Business Cycle Fluctuations in Nigeria: Some Insights from an Estimated DSGE Model

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Abstract

This paper develops a two-agent New Keynesian model, which is suitable for identifying the drivers of business cycle fluctuations in small open, resource-rich, resource-dependent emerging economies. We confront the model with Nigerian data on eleven macro-economic variables using the Bayesian likelihood approach and show that output fluctuations are driven mainly by oil and monetary policy shocks in the short run and domestic supply shocks in the medium term. On the other hand, monetary and domestic supply shocks jointly account for around 70 per cent of short run variations in headline and core measures of inflation while oil shocks play a less prominent role owing partly to the low pass-through effect arising from the extant fuel subsidy regime in the country. Interrogating these findings further, we find that negative oil price shocks generate a persistent negative impact on output and a short-lived positive effect on headline inflation. In terms of policy responses, the estimated Taylor rule indicates a hawkish monetary policy stance over the sample period while the estimated fiscal rule provides evidence for a pro-cyclical and rather muted fiscal policy. Since domestic supply and oil-related shocks are key sources of macroeconomic fluctuations, the study calls for a more creative use of the country's stabilisation funds as well as strategic fiscal interventions aimed at addressing the issues of domestic supply constraints and promoting private sector investments.

Keywords: Business cycles, resource-rich economy, DSGE model
JEL classification: E31, E32, E52, E62

1.0 Introduction

Business cycles refer to the common movement in several economic variables such as output, consumption, investment, employment and prices (Long and Plosser, 1983). According to Gottfried (1946); Burns and Mitchell (1946); and Harding and pagan (2002), such co-movements occur in a recurring sequence characterised by four phases; namely: expansion, contraction, down-turn and recovery[1]. This implies that aggregate economic activities (often represented by the real gross domestic product) tend to move in a wave-like manner around their long-term trends overtime. However, the amplitude and spacing of the cycles are irregular and subject to empirical observation (Burns and Mitchell, 1946; Gottfried, 1946; Romer, 2012; Škare and Stjepanović, 2016).

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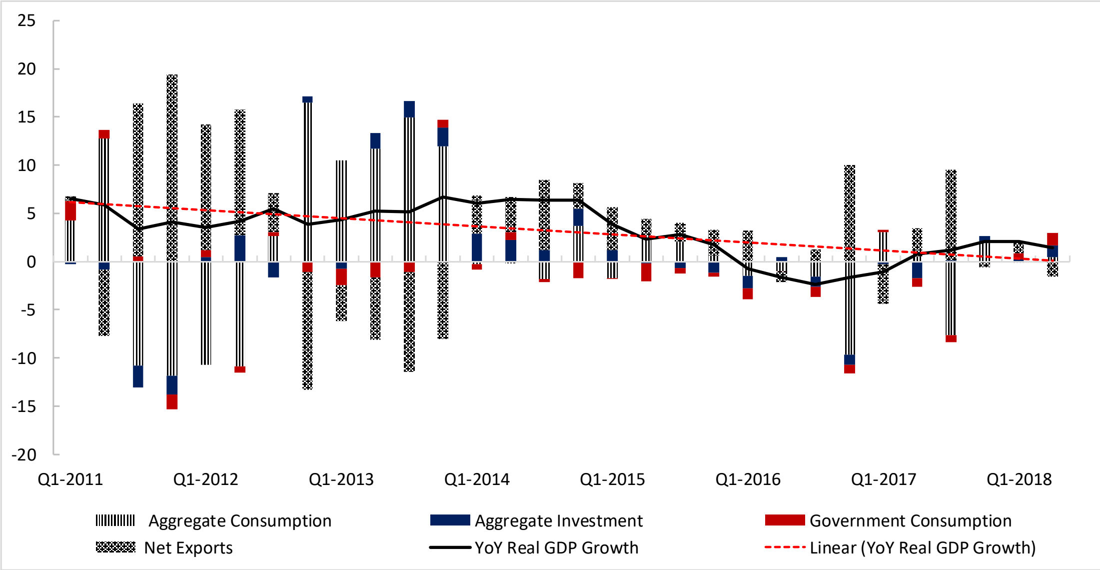
[1] See Gottfried (1963) for an expansive discussion of the definitions, measurement and identification of business cycles.

Business cycles are an intrinsic feature of any economy. Thus, a major objective of macroeconomic policy is to evolve strategies for ensuring that the economy remains in the expansion phase for a longer period while also mimising the likelihood of recessions. However, achieving this objective requires a proper identification of the shocks driving business cycles. The sources of business cycles differ from one country to another and so also is the extent of the swings (Agenor, McDermott and Prasad, 2000; Mehrara and Oskoui, 2007; Rand and Tarp, 2002). Indeed, one of the legacies of the 2008/09 global financial crisis is the realization that business cycles generated in a relatively large economy can easily spread to other countries, generating non-trivial consequences for the global economy. This sort of interconnectedness and vulnerabilities remain a concern with the increasing spate of globalization and financial integration around the world (Huseynov and Ahmadov, 2014). Thus, policy makers and macroeconomists are generally interested in knowing the sources of business cycles with a view to evolving countercyclical measures for containing their welfare-reducing effects.

The literature is replete with studies focused on understanding business cycles in different economies but there is yet to be a consensus, especially with regards to the number and nature of its drivers (Andrie, Bruha and Solmaz, 2017). An interesting feature of the literature points to the fact that the ramifications of business cycle drivers have also evolved overtime. These range from the traditional total factor productivity shocks identified in the real business cycle models of the 1980s to more contemporary sources such as financial risks, excess optimism and self-fulfilling prophecies that emerged in the aftermath of the 2008 global economic crisis (Andrie et al., 2017; Angeletos, Collard and Dellas, 2018; Spatafora and Sommer, 2007). In commodity-exporting and commodity-importing countries alike, terms of trade shocks - such as relating to oil price movements have also been identified as a prominent source of business cycles (Bacchiocchi and Sarzaeem, 2015; Bergholt, Larsen and Seneca, 2017; Brown and Yücel, 2002; Engemann, Kliesen and Owyang, 2011; Hamilton, 1985, 2008; Hollander, Gupta and Wohar, 2018; Mehrara and Oskoui, 2007; Mork, 1989; Mork, Mysen and Olsen, 1990).

As the move towards the creation of a monetary union in Africa gathers steam, it is important that the idiosyncratic factors driving economic volatilities in the member countries are well identified and understood. It is against this backdrop that we seek to contribute to this important sphere of research, taking the case of Nigeria - the largest economy on the continent (IMF, 2018). Figure 1 presents Nigeria's GDP growth and the contribution of its components during the period 2011Q1-2018Q2. The figure shows that output growth trended downwards during the period, with negative growth rates recorded in 2016 and the first quarter of 2017. It is also clear from the figure that growth was above its linear trend during the periods 2013Q2 – 2015Q1 and 2017Q3 – 2018Q2 while it stayed below trend during the periods 2011Q3 – 2012Q2 and 2015Q4 – 2017Q2. Figure 1 also shows that the business cycles are subject to irregular behaviour in terms of size and space. For instance, the below-trend output growth for 2011Q3 – 2012Q2 is shorter and less severe than that of 2015Q4 – 2017Q2. The sources of these sorts of irregularities in the evolution of real GDP growth (often regarded as business cycle fluctuations) are of concern to this paper.

Figure 1: **Contribution of output components to GDP growth**



A decomposition of output growth according to its various components further shows that aggregate consumption and net exports are the key sources of GDP growth in Nigeria. The average output growth of 4.7 per cent recorded in the pre-recession period of 2011Q1 – 2015Q4 was largely accounted for by aggregate consumption as its share in GDP stood at 62.8 per cent (Table 1). On the other hand, while the other components of GDP recorded negative growth rates in the 2016Q1 -2018Q2 period, net exports (with a share of GDP at 20.0 per cent) grew by 2.1 per cent. Thus, the positive average GDP growth of about 0.01 per cent recorded the period is driven by net exports, implying that the economy is vulnerable to external shocks. Finally, we note from Table 1 that changes in the average GDP growth are not uniformly distributed over the components of aggregate demand.

Table 1: **Components of output, 2011-2018**

Component of GDP	Pre 2016 economic recession (2011Q1-2015Q4)		Since 2016 economic recession (2016Q1 -2018Q2)	
	Average share in GDP (%)	Contribution to GDP growth (%)	Average share in GDP (%)	Contribution to GDP growth (%)
Consumption	62.8	2.3	60.0	-1.5
Investment	15.6	0.4	15.4	-0.3
Government	7.0	-0.3	4.5	-0.3
Net exports	14.6	2.3	20.0	2.1
Total	100.0	4.72	100.0	0.01

Quite a number of studies have been conducted in recent years to understand the Nigerian business cycles and identify the appropriate policy response for responding to such macroeconomic fluctuations (see, for instance Abayomi, Adam and Alumbugu, 2015; Abeng and Hilili, 2017; Adeniyi, Oyinlola and Omisakin, 2011; Aigheyisi, 2018; Akinleye and Ekpo, 2013; Akinlo, 2012; Alege, 2012; Fredrick, Ugwuanyi, Obidike and Eze, 2014; Lartey, 2018; Olaniran, D and Yusuff, 2017). However, besides relying on vector autoregression - or vector error correction-based macro-econometric models that are subject to the Lucas (1976) critique, most of these studies focused on commodity prices as the key sources of macroeconomic volatility (see for instance, Abayomi et al., 2015; Abeng and Hilili, 2017; Aigheyisi, 2018; Akinleye and Ekpo, 2013; Akinlo, 2012).

This study is different from those mentioned above as it focuses on other important structural sources of business cycles (in addition to the oil price) within the framework of a New Keynesian dynamic stochastic general equilibrium (DSGE) model[2]. Our choice of a DSGE model derives from its ability to disentangle the contribution of various shocks from a micro-founded perspective. Medina and Soto (2007) and Smets and Wouters (2007) have also noted that Keynesian models are quite useful for understanding business cycle fluctuations and conducting monetary policy analysis. Of the studies on Nigeria cited above, Alege (2012) stands out and is of particular interest to our work- being the only one that adopted a general equilibrium approach[3]. While Alege (2012) considered only three shocks (i.e. technology, terms of trade, and money growth), the model developed in this paper is more robust in terms of the number of shocks as well as the bells and whistles introduced to capture the unique realities of the Nigerian economy.

Against this background, the broad objective of this paper is to investigate the drivers of business cycle fluctuations in Nigeria through the lens of an estimated DSGE model. We develop a small open economy model for a resource-rich, resource-dependent emerging economy in the fashion of Gali and Monacelli (2005) and Medina and Soto (2007). Ten types of structural shocks are introduced to drive the stochastic dynamics of the model, including shocks relating to total factor productivity, domestic risk premium, foreign risk premium, monetary policy, fiscal policy, oil price, oil sector productivity, law of one price gap in the oil sector, foreign monetary policy, and foreign inflation[4]. The model is fitted to Nigerian data via Bayesian methods, using quarterly data on eleven macroeconomic variables covering the period 2000Q2 - 2018Q2. Based on the estimated model, the study characterises the Nigerian economy; draws useful insights regarding the sources of business cycle dynamics; and analyses the stance of macroeconomic policies over the sample period.

