)}{\sigma} \tilde{s}_t \tag{39}$$

**4.5.4 Uncovered Interest Parity**

There is an incomplete international financial market that accommodates risk premiums between investors buying domestic or foreign bonds. This is written as:

$$\tilde{r}_t = \tilde{r}_t^* + E_t(\tilde{e}_t - \tilde{e}_{t+1}) \tag{40}$$

Re-arranging, it becomes:

$$\tilde{r}_t - \tilde{r}_t^* = E_t \Delta e_{t+1} \tag{41}$$

The expression shows that changes in the nominal exchange rate depend on the wedge between domestic and foreign interest rates.

**4.6 Rest of the World**

Nigeria is assumed to be a small open economy relative to the large global economy and can barely affect foreign economies’ interest rate, inflation, and output. The foreign variables are modeled as exogenous and follow AR(1) processes such that:

Foreign Output:

$$Y_t^* = \rho_{y_t^*} Y_{t-1}^* + \varepsilon_t^{y_t^*} \tag{42}$$

Foreign Inflation:

$$\Pi_t^* = \rho_{\pi_t^*} \Pi_{t-1}^* + \varepsilon_t^{\pi_t^*} \tag{43}$$

Foreign Interest rate:

$$R_t^* = \rho_{r_t^*} R_{t-1}^* + \varepsilon_t^{r_t^*} \tag{44}$$

The stochastic processes,  $\varepsilon_t^i \sim iiN(0, \sigma_i^2)$  for  $i = Y_t^*, \Pi_t^*, R_t^*$ . This means that the stochastic processes of foreign output, inflation, and interest rate are identically, independently and normally distributed of zero mean and variance of  $\sigma_i^2$ .

#### 4.7. Aggregation and Market Clearing

Aggregate demand combines oil ( $Y_{o,t}$ ) and non-oil outputs ( $Y_{no,t}$ ).

$$Y_t = Y_{o,t} + Y_{no,t} \quad (45)$$

The non-oil output comprises of consumption of domestic ( $CD_t$ ), and imported goods ( $CF_t$ ), investment ( $I_t$ ) and government spending ( $G_t$ )

$$Y_{no,t} = CD_t + CF_t + I_t + G_t \quad (46)$$

$$Y_t = Y_{o,t} + Y_{no,t} = CD_t + CF_t + I_t + G_t + NX_t \quad (47)$$

$$NX_t = EX_t - IM_t \quad (48)$$

Labour market clearing requires that:

$$N_t = \int_0^1 N_{R,t(j)} dj + \int_0^1 N_{NR,t(j)} dj \quad (49)$$

Capital market clearing requires that:

$$K_t = \int_0^1 K_{t(j)} dj \quad (50)$$

#### 4.8 Exogenous Stochastic processes

It is assumed that both real and nominal shocks perturb the economy. The shocks are modelled as autoregressive processes of lagged innovations of order one

$$Z_t^j = \rho Z_{t-1}^j + \varepsilon_t^j \quad (51)$$

where,  $Z_t^j$  is exogenous shock process.  $j \in \{\text{risk premia, foreign risk premia, technology, oil-specific technology, international oil price, monetary policy, public investment, government consumption, transfer payment, consumption tax, labour income tax, debt, foreign output, foreign inflation, foreign interest rate.}$

**4.9 Model Estimation**

The DSGE model is estimated using the Bayesian method. The set of equations of the DSGE model are represented in a canonical form as:

$$E_t f(y_{t+1}, y_t, y_{t-1}, e_t) = 1 \tag{52}$$

where:  $y_t$  is a vector of endogenous variables of the model. There are current, lead, and lag values of the endogenous variable;  $y_{t-1}$  is a vector of predetermined variables; while  $e_t$  is a vector of stochastic exogenous variables,  $e_t \sim iin(0, \sigma_i^2)$ .

The solution to the DSGE model is derived by approximating the non-linear set of equations using the log-linear approximation method. The procedure of log-linearising begins with finding the steady state of the model where there are no exogenous shocks and variables have no time sub-scripts such that:

$$f(\bar{y}, \bar{y}, \bar{y}, 0) = 1 \tag{53}$$

Equation (53) is thereafter approximated by a first-order Taylor expansion of its logarithm around the steady-state (53) such that:

$$E_t f_{y_{t+1}} \hat{y}_{t+1}, f_{y_t} \hat{y}_t, f_{y_{t-1}} \hat{y}_{t-1}, f_{e_t} e_t = 1 \tag{54}$$

The log-linear approximation method usually produces a system of linear stochastic difference equations which can be cast in state-space form as:

$$Ay_t = By_{t-1} + Ce_t \tag{55}$$

where; A, B and C are matrices that contain the reduced-form parameters of the model; and  $y_t$  is a vector of endogenous variables. Let  $z_t$  be a vector of observable

variables that can be related to  $y_t$  in the model through the measurement equation. The measurement equation, on the other hand, links the DSGE model to data.

