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Evaluating monetary policy options for managing resource revenue shocks when fiscal policy is laissez-faire

Application to Nigeria

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Abstract: This study considers the implications of alternative monetary policy regimes to deal with a laissez-faire fiscal policy rule, where the government completely spends resource revenue windfall contemporaneously. A three sector dynamic stochastic general equilibrium model, which features key structural characteristics of resource-rich developing economies, such as; the Dutch disease, limited international capital mobility, credit constrained consumers, and limited labour mobility are core ingredients of the model. The model is calibrated to match the Nigerian economy. Three alternative mainstream monetary policy regimes are considered: i) a flexible exchange rate regime; ii) a crawling peg; and iii) a money growth target. The results show that the macroeconomic responses to these monetary policy regimes, depends on other auxiliary polices of the central bank, such as; sterilization policy, foreign reserve accumulation policy and open-market operations. In particular, we find that a flexible exchange rate regime with full domestic absorption delivers the highest level of aggregate employment, though with higher volatility for other macroeconomic variables. The other policy rules deliver lower macroeconomic volatility but at the cost of crowding-out the private sector, depending on the mix of open-market operations. In welfare terms, policy regime (i) delivers the best outcome to economic agents.

Keywords: windfall spending, monetary policy, Dutch disease, New Keynesian models
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1 Introduction

The observation that resource-rich developing countries tend to experience more macroeconomic instability than their developed counterparts is only partly attributable to resource price shocks, as institutional and political economy factors also work to exacerbate the procyclicality of these kinds of shocks (see evidence in Frankel et al., 2013). The mechanism is such that when there is a windfall arising from a surge in the international price of the resource, fiscal authorities, because of weak institutions, face political pressures to increase spending which inevitably increases the demand for non-tradable goods in the domestic economy; these demand-driven pressures, coupled with real exchange rate appreciation, leads to a reallocation of resources in the domestic economy in such a way that is often not Pareto efficient, an effect that is commonly referred to as the Dutch disease (see Gelb, 1988; Sala-i-Martin and Subramanian, 2013). A popular recommendation to mitigate these kinds of inefficient reallocation of resources, is for government to restrict fiscal expansion during times of boom, and save a significant portion of the windfall in a sovereign wealth fund abroad (see Collier et al., 2010, for details of possible options and their trade-offs). Unfortunately, these kinds of recommendations are usually not popular with politicians and are hardly followed in resource-rich developing economies.

Under these circumstances, the entire responsibility for macroeconomic stability would now lie with the central bank, and the natural question that confronts the central banker is this; if fiscal indiscipline is inevitable, (i.e., politicians completely spend all resource windfall revenues contemporaneously), what sorts of monetary policy rules achieve superior stabilization effects on domestic macroeconomic variables when there is a shock to natural resource revenue? This study seeks to provide answers to these kinds of questions. In particular, we are interested in the following questions. First, what are the macroeconomic effects of alternative monetary policy regimes including; (i) a flexible exchange rate regime, (ii) a crawling peg regime, and (iii) a money growth target regime, given a one-for-one spending of windfall revenue? Second, what mechanisms drive the effects and thirdly, what are the welfare implications of these alternative monetary policy regimes.

In endeavouring to address these questions, we develop a three-sector dynamic stochastic general equilibrium (DSGE) model of a small open economy in the spirit of Berg et al. (2010), Dagher et al. (2012) and Benkhodja (2014). The appropriateness of the model is in the fact that it features key structural characteristics of resource-rich developing economies including; fiscal indiscipline, credit constrained consumers[1], learning-by-doing (LBD) externalities, which drives the Dutch disease effect, limited intersectoral labour mobility, and also limited international capital mobility. The model is then calibrated to match the structure and data of the Nigerian economy, which is a excellent example of a resource dependent economy which has experienced typical syndromes of the Dutch disease, and other structural characteristics considered in the paper (see Gelb, 1988; Sala-i-Martin and Subramanian, 2013, for evidence).

[1]For example, the most recent Findex survey for Nigeria shows that only about 65 percent of the adult population have access to savings facilities (see Carlson et al., 2015).

Overall, the main results are summarized as follows. First, in-spite of the monetary authority's responses, resource windfall spending is beneficial to the domestic economy in the short run, as it creates sizeable aggregate demand pressures especially for non-traded goods, and with nominal rigidities present, agents respond by increasing hours of work and hence the level of output in the short term. The presence of specific structural characteristics in these types of economies, particularly; credit constrained consumers and limited capital mobility, works to amplify the aggregate demand pressures. In the medium term, GDP stabilizes at a higher positive level which may be explained by the increased capital accumulation in the economy driven by the share of government spending on public infrastructure. Second, a flexible exchange rate regime with full domestic absorption delivers the highest level of short-run aggregate employment but with higher volatility in aggregate output. Further, this policy regime encourages private sector spending as there are no crowding-out effects of government spending, and there is no accumulation of external reserves.

Third, a strict exchange rate crawl is effective in mitigating the Dutch disease; delivering lower levels of domestic inflation, leading to lower nominal interest rates, and containing trade deficits within acceptable ranges, thereby leading to the highest levels of relative foreign reserve accumulation. The down size of this policy regime, is that it crowds-out private sector investments and consumption. Finally, a money growth target with full sterilization using open-market operations delivers similar results to that of a crawling exchange rate band, the only major difference being in the more aggressive nominal interest rate used to anchor the higher levels of inflation. Here again, there is private sector crowding-out which is a trade-off to obtain more stable and persistent employment and output dynamics. Finally, when comparing the desirability of the alternative policy regimes in terms of welfare costs, the flexible exchange rate policy with inflation targeting, delivers the least welfare cost in terms of lost steady state consumption to households.

Our paper is related to three strands of literature: (i) the literature on Dutch disease and macroeconomic performance, (see Benkhodja, 2014; Sachs and Warner, 2001; Gelb, 1988; Gylfason, 2002), (ii) the literature on fiscal and monetary counter-cyclicality (see Taylor, 1993; Galí et al., 2007; Frankel et al., 2013; García-Cicco and Kawamura, 2015) and (iii), the borrowed theoretical insights from the aid literature (see Berg et al., 2015; Agénor and Yilmaz, 2013; Adam and Bevan, 2006; Adam et al., 2009; Berg et al., 2010).