This paper is organized into five sections. In the next section, we present the theoretical model by describing the economic environment and deriving the optimality conditions guiding the agents' decisions. The estimation procedure as well as the data used for the empirical investigation are discussed in section three. Section 4 presents the estimation results, including the impulse responses and variance decompositions. Section five concludes. Some useful results are presented in the Appendix.

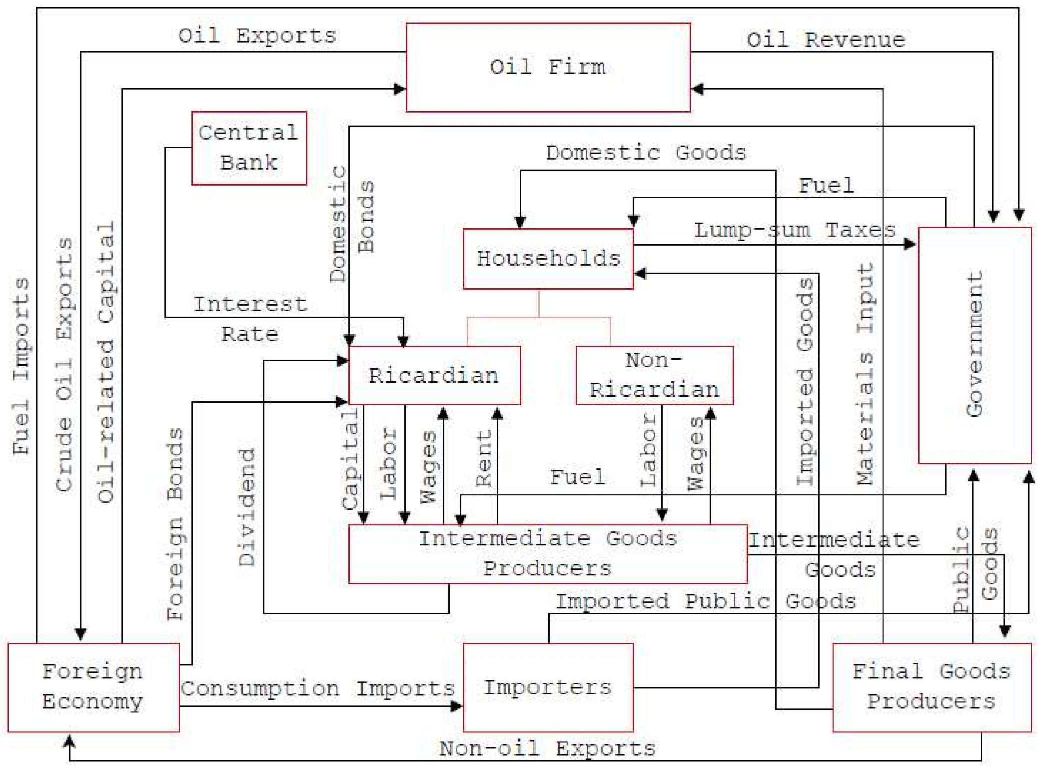
2.0 The Model

The model developed in this paper extends the basic small open economy New Keynesian framework of Gali and Monacelli (2005) by incorporating an oil sector as in Ferrero and Seneca

[2] Hollander et al. (2018); Hou, Mountain and Wu (2016); Paetz and Gupta (2016) argued that a general equilibrium approach is useful and preferred to the non-structural macro-econometric models in correctly estimating the effects and contributions of shocks to business cycle fluctuations.
[3] Applications of simulated DSGE model to other areas of economic research for Nigeria include, for instance Ncube and Balma (2017)
[4] See Škare and Stjepanović (2016) for a discussion on some of these sources of business cycles.

(2019), oil in domestic consumption as in Medina and Soto (2005), oil in domestic production (Allegret and Benkhodja, 2015), five different measures of inflation[5] as in Medina and Soto (2007), an inefficient financial sector (Smets and Wouters, 2007), and a fiscal policy rule as in Algozhina (2015). In addition, we introduce non-Ricardian consumers into our model so as to capture the financial imperfections, which are quite prevalent in developing and emerging economies, debarring financially constrained households from engaging in intertemporal optimisation[6]. Furthermore, we allow for law of one price gap in imports and by implication assume incomplete exchange rate pass-through (Monacelli, 2005; Senbeta, 2011). Following Smets and Wouters (2007), we reflect the usual inefficiencies in the financial sector of most emerging economies by incorporating an exogenous risk premium in the return to bonds. As standard in most DSGE models, we allow for nominal and real rigidities, including wages stickiness, consumption habits, investment adjustment costs, and stickiness in the prices of certain goods.

Figure 2: **Flow chart of the model economy**



Source: Constructed by the author based on model set up

Figure 2 presents a bird's-eye view of the economy, highlighting the agents operating in the model as well as the inter-relationships among them. Households consume goods (which include domestically produced goods, imported goods and fuel), supply labour to earn wages, and pay taxes to the government. However, only Ricardian consumers are able to save, invest in bonds and accumulate capital. The accumulated capital is leased to domestic intermediate

[5] These are core inflation, oil inflation, imports inflation, domestic inflation, and total inflation.
[6] A survey conducted in 2018 showed that about 36.8 per cent of adults in Nigeria are financially excluded that year (EFInA, 2018).

goods producing firms at a rental rate. The final goods producer buys intermediate goods and transforms them into final goods, which are consumed by domestic households, government, oil firm, or exported to the foreign economy by way of non-oil exports. The intermediate goods firms produce differentiated goods by combining labour, capital, and imported refined oil; and set prices a la Calvo (1983). Also, the importing firms buy goods from the foreign economy and sell to households and the government at a price determined based on the Calvo model.

The oil firm uses materials sourced from the domestic economy as well as capital sourced from government and foreign investors to produce crude oil, which is exported to the rest of the world at an exogenously determined price. The government then imports refined fuel, which is sold to households and domestic intermediate firms at a price determined by a fuel pricing rule as in Allegret and Benkhodja (2015). The government receives tax revenues from households, oil revenues from the oil firm, and issues one period bonds. These revenues are used to purchase domestically produced and imported public goods as well as to finance the energy subsidy programme. The central bank acts as the monetary authority, setting interest rate based on a standard Taylor rule in order to achieve macroeconomic stability. Details regarding the economic environments within which each of the agents operates as well as the rules guiding their decisions are discussed next.

2.1 Households

The model economy features two types of households: Ricardian (*R*) and non-Ricardian or and-to-mouth (*NR*). The former comprises a fraction (γ_R) of households who are optimisers and have access to financial markets. Each household *j* in this category can buy and sell financial assets without any form of constraints and are thus able to smooth their consumption over time. The latter category, *NR*, represents the remaining fraction $(1-\gamma_R)$ who are financially constrained and completely consume their labour income within the period (Gabriel, Levine, Pearlman and Yang, 2010; Melina, Yang and Zanna, 2016). However, both categories of households have identical preferences as the representative household *j* derives utility from private consumption, C_t, as well as government consumption, $G_{c,t}$ and dis-utility from labour, N_t, while seeking to maximise the objective function expressed in equation (1). Thus, the representative optimising household *j* makes inter-temporal consumption and savings decisions in a forward-looking manner by maximising an expected discounted utility function given by

$$U_0^R = E_0 \sum_{s=0}^{\infty} \beta^s \left[\frac{(C_{t+s}^R(j) - \emptyset_c C_{t+s-1})^{1-\sigma}}{1-\sigma} - \frac{N_{t+s}^R(j)^{1+\varphi}}{1+\varphi} + h(G_{c,t+s}) \right], \tag{1}$$

where E_0 denotes the mathematical expectation operator, $\beta \in (0,\ 1)$ is a discount factor, σ is relative risk aversion coefficient, and $\varphi > 0$ is the inverse of the Frisch elasticity of labour supply. The superscript *R* indicates that the household *j* in equation (1) is Ricardian. The utility derived by household from government spending, $h(G_{c,t})$, is taken as given. Consumption in equation (1) is subject to external habit formation, implying that the external habit stock is proportional to aggregate past consumption. The parameter $\emptyset_c \in (0,1)$ measures the degree of consumption habit, with $\emptyset_c = 0$ implying that there is no habit formation. Household consumption is a composite index comprising core (non-oil) consumption bundle, $C_{NO,t}(j)$, and fuel (oil) consumption, $C_{O,t}(j)$:

$$C_t(j) = \left[(1-\gamma_O)^{\frac{1}{\eta_O}}\left(C_{no,t}(j)\right)^{\frac{\eta_O-1}{\eta_O}} + \gamma_O^{\frac{1}{\eta_O}}\left(C_{o,t}(j)\right)^{\frac{\eta_O-1}{\eta_O}}\right]^{\frac{\eta_O}{\eta_O-1}}, \quad (2)$$

where parameter $\eta_O > 0$ measures the degree of substitution between core and fuel consumption and γ_O represents the share of domestic consumption devoted to fuel consumption, $C_{O,t}(j)$. Expenditure minimization subject to equation (2) yields the demand for core consumption and fuel consumption as follows:

$$C_{no,t}(j) = (1-\gamma_o)\left[\frac{P_{no,t}}{P_t}\right]^{-\eta_o} C_t(j), \quad C_{o,t}(j) = \gamma_o\left[\frac{P_{ro,t}}{P_t}\right]^{-\eta_o} C_t(j),$$

where the price of fuel and non-oil (core) goods are denoted as $P_{ro,t}$ and $P_{no,t}$, respectively, and P_t is the aggregate consumer price index. As will be discussed in greater details later, $P_{ro,t}$ is a regulated price of imported fuel determined by a fuel pricing rule. Similarly, the core consumption bundle, $C_{no,t}(j)$ is defined as a composite index combining imported bundle, $C_{f,t}(j)$, and domestically produced goods, $C_{h,t}(j)$, as follows:

$$C_{no,t}(j) = \left[(1-\gamma_C)^{\frac{1}{\eta_C}}\left(C_{h,t}(j)\right)^{\frac{\eta_C-1}{\eta_C}} + \gamma_C^{\frac{1}{\eta_C}}\left(C_{f,t}(j)\right)^{\frac{\eta_C-1}{\eta_C}}\right]^{\frac{\eta_C}{\eta_C-1}}, \quad (3)$$