#### 4.9.1 Measurement equation

$$y_t^* = F\widehat{y}_t + u_t \quad (56)$$

where  $u_t$  and  $e_t$  are innovations and assumed to be Gaussian white noise processes:  $u_t \sim NID(0, \sigma^2)$ ;  $e_t \sim NID(0, \sigma^2)$ . If  $u_t$ ,  $e_t$  and  $\widehat{Y}_0$ , the initial conditions are normally distributed, then  $\widehat{Y}_t$  and  $Y_t^*$  are also assumed to be normally distributed. The next procedure entails using the Kalman filter to derive the log-likelihood function

$$L = (y^*|\bar{y}^*) - \frac{Tn}{2} \log 2\pi - \frac{1}{2} \log |\Sigma_{y^*}| - \frac{1}{2} (y^* - \bar{y}^*)' \Sigma_{y^*}^{-1} (y^* - \bar{y}^*) \quad (57)$$

where:  $y^*$  is whole sample data;  $n$  is number of observed variables;  $T$  is number of periods in the sample;  $\bar{y}^*$  is the expected value of  $y^*$ ; and  $\Sigma_{y^*}$  is variance-covariance matrix.

The prior  $P(\theta)$  which captures a researcher's subjective belief about the true value of the model's parameters can be updated using the likelihood function  $P(Y^T | \theta)$ . The link among the likelihood function, and prior and posterior distribution is summarised by Bayes' Theorem. It shows that the posterior distribution is proportional to the product of the likelihood function and priors

$$P(\theta|Y^T) = \frac{P(Y^T|\theta) P(\theta)}{P(Y^T)} \quad (58)$$

$$P(\theta|Y^T) \propto P(Y^T|\theta) P(\theta) = K(\theta|Y^*) \quad (59)$$

where:  $P(\theta|Y^T)$  is posterior distribution;  $P(Y^T|\theta)$  is likelihood Function;  $P(\theta)$  is parameter Vector; while,  $P(Y^T)$  is data.

The three main procedures for Bayesian estimation include: calculating the log-likelihood function; specifying Priors; and simulating the posterior distribution using the Markov Chain Monte Carlo (MCMC) method, specifically the Metropolis-

Hasting algorithm.

#### **4.9.2 Data**

The model was estimated using quarterly data on domestic variables obtained from the Central Bank of Nigeria’s Statistical Database on GDP, domestic inflation, nominal interest rate, private consumption, government spending, public investment, oil revenue, and government debt over the quarterly period 2010Q1-2021Q1. Data for foreign variables was obtained from the Federal Reserve Bank of St. Louis (FRED) database on output and interest rates for the United States. The dataset was detrended using the one-sided Hodrick- Prescott filter. The choice of the sample period was influenced by the availability of quarterly data for the Nigerian economy.

### **5. Results and Discussion**

#### **5.1 Priors**

Priors were chosen based on existing long-trend data, values reported in existing studies, and the researchers’ subjective beliefs as informed by related literature in resource-rich economies. Some parameters were also fixed in the estimation. For instance, the discount factor ( $\beta$ ) was fixed at 0.95 in line with Tule *et al.*, (2017); the capital depreciation rate ( $\delta$ ) was set as 0.025 as obtained from Allegret and Benkhodja (2015). The steady-state real interest rate ( $\bar{r}$ ) is fixed as 0.136. The share of wages in non-Ricardian consumption ( $\frac{\bar{W}N}{\bar{P}C}$ ) is set as 3.2 while the share of transfers in non-Ricardian ( $\frac{\bar{T}P}{\bar{P}C}$ ) is fixed as 1.35 in line with Oye (2018). The share of capital ( $\alpha_k$ ), labour ( $\alpha_n$ ) and oil ( $\alpha_o$ ) in the production of non-oil goods were set as 0.23, 0.52, and 0.25. The share of capital ( $\alpha_o$ ) and oil reserve ( $\theta_o$ ) in the production of oil is fixed at 0.31 and 0.24, respectively. The parameters on input shares were derived from Allegret and Benkhodja (2015). Persistence parameters were inferred from Traum and Yang (2011) to depict the high persistence of the shock processes and set as 0.7. The steady state of oil GDP ( $\bar{O}Y_{d,ss}$ ) and non-oil GDP ( $\bar{Y}_{d,ss}$ ) were set as 0.25 and 0.75. Consumption to GDP ratio ( $\frac{\bar{C}}{\bar{Y}_d}$ ), investment to GDP ratio ( $\frac{\bar{I}}{\bar{Y}_d}$ ), imports to GDP ratio ( $\frac{\bar{M}}{\bar{Y}_d}$ ), and government to GDP ratio ( $\frac{\bar{G}C}{\bar{Y}_d}$ ), are fixed as 0.69, 0.15, 0.15 and 0.070, respectively. The share of oil consumption in domestic consumption ( $\alpha$ ) is 0.085 while the degree of openness ( $\gamma$ ) is 0.35 as in Omotosho (2021). The steady-state values on consumption tax ( $\tau_{css}$ ) and income tax ( $\tau_{nss}$ ) were set as 0.1 and 0.05 while royalty on oil revenue ( $\tau_{or}$ ) was fixed as 0.65 in line with Mellina and

Drygalla (2017).