In what follows, we review only very closely related studies to this. Sosunov and Zamulin (2012) study monetary policy in the Russian economy where the manufacturing sector is overshadowed by the presence of a large natural resource industry (oil and gas). Their results show that in the absence of a well-functioning fiscal stabilization fund, it is optimal for the monetary authority to respond to the real exchange rate. Similarly, Dagher et al. (2012) analyse the short-term impacts of oil windfalls, and the role of monetary and fiscal policies in a low-income country, within a multi-sector dynamic stochastic general equilibrium (DSGE) model, calibrated to match the Ghanian economy. Their findings imply that a policy of fiscal smoothing, associated with a sovereign wealth fund can help to achieve macroeconomic

stability. They also find that reserve accumulation without fiscal backing could crowd-out the private sector and reduce welfare. In an influential paper, Berg et al. (2010) develop a fully fledged DSGE model which they use to study the macroeconomics of medium-term aid scaling-up scenarios. Their findings indicate that when a policy combination that entails full aid spending, and full absorption of aid by the domestic economy, is implemented, the effect is to generate temporary demand and real exchange rate appreciation pressures which then affects GDP positively in the medium term.

Our study is aimed at extending the contributions of these papers by closing some of the observed gaps. For example, these papers ignore the existence of a natural resource sector, thereby assuming that the tradable sector and the natural resource sectors operate under similar conditions. This is hardly the case in a typical resource-rich developing economy. Therefore, in this paper, we model a natural resource sector, different from the traded goods sector only in the production and endowment characteristics. Further, unlike the reviewed papers, we consider practical and implementable simple policy rules, which are relevant for central banks in todays world (see Clarida et al., 1998). The balance of the paper is organized as follows. Section 2 presents the model structure and the characterizing equations of the four agents in the economy. Section 3 contains the calibration of the model and the explanation of the values assigned to the parameters. Section 4 presents the results from the policy experiments, while Section 5 concludes.

2 Model structure

We construct a three sector DSGE model of a resource-rich small open economy, similar in spirit to Berg et al. (2015), Benkhodja (2014) and Dagher et al. (2012). The core ingredients of the model are as follows; the economy consists of four agents: (i) firms, (ii) households, (iii) the monetary authority, and (iv) the fiscal authority. The domestic economy produces three types of goods; tradables, non-tradables, and a natural resource commodity. The production of the natural resource commodity is treated as an endowment which is completely exported abroad at the stochastic world price. Treating the resource sector as an endowment sector enables us to conveniently generate fluctuations in the resource revenue which monetary and fiscal authorities are expected to respond to. We now proceed to characterize the problem faced by each agent.

2.1 Sectors

Firms operate in either the tradable sector (T) or the non-tradable sector (N) and produce goods by using the sector specific technology (z^j) in combination with labour (l_{it}^j), firm-specific private capital (k_{it}^j), and public capital (q_t), whereas, the natural resource sector is an endowment sector.

The natural resource sector

By setting up the natural resource sector as an endowment sector, the implication is that production in the sector is exogenous. This is a reasonable assumption especially if one considers the inelastic response of output to short-term fluctuations in the world price of the commodity. Also, because the capital intensive technologies used in these sectors are often financed by foreign direct investments from abroad, in addition to the limited labour mobility in the sector, these factors render the production structure of the sector almost exogenous and unlikely to be responsive to short-term monetary and fiscal policy changes, hence the need to model the sector as an endowment sector. Similar constructions are used in Sosunov and Zamulin (2012), and Berg et al. (2013).

Output in the natural resource sector is given by;

$$\frac{y_t^O}{y^O} = \left(\frac{y_{t-1}^O}{y^O}\right)^{\rho_{y_O}} e^{\epsilon_t^{yO}}, \tag{1}$$

where y_t^O is the natural resource output, $\rho_{y_O} \in (0,1)$ is the persistence of the production level, and $\epsilon_t^{yO} \sim N(0, \sigma_{y^O}^2)$ is the normally distributed resource production shock process. Note that variables without a t subscript indicates the long run steady state equivalents. Further, the domestic economy has no influence over the world price of the natural resource, it is given. Hence, it follows the exogenous price process;

$$\frac{p_t^{O*}}{p^{O*}} = \left(\frac{p_{t-1}^{O*}}{p^{O*}}\right)^{\rho_{pO}} e^{\epsilon_t^{pO}} \tag{2}$$

where p_t^{O*} is the international price of the resource, $\rho_{p_O} \in (0,1)$ and $\epsilon_t^{pO} \sim i.i.d.N(0, \sigma_{p^O}^2)$ is the normally distributed resource price shock. Production in the resource sector is subject to a royalty at the rate of τ^o, so that the resource revenue that accrues to government (in foreign currency) is given as;[2]

$$R_t^{O*} = \tau^o p_t^{O*} y_t^O \tag{3}$$

The tradable and non-tradable sectors

Firms in the tradable sector ($j = T$) operate in a perfectly competitive market, and hence face flexible prices. They combine firm-specific capital k_{it}^T, public capital q_t^T and labour l_{it}^T to produce output using the technology;

$$y_{it}^T = z^T \left[(k_{it}^T)^{\phi}(q_t^T)^{1-\phi}\right]^{1-\alpha} (l_{it}^T)^{\alpha}, \tag{4}$$

[2]It is also possible to consider modelling other practical instruments that government uses to collect revenue from the sector. Examples include production sharing using joint venture agreements, corporate income taxes or the direct ownership of the resource firm by the government. We use the royalty instrument as it is consistent with the situation in Nigeria the benchmark economy. Benkhodja (2014) is an example of a situation where the government directly owns the oil company as is the case in Algeria, etc.

where z^T is the productivity parameter, ϕ is the share of private capital in total capital, and (α) is the production share of labour. Note that the accumulation of private capital via investments (x_{it}) in this economy is subject to a depreciation rate (δ) and capital adjustment costs $\Psi^j_{it}\left(\frac{x^j_{it}}{x^j_{it-1}}\right) = \frac{\psi}{2}\left(\frac{x^j_{it}}{x^j_{it-1}} - 1\right)^2$ as in Ireland (2003), so that the evolution of capital is thus;

$$k^j_{it} = (1-\delta)k_{it-1} + (1 - \Psi^j_{it}(.))x^j_{it}, \tag{5}$$

where ψ governs the size of the capital adjustment cost.[3] Further, the price of foreign tradable goods (P^{T*}_t) are given exogenously, and by invoking the law of one price on tradable commodities, the price of domestically produced traded goods is given as $P^T_t = S_t P^{T*}_t$, where S_t is the nominal exchange rate.