Where $\eta_C > 0$ represents the elasticity of substitution between home and foreign goods in the core consumption basket and the parameter γ_C indicates the degree of openness of the domestic economy. Expenditure minimization subject to equation (3) yields the demands for $C_{h,t}(j)$ and $C_{f,t}(j)$ as follows:

$$C_{h,t}(j) = (1-\gamma_C)\left[\frac{P_{h,t}}{P_{no,t}}\right]^{-\eta_C} C_{no,t}(j), \quad C_{f,t}(j) = \gamma_C\left[\frac{P_{f,t}}{P_{no,t}}\right]^{-\eta_C} C_{no,t}(j),$$

where $P_{h,t}$ represents the price of domestically produced goods and $P_{f,t}$ is the price of imported goods. The corresponding aggregate price index, P_t, and core consumption price index, $P_{no,t}$, are as follows:

$$P_t = \left[(1-\gamma_O)P_{no,t}^{1-\eta_O} + \gamma_O P_{ro,t}^{1-\eta_O}\right]^{\frac{1}{1-\eta_O}}, \quad P_{no,t} = \left[(1-\gamma_C)P_{h,t}^{1-\eta_C} + \gamma_C P_{f,t}^{1-\eta_C}\right]^{\frac{1}{1-\eta_C}}.$$

2.1.1 Ricardian households

The representative Ricardian household j makes its inter-temporal decisions by maximising equation (1) subject to the following per period budget constraint:

$$P_t C_t^R(j) + P_{i,t} I_{no,t}(j) + \frac{B_{t+1}(j)}{R_t \mu_t} + \frac{\epsilon_t B_{t+1}^*(j)}{R_t^* \mu_t^*} = W_t N_t^R(j) + R_{h,t} K_{h,t}^R(j) + B_t(j) + \epsilon_t B_t^*(j) + D_t - TX_t. \quad (4)$$

On the income side of equation (4), the Ricardian consumer supplies $N_t^R(j)$ hours of work at a nominal wage rate, W_t, yielding a labour income, $W_t N_t^R(j)$. The household owns an amount of non-oil capital, $K_{h,t}^R(j)$, which it leases to the domestic (non-oil) firms at a rental rate, $R_{h,t}$, to generate a capital income, $R_{h,t} K_{H,t}^R(j)$. Also, the household receives an aliquot share, D_t from the profits of the firms. Each household enters the period with the stock of nominal domestic bonds, $B_t(j)$, and foreign bonds, $B_t^*(j)$ maturing in period $t+1$, with $B_{t+1}(j)$ and $B_{t+1}^*(j)$ representing household's investments in domestic and foreign bonds at the end of period t, respectively. Each domestic bond pays a gross nominal rate of return, R_t in domestic currency while its foreign counterpart pays an exchange rate (ϵ_t) adjusted nominal rate of return, R_t^*. We allow for domestic risk premium, μ_t over the monetary policy rate when households hold domestic assets as well as a stochastic disturbance term that represents the risk premium faced by households when borrowing abroad, μ_t^* (Gupta, Hollander and Wohar, 2016; Smets and Wouters, 2007)[7]. The income received by the household is used to finance the purchase of consumption goods, $C_t^R(j)$, and non-oil investment goods, $I_{no,t}(j)$. P_t is the aggregate Consumer Price Index (CPI) in the domestic economy while $P_{i,t}$ represents the price index of investment goods. Lastly, TX_t represents per-capita lump-sum net taxes from the government.

As with consumption, non-oil investment goods, $I_{no,t}$, in equation (4) comprise home-produced, $I_{h,t}$, and foreign-produced, $I_{f,t}$, which are combined using a CES aggregator given

by:

$$I_{no,t}(j) = \left[(1-\gamma_I)^{\frac{1}{\eta_I}} \left(I_{h,t}(j)\right)^{\frac{\eta_I - 1}{\eta_I}} + \gamma_I^{\frac{1}{\eta_I}} \left(I_{f,t}(j)\right)^{\frac{\eta_I - 1}{\eta_I}}\right]^{\frac{\eta_I}{\eta_I - 1}}, \tag{5}$$

where γ_I is the share of imports in aggregate non-investment goods and η_I is the elasticity of intra-temporal substitution between domestically produced and imported investment goods. The demand equations for home and imported investment goods are standard, and derived as follows:

$$I_{h,t} = (1-\gamma_I)\left[\frac{P_{h,t}}{P_{i,t}}\right]^{-\eta_I} I_{no,t}, \quad I_{f,t} = \gamma_I \left[\frac{P_{f,t}}{P_{i,t}}\right]^{-\eta_I} I_{no,t},$$

and the aggregate investment price deflator, $P_{i,t}$, is given by:

$$P_{i,t} = \left[(1-\gamma_I) P_{h,t}^{1-\eta_I} + \gamma_I P_{f,t}^{1-\eta_I}\right]^{\frac{1}{1-\eta_I}}$$

To accumulate capital, the Ricardian household follows the following process:

$$K_{h,t+1}^R(j) = \left(1-\delta^h\right) K_{h,t}^R(j) + I_{no,t}(j)\left[1 - S\left(\frac{I_{no,t}(j)}{I_{no,t-1}(j)}\right)\right], \tag{6}$$

where parameter $0 < \delta^h < 1$ represents the rate at which capital depreciates and the investment adjustment cost function is defined as:

[7] The domestic and foreign premia are driven by *AR(1)* processes with exogenous shocks ε_t^{μ} for the domestic risk premium, and $\varepsilon_t^{\mu^*}$ for the foreign risk premium.

$$S\left(\frac{I_{no,t}(j)}{I_{no,t-1}(j)}\right) = \frac{\chi}{2}\left(\frac{I_{no,t}(j)}{I_{no,t-1}(j)} - 1\right)^2, \tag{7}$$

where parameter $\chi \geq 0$ governs the size of the adjustment cost. The representative Ricardian household maximises equation (1) subject to a per period nominal budget constraint (equation 4) and a capital accumulation process (equation 6). The relevant first order conditions yield the equations for consumption Euler, demand for foreign bonds, supply of capital, and demand for investment goods.

2.1.2 Non-Ricardian households

The non-Ricardian consumers are credit constrained. Therefore, they are incapable of inter-temporal optimisation. Thus, the representative non-Ricardian consumer j chooses its consumption, $C_t^{NR}(j)$ by maximising a utility function that is similar to equation (1) subject to a budget constraint given by:

$$P_t C_t^{NR}(j) = W_t N_t^{NR}(j) - TX_t. \tag{8}$$

2.1.3 Labour supply and wage setting

Following Medina and Soto (2007), we make a simplifying assumption that the determination of wages for both the Ricardian and non-Ricardian households are similar and based on Calvo (1983) rule. Households sell their differentiated labour, $N_t(j)$, in a monopolistic market to a representative firm that aggregates the different labour types into a single labour input, N_t. Thus, the labour-aggregating firm uses the following technology:

$$N_t = \left[\int_0^1 N_t(j)^{\frac{\eta_w - 1}{\eta_w}} dj\right]^{\frac{\eta_w}{\eta_w - 1}}, \tag{9}$$

where parameter η_w is the elasticity of substitution between differentiated jobs. To derive the demand equation for differentiated labour, j, and the aggregate wage level, the labour-aggregating firm maximises its profit subject to equation (9). Thus, the demand for differentiated labour, $N_t(j)$, and the aggregate wage level, W_t, are as follows:

$$N_t(j) = \left[\frac{W_t(j)}{W_t}\right]^{-\eta_w} N_t, \quad W_t = \left[\int_0^1 W_t(j)^{1-\eta_w} dj\right]^{\frac{1}{1-\eta_w}}.$$

We assume that $1 - \theta_w$ fraction of households is chosen at random to optimally set their wages in each period while the remaining fraction, θ_w, keep their wages at the previous period's level. Thus, the optimal wage setting problem involves maximising equation (1) subject to the household budget constraint as well as the demand for the differentiated labour shown above. This yields the optimal reset wage equation given by:

$$W_t^{\blacksquare}(j) = \left(\frac{\eta_w}{\eta_w - 1}\right) E_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left[\frac{\left(N_{t+s}(j)\right)^{\varphi}}{\lambda_{c,t+s}}\right], \tag{10}$$

where $W_t^{\blacksquare}(j)$ is the optimal reset wage, θ_w, measures the degree of nominal wage rigidity, and the aggregate nominal wage rule is:

$$W_t = \left[\theta_w W_{t-1}^{1-\eta_w} + (1-\theta_w) W_t^{■}(j)^{1-\eta_w}\right]^{\frac{1}{1-\eta_w}}$$

The economy-wide consumption, C_t, and labour, N_t, for the Ricardian and non-Ricardian households are aggregated as follows:

$$C_t = \gamma_R C_t^R + (1-\gamma_R) C_t^{NR}, \quad N_t = \gamma_R N_t^R + (1-\gamma_R) N_t^{NR}.$$

2.2 Open economy features

Given that the model being developed is for a small open economy, we assume that activities in the foreign economy are not impacted by developments in the domestic economy. The interactions between the domestic economy and the foreign economy is discussed next. In terms of notation, variables in real terms are denoted by small letters.

Real exchange rate, terms of trade and incomplete pass-through: We allow for law of one price gap, Ψ_t, as in Monacelli (2005) given by the ratio of foreign price index expressed in domestic currency to the domestic currency price of imports:

$$\Psi_t = \frac{\epsilon_t P_t^*}{P_{f,t}}, \tag{11}$$

where P_t^* is aggregate consumer price index of the foreign economy and $P_{f,t}$ is the average domestic price of imported goods. The law of one price gap takes the value of one if the law of one price (LOP) holds. The real exchange rate, s_t, is defined as the ratio of price index of the rest of the world (in terms of domestic currency) to the aggregate domestic price index as follows:

$$s_t = \frac{\epsilon_t P_t^*}{P_t}. \tag{12}$$

Making use of the definition of real exchange rate in equation (12), we can re-write the equation for the law of one price gap (equation 11) as:

$$\Psi_t = \frac{s_t}{p_{f,t}}, \tag{13}$$

where $p_{f,t} = P_{f,t}/P_t$ denotes the real price of imported goods. As in Gali and Monacelli (2005), the terms of trade of the domestic economy, τ_t, is defined as the domestic currency price of imports, $P_{f,t}$, relative to the export price (price of domestically produced tradable goods), $P_{h,t}$, given by: $\tau_t = P_{f,t}/P_{h,t}$.