The prior mean of structural parameters such as habit formation ( $h$ ), was set to 0.60. The inverse elasticity of substitution ( $\sigma$ ) was set to 3.00 based on Cebi (2011). Calvo price setting ( $\theta$ ) was fixed at 0.50 in line with Adegboye (2015). The prior mean of the investment adjustment cost ( $\tau$ ) is 4.85 based on (Bergholt & Larsen, 2016). The share of non-Ricardian households

The priors for the monetary policy parameters including the Taylor rule feedback coefficient on inflation ( $v_\pi$ ) and output ( $v_y$ ) were 1.5 and 0.5, respectively. The feedback on the exchange rate ( $v_e$ ) was set as 0.25 in line with Adebisi and Mordi (2016). Interest rate smoothing ( $\rho_r$ ) was set at 0.70. The fiscal policy parameters were informed by Omotosho (2021). The response of government spending to debt ( $v_{gd}$ ), output ( $\rho_{gy}$ ) and oil revenue ( $v_{gor}$ ) are set as 0.00, 0.00, and 0.00. The reaction of government investment to debt ( $v_{gdi}$ ), output ( $\rho_{gyi}$ ) and oil revenue ( $v_{gori}$ ) are set as 0.30, 0.00, and 0.80. Transfer feedback coefficient on debt ( $\%o_{tpd}$ ), output ( $\%o_{tpy}$ ) and oil revenue ( $v_{tpor}$ ) are set as 0.40, 0.00, and 0.30, respectively. The response of consumption tax and income tax to changes in debt ( $v_{\tau c}, v_{\tau n}$ ) and output ( $\rho_{\tau c}, \rho_{\tau n}$ ) are fixed at 0.30 and 0.00, respectively. The persistence parameters on fiscal variables were set as 0.7 for persistence in government spending, government investment, lump-sum transfers, consumption tax, income tax, and debt. The values were inferred from Traum and Yang (2011) to depict the high persistence of shock processes.

For the persistence parameters on shock processes, the AR (1) parameter on non-oil technology and oil technology ( $\rho_A, \rho_{AO}$ ) are 0.74 and 0.85 as in Oladunni (2021). The AR (1) parameter on crude oil prices ( $\rho_{p_o^*}$ ), domestic risk premia ( $\rho_{v_i}$ ), foreign risk premia ( $\rho_{v_i^*}$ ) are each set at 0.70. The persistence parameter on foreign output ( $\rho_{y_i^*}$ ), foreign inflation ( $\rho_{\pi_i^*}$ ) and foreign interest rate ( $\rho_{r_i^*}$ ) are fixed at 0.6, 0.5, and 0.4, respectively in line with Adebisi and Mordi (2016). In summary, the beta distribution is used for all parameters in the 0 to 1 interval. This applies to persistence parameters on exogenous processes that are fixed at 0.7 with a standard deviation of 0.1. The gamma distribution and the inverse gamma distribution are used for parameters assumed to be positive. These include the Taylor rule coefficients and the



standard deviation of the shock processes with a mean of 0.1. The normal distribution is used for unbounded parameters.

**Table 2:** Calibration of Parameters

S/N	Parameter	Description	Value	Source
1.	$\beta$	The discount factor	0.95	Yule et al. (2017)
2.	$\delta$	Rate of capital depreciation	0.025	Allegret and Benkhoda (2015)
3.	$\frac{\overline{WN}}{\overline{PC}}$	Share of wage in non-Ricardian consumption	3.2	Oye (2018)
4.	$\frac{\overline{TP}}{\overline{PC}}$	Share of transfer in non-Ricardian consumption	0.135	Oye (2018)
5.	$\alpha_k$	Share of capital in production	0.23	Allegret and Benkhoda (2015)
6.	$\alpha_n$	Share of labour in production	0.52	Allegret and Benkhoda (2015)
7.	$\alpha_o$	Share of oil in production	0.25	Allegret and Benkhoda (2015)
8.	$\alpha_{ko}$	Share of capital in oil production	0.31	Allegret and Benkhoda (2015)
9.	$\theta_o$	Share of oil reserve in the production of oil	0.24	Allegret and Benkhoda (2015)
10.	$\overline{OY}_{d,ss}$	the steady state of oil GDP	0.25	Authors' calculation based on average Nigerian data (2000Q1-2021Q1)
11.	$\overline{Y}_{d,ss}$	Steady-state on non-oil GDP	0.75	Authors' calculation based on average Nigerian data (2000Q1-2021Q1)
12.	$\frac{\overline{C}}{\overline{Y}_d}$	Consumption to GDP ratio	0.69	Authors' calculation based on average Nigerian data (2000Q1-2021Q1)
13.	$\frac{\overline{I}}{\overline{Y}_d}$	investment to GDP ratio	0.15	Authors' calculation based on average Nigerian data (2000Q1-2021Q1)
14.	$\frac{\overline{M}}{\overline{Y}_d}$	import to GDP ratio	0.15	Authors' calculation based on average Nigerian data (2000Q1-2021Q1)
15.	$\frac{\overline{GC}}{\overline{Y}_d}$	Government consumption to GDP ratio	0.070	Authors' calculation based on average Nigerian data (2000Q1-2021Q1)

**Table 2: Cont'd**

S/N	Parameter	Description	Value	Source
16.	$\alpha$	share of oil consumption in domestic consumption	0.085	Authors' calculation based on average Nigerian data (2000Q1-2021Q1)
17.	$\gamma$	the degree of openness	0.35	Omotosho (2021)
18.	$\tau_{css}$	steady-state values on consumption tax	0.1	Mellina and Drygalla (2017)
19.	$\tau_{nss}$	Steady-state value of income tax	0.05	Mellina and Drygalla (2017)
20.	$\tau_{or}$	royalty on oil revenue	0.65	Mellina and Drygalla (2017)

## 5.2 Posterior Estimates

The New Keynesian DSGE model estimated in this study is a system of 51 equations and 42 estimated parameters. The posterior moments of this model were computed by using the Metropolis-Hastings algorithm.