The non-tradable goods sector $(j = N)$ features monopolistic competition, with the goods produced being a composite of a continuum of varieties satisfying $y^N_t = \left(y^{N\frac{\theta-1}{\theta}}_{it} di\right)^{\frac{\theta}{\theta-1}}$ and a Dixit-Stiglitz type demand constraint $y^N_{it} = \left(\frac{P^N_{it}}{P^N_t}\right)^{-\theta} y^N_t$, with θ measuring the elasticity of substitution between varieties. Production technology in the non-traded sector is similar to that of the traded sector in (5), with an N superscript. The main difference however, is that firms in the non-traded sector are faced with sticky prices, in which case, there is a quadratic cost of adjusting nominal prices between periods measured in terms of its finished goods, as in Rotemberg (1982). Thus, price stickiness is driven by $\frac{\xi}{2}\left(\frac{P^N_t}{\pi_{t-1}P^N_{t-1}} - 1\right)^2 p^N_t y^N_t$, where $\xi \geq 0$ governs the degree of stickiness. Firms in both the traded and non-traded sectors choose capital, labour and investments, that maximize their discounted flow of profits. In addition, for firms in the non-traded sector, they also have to choose, in a dynamic setup, the profit maximising prices of their goods p^N_{it} by solving the following problem;

$$\mathbb{E}_0 \sum_{t=0}^{\infty} J_t \left[p^N_{it}\left(\frac{p^N_{it}}{p^N_t}\right)^{-\theta} y^N_t(1+\iota) - w^N_t \left(\frac{p^N_{it}}{p^N_t}\right)^{-\frac{\theta}{\alpha}} \left(\frac{y^N_t}{z^N_t}\right)^{\frac{1}{\alpha}} - \frac{\xi}{2}\left(\frac{P^N_t}{\pi_{t-1}P^N_{t-1}} - 1\right)^2 y^N_t - \iota p^N_t y^N_t \right], \tag{6}$$

where J_t is the stochastic discount factor, and ι is a distortion tax used to eliminate the inefficiency arising from monopolistic competition in the steady state.

The Dutch disease and learning-by-doing effects

To capture the general form of the Dutch disease syndrome, we follow a variant of the specification in Krugman (1987), and the integration of learning-by-doing effects in Berg et al. (2015), which assumes that the productivity situation in the traded sector depends on the deviation of past output values in the traded sector from its steady state. Thus, Dutch disease

[3] The use of this functional form ensures that the the total and marginal cost of capital adjustment are both zero in the steady state see Benkhodja (2014), and Ireland (2003).

effects and the learning-by-doing transmission is jointly described by;

$$\frac{z_t^T}{\bar{z}^T} = \left(\frac{z_{t-1}^T}{\bar{z}^T}\right)^{\rho_z} \left(\frac{y_{t-1}^T}{\bar{y}^T}\right)^{\mathfrak{b}}, \tag{7}$$

where $\bar{z}^T$ is the steady state level of productivity in the traded sector, $\rho_z \in (0,1)$ is the persistence of productivity in the sector and $\mathfrak{b} > 0$ governs the degree of learning-by-doing externalities. In general, (7) implies that a decline in the output from the traded sector relative to steady state, would impose an economic cost through lost total factor productivity (TFP) in this sector. It also implies that learning-by-doing externalities have no permanent effects, rather, its effects are transitory, depending on the degree of persistence. Note that by setting $\mathfrak{b} = 0$, the learning-by-doing effects could be switched off.

2.2 Households

There are two kinds of households in this economy. A fraction $\mathfrak{p}$ of households are Ricardian and forward-looking, so that they smooth consumption by trading in foreign and domestic financial instruments. This category of households are referred to as dynamic optimizers. Whereas the other fraction $(1-\mathfrak{p})$ are credit constrained and so behave in a "hand-to-mouth" fashion and are referred to as static consumers. Dynamic optimizers consume a composite good consisting of traded (c_t^T) and non-traded goods (c_t^N), combined in a constant elasticity of substitution (CES) basket;

$$c_t = \left[\varphi^{\frac{1}{\chi}}(c_t^N)^{\frac{\chi-1}{\chi}} + (1-\varphi)^{\frac{1}{\chi}}(c_t^T)^{\frac{\chi-1}{\chi}}\right]^{\frac{\chi-1}{\chi}}, \tag{8}$$

with the associated demand functions for the traded and non-traded goods given as $c_t^T = (1-\varphi)(s_t)^{-\chi}c_t$ and $c_t^N = \varphi(p_t^N)^{-\chi}c_t$ where χ denotes the intertemporal elasticity of substitution, and φ is the degree of home bias.[4] The representative consumer maximizes expected life-time utility of the form;

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^j \left\{\frac{\eta}{\eta-1}\log\left[\vartheta(c_t^j)^{\frac{\eta-1}{\eta}} + (1-\vartheta)(m_t^j)^{\frac{\eta-1}{\eta}}\right] - \frac{\Upsilon}{1+\phi_l}(l_t^j)^{1+\phi_l}\right\}, \tag{9}$$

where $m_t^j \equiv \frac{M_t^j}{P_t}$ are holdings of real money balances, l_t^j is labour supplied to firms, $\vartheta \in (0,1)$ is the share of consumption in utility, $\beta \in (0,1)$ is the subjective discount factor, η is the elasticity of substitution between consumption and money holdings, ϕ_l is the inverse of the (Frisch) elasticity of labour supply to wage rate and Υ is a scaling factor.