International risk sharing: In order to link domestic consumption with foreign consumption, we assume that agents in the rest of the world have access to the same set of bonds and share the same preferences with their domestic counterparts. Thus, the Euler equation for the rest of the world can be written analogously to that of the domestic economy. Combining the Euler equations for both the domestic and foreign economies, and making use of the definition of the real exchange rate, s_t, yields the international risk sharing equation in Gali and Monacelli (2005) as follows:

$$C_t^R(j) - \phi_c C_{t-1} = \varrho S_t^{\frac{1}{\sigma}}(C_t^*(j) - \phi_c C_{t-1}^*), \tag{14}$$

where ϱ represents a constant that depends on the relative initial conditions in asset holdings given by

$$\varrho \equiv E_t \frac{C_{t+1}^R(j) - \phi_c C_t}{(C_{t+1}^*(j) - \phi_c C_t^*) s_{t+1}^{\frac{1}{\sigma}}}$$

2.3 Non-oil goods producing firms

Final-good firms: Final goods, $Y_{h,t}$ and $Y_{h,t}^*$ are produced by a set of perfectly competitive firms for domestic use and exports, respectively. Accordingly, these firms bundle domestically produced differentiated goods, $Y_{h,t}(z_h)$ and $Y_{h,t}^*(z_h)$, produced by a continuum of intermediate-goods firms using an aggregation technology. In bundling the intermediate varieties for the domestic market, the final-good firm pursues the following objective:

$$\max_{Y_{h,t}(z_h)} \Pi_{h,t} = P_{h,t} Y_{h,t} - \int_0^1 P_{h,t}(z_h) Y_{h,t}(z_h) dz_h, \tag{15}$$

subject to a constant return to scale technology

$$Y_{h,t} = \left[\int_0^1 Y_{h,t}(z_h)^{\frac{\epsilon_h - 1}{\epsilon_h}} dz_h\right]^{\frac{\epsilon_h}{\epsilon_h - 1}}, \tag{16}$$

where $P_{h,t}(z_h)$ is the price charged on intermediate goods, $Y_{h,t}(z_h)$, produced by an intermediate goods producing firm, z_h. $P_{h,t}$ is the domestic price index and the parameter $\epsilon_h > 1$ represents the elasticity of substitution among different intermediate goods. The first-order condition for the above optimization problem yields a standard downward sloping demand function for intermediate inputs meant for domestic market ($Y_{h,t}(z_h)$) and an analogous variant for goods meant for the export market ($Y_{h,t}^*(z_h)$) as follows:

$$Y_{h,t}(z_h) = \left[\frac{P_{h,t}(z_h)}{P_{h,t}}\right]^{-\epsilon_h} Y_{h,t}, \qquad Y_{h,t}^*(z_h) = \left[\frac{P_{h,t}^*(z_H)}{P_{h,t}^*}\right]^{-\epsilon_h} Y_{h,t}^* \tag{17}$$

while the corresponding price aggregators for home goods meant for the domestic market ($P_{h,t}$) and the export market ($P_{h,t}^*$) are given by:

$$P_{h,t} = \left[\int_0^1 P_{h,t}(z_h)^{1-\epsilon_h} dz_h\right]^{\frac{1}{1-\epsilon_h}} \qquad P_{h,t}^* = \left[\int_0^1 P_{h,t}^*(z_h)^{1-\epsilon_h} dz_h\right]^{\frac{1}{1-\epsilon_h}}$$

where $P_{h,t}^*(z_h)$ is the price charged on export-bound intermediate goods $Y_{h,t}^*(z_h)$ produced by an intermediate goods producing firm, z_h.

Intermediate-goods firms: The model economy consists of a continuum of intermediate goods firms, indexed by $z_h \in (0,1)$ producing differentiated goods in a monopolistically competitive environment. It is assumed that each representative intermediate-goods firm combines three inputs: capital – $K^R_{h,t}(z_h)$, refined oil - $O_{h,t}(z_h)$, and labour- $N_t(z_h)$ to produce good z_h using a constant returns to scale technology specified as:

$$Y_{h,t}(z_h) = A_{h,t}K^R_{h,t}(z_h)^{\alpha^k_h}O_{h,t}(z_h)^{\alpha^o_h}N_t(z_h)^{\alpha^n_h}, \tag{18}$$

where $Y_{h,t}(z_h)$ is the output of the intermediate firm z_h, and the parameters $1 > \alpha^k_h > 0$, $1 > \alpha^o_h > 0$ and $1 > \alpha^n_h > 0$ are elasticities of an intermediate firm's output with respect to capital, refined oil and labour inputs, respectively. We assume that the total factor productivity, $A_{h,t}$, follows a first order autoregressive process with an exogenous shock. Each firm chooses its input factors by minimize total cost given by:

$$\min_{N_t(z_h),K^R_{h,t}(z_h),O_{h,t}(z_h)} W_tN_t(z_h) + R_{h,t}K^R_{h,t}(z_h) + P_{ro,t}O_{h,t}(z_h), \tag{19}$$

subject to equation (18). This yields optimal input combinations given by:

$$\frac{K^R_{h,t}(z_h)}{N_t(z_h)} = \frac{\alpha^k_h w_t}{\alpha^n_h r_{h,t}}, \quad \frac{O_{h,t}(z_h)}{N_t(z_h)} = \frac{\alpha^o_h w_t}{\alpha^n_h p_{ro,t}},$$

which are substituted into the production technology to obtain an expression for the real marginal cost:

$$mc_t = \frac{1}{A_{h,t}p_{h,t}}\left(\frac{r_{h,t}}{\alpha^k_h}\right)^{\alpha^k_h}\left(\frac{p_{ro,t}}{\alpha^o_h}\right)^{\alpha^o_h}\left(\frac{w_t}{\alpha^n_h}\right)^{\alpha^n_h}, \tag{20}$$

where $mc_t = MC_t/P_t$ is the real marginal cost, $r_{h,t} = R_{H,t}/P_t$ is the real rental rate on capital, $p_{ro,t} = P_{ro,t}/P_t$ is the subsidised real domestic price of fuel (oil), $w_t = W_t/P_t$ is the real wage, and $p_{h,t} = P_{h,t}/P_t$ is the price of domestically produced goods in real terms. Furthermore, the intermediate goods producers choose price to maximize their expected discounted profit. We follow Calvo (1983) staggered pricing model, allow a proportion of the intermediate goods producing firms, $(1 - \theta_h)$, to reset their prices optimally in any given period while the other fraction, θ_h maintain the price as at last fixing. It then follows that the evolution of domestic price level is given by a law of motion:

$$P_{h,t} = \left[\theta_h P^{1-\epsilon_h}_{h,t-1} + (1-\theta_h)\left(P^{\blacksquare}_{h,t}\right)^{1-\epsilon_h}\right]^{\frac{1}{1-\epsilon_h}}, \tag{21}$$

where $\theta_h \in [0,1]$ is an index of price stickiness (Calvo, 1983) and $P^{\blacksquare}_{h,t}$ represents the optimal reset price. Profit maximisation subject to the demands for intermediate goods (equation 17) yields the optimal reset price for intermediate goods meant for the domestic market given by:

$$P^{\blacksquare}_{h,t} = \frac{\epsilon_h}{\epsilon_h - 1}\frac{E_t\sum^{\infty}_{s=0}(\beta\theta_h)^s P_{h,t+s}Y_{h,t+s}mc_{t+s}}{E_t\sum^{\infty}_{s=0}(\beta\theta_h)^s Y_{h,t+s}} \tag{22}$$

and its analogous variant for intermediate goods that are meant for the export market ($P^{*\blacksquare}_{H,t}$), with θ_{hf} denoting the Calvo parameter for such a commodity.

2.4 Imports retailers

In order to accommodate incomplete exchange rate pass-through into import prices in the short run, we introduce local currency pricing (Medina and Soto, 2005). Thus, we consider a set of competitive assemblers that produce a final foreign good, $Y_{f,t}$, which is consumed by households and used for accumulating new capital goods. To produce $Y_{f,t}$, the competitive assemblers combine a continuum of differentiated imported varieties, $Y_{f,t}(z_f)$, using a Dixit-Stiglitz aggregation technology:

$$Y_{f,t} = \left[\int_0^1 Y_{f,t}(z_f)^{\frac{\epsilon_f - 1}{\epsilon_f}} dz_f\right]^{\frac{\epsilon_f}{\epsilon_f - 1}}, \tag{23}$$

where the parameter $\epsilon_f > 1$ represents the elasticity of substitution among different imported goods. With $P_{f,t}$ being the price index for imported goods and $P_{f,t}(z_f)$, the price charged on an imported intermediate product, z_f , the problem of the import good retailers is to choose $Y_{f,t}(z_f)$ by maximising its profit function subject to the aggregation technology, equation (23). The first-order condition for the above optimization problem yields a downward sloping demand function for imported intermediate goods, $Y_{f,t}(z_f)$ with the corresponding pricing rule for retail imported goods ($P_{f,t}$) as follows:

$$Y_{f,t}(z_f) = \left[\frac{P_{f,t}(z_f)}{P_{f,t}}\right]^{-\epsilon_f} Y_{f,t}, \quad P_{f,t} = \left[\int_0^1 P_{f,t}(z_f)^{1-\epsilon_f} dz_f\right]^{\frac{1}{1-\epsilon_f}}.$$

Each import goods retailer has monopoly power to determine the domestic price of their varieties, albeit infrequently as in Calvo (1983). The frequency at which prices can be optimally reset is guided by a price stickiness parameter, θ_f. Thus, an importing firm has a probability, θ_f, of keeping the price of its good fixed in the next period and a probability, $1 - \theta_f$, of optimally resetting its price. For a firm that can reset its price, $P_{f,t}^{\blacksquare}$, it does so by maximising the present value of expected profits subject to the demand for the imported variety given above. Making use of the equation for law of one price gap (equation 11), the optimal reset price is derived as:

$$P_{f,t}^{\blacksquare} = \frac{\epsilon_f}{\epsilon_f - 1} \frac{E_t \sum_{s=0}^{\infty} (\beta\theta_f)^s P_{f,t+s} Y_{f,t+s} \Psi_{t+s}}{E_t \sum_{s=0}^{\infty} (\beta\theta_f)^s Y_{f,t+s}} \tag{24}$$

2.5 Oil producing firm

We assume that the oil firm operates under perfect competition, combining technology ($A_{o,t}$), materials sourced from the domestic economy (M_t) and oil-related capital ($K_{o,t}$) to produce oil output ($Y_{O,t}$) which is exported to the rest of the world at a price determined at the world crude oil market. We extend the oil sector in Ferrero and Seneca (2019) by including oil-related capital accumulated by foreign direct investment in the production technology of the oil firm as in Algozhina (2015). The oil firm's decision problem involves choosing production inputs to maximise its profit subject to a constant return to scale Cobb-Douglas extraction technology given by:

$$Y_{O,t} = A_{O,t} K_{O,t}^{\alpha_o^k} M_t^{\alpha_o^m}, \tag{25}$$

The parameters $\alpha_o^k \in (0,1)$ and $\alpha_o^m \in (0,1)$ represent the elasticities of oil output with respect to oil-related capital and material inputs, respectively. The oil-related capital, $K_{o,t}$ is accumulated by foreign direct investment, FDI_t^* as follows:

$$K_{o,t} = (1-\delta^o)K_{o,t-1} + FDI_t, \tag{26}$$

where δ^o represents the rate at which oil-related capital depreciates. Foreign direct investment responds to international oil price as follows:

$$FDI_t^* = (FDI_{t-1}^*)^{\rho_{FDI}} \left(P_{o,t}^*\right)^{1-\rho_{fdi}}, \tag{27}$$

where ρ_{fdi} measures the degree of smoothing in the accumulation of FDI_t^* and $P_{o,t}^*$ is the international price of oil (in foreign currency) and oil technology follow $AR(1)$ processes with exogenous shocks as follows:

$$P_{o,t}^* = \left(P_{o,t-1}^*\right)^{\rho_o} exp\left(\varepsilon_t^{p_o^*}\right), \quad A_{o,t} = \left(A_{o,t-1}\right)^{\rho_{A_o}} exp\left(\varepsilon_t^{A_o}\right)$$

Following Algozhina (2015), we assume that the oil firm, which is jointly owned by foreign direct investors and the government, receives its profits net of royalties levied on production quantity at a rate τ^o as follows: $\Pi_t^{o*} = (1-\tau^o)P_{o,t}^* Y_{o,t}$.