### 5.2.1 Structural Parameters

The estimated parameters of the DSGE model are displayed in Table 3. The estimated value of habit formation, ( $h = 0.59$ ) is lesser than its prior mean. This implies that a good proportion of Nigerian households base their current preferences on past consumption patterns. The posterior estimate of the inverse elasticity of intertemporal substitution ( $\sigma$ ) is 3.02. The estimated value of the share of non-Ricardian households, ( $\psi$ ) is 0.702, which is higher than the reported estimate of 0.37 in Muscatelli *et al.* (2005). The posterior mean of Calvo price stickiness ( $\theta$ ) is estimated to be 0.34. This differs from the finding of Rasaki (2017), which estimated the parameter as 0.71. The estimated value of Calvo price stickiness at 0.34 revealed that about 34 percent of firms do not re-optimize their prices in a given quarter. It also implies that price contracts remain fixed for about two quarters. The posterior estimate of the investment adjustment cost ( $\tau$ ) is 3.95.

**Table 3:** Posterior Estimates of Structural Parameters

Symbol	Parameters	Density	Prior Distribution		Posterior Distribution		
			Mean	Std. Dev.	Mean	HPD Interval	
					Lower	Upper	
h	Habit formation	Beta	0.60	0.01	0.59	0.5830	0.6062
( $\sigma$ )	Inverse elasticity of substitution	Normal	3.00	0.05	3.02	2.9582	3.0887
( $\psi$ )	Share of non-Ricardian household	Beta	0.70	0.01	0.701	0.6899	0.7139
(( $\tau$ )	investment adjust-ment cost	Gamma	4.00	0.05	3.95	3.8869	4.0117
( $\theta$ )	Calvo Price Stickiness	Beta	0.50	0.05	0.34	0.3034	0.3716

**5.2.2 Policy Parameters**

In terms of the monetary policy parameters, the posterior mean of the inflation coefficient in the Taylor rule, ( $\nu_\pi$ ), is 1.54, while the estimated value of the coefficients of output ( $\nu_y$ ) and exchange rate ( $\nu_{exr}$ ) are 0.86 and 0.24, respectively. The posterior estimates of the monetary policy parameters imply that the CBN places a higher weight on price stability than on economic growth and exchange rate stability, in line with the findings of Adebisi and Mordi (2016) that showed that the CBN prioritizes price stability. In the sense of Leeper (1991), monetary policy is active since the estimated value of the coefficient of Taylor’s rule reaction to inflation is greater than one. Furthermore, the posterior value of the degree of interest rate smoothing ( $\rho_r$ ) of 0.59 shows that the monetary authority slowly adjusts the interest rate.

Turning to the estimated value of fiscal parameters, the posterior estimate of the reaction of government spending ( $\rho_{gy}$ ) and government investment( $\rho_{gyi}$ )to changes in output was estimated at -0.16 and -0.03. The output feedback coefficient on transfer payment( $\rho_{tpy}$ ), consumption tax ( $\rho_{\tau c}$ ) and income tax ( $\rho_{\tau n}$ ) are estimated at 0.07, -0.06, and 0.02, respectively. The negative coefficients of output indicate the existence of counter-cyclicality in government spending. It corroborates the findings of Economic Commission for Africa (2019) that Nigeria implemented a counter-cyclical fiscal stance. According to ECA (2019), Nigeria is one of four African countries that practiced countercyclical fiscal policy. The posterior estimates of the response to government spending ( $\nu_{gd}$ ), government investment ( $\nu_{gdi}$ ), transfer payment ( $\rho_{tpd}$ ),

**Table 4:** Posterior Estimates of Monetary and Fiscal Policy Parameters

Symbol	Parameters	Density	Prior Distribution		Posterior Distribution			
			Mean	Std. Dev.	Mean	HPD Interval Lower	Upper	
Monetary Policy Parameters								
$(v_{\pi})$	Taylor feedback on Inflation	Gamma	1.50	0.05	1.54	1.4928	1.5950	
$(v_y)$	Taylor feedback on Output	Gamma	0.80	0.05	0.86	0.8179	0.9073	
$(v_{exr})$	Taylor feedback on the exchange rate	Gamma	0.25	0.05	0.24	0.1693	0.3043	
$(\rho_r)$	Interest rate smoothing	Beta	0.50	0.05	0.59	0.5462	0.6273	
Fiscal Policy Parameters								
$(\rho_{gy})$	Government spending: output	Normal	0.00	0.10	-0.16	-0.2891	-0.0043	
$(\rho_{gyi})$	Government investment: output	Normal	0.00	0.10	-0.03	-0.1338	0.0644	
$(\%_{tpy})$	Transfer payment: output	Normal	0.00	0.10	0.07	-0.0740	0.1957	
$(\rho_{\tau c})$	Consumption tax: output	Normal	0.00	0.10	0.001	-0.1571	0.1647	
$(\rho_{\tau n})$	Income tax: output	Normal	0.00	0.10	0.02	-0.1572	0.1684	
$(v_{gd})$	Government spending: debt	Normal	0.30	0.05	0.24	0.1857	0.2941	
$(v_{gdi})$	Government investment: debt	Normal	0.30	0.10	0.32	0.2043	0.4436	
$(\%_{tpd})$	Transfer payment: debt	Normal	0.40	0.10	0.27	0.1847	0.3607	
$(v_{\tau n})$	Income tax: debt	Normal	0.30	0.10	0.32	0.2649	0.3978	
$(v_{\tau c})$	Consumption tax: debt	Normal	0.30	0.10	0.36	0.2111	0.4882	

and income tax ( $v_{\tau n}$ ) to changes in debt are 0.24, 0.32, 0.27, and 0.32, respectively. This implies that these fiscal instruments increased in response to rising debt stock in Nigeria, over the sample period. Also, the debt coefficient in the consumption tax rule ( $v_{\tau c}$ ) is positive at 0.36. This implies that taxes were raised in response to increased debt stock in Nigeria, over the sample period. In addition, fiscal instruments responded positively to oil revenue. For instance, the posterior estimates of  $\rho_{gor}$  and

$\rho_{gori}$  were 0.45 and 0.36.