To capture the notions of limited intersectoral labour mobility, and the possibility of

[4] This parameter is often also interpreted as a measure of trade openness.

intersectoral wage differentials, the aggregated labour supply is given by;

$$l_t = \left[\mathfrak{d}^{-\frac{1}{\varrho}}(l_t^N)^{\frac{1+\varrho}{\varrho}} + (1-\mathfrak{d})^{-\frac{1}{\varrho}}(l_t^T)^{\frac{1+\varrho}{\varrho}}\right]^{\frac{\varrho}{1+\varrho}}, \tag{10}$$

where $\mathfrak{d} \in (0,1)$ is the fraction of labour supplied to the non-traded sector and $\varrho > 0$ is the degree of substitutability of labour between sectors. In a similar sense, the index of real wages that correspond to aggregate labour supply is given by;

$$w_t = \left[\mathfrak{d}(w_t^N)^{\frac{1+\varrho}{\varrho}} + (1-\mathfrak{d})(w_t^T)^{\frac{1+\varrho}{\varrho}}\right]^{\frac{\varrho}{1+\varrho}}. \tag{11}$$

The expenditure and revenue streams of the representative agent in real terms (deflating by domestic CPI), can be summarized by the budget constraint thus;

$$c_t + m_t + b_t + s_t b_t^* + s_t \mathcal{P}_t \leq (1-\tau)w_t l_t + \frac{m_{t-1}}{\pi_t} + i_{t-1}\frac{b_{t-1}}{\pi_t} + s_t i_{t-1}^* \frac{b_{t-1}^*}{\pi_t^*} + \Omega_t + \varpi^d, \tag{12}$$

where c_t is the aggregated consumption, b_t and b_t^* are real holdings of domestic and foreign assets, which pay a nominal interest of i_t and i_t^* respectively. Note that foreign assets are subject to portfolio adjustment costs $\mathcal{P}_t$. s_t is the real exchange rate, l_t is the aggregated labour supply, $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is the domestic inflation rate, π_t^* is foreign inflation, which is assumed to be constant and Ω are the real profits from domestic firms. Intertemporal transfers between dynamic and static consumers is given by ϖ which guarantees that in steady state, consumption and labour hours are the same between dynamic and static consumers as in Galí et al. (2007).

The advantage of introducing portfolio adjustment costs to the household's budget constraint are two fold; first, it induces stationarity in foreign assets (b_t^*), in which case we follow the specification in Schmitt-Grohé and Uribe (2003) and set $\mathcal{P}_t = \frac{\mathfrak{c}}{2}(b_t^* - \bar{b}^*)^2$, where $\bar{b}^*$ is the steady state value of real foreign assets and $\mathfrak{c} > 0$ is a constant parameter. Second, as in Berg et al. (2015) and Kollmann (2002), it allows us to model different scenarios of international capital mobility. Note that when $\mathfrak{c} \to +\infty$, then the capital account is virtually closed, whereas, when $0 < \mathfrak{c} < \infty$, it is partially open. In sum, the consumer's problem reduces to maximizing discounted lifetime utility with respect to consumption, money holdings, labour supply, domestic and foreign assets, subject to the budget constraint in (12) and the relevant transversality conditions for the assets. The problem for the dynamic optimizer $j = (d)$ is similar to that of the static consumer $j = (s)$, the only difference being that the discount factor is set to zero and there are no financial assets in the budget constraint for static consumers.

2.3 The fiscal authority

Government is the recipient of revenue from the natural resource sector in foreign currency. It decides on how much of the revenue to save in a sovereign wealth fund and how much to convert to domestic currency and spend on domestic investments and a basket of traded and non-traded goods. Revenue from the natural resource sector inherits the stochastic properties

of the processes for its price and production in eqs. (2) and (1). Hence, it is given as

$$R_t^{O*} = \bar{R}^{O*} + \rho_{R^O}(R_t^{O*} - \bar{R}^{O*}) + \epsilon_t^{R^O} \tag{13}$$

where $\bar{R}^{O*}$ is the steady state level of the resource revenue, $\rho_{R^O} \in (0,1)$ is the persistence of revenue deviations from the steady state and $\epsilon_t^{R^O} \sim N(0, \sigma^2_{R^O})$ are shocks to the resource revenue. Government consumption expenditure is aggregated in a CES basket given as;

$$g_t = \left[\nu^{\frac{1}{\chi}}(g_t^N)^{\frac{\chi-1}{\chi}} + (1-\nu)^{\frac{1}{\chi}}(g_t^T)^{\frac{\chi-1}{\chi}}\right]^{\frac{\chi-1}{\chi}}, \tag{14}$$

where the degree of substitutability of traded and non-traded goods χ is the same as that of the private sector but the shares ν are different.

The period-by-period government budget constraint is given by;

$$g_t + \frac{(i_{t-1}-1)b_{t-1}^p}{\pi_t} \leq \tau w_t l_t + s_t R_t^{O*} + \left(b_t - \frac{b_{t-1}}{\pi_t}\right) - \left(swf_t - \frac{swf_{t-1}}{\pi_t^*}\right). \tag{15}$$

The expenditure side of the budget constraint (left hand side) consists of government consumption expenditure (g_t), and payment of interest on the share of government instruments held by the private sector (b_t^p)[5]. The government can finance its expenditure by using income tax revenue $\tau w_t l_t$, revenue from the natural resource sector $s_t R_t^{O*}$, issuing new debt instruments $\left(b_t - \frac{b_{t-1}}{\pi_t}\right)$ or through changes in deposits held at the the soverign wealth fund– $\left(swf_t - \frac{swf_{t-1}}{\pi_t}\right)$.[6] Further, we have used the assumption that government debt is constant and held by either the private sector (b_t^p) or the central bank (b_t^{cb}), so that $b_t = b = b_t^p + b_t^{cb}$. Therefore, the relative share of government debt held by the private sector and the central bank varies according to the open market operations of the central bank. Note that the budget constraint as constructed implies that government spending and/or savings would always adjust to satisfy the constraint, also, taxes are held constant so that the only source of volatility is the resource revenue R_t^{O*}.

Fiscal policy in this environment is determined by a rule which defines government's deposits and spending behaviour as follows;

$$swf_t^* = \rho_s swf_{t-1}^* + (1+\rho_s)s\bar{w}f + (1-\gamma)s_t(R_t^{O*} - \bar{R}^{O*}), \tag{16}$$

where $s\bar{w}f$ is a deposit target or the steady state level of government savings at the fund and $\gamma \in [0,1]$ governs the degree of short-term resource revenue spending. A value of $\gamma = 1$ implies that the government spends all resource revenue shocks (above the steady state) in the short run and hence is termed undisciplined, whereas any values of $\gamma \neq 1$ implies some level of savings from revenue shocks. ρ_{R^O} measures the rate at which resource revenue deposits in

[5]Note that for simplicity, it is convenient to assume that public investment is a constant share of government spending.