2.6 Fiscal authority

The government receives revenues from lump-sum tax, TX_t, receives oil revenues in form of royalties from oil firms, OR_t, and issues one period bonds that results in a net debt position, B_t. These receipts are used to finance a given government expenditure on public goods, $G_{c,t}$, and effect subsidy payments, OS_t, within a framework that allows for the stabilisation of domestic fuel price, $P_{ro,t}$. Thus, we assume the government respects a budget constraint given by:

$$TX_t + OR_t + B_t = P_{g,t}G_{c,t} + OS_t + \frac{B_{t+1}}{R_t}. \tag{28}$$

As in Medina and Soto (2007), we assume that government consumption basket consists of foreign, $G_{f,t}$, and domestically produced goods, $G_{h,t}$:

$$G_{c,t} = \left[(1-\gamma_g)^{\frac{1}{\eta_g}} G_{h,t}^{\frac{\eta_g - 1}{\eta_g}} + \gamma_g^{\frac{1}{\eta_g}} G_{f,t}^{\frac{\eta_g - 1}{\eta_g}}\right]^{\frac{\eta_g}{\eta_g - 1}}, \tag{29}$$

where η_g is the elasticity of substitution between home and foreign goods consumed by government and γ_g is the share of foreign goods in government's consumption basket. Cost minimisation by government subject to equation (29) yields the demands for home and foreign goods as follows:

$$G_{h,t} = (1-\gamma_g)\left(\frac{P_{h,t}}{P_{g,t}}\right)^{-\eta_g} G_{c,t}, \quad G_{f,t} = \gamma_g \left(\frac{P_{f,t}}{P_{g,t}}\right)^{-\eta_g} G_{c,t},$$

where $P_{g,t}$ is the deflator of government expenditure. Government consumption price index is:

$$P_{g,t} = \left[(1-\gamma_g)P_{h,t}^{1-\eta_g} + \gamma_g P_{f,t}^{1-\eta_g}\right]^{\frac{1}{1-\eta_g}}, \tag{30}$$

Government consumption is the key fiscal policy instrument available to government in this model and its evolution (in log-linearised form) is given by:

$$\widetilde{G_{c,t}} = \rho_g \widetilde{G_{c,t-1}} + (1-\rho_g)\left[\omega_{yo}\widetilde{y_{o,t}} - \omega_b \widetilde{b_t} + \omega_{or}\widetilde{or_t}\right] + \varepsilon_t^{G_c}, \tag{31}$$

with the variables in tildes denoting log deviations from their respective steady state values. In equation (31), ρ_g is government consumption smoothing parameter, while ω_{yo}, ω_b and ω_{or} are government consumption feedback coefficients with respect to oil output, domestic debt and oil revenues, respectively. The feedback parameter with respect to oil output, ω_{yo}, defines the cyclicality of government spending and $\varepsilon_t^{G_c}$ represents government spending shock that is given by an exogenous process.

We also allow for the prevailing fuel subsidy regime in Nigeria, following the approach by Allegret and Benkhodja (2015). To define the amount of fuel subsidy (OS_t), we assume that aggregate refined oil (fuel), O_t, is produced abroad and imported into the domestic economy by government at a foreign price $P_{o,t}^*$ (denominated in foreign currency). The imported fuel is then sold at a regulated price, $P_{ro,t}$ based on a fuel pricing regime given by

$$P_{ro,t} = (P_{ro,t-1})^{(1-\nu)}(P_{lo,t})^{\nu}, \tag{32}$$

where $P_{lo,t}$ is the landing price of imported fuel given by[8]

$$P_{lo,t} = \epsilon_t P_{o,t}^* \Psi_t^o. \tag{33}$$

The variable $P_{o,t}^*$ is the foreign currency price of oil abroad, ϵ_t is the nominal exchange rate and Ψ_t^o is the law of one price gap associated with the import price of fuel. The parameter $0 < \nu < 1$ governs the level to which government subsidises fuel consumption. When $\nu = 1$, the subsidy regime seizes to exist while $\nu = 0$ implies complete price regulation. Thus, the fuel subsidy payment by government is given by the difference between the value of fuel imports (in domestic currency) and the amount realised from fuel sales in the domestic economy:

$$OS_t = (P_{lo,t} - P_{ro,t})O_t, \tag{34}$$

where total imported fuel, O_t, comprises fuel consumption by households, $C_{o,t}$, and consumption by domestic firms, $O_{h,t}$. On the revenue side of the budget constraint, the government collects lump-sum taxes and oil revenues. The amount of oil revenue accruing to government is given by:

[8] This is similar to the specification in Poghosyan and Beidas-Strom (2011). The law of one price gap variable, Ψ_t^o, captures the inefficiencies associated with petroleum pricing in the domestic economy.

$$OR_t = \tau^o \epsilon_t P_{O,t}^* Y_{O,t}, \tag{35}$$

where τ^o is the royalty rate on oil production quantity. Since fiscal debt clears the government's budget constraint, an additional equation is required for lump-sum taxes, TX_t. This is written in log-linearised form as

$$\widetilde{tx_t} = \varphi_b \widetilde{b_{t-1}} + \varphi_g \widetilde{g_{c,t}} + \varphi_{os} \widetilde{os_t} - \varphi_{or} \widetilde{or_t},$$

where the parameters φ_b, φ_g, φ_{os} and φ_{or} represent the responses of lump-sum tax to fiscal debt, government consumption, fuel subsidy payments and oil revenue, respectively.

2.7 Monetary authority

We assume that in setting the short-term nominal interest rate (R_t), the central bank follows a simple Taylor rule by gradually responding to aggregate inflation (π_t), domestic output ($y_{h,t}$), and real exchange rate (s_t) as follows:

$$\widetilde{R_t} = \rho_r \widetilde{R_{t-1}} + (1 - \rho_r)\left[\omega_\pi \widetilde{\pi_t} + \omega_y \widetilde{y_{h,t}} + \omega_s \widetilde{s_t}\right] + \varepsilon_t^r, \tag{36}$$

with the variables in tildes denoting log deviations from their respective steady state values. The parameter ρ_r is the interest rate smoothing parameter capturing monetary policy inertia to structural shocks, while ω_π, ω_y and ω_s are the feedback coefficients on inflation, output and real exchange rate, respectively. The monetary policy shock, ε_t^r, is assumed independent and identically distributed (*iid*).

2.8 Market clearing and aggregation

The aggregate demand equations derive from the model set up, where domestic output ($Y_{h,t}$) is absorbed by domestic consumption (comprising households - $C_{h,t}$, oil producing firms - M_t, and government - $G_{h,t}$), non-oil exports ($C_{h,t}^*$), and domestic investment ($I_{h,t}$)[9]. Consequently, the domestic resource constraint in real terms is given by: $Y_{h,t} = C_{h,t} + C_{h,t}^* + M_t + I_{h,t} + G_{h,t}$, while the aggregate real gross domestic product (GDP), which combines both oil ($Y_{o,t}$) and non-oil output ($Y_{h,t}$) is given by: $Y_t = Y_{h,t} + Y_{o,t} = C_{h,t} + M_t + I_{h,t} + G_{h,t} + nx_t$. Real net exports ($nx_t$) is given by: $nx_t = ex_t - im_t$, where ex_t is aggregate exports and im_t represents aggregate imports. Since the economy is open and there is no external reserves accumulation by the central bank, the current account is set equal to the financial account. We therefore obtain the following expression for the Balance of Payments (BOP):

$$\frac{s_t B_t^*}{R_t^*} = s_t B_{t-1}^* + nx_t - (1 - \tau^o) s_t P_{O,t}^* Y_{O,t} + s_t FDI_t^*. \tag{37}$$

The labour and capital markets clear as follows:

$$\mathrm{N_t} = \int_0^1 N_t^R(j)dj + \int_0^1 N_t^{NR}(j)dj, \qquad \mathrm{K_{H,t}^R} = \int_0^1 K_{H,t}^R(j)dj.$$

[9] Which is used to augment the stock of physical capital available for use in the production process in period $t + 1$

3.0 Model Estimation

3.1 Estimation methodology

The model developed in the previous section is estimated using Bayesian methodology outlined in Schorfheide (2000). The first step is to solve a system of linear rational expectations equations of our model. The solution to the system of equations can be expressed as a Vector autoregressive representation (VAR) in z_t:

$$z_t = \Gamma_1(\Omega)z_{t-1} + \Gamma_2(\Omega)\epsilon_t, \tag{38}$$

where the coefficient matrices $\Gamma_1(\Omega)$ and $\Gamma_2(\Omega)$ are non-linear functions of the structural parameters of our model. Thus, equation (38) forms the basis for the model to be estimated (Herbst and Schorfheide, 2015). In the next stage, we add measurement equations in order to link the observable variables to the vector of state variables. Thus, we assume there is a vector g_t of observable variables that is of a lower dimension than z_t and related to the variables in our model set-up via a measurement equation that can be written as:

$$g_t = Hz_t, \tag{39}$$

where H is a selection matrix containing ones and zeros that selects the observable variables from the vector z_t. The state space representation of g_t is therefore given by equations (38) and (39). In our proposed model, the vector of observable variables is

$$g_t \equiv \left[y_t, c_t, i_t, s_t, \pi_t, \pi_{no.t}, R_t, y_t^*, \pi_t^*, R_t^*, p_{o,t}^*\right]',$$

while the remaining variables are considered unobserved. Equation (39) allows us to construct the likelihood function (i.e. the probability of observing the data given the parameters) for the structural parameters via Kalman Filter[10]. The likelihood density is then combined with the prior distribution of the parameters in order to obtain the posterior density function. Finally, we numerically derive the posterior distribution of the parameters using Metropolis-Hastings Monte Carlo Markov Chain (MCMC) algorithm. We simulate some draws from the random walk Metropolis-Hastings, discarding 30 per cent of the first draws as burn-in. Also, the covariance matrix is scaled to achieve an acceptance ratio that is within the 20 - 40 per cent often targeted by most practitioners (Herbst and Schorfheide, 2015)[11].