### 5.2.3 Persistent Parameters

The posterior estimates of the fiscal smoothening parameters on government consumption ( $\rho_{gc}$ ) and government investment ( $\rho_{gi}$ ) are 0.93 and 0.77, respectively. The persistence parameters on transfer payment ( $\rho_{tp}$ ), consumption tax ( $\rho_{tc}$ ) and income tax ( $\rho_{tn}$ ) are 0.85, 0.71, and 0.73 which depicts that the Nigerian economy slowly adjusts to shocks emanating from the fiscal variables. The posterior estimate on foreign output ( $\rho_{y_i^*}$ ), foreign inflation ( $\rho_{\pi_i^*}$ ) and foreign interest rates ( $\rho_{r_i^*}$ ), are 0.46, 0.40, and 0.48, respectively. These imply that these shocks die off quickly.

### 5.2.4 Shock Processes

The standard deviation of the shock processes on government consumption, government investment, transfer payment, consumption tax, labour tax, international oil price and oil revenue were found to be less volatile.

## 5.3 Impulse Responses to Fiscal Shocks

### 5.3.1 Government Consumption Shock

A positive government consumption shock increased government spending. As government spending increases, the consumption of non-Ricardian households rises. It occurs primarily through the transfer channel. Ricardian consumption declines. It occurs from the rise in interest rate in response to increased inflationary pressure. Aggregate consumption rises on impact but falls from the 10<sup>th</sup> quarter. Aggregate output rises in response to the fiscal shock. The increased government spending crowds out private investment, causing it to fall alongside private consumption. Increased government spending also induced an upward inflationary trend, as proposed by the proponents of the Fiscal theory of price level. Reduced Ricardian consumption leads to a fall in the exchange rate as expected from the international risk sharing condition.

**Table 5:** Posterior Estimates of Shock Process

Symbol	Parameters	Density	Prior Distribution		Posterior Distribution		
			Mean	Std. Dev.	Mean	HPD Interval Lower	Upper
$(\rho_g)$	AR(1) parameter on government spending	Beta	0.80	0.05	0.93	0.9170	0.9560
$(\rho_{gi})$	AR(1) parameter on government investment	Beta	0.80	0.05	0.77	0.6791	0.8491
$(\rho_{tp})$	AR(1) parameter on transfer payment	Beta	0.80	0.05	0.85	0.8147	0.8993
$(\rho_{\tau c})$	AR(1) parameter on consumption tax	Beta	0.70	0.10	0.71	0.5606	0.8443
$(\rho_{\tau n})$	AR(1) parameter on income tax	Beta	0.70	0.10	0.73	0.6028	0.8530

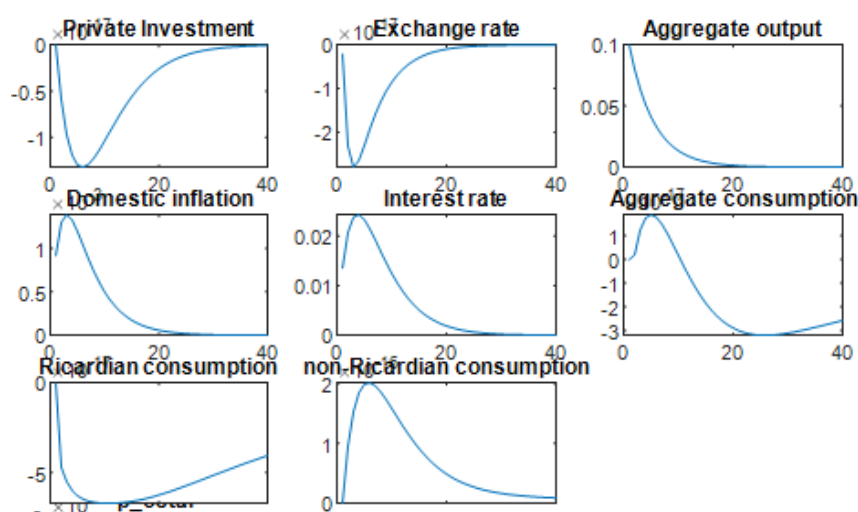


Figure 1: Impulse Responses to Positive Government Consumption Shock

### 5.3.2 Government Investment Shock

A shock to government investment leads to increased public investment spending and contemporaneous decrease in government consumption spending. The increased public investment crowds in private investment. Public investment can induce private investment primarily through infrastructure spending and through public-private partnership projects that require government to invest in strategic sector in collabo-

ration with the private sector (Nguyen, 2018). Private consumption increases in response to this shock. Generally, it has an expansionary output effect. It also induces an upward inflationary trend.