[6]Here, we assume that the deposits into the sovereign wealth fund do not attract interest payments.

the sovereign wealth fund is drawn down.

Total government debt accumulation follows a simple feedback rule given by

$$b_t = b_{t-1} - \mathfrak{c}(b^{cb}_{t-1} - \bar{b}^p) \tag{17}$$

where $\mathfrak{c}$ is positive but small. This simple rule has no noticeable effect on the fiscal response but serves as a technical requirement to ensure that the open market operations of the central bank which shifts government bonds from the central bank's balance sheet do not have permanent effects on the required interest payments by government (see Dagher et al., 2012).

2.4 The central bank

The central bank uses open market operations and interventions in the domestic foreign exchange market to determine how much of the revenue from the resource sector is absorbed by the domestic economy, and the rate of accumulation or depletion of international reserves, held abroad. To understand the operations of the central bank, it is instructive to start with the central bank's balance sheet in real terms, thus;

$$m_t - \frac{m_{t-1}}{\pi_t} = b^{cb}_t - \frac{b^{cb}_{t-1}}{\pi_t} + s_t\left(F^*_t - \frac{F^*_{t-1}}{\pi^*_t}\right), \tag{18}$$

where the central bank's liabilities in terms of changes in real money supply $m_t - \frac{m_{t-1}}{\pi_t}$, depends on open market operations $b^{cb}_t - \frac{b^{cb}_{t-1}}{\pi_t}$, and changes in net foreign assets, driven by foreign reserves $s_t\left(F^*_t - \frac{F^*_{t-1}}{\pi_t}\right)$. Here, we abstract from interest payments on the central bank's foreign reserves. In which case there are no direct benefits accruing to the public sector for accumulating reserves, so that it does not enter the government's budget constraint directly.

Monetary policy rules

Typically, central banks in resource abundant developing countries target more variables than the standard inflation based targets used by developed economies. In particular, exchange rates and foreign reserves are often operational targets too. For this particular environment, we assume that the central bank has twin targets and uses two different rules simultaneously to pursue these operational targets.

On the one hand, the central bank uses variations in the short-term interest rate to stabilize some combination of domestic inflation and the output gap, the rule followed is the standard Taylor rule thus;

$$\frac{1+i_t}{1+\bar{i}} = \left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi}\left(\frac{y_t}{\bar{y}}\right)^{\phi_y} \tag{19}$$

where $\bar{i}$ is the long-run equilibrium nominal interest rate, $\bar{\pi}$ is the implied inflation target, ϕ_π governs the central bank's commitment to achieving the inflation target and ϕ_y is the weight

on the output gap.

On the other hand, in addition to the interest rate rule, the central bank also sets operational targets on reserve accumulation which it partly achieves through interventions in the foreign exchange market and the exchange rate policy in operation. Following the modified specifications in Dagher et al. (2012) and Berg et al. (2015), we assume that the central bank implements the following rule to achieve exchange rate and reserve accumulation targets;

$$F_t^* = \rho_F F_{t-1}^* + (1-\rho_F)\bar{F}^* + (1-\omega\gamma)(R_t^{O*} - \bar{R}^{O*}) - \zeta_{ex}\left(\frac{S_t - \bar{S}}{\pi_t/\bar{\pi}^*}\right). \tag{20}$$

Here, the accumulation of foreign reserves is driven by two separate factors. First is the degree of absorption of windfall revenue $\omega \in (0,1)$, and next is the exchange rate regime ζ_{ex}. The amount of foreign currency from government spending of resource windfall that the central bank decides to sell to the domestic economy is governed by the parameter $\omega \in (0,1)$, which determines the extent of domestic absorption of the monetary emission from government. When $\omega = 0$, it implies that all additional dollar spending from resource windfalls are deposited in foreign reserves and there is no absorption by the private sector. Further, the central bank targets a particular long-run level of reserves given by $\bar{F}^*$, with the persistence of deviations from this target captured by ρ_F.

Depreciation of the domestic currency is given by $(S_t - \bar{S})$, where the (steady state) nominal exchange rate reference target by the central bank is $\bar{S}$. The policy parameter $\zeta_{ex} \geq 0$ in (20) governs the central bank's commitment to the nominal exchange rate band (crawl). A flexible exchange rate regime is implied by a rule where $\zeta_{ex} = 0$, whereas as $\zeta_{ex} \to \infty$ the rule replicates a strict commitment to a fixed exchange rate regime where $(S_t = \bar{S})$. Any positive values for $\zeta_{ex} >> 0$ represents varying degrees of crawling peg regimes[7]. An important point to note is that if the central bank decides to follow a fixed (crawling) exchange rate regime, it would have to determine the amount of forex to be sold to the private sector to achieve this target. In this case, the degree of absorption of resource revenues (ω) would then be endogenously determined (see Berg et al., 2010).

Aggregation and the balance of payments

The characterization of the model is completed by describing how resource revenues affect the balance of payments of the home country, thus;

$$R_t^{O*} = \underbrace{c_t^T + g_t^T + x_t^{NT} + \mathcal{P}_t - y_t^T - \frac{(i_{t-1}^*)b_{t-1}^*}{\pi^*}}_{\text{CAD}} + \underbrace{\left(b_t^* - \frac{b_{t-1}^*}{\pi_t}\right)}_{KAS} + \underbrace{\left(F_t^* - \frac{F_{t-1}^*}{\pi_t}\right)}_{FRA} \tag{21}$$

where x_t^{NT} is the aggregate of the non-traded and traded components of investment. The balance of payments identity describes how revenue from the resource sector could be used

[7]Note that under a flexible exchange rate regime, the central bank can still accumulate reserves in response to changes to the amount of natural resource revenue (see Berg et al., 2015).

to finance the current account deficit (CAD) net of oil revenue, the capital account surplus (KAS) and foreign reserve accumulation (FRA).