3.2 Data

The data set used for the estimation consists of 73 quarterly observations on eleven variables covering the period 2000Q2 - 2018Q2[12]. While Nigeria represents the small open economy in our model, the rest of the world consists of Nigeria's major trading partners of the Euro area, the United States, and India[13]. The domestic variables, which relate to the Nigerian economy are: real GDP per capita (y_t^{obs}), real consumption per capita (c_t^{obs}), real investment per capita

[10] This is computed under the assumption of normally distributed disturbances.
[11] This was achieved by setting the Metropolis-Hastings jump scale to 0.26 heuristically
[12] The choice of the estimation sample is largely influenced by data availability for the domestic economy.
[13] These three regions account for about 65 per cent of Nigeria's total external trade over the last two decades. In the normalised weights for the computation of foreign variables, the Euro area is predominant with a trade weight of 0.39 while the weights for the United States and India are 0.36 and 0.25, respectively.

(i_t^{obs}), real effective exchange rate (s_t^{obs}), aggregate Consumer Price Index (P_t^{obs}), core CPI ($P_{no,t}^{obs}$), and the nominal interest rate (R_t^{obs}). Data set on these variables are sourced from the National Bureau of Statistics (NBS) and the Central Bank of Nigeria (CBN) Statistics database. On the other hand, the foreign economy variables include trade-weighted foreign real GDP per capita (y_t^{*obs}), trade-weighted foreign aggregate CPI (P_t^{*obs}), and trade-weighted foreign interest rate (R_t^{*obs}). The data set used for the computation of the trade-weighted foreign variables as well as the international price of oil ($P_{o,t}^{*obs}$) are retrieved from the Federal Reserve Bank of St. Louis (FRED) and the International Financial Statistics (IFS) of the International Monetary Fund (IMF). We carry out necessary transformations on the data set in order to make them model consistent.

3.3 Model parameters

3.3.1 Parameterization

The values of calibrated parameters, which are kept fixed in the estimation process are derived from three sources. The first category of parameters are parameterized according to standard values assumed for small open economies as in Gali and Monacelli (2005) and resource-rich emerging economies such as Romero (2008); Wolden-Bache, Brubakk and Maih (2008); Hove, Mama and Tchana (2015); Ferrero and Seneca (2019); and Iklaga (2017). These values are borrowed from related studies due to data paucity for the Nigerian economy. The second category are parametrized so as to match the corresponding data sample meanwhile the last set of parameters correspond to the implied steady state values from the model setup. The parameterization is done to fit quarterly data. Table A.1 presents a list of these parameters and their values.

3.3.2 Prior moments

Table A.3 presents our assumptions regarding the prior distributions of the estimated parameters. The priors for the small open economy are chosen based on calibration, the data (which reflect broad characteristics of emerging economies) and partly based on Iklaga (2017). On the other hand, the foreign priors are based on Smets and Wouters (2007). In cases where we have limited information to form a credible prior, we allow such priors to have a more diffuse distribution than those typically found in related literature, so as to reflect greater uncertainty regarding the values for the parameters. In other words, we impose less informative priors and allow for the data to determine the parameters' location.

The reaction coefficients in the monetary policy function are assumed to follow gamma distributions with the coefficient for inflation (ω_π) centered at 1.5 while the coefficients for output (ω_y) and exchange rate (ω_s) are each set to 0.125 (Iklaga, 2017; Smets and Wouters, 2007). Of importance to this study also are the priors for the shocks. The autoregressive coefficients for the exogenous disturbances are uniformly set to follow beta distributions centered at 0.50 in line with (Smets and Wouters, 2007). However, we assume larger standard deviations of 0.25 to reflect some level of uncertainty about the assumed parameter values. Finally, with regards to the distribution for the parameters of the shock processes, we allow for relatively flat priors as in Medina and Soto (2007). Thus, an inverse gamma distribution with a mean of 0.10 and a standard deviation of 4.0 is assumed for each of the shock processes. While the assumed mean for the shocks are in line with Smets and Wouters (2007), the assumed standard deviation of 4.0 is much larger than 2.0 in Smets and Wouters (2007) and 3.0 in Medina and Soto (2007). As earlier explained, this is to reflect our uncertainty about the assumed priors and allow the data determine the parameter values.

4.0 Results

In this section, we present the posterior distributions of the estimated parameters, analyse some Bayesian impulse responses and discuss the important shocks driving the Nigerian economy. Table A.2 reports statistical moments produced by the estimated model vis-a-vis similar moments that characterise actual observations from the data. The estimated model reasonably replicates the volatilities in interest rate and the real exchange rate. However, they over-predicted the volatility in output and under-predicted the volatilities in headline and core measures of inflation. The performance with regards to output is common outcome in studies of emerging economies (Iklaga, 2017).

4.1 Posterior moments

Table A.3 reports the assumptions for the prior distribution of the estimated parameters, the posterior means, and the 90 per cent credible sets. The proportion of Ricardian consumers (γ_R) is estimated to be around 0.69, which is higher than the assumed prior of 0.60 and the estimate of 0.62 obtained by Iklaga (2017) for the period 2003-2015. The estimated values for the parameters in the utility function are lower than the values assumed a priori. For instance, the estimated relative risk aversion parameter (σ) of about 1.41 implies that the response of savings/investment decision of households to structural shocks is not as high as 2.0 initially assumed but higher than the 1.07 obtained by Iklaga (2017) for the Nigerian economy and 1.38 estimated by Smets and Wouters (2007) for the US economy. Similarly, the parameter for labour supply elasticity (φ), which controls the response of hours to structural shocks is estimated to be slightly lower (1.44) than its assumed prior (1.45). At $\emptyset_c = 0.44$, the estimated external habit parameter is lower than the assumed 0.7.

The fuel pricing rule parameter (v), which controls the extent to which government subsidises the consumption of fuel in the domestic economy, is estimated to be about 0.43, much higher than the assumed prior of 0.30. Being the first attempt at estimating v for the Nigerian economy, this estimate suggests that domestic fuel price is less subsidised than assumed a priori over the sample period. This estimate implies there is about 43.0 per cent pass-through of international fuel price to domestic petrol price as against a pass-through of 30.0 per cent initially assumed.

Turning to the behaviour of the CBN, the estimated monetary policy reaction function suggests that the central bank has been quite aggressive in containing price inflation while also making some efforts to stabilise output and the exchange rate. For instance, the CBN's reaction coefficient to inflation (ω_π) is estimated at 2.86, much higher than the assumed prior of 1.50 and the value of 1.45 obtained by Iklaga (2017). It is also higher than 1.54 estimated for an oil-importing economy of South Africa (Hollander et al., 2018). Furthermore, the estimated reaction coefficients to output (ω_y = 0.12) and exchange rate (ω_s = 0.11) are lower than their assumed priors of 0.125. Thus, in setting the policy rate, the monetary authority appears to react more to output than the exchange rate. The estimated interest rate smoothing parameter is low ($\rho_r = 0.22$), compared to the assumed prior of 0.5 and close to the value of 0.26 obtained by Medina and Soto (2005) for the Chilean economy. In terms of fiscal policy, the estimated posterior mean of the feedback parameter with respect to oil output (ω_{yo}) is 0.35, suggesting that government spending is pro-cyclical over the sample period.

The results for the estimated autoregressive coefficients suggest that most of the shock processes are more persistent than assumed. The most persistent of these shocks are international oil price ($\rho_{p_o^*} = 0.92$), foreign risk premium ($\rho_{\mu^*} = 0.86$), domestic risk premium ($\rho_{\mu} = 0.79$), and domestic total factor productivity ($\rho_{a_h} = 0.77$). This implies that these shocks may account for the medium to long term forecast error variance of the real variables (Smets and Wouters, 2007). However, shocks relating to domestic monetary policy, fiscal policy and oil sector productivity are less persistent. At $\varepsilon_t^{a_h} = 0.25$, the standard deviation of the domestic total factor productivity shock is relatively low, compared to the estimated standard deviation for shocks relating to law of one price gap for fuel price ($\varepsilon_t^{\psi^o} = 0.90$) and domestic monetary policy ($\varepsilon_t^{r} = 0.38$). The estimated standard deviation for the shock to law of one price gap for oil price is most volatile, reflecting possible inefficiencies in the pricing of petroleum products in the country.

4.2 Bayesian impulse responses

In this section, we present the Bayesian impulse responses to five different shocks. We consider the responses of the economy to positive innovations to domestic productivity, monetary policy, fiscal policy and domestic risk premium while a negative shock is applied to the real international price of oil.

Productivity shock: Figure A.3 shows that a positive total factor productivity shock leads to an increase in both total output and domestic output, albeit with an initially muted response by domestic output. All the measures of inflation drop, with domestic inflation experiencing the largest decline. Consequently, the real exchange rate depreciates. In response to the lower total inflation, the central bank cuts interest rate. These results are consistent with the findings by Iklaga (2017) and Medina and Soto (2007).

Monetary policy shock: A positive monetary policy shock leads to output contraction (i.e. both the total GDP and domestic output) and reins in inflationary pressures. Also, the contractionary monetary policy reduces aggregate demand, which also causes an appreciation in the real exchange rate (Figure A.4). We observe some degree of exchange rate overshooting in line with the postulations of Dornbusch (1976).

Government spending shock: An expansionary fiscal policy stimulates the economy, leading to increased output and consumption (Figure A.5). This in turn increases domestic inflation while the total and core measures of inflation also increase slightly, albeit after an initial decline was recorded upon impact. The initial decline in total inflation required a temporary reduction in interest rate, followed by an upward adjustment in order to stabilise the economy. The positive response of private consumption to a positive fiscal policy shock is consistent with the outcomes expected under a model with non-Ricardian consumers (Galí, López-Salido and Vallés, 2007).

Domestic risk premium shock: Figure A.6 shows that a positive shock to domestic risk premium, implying increased financial market inefficiencies, leads to output loss and lower private consumption, contrary to the findings of Smets and Wouters (2007) for the United States economy. The decline in aggregate demand is accompanied by lower prices, justifying monetary policy easing by the central bank in order to boost aggregate demand.

International oil price shock: The responses of the economy to a negative international oil price shock is shown in figure A.7. A negative oil price shock causes total GDP and government consumption to decline, owing to lower oil revenues. These outcomes are consistent with observed behaviour of the Nigerian economy but contrary to the results presented by Iklaga (2017). The impact of oil price shock on aggregate output is very persistent, lasting over 40 quarters. On the other hand, domestic output is boosted following a negative oil price shock, albeit after an initial negative response that results from a reduction in oil firm's demand for domestically produced goods. As a consequence of lower marginal cost being faced by domestic firms, domestic inflation falls. However, total and core measures of inflation initially increase due to higher imported prices resulting from the depreciated real exchange rate. In response, the central bank embarks on an initial interest rate hike in order to stabilise prices, thereby aggravating the negative impacts of reduced international oil price on the GDP.