**5.3.3 Government Transfers Shock**

The transfer shock increases government consumption and public investment. The increased transfer payment does not increase the consumption of non-Ricardian households and aggregate consumption. Rather, it boosts only the consumption of Ricardian household. This makes it counter-productive as it is expected that transfer will create the redistribution of wealth from rich to poor households. The transfer shock has large stimulus effect and is expansionary as aggregate output rises in response to it.

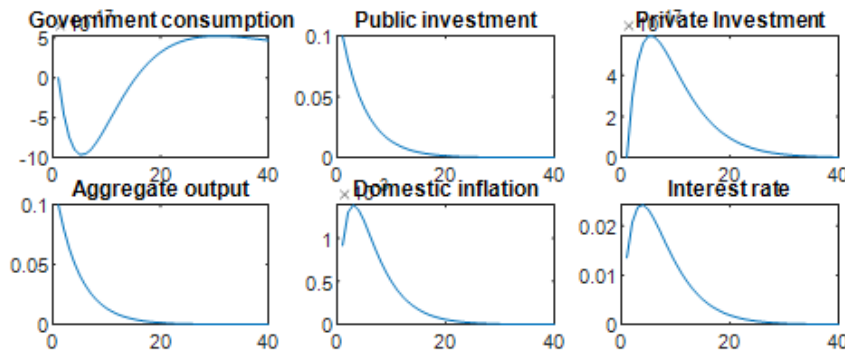


Figure 2: Impulse Responses to Positive Government Investment Shock

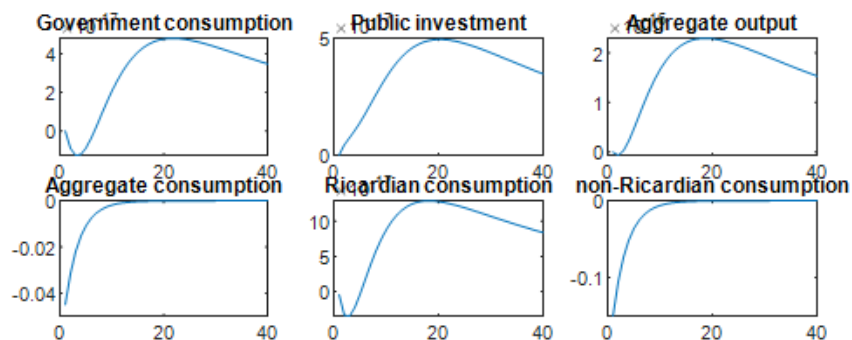


Figure 3: Impulse Responses to Positive Government Transfers Shock

### 5.3.4 Labour Income Tax Shock

An unexpected rise in the labour income tax rate leads to a fall in the disposable wages of household. This yields a fall in the consumption of Ricardian households and an increase in non-Ricardian demand. The consumption spending of non-Ricardian household is insulated by transfer receipts. The increase in non-Ricardian consumption offsets the decline in the consumption of Ricardian households, leading to a rise in aggregate household consumption. Output responds positively in the short-term but declines from the 5<sup>th</sup> quarter. Djinkpo (2019) found that labour income tax shocks are contractionary in The Gambia.

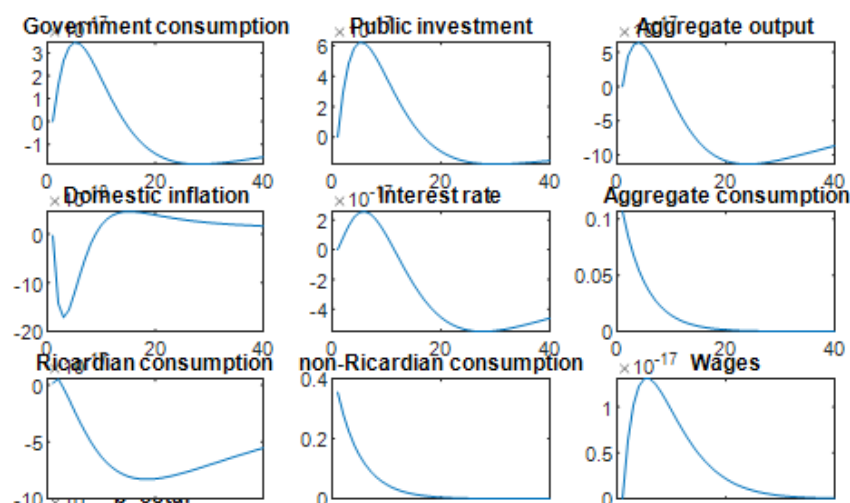


Figure 4: Impulse Responses to Positive Income Tax Shock

### 5.3.5 Consumption Tax Shock

In response to an increase in consumption tax shock, households reduce their consumption demand. This is expected since taxes reduce purchasing power causing goods and services to become more expensive as the burden of the increased tax is transferred to the final consumers. In addition, the Ricardian households demand higher wages and increase consumption due to the wealth effect. This induces an expansionary effect on output (Drygalla *et al.*, 2017). The consumption tax increases non-oil revenue as it leads to increased government consumption and investment spending.



### 5.3.6 International Oil price shock

A positive shock to international oil price induces a surge in oil revenue. As the mainstay of the Nigerian economy, when oil revenue increases, both government consumption and investment spending respond positively. It has an expansionary effect as aggregate output rises. It also leads to upward inflationary trend and hike in the interest rate.