3 Model calibration and parametrization

Analysis of DSGE models of this form are often based on numerical simulations of the calibrated relationships between the variables in the model[8]. Because the model is based on optimizing decisions of agents, it is possible to obtain plausible parameters of the model based on microeconomic evidence (for example, the elasticity of labour supply). Also, values for some parameters could be derived from macroeconometric estimates of structural equations, whereas others depend on the steady state ratios which could be obtained from input-output tables and National Income Accounts. Another category of parameters are the policy parameters which describe the monetary and fiscal policy regimes in place, these are free parameters used for policy experiments in the study. Although our objective is to understand the implications of different monetary policy responses to spending of natural resource windfalls in developing economies, we specifically calibrate the model to the Nigerian economy which is a perfect example of a natural resource dependent economy with fiscal pressures. Values for the deep parameters are chosen in two major ways, one to match average ratios observed in the Nigerian data for the period 2000 to 2013, and the other to match standard values used in the literature.

The preference, technology and policy parameters used in the study are organized in Tables 1, 2 and 3 respectively. The chosen values for each parameter and the method of construction or sources are given in the respective tables. A brief discussion is now provided for parameters that are considered to be crucial for the policy experiments. Regarding the preference parameters, the degree of home bias in consumption ψ is chosen to be consistent with National Income Accounts. The value for the intertemporal elasticity of substitution is set at -0.89 which is based on Tokarick (2010)'s short-run estimates using the Global Trade Analysis Project (GTAP) data for Nigeria. The other preference parameters are set to the standard values in the literature.

Regarding the technology parameters, the value of ϕ is set to 0.66 which is derived from Arslanalp et al. (2010) estimates of public capital share of 0.33 in developing economies, hence the balance of 0.66 is assumed to be the share of private capital in total capital. The degree of price stickiness ξ is set at 58, which corresponds to price spells with duration of about one year. As for the effects of the Dutch disease, which is captured using learning-by-doing externalities, we follow Berg et al. (2015) by calibrating the lagged dependence of TFP in the traded sector to be $\rho_z = 0.11$ in other to match firm-level evidence in Mengistae and Pattillo (2004) which shows that TFP premium for export manufacturers in sub-Saharan Africa between 11 and 28 percent. As for the degree of LBD effects ($\mathfrak{b}$), we set this to 0.1 which is consistent with Fernandes and Isgut (2015)'s estimates of the lagged ratio of exports

[8]It is also becoming increasingly popular to use Bayesian estimation techniques to find plausible values for the model parameters see An and Schorfheide (2007) for a recent review and comparison of techniques.

Table 1: Baseline Calibration for Preference Parameters

Parameter	Description	Value	Source/Construction
φ	Degree of home bias in consumption	0.51	Consistent with National Income Accounts.
β^R	Discount factor of static optimizers	0.83	To match interest rates of 20% per annum.
χ	Intertemporal elasticity of substitution between traded and non-traded goods	-0.89	Based on Tokarick (2010) short-run estimates using GTAP data for Nigeria.
ϑ	Share of consumption in utility	0.99	Helps to match money to GDP ratio in Nigeria.
η	Elasticity of substitution between consumption and money	0.47	To match interest elasticity of money based on regression of real money balances on nominal interest rate and GDP.
ϕ_l	Inverse of the Frisch labour supply elasticity	1.5	Approximate value used in the literature
Υ	Labour scaling factor	0.64	Used to normalize labour to 1 in steady state.
$\mathfrak{d}$	Fraction of labour supplied to the non-traded sector	0.7	To match share of non-traded production in value added. National Income Accounts.
ϱ	Degree of substitutability of labour between sectors	1	Consistent with the literature, (see Horvath, 2000).

Source: Author's parametrization based on stylized facts and relevant literature.

to output for Columbian manufacturing firms. Depreciation of private capital is set at 0.017 following the estimates by Bu (2006) for developing countries which is quite different from the standard value of 0.025 used in the literature. The values for the other parameters in the technology block are consistent with the typical values used in the literature.

Four categories of policy parameters are presented in Table 3. The first set are the parameters that describe the dynamics of natural resource revenue. Here, the persistence of windfall revenue is set at $\rho_R = 0.95$ and the size of the typical oil revenue shock for Nigeria is $\epsilon^R = 0.04$, which were obtained by an autoregression of the monthly weighted prices of Nigerian crude sold in the world market. As for the fiscal authority block, income tax τ is set to 0.23 which helps to match government spending to GDP ratio. The persistence of deposits or withdrawals from the sovereign wealth fund ρ_s is set at 0.9, which is a free policy parameter and could be varied for sensitivity. Finally, γ is the main policy parameter which governs the contemporaneous spending of windfall revenue, It is set to one to depict an undisciplined fiscal policy rule, whereby government completely spends all resource windfall revenue contemporaneously.

As for the monetary authority, its commitment to an inflation target is set to the standard value in the Taylor-rule literature, i.e. $\phi_\pi = 2$. Steady state foreign reserves target and the persistence of deviations from the target are set to 0.31 and 0.9 respectively to match

Table 2: Baseline Calibration for Technology Parameters

Parameter	Description	Value	Source/Construction
ϕ^T, ϕ^N	Share of private capital in total capital	0.66	Consistent with Arslanalp et al. (2010) estimates for Non-OECD countries (0.33 for public capital).
α^N, α^T	Production share of labour	0.7	Value consistent with Input-Output tables.
z^T	Productivity parameter in traded sector	1	Normalized.
z^N	Productivity parameter in non-traded sector	1.04	Ensures real exchange rate is 1 at steady state.
ψ^N, ψ^T	Size of the capital adjustment cost	25	Ensures smooth impluse responses for investments.
δ^N, δ^T	Depreciation of private capital in traded and non-traded sectors	0.017	To match average depreciation of fixed assets in Africa as in Bu (2006).
θ	Elasticity of substitution between produced varieties	12	Standard in the macro literature.
ξ	Degree of price stickiness	58	Calibrated to match price spells with duration of 1 year.
ι	Distortion tax	0.09	Used to correct distortions arising from monopolistic competition at steady state.
ρ_z	Persistence of TFP in the traded sector	0.11	Consistent with estimates of TFP premium by Mengistae and Pattillo (2004) to lie between 11 and 28% for SSA.
$\mathfrak{b}$	Degree of learning by doing externalities	0.1	In line with estimates by Fernandes and Isgut (2015) for Colombia.