4.3 Drivers of the economy

In this section, the sources of business cycles are analysed based on the forecast error variance decomposition. This allows us to evaluate the relative contributions of the different shocks to variations in key endogenous variables, such as total GDP and the different measures of inflation. In addition, we employ historical decomposition to disentangle the relative importance of the different shocks to changes in the observable variables during the sample period. For ease of presentation and analysis, the model's structural shocks are grouped into five categories as follows: oil shocks (oil sector productivity, international oil price, and the law of one price gap for fuel), external shocks (foreign inflation, foreign interest rate and external risk premium), domestic shocks (domestic productivity, domestic risk premium), monetary policy shock, and fiscal policy shock.

4.3.1 Historical decomposition

In this section, the historical decompositions of observed total output (GDP) and headline inflation over the sample period of 2001Q2 - 2018Q2 are discussed.

Output: The historical contributions of the five groups of shocks to total GDP growth are shown in Figure A.1. Over the sample period, aggregate output recorded two spikes, both occurring between 2000 and 2005. The first spike, which occurred in the second half of 2001 was largely caused by positive oil price shocks arising from high oil prices and monetary policy easing of the CBN. Similarly, the second episode of increased output growth occurring during the latter part of 2004 was driven by oil price shocks, monetary policy easing and improved domestic productivity. During the period 2005 - 10, output growth remained relatively stable and above its average level with monetary policy shocks, domestic supply shocks and oil shocks playing important roles. The first negative output growth recorded over the sample period, which occurred in the third quarter of 2011, is largely explained by the monetary policy tightening of the CBN aimed at containing mounting inflationary pressures that arose in the aftermath of the global financial crisis.

Also, domestic supply shocks as well as oil price shocks resulting from a slight dip in the international price of oil contributed to the negative output growth outcomes of 2011. The declining output growth, which started gradually in 2014 and slipped the Nigerian economy into recession in 2016 is principally explained by oil price shocks and domestic supply shocks while monetary policy seems to play a stabilising role during the period. The negative oil price shock of the period 2014-2016 led to lower oil earnings, rapid depletion in the country's foreign exchange reserves and caused severe foreign exchange supply constraints. Thus, the negative domestic supply shocks experienced during the recession was largely driven by lower total factor productivity of domestic firms, occasioned partly by their inability to source foreign exchange to import necessary production inputs. A striking observation from the analysis of the historical decomposition of output growth during the sample period is that the two negative growth outcomes were partially explained by oil price shocks.

Headline inflation: Figure A.2 shows the historical decomposition of aggregate inflation. It indicates that monetary and domestic shocks largely account for the evolution of aggregate prices during the sample period. Two periods of steady decline in inflation are discernible. The first period of declining prices, occurring during 2001-2002, is mainly driven by monetary, oil and domestic supply shocks while external shocks played minimal roles. The increasing inflationary trend experienced during the 2004-2005 period and the second half of 2015 are attributable to negative domestic supply shocks as well as external and monetary policy shocks. Towards the end of the sample period, aggregate inflation declined steadily in response to a hawkish monetary policy stance of the CBN, aimed at counteracting the inflationary effect of exchange rate depreciation recorded during the period.

4.3.2 Forecast error variance decomposition

Table A.4 reports the forecast error variance decomposition of total output, real exchange rate, interest rate, CPI inflation, core inflation, domestic inflation and imports inflation at four forecast horizons. The grouping of the shocks remains as in sub-section 4.3.1.

Output: Monetary policy and oil shocks predominantly account for variations in total output in the short run (1-4 quarters) while domestic shocks are important in the medium term (5-20 quarters). The results show that domestic shocks are quite strong and persistent, contributing about 46.4 per cent of variations in total GDP in the first year and about 55.9 per cent up to the fifth year. However, in the first quarter, monetary policy shocks account for about 51.4 per cent while its contribution wanes steadily to about 19.6 per cent by the fifth year. Also, the effect of oil shocks is non-trivial and relatively persistent as they contribute about 26.0 per cent in the first quarter and 22.5 per cent up to the fifth-year horizon.

Headline inflation: The most important shock explaining variations in aggregate inflation (both in the short- and medium-term horizons) is monetary policy as it accounts for about 48.9

per cent of the forecast variance in the first quarter and 37.9 per cent up to the fifth year. This further supports our earlier findings regarding the efforts of the monetary authority in containing inflationary pressures in line with its primary mandate. Furthermore, domestic supply shocks (total factor productivity and domestic risk premium shocks) play prominent roles in explaining variations in aggregate inflation, with its contribution to the forecast variance increasing from 23.8 per cent in the first quarter to about 35.2 per cent by the fifth year. This shows that the effects of domestic supply shocks on total inflation are quite persistent.

Core, domestic and imports inflation: Our model set up allows us to disentangle the effects of shocks on the different components of inflation. In Table A.4, the variance decompositions for core inflation, domestic inflation and imports inflation are reported. Across these three measures, the contributions of domestic shocks are quite dominant and persistent, with the largest effect manifesting in domestic inflation (it accounts for an average of about 84.7 per cent of the forecast variance in domestic inflation in the first 20 quarters). Monetary policy plays a dominant role in explaining variations in core inflation, implying that the CBN is quite successful at reining-in this measure of inflation. However, when decomposed into its two components (domestic and imports inflation), we find that the monetary authority has a greater strength in containing imports inflation, probably due to a strong exchange rate channel of monetary policy. For instance, whereas monetary policy explains 32.2 per cent of the forecast variance in imports inflation during the first quarter, its contribution to domestic inflation is lower at about 16.7 per cent.

5.0 Conclusion

In this paper, a Two- Agent New Keynesian (TANK) model for a resource-rich emerging economy was developed and fitted to Nigerian data using Bayesian methods. The estimated model was used to understand the drivers of business cycle fluctuations in Nigeria and characterise the behaviour of monetary and fiscal policies over the sample period. We find that monetary policy shocks and oil price movements are important drivers of output in the short run (1-4 quarters) while domestic supply shocks (such as productivity and domestic risk premium shocks) explain most of the fluctuations in the medium to long term horizons. Particularly, the contribution of oil shocks to output variations is about 21 per cent in the short run, while they also account for about 23 per cent by the twentieth quarter. In terms of historical decomposition, we find that episodes of output contractions over the sample period (including the 2016 economic recession) are generally associated with oil and domestic supply shocks.

On the other hand, inflation dynamics are largely driven by monetary policy and domestic supply shocks both in the short- and medium-term horizons. In particular, monetary policy shock plays a dominant role in explaining the forecast variance of headline and core inflation as it contributes an average of about 38.0 and 36.6 per cent, respectively, up to the fifth year. This tends to imply that monetary policy is active in containing inflationary pressures during the sample period. However, oil shocks play a less prominent role due to the low pass-through effects arising from the extant fuel subsidy regime in the country. A further disaggregation of core inflation into its domestic and imported components shows that monetary policy contributes more to the evolution of the later than the former.

The estimated monetary policy reaction function showed that the CBN, in line with its primary mandate of price stability, was quite hawkish over the sample period. The estimated feedback coefficient on inflation in the Taylor rule is greater than unity and significantly larger than its prior value. In addition to the price stability objective, the CBN also keeps an eye on output and exchange rate. However, a relatively higher weight is placed on output (0.12) than exchange rate (0.11) in the Taylor rule. This implies that in setting the interest rate, the CBN is more responsive to developments in output than the exchange rate. On the other hand, fiscal policy appears pro-cyclical and rather muted, contributing minimally to business cycle fluctuations in the economy. Since domestic supply and oil-related shocks are key sources of macroeconomic fluctuations, the study calls for strategic fiscal interventions toward addressing the issues of domestic supply constraints and the promotion of private investment as a key component of aggregate demand.

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Appendix

Table A1: **Calibrated Parameters**

Parameter Definition	Symbol	Value
Discount factor	β	0.990
Depreciation rate	$\delta^h = \delta^o$	0.025
Share of imports in household's consumption	γ_c	0.400
Share of fuel in household's consumption	γ_o	0.085
Share of imports in household's investment	γ_i	0.200
Calvo - wages	θ_w	0.750
Elasticity of domestic output with respect to capital	α_h^k	0.330
Elasticity of domestic output with respect to oil	α_h^o	0.120
Elasticity of domestic output with respect to labour	α_h^n	0.550
Elasticity of oil output with respect to capital	α_o^k	0.700
Elasticity of oil output with respect to materials	α_o^m	0.300
Share of imports in government's consumption	γ_g	0.120
Elasticity of substitution between foreign & domestic goods - Govt	η_g	0.600
Response of public consumption to fiscal debt	ω_b	0.300
Response of public consumption to oil revenue	ω_{or}	0.800
Response of lump-sum taxes to fiscal debt	φ_b	0.400
Response of lump-sum taxes to government consumption	φ_g	0.950
Response of lump-sum taxes to fuel subsidy payments	φ_{os}	0.100
Response of lump-sum taxes to oil revenue	φ_{or}	0.300
Coefficient of inflation in Taylor Rule - foreign economy	ω_{π^*}	1.500
Coefficient of output in Taylor Rule - foreign economy	ω_{y^*}	0.500
Implied steady state ratios		
Consumption - output	C_h/Y_h	0.690
Investment - output	I_{no}/Y_h	0.150
Domestic materials - output	M/Y_h	0.010
Government consumption - output	G_c/Y_h	0.070
Export - output	C_h^*/Y_h	0.070
Import - output	IM/Y_h	0.150

Table A.2: **Data and model implied business cycle moments**

Data/Model	Output	Headline inflation	Core inflation	Interest rate	Exchange rate
Standard deviation					
Data	0.21	0.59	0.56	0.44	0.27
Model	1.01	0.22	0.21	0.41	0.27
Cross-correlation with output					
Data	1.00	0.02	0.07	-0.03	0.10
Model	1.00	0.03	0.04	-0.01	0.10