### 5.3.7 Oil revenue shock

Increased oil revenue means more financing for government to spend on both public consumption and investment. Through public investment, government can reallocate resources to expand the non-oil sector. A positive oil revenue shock expands the economy as aggregate output rises. It is also inflationary in nature and induces rise in interest rate.

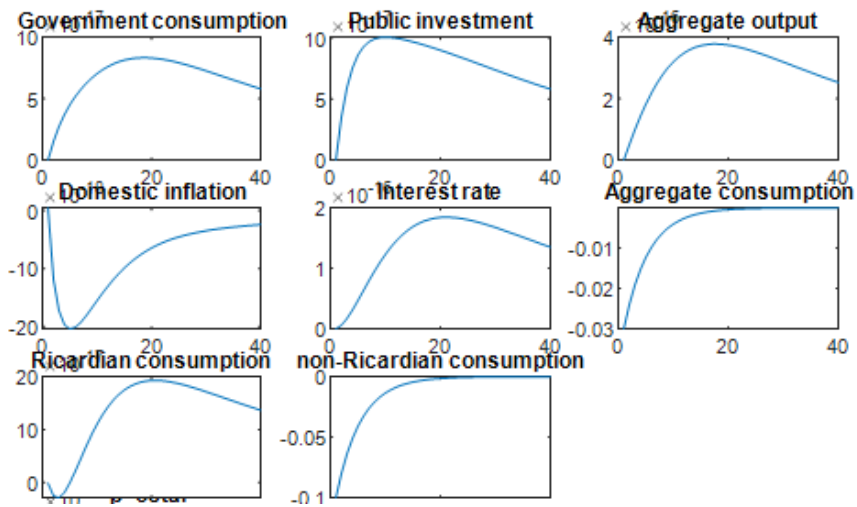


Figure 5: Impulse Responses to Positive Consumption Tax Shock

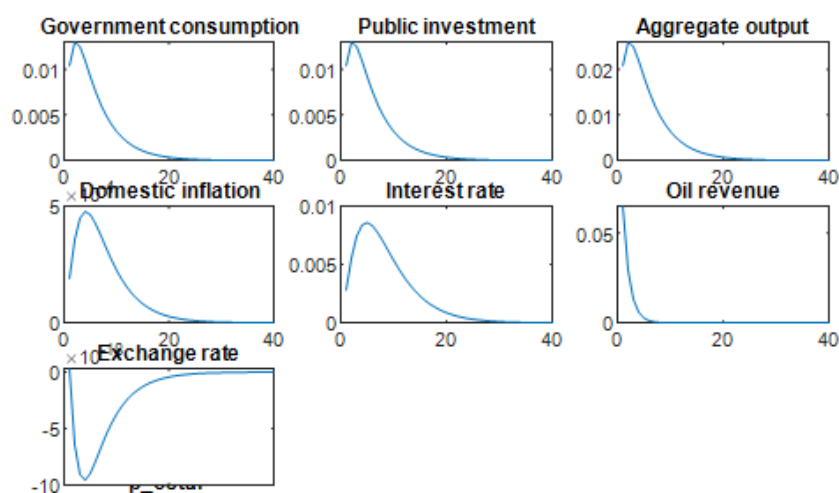


Figure 6: Impulse Responses to Positive Oil Price Shock

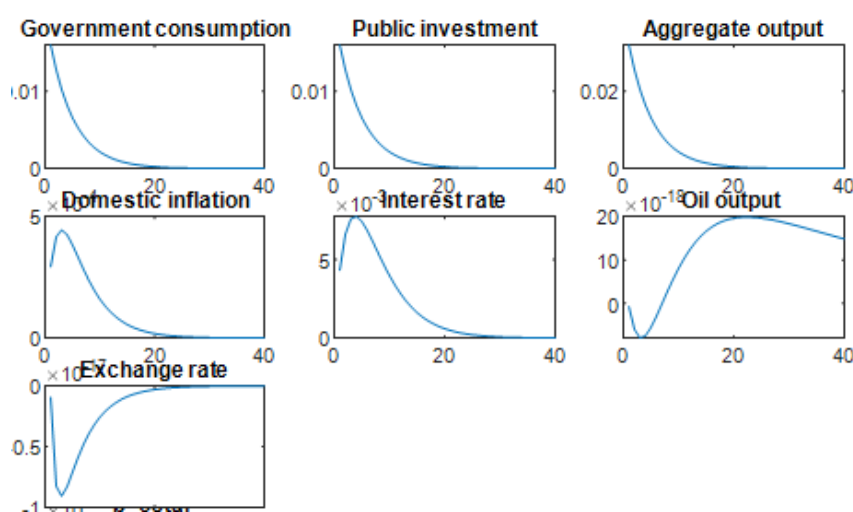


Figure 7: Impulse Responses to Positive Oil Revenue Shock

#### 5.4 Fiscal Multipliers

The fiscal multiplier is a necessary concept used to assess the effectiveness of fiscal instruments, such as tax and expenditure, in driving economic activity. It is defined as a change in output relative to a change in a fiscal policy instrument. In other words, it is the response of output,  $y_t$  to an unexpected one-period unit shock to fiscal variables,  $f_t$ . The impact and k-periods ahead cumulative fiscal multipliers are

computed in this study using the generalized impulse response function. The formula for the cumulative fiscal multiplier for fiscal variable,  $f_t$  is:

$$FM^K = \frac{E_t \sum_{j=0}^k \Delta y_{t+j}}{E_t \sum_{j=0}^k \Delta f_{t+j}} \tag{60}$$

The impact multiplier and cumulative multipliers for four fiscal measures-government spending, government transfers, consumption tax, and income tax up to 20 quarters are presented in Table 6.