Source: Author's parametrization based on stylized facts and relevant literature.

Nigeria's foreign reserves to GDP ratio of 10 percent. The degree of domestic absorption of government spending of the resource revenue is given by ω, in the baseline, ω is set to one, which corresponds to full domestic absorption of windfall spending by the private sector . Exchange rate policy is controlled by ζ_{ex}, a value of zero used in the baseline corresponds to a flexible exchange rate regime. Finally, $\mathfrak{c}$ is set to a very large number (10^5) to mimic a relatively closed capital account, typical of the modelled economy.

4 Results from policy experiments

4.1 The baseline scenario

The baseline scenario for our policy experiment is based on the parametrization presented in Tables 1 to 3. The baseline policy scenario is characterized by four distinctive features. First, the fiscal authority spends all resource revenue contemporaneously, so that, $\gamma = 1$. Second,

Table 3: Baseline Calibration for Policy Parameters and Resource Dynamics

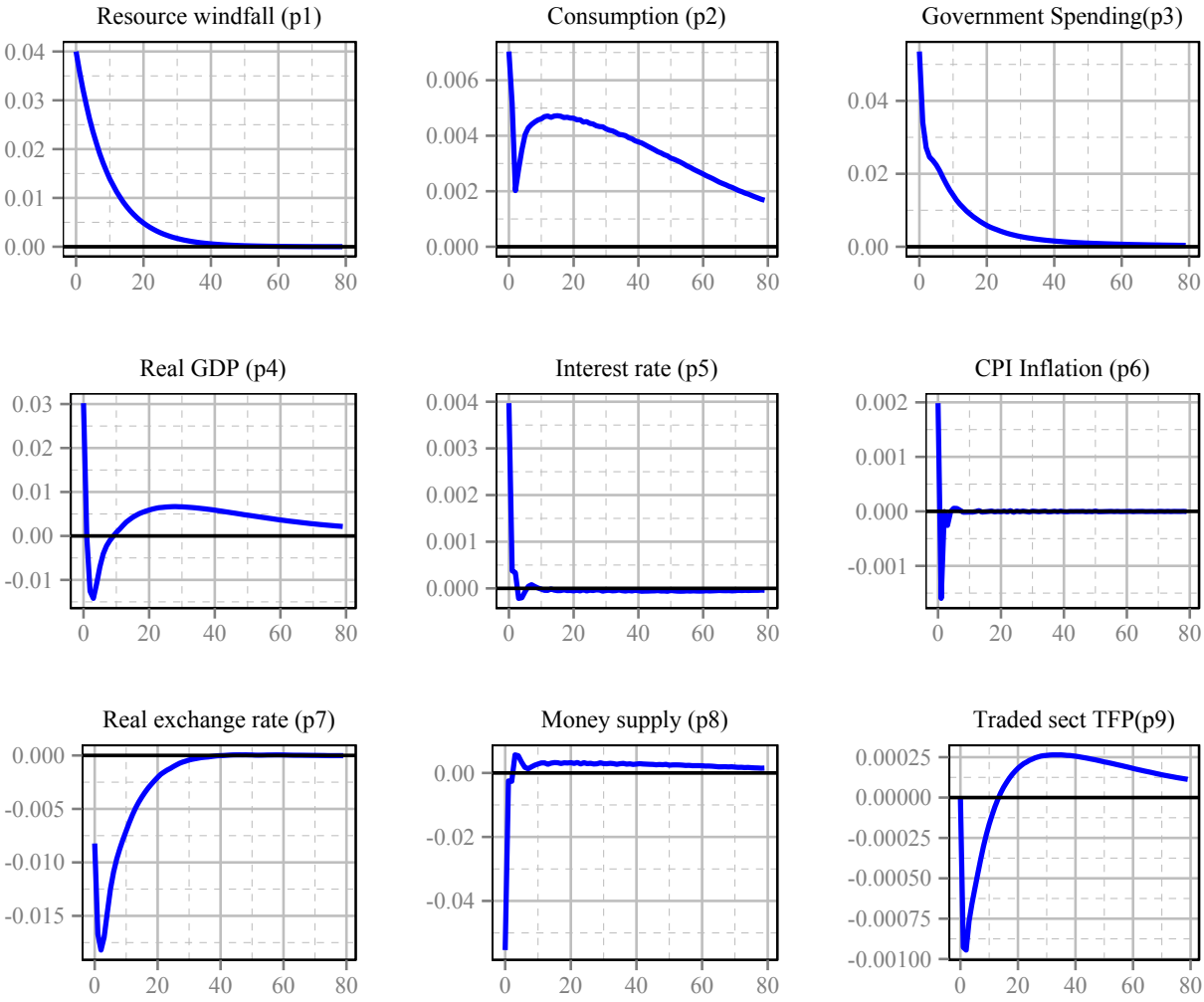
Parameter	Description	Value	Source/Construction
Resource windfall dynamics			
ρ_R	Resource windfall persistence	0.95	To match persistence in oil revenue data.
ϵ^R	Size of shock to resource windfall	0.04	Implied magnitude of typical oil revenue shock.
Fiscal authority			
ν	Share of non-traded goods in government consumption.	0.7	Endogenously determined to clear markets.
τ	Tax rate	0.23	Helps to match government spending to GDP ratio.
ρ_s	Persistence of deposits or withdrawals from swf	0.9	Free policy parameter, could be changed for sensitivity analysis.
γ	Degree of short term windfall revenue spending	1	To depict an undisciplined government that contemporaneously spends all windfall revenue.
Monetary authority			
ϕ_π	Commitment to inflation target	2	Consitent with a typical Taylor-rule specification.
ϕ_y	Commitment to stabilization of output gap	0	This ensures the existence of a steady state solution.
$\bar{\pi}$	Implied inflation target	1.021	Consistent with an inflation target of 8% per annum
F^*	Foreign reserves target	0.31	To match Nigeria's steady state stock of reserves (10% of GDP).
ρ_F	Persistence of deviations from steady state foreign reserves	0.9	Free policy parameter.
ω	Degree of domestic absorption of windfall spending	1	Free policy parameter, 1 for baseline of full private sector absorption and 0 for no absorption.
ζ_{ex}	Commitment to an exchange rate regime	0	Policy parameter, baseline for flexible exchange rate regime.
Capital mobility			
$\mathfrak{c}$	Degree of capital mobility	10^5	Policy parameter, baseline for a closed capital account.