Table A.3: **Priors and Posterior Estimates**

	Prior distribution			Posterior distribution	
Parameter	Density	Mean	Std. Dev.	Mean	90% HPD Int.
Structural parameters					
Ricardian consumers: γ_R	Beta	0.60	0.10	0.692	0.562 - 0.824
Labour supply elasticity: φ	Gamma	1.45	0.10	1.439	1.274 - 1.600
Relative risk aversion: σ	Inv. Gamma	2.00	0.40	1.409	1.109 - 1.694
External habit: ϕ_c	Beta	0.70	0.10	0.438	0.310 - 0.568
Investment adj. cost: χ	Gamma	4.00	3.00	6.181	1.751 - 10.490
Fuel pricing parameter: ν	Beta	0.30	0.10	0.429	0.190 - 0.640
Oil - core cons. elasticity: η_o	Gamma	0.20	0.10	0.188	0.044 - 0.328
For. - dom. cons. elasticity: η_c	Gamma	0.60	0.20	0.609	0.287 - 0.926
For. - dom. inv. elasticity: η_i	Gamma	0.60	0.20	0.615	0.286 - 0.933
Calvo - domestic goods: θ_h	Beta	0.70	0.10	0.719	0.620 - 0.826
Calvo - imported goods: θ_f	Beta	0.70	0.10	0.691	0.525 - 0.860
Policy parameters					
Taylor rule - inflation: ω_π	Gamma	1.500	0.20	2.857	2.579 - 3.141
Taylor rule - output: ω_y	Gamma	0.125	0.05	0.118	0.043 - 0.191
Taylor rule - exch. rate:ω_s	Gamma	0.125	0.05	0.109	0.040 - 0.176
Interest rate smoothing: ρ_r	Beta	0.500	0.25	0.224	0.054 - 0.382
Fiscal policy cyclicality: ω_{yo}	Normal	0.400	0.50	0.351	-0.47 - 1.184
Fiscal policy persistence: ρ_g	Beta	0.500	0.25	0.487	0.073 - 0.896
Autoregressive coefficients of shocks					
Dom. productivity: ρ_{a_h}	Beta	0.5	0.25	0.771	0.593 - 0.957
Oil productivity: ρ_{a_0}	Beta	0.5	0.25	0.502	0.100 - 0.905
Dom. risk premium: ρ_μ	Beta	0.5	0.25	0.786	0.703 - 0.871
Law of one price gap-oil: ρ_{ψ^o}	Beta	0.5	0.25	0.608	0.250 - 0.957
Int'l oil price shock: $\rho_{p_o^*}$	Beta	0.5	0.25	0.923	0.827 - 0.987
For. risk premium: ρ_{μ^*}	Beta	0.5	0.25	0.859	0.790 - 0.929
For. inflation: $\rho_t^{\pi^*}$	Beta	0.4	0.25	0.138	0.001 - 0.257
For. monetary policy: ρ_{r^*}	Beta	0.5	0.25	0.442	0.303 - 0.584
Standard deviation of shocks					
Dom. productivity: $\varepsilon_t^{a_h}$	Inv. Gamma	0.1	4	0.246	0.105 - 0.407
Oil productivity:$\varepsilon_t^{a_o}$	Inv. Gamma	0.1	4	0.076	0.024 - 0.133
Dom. risk premium: ε_t^{μ}	Inv. Gamma	0.1	4	0.162	0.132 - 0.192
Dom. fiscal policy:$\varepsilon_t^{g_c}$	Inv. Gamma	0.1	4	0.098	0.023 - 0.177
Law of one price gap-oil: $\varepsilon_t^{\psi^o}$	Inv. Gamma	0.1	4	0.904	0.444 - 1.490
Dom. monetary policy: ε_t^{r}	Inv. Gamma	0.1	4	0.379	0.300 - 0.455
Int'l oil price shock: $\varepsilon_t^{p_o^*}$	Inv. Gamma	0.1	4	0.151	0.130 - 0.171
For. risk premium: $\varepsilon_t^{\mu^*}$	Inv. Gamma	0.1	4	0.041	0.032 - 0.050
For. inflation: $\varepsilon_t^{\pi^*}$	Inv. Gamma	0.01	4	0.005	0.004 - 0.006
For. monetary policy: $\varepsilon_t^{r^*}$	Inv. Gamma	0.1	4	0.101	0.079 - 0.121

Table A.4: **Forecast error variance decomposition of endogenous variables**

Shock	1 quarter	1 year	2 years	5 years
Variance decomposition of total output (% contribution)				
Domestic supply shocks	18.39	46.43	55.80	55.86
External shocks	3.38	2.42	1.95	1.79
Oil shocks	26.00	21.37	20.04	22.53
Monetary policy shocks	51.37	29.46	21.95	19.58
Fiscal policy shocks	0.86	0.33	0.25	0.24
Variance decomposition of headline inflation (% contribution)				
Domestic supply shocks	23.76	31.54	34.50	35.18
External shocks	26.93	26.39	25.22	24.89
Oil shocks	0.38	1.60	1.79	2.00
Monetary policy shocks	48.92	40.46	38.48	37.92
Fiscal policy shocks	0.00	0.00	0.00	0.00
Variance decomposition of core inflation (% contribution)				
Domestic supply shocks	24.31	32.57	35.42	36.02
External shocks	26.10	25.49	24.21	23.87
Oil shocks	1.30	2.67	3.22	3.54
Monetary policy shocks	48.29	39.27	37.15	36.56
Fiscal policy shocks	0.00	0.00	0.00	0.00
Variance decomposition of domestic inflation (% contribution)				
Domestic supply shocks	85.83	84.62	85.14	84.71
External shocks	0.80	1.28	1.37	1.49
Oil shocks	2.67	2.89	3.09	3.68
Monetary policy shocks	16.65	11.19	10.37	10.10
Fiscal policy shocks	0.03	0.03	0.02	0.02
Variance decomposition of imports inflation (% contribution)				
Domestic supply shocks	49.38	61.85	66.16	67.27
External shocks	16.71	11.96	10.11	9.54
Oil shocks	1.73	2.39	3.72	4.59
Monetary policy shocks	32.17	23.77	19.99	18.58
Fiscal policy shocks	0.02	0.02	0.02	0.02

Figure A.1: **Historical decomposition of output**

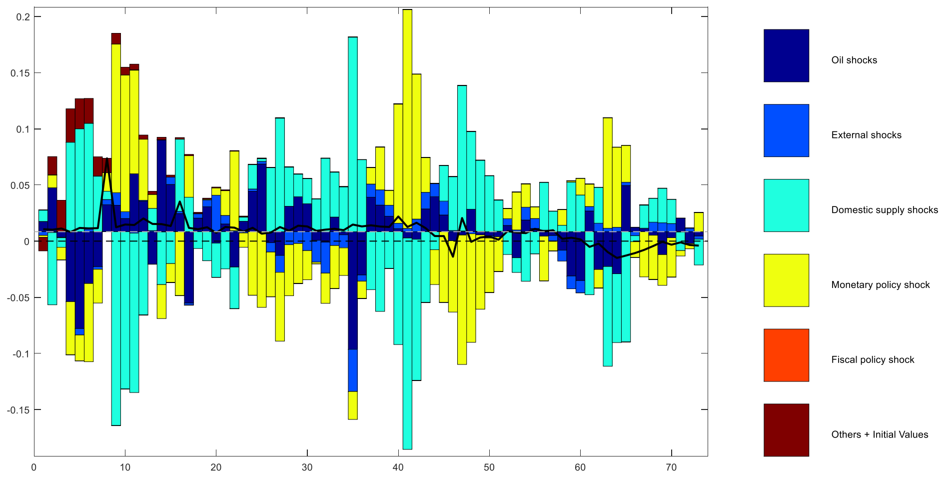

Figure A.2: **Historical decomposition of headline inflation**

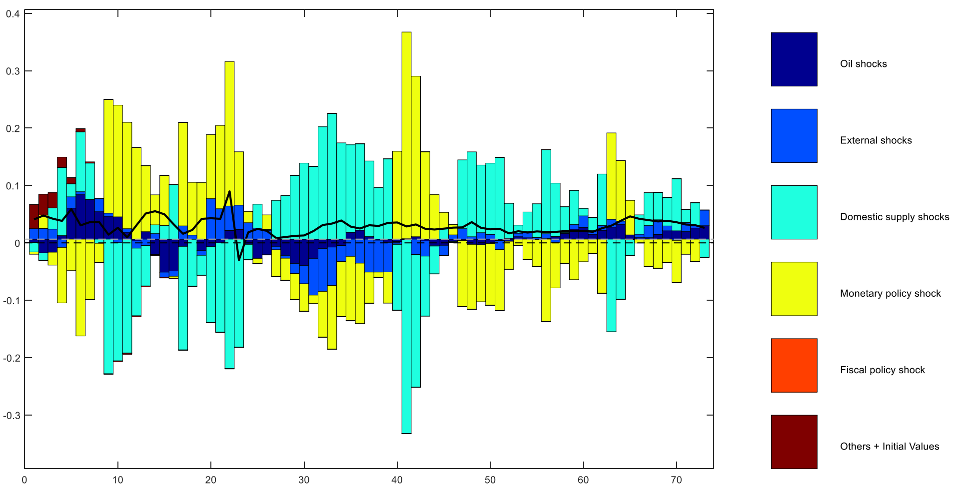

Figure A.3: **Bayesian impulse response to domestic technology shock**

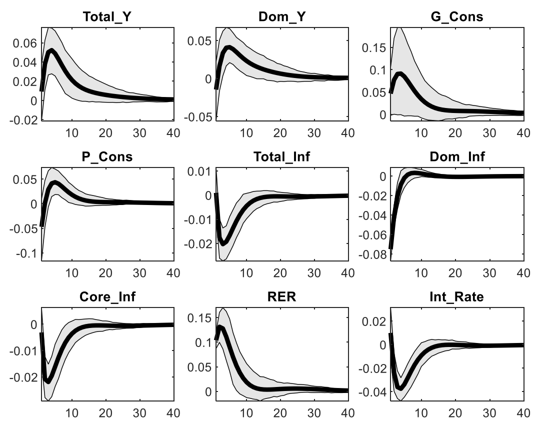

Figure A.4: **Bayesian impulse response to monetary policy shock**

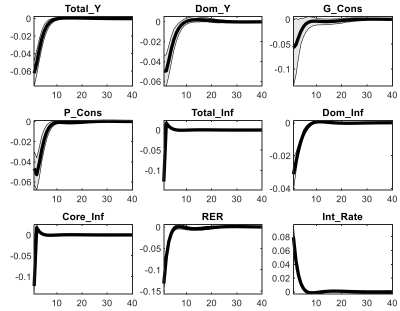

Figure A.5: **Bayesian impulse response to a fiscal policy shock**

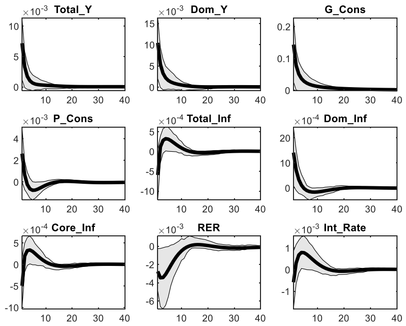

Figure A.6: **Bayesian impulse response to domestic premium shock**

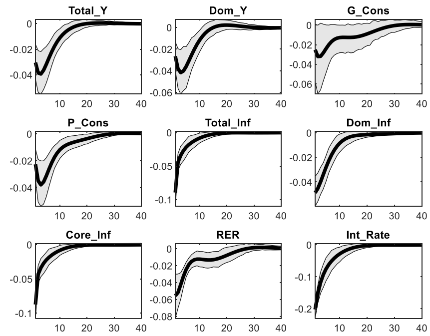

Figure A.7: **Bayesian impulse response to a negative oil price shock**