The results indicate that government spending multiplier on impact and over the medium term are generally positive and smaller than one. This implies that one Naira increase in government spending leads to an increase in the level of domestic output less than one-for-one. Its impact seems to fade out with each subsequent quarter. Government transfers and consumption tax multipliers are also found to be positive and their effects fade out over the medium term. It can also be observed that income taxes are distortionary, with negative multipliers from the 12<sup>th</sup> quarter. Although these impacts seem to be negligible by their small quantitative magnitude. From the results, government spending can be deduced to be the most effective instrument for output stabilization in Nigeria.

The results from Table 6 show that all the fiscal instruments except labour tax has expansionary effect on the economy over the study’s period. Although, apart from government spending, the shock impact of other instruments are found to be negligible on the Nigerian economy.

**Table 6:** Impact and Cumulative Fiscal Multipliers

Shock	1 Quarter	4 Quarters	8 Quarters	12 Quarters	16 Quarters	20 Quarters
Government spending	1.00	0.051	0.021	0.009	0.004	0.001
Government Transfers	$1.3 \times 10^{-18}$	$2.2 \times 10^{-17}$	$1.2 \times 10^{-16}$	$1.9 \times 10^{-16}$	$2.25 \times 10^{-16}$	$2.28 \times 10^{-16}$
Consumption tax	$1.0 \times 10^{-33}$	$1.4 \times 10^{-16}$	$2.8 \times 10^{-16}$	$3.5 \times 10^{-16}$	$3.76 \times 10^{-16}$	$3.74 \times 10^{-16}$
Labour tax	-0.30	$6.4 \times 10^{-17}$	$1.7 \times 10^{-17}$	$-4.7 \times 10^{-17}$	$-8.9 \times 10^{-17}$	$-1.08 \times 10^{-16}$
	$1.8 \times 10^{-33}$					

### 5.5 Historical Decomposition

Figure 7 presents the historical decomposition of domestic output from the period 2010Q1 - 2020Q3. The shocks are grouped into four categories: fiscal shock (blue), monetary shock (green), oil priceshock (red), and other shocks (grey). The fiscal shocks comprise shocks to government spending. It can be seen from Figure 7 that aggregate output in the Nigerian economy from 2010Q1 and recorded the highest expansion as output spiked in the first quarter of 2012. This was largely driven by expansionary productivity shocks and oil price shocks. The economy declined in 2013Q1 and between 2014Q1-2016Q1 in response to the restrictive fiscal stance that was implemented. This period coincided with a negative oil price shock that depleted government revenue, leading to a decline in government revenue. The economy rebounded in 2016Q2 till it reached its peak in 2019Q3 due to expansionary fiscal shocks. With the onset of the COVID-19 pandemic, the economy dipped.

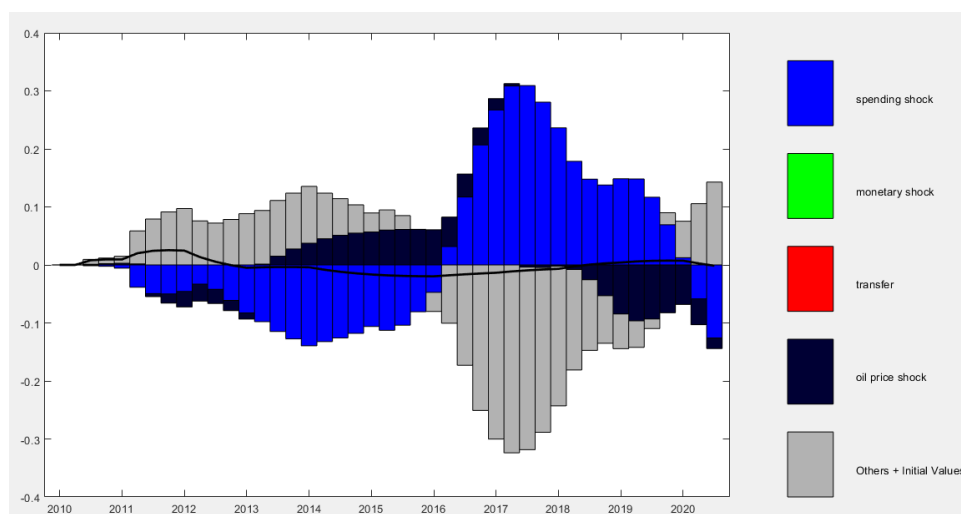


Figure 8: Historical Decomposition of output

### 6. Conclusion

In this paper, we investigate the dynamic effect of fiscal policy on selected macroeconomic aggregates. We specify a small open economy dynamic stochastic general equilibrium model featuring fiscal instruments that react to oil revenues. The model is estimated using the Bayesian method over the sample period, 2010Q1 to

2021Q1. The posterior means and impulse response results indicate the following: (1) the feedback coefficient of output in the fiscal rules is mainly negative indicating a counter-cyclical fiscal stance; (2) increased oil revenue leads to a rise in government consumption, investment and transfer payments; (3) government spending and transfer payments rose in response to increased debt; (4) fiscal shocks are highly persistent; and (5) government spending, both its consumption and investment components, tax instruments and transfer spending are expansionary.

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