Source: Author's parametrization based on stylized facts and relevant literature.

we assumed that the monetary authority does not target the exchange rate, hence, it follows a flexible exchange rate regime where $\zeta_{es} = 0$. Third, there are no efforts by the monetary authority to mop-up windfall spending by the government in the domestic economy, so that there is full absorption of the spending by the private sector i.e., $\omega = 1$. Finally, the monetary authority targets only the domestic inflation, there is no money growth target, and capital mobility is highly restricted.

Figure 1 and Figure 2 display the macroeconomic and sectoral responses of selected

Figure 1: Baseline scenario: Aggregate macroeconomic responses to windfall spending

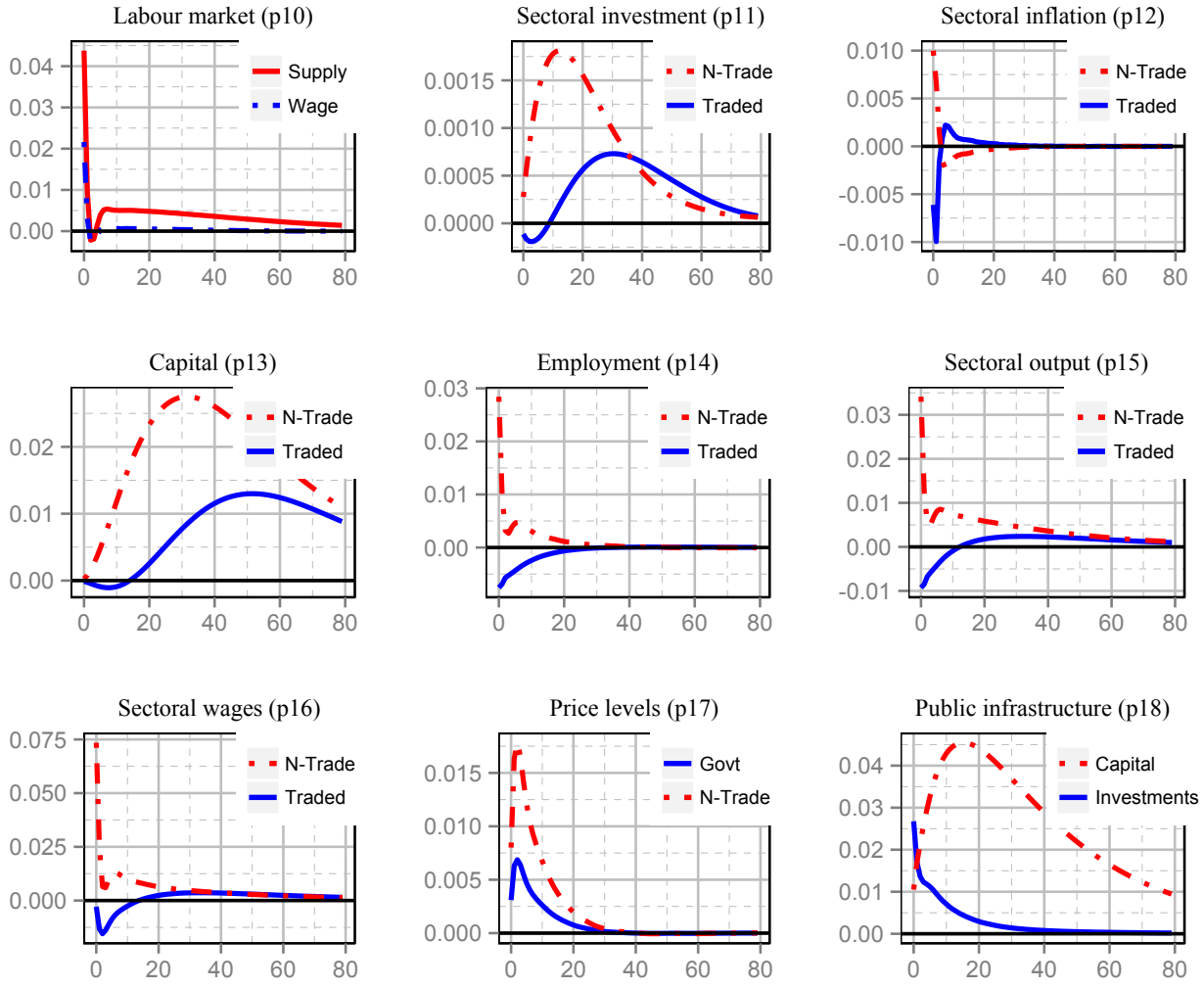


Source: Author's illustration based on impulse responses from DSGE model

variables to the baseline policy regime. In particular, the figure shows the impulse responses of selected sectoral, and aggregate macroeconomic variables to a windfall shock in resource revenue as a percentage deviation from the steady state. It is possible to summarize the impact of the windfall spending on the rest of the economy under two main mechanisms. First is the demand-driven effect that is generated by the additional spending. This demand drive is mainly focused on the non-tradable sectors (construction, services, etc), because of nominal rigidities in this sector, agents are able to respond to the increased demand by expanding supply. This explains the prompt but short-lived upward spike observed in non-traded output (see panel 15 in Figure 2), and hence overall GDP (see panel 4 in Figure 1). With passing time, price rigidities fizzle out, and flexible prices coupled with the higher inflation in the non-traded sector, (see panel 12 in Figure 2), ensures that GDP reclines closer to the steady state. The expansion of non-traded output is made possible by increased employment in the sector, which is driven by labour mobility from the traded sector motivated by the increased wages in the non-traded sector (see panels 14 and 16 in Figure 2).

The second channel of impact is through the exchange rate mechanism. Because government

Figure 2: Baseline scenario: Responses of sectorial variables to full windfall spending



Source: Author's illustration based on impulse responses from DSGE model

spending leads to an abundant supply of the foreign currency (as there is full domestic absorption of spending), this leads to real exchange rate appreciation in the short run (see panel 7 in Figure 1). Further, from the plots in Figure 2, we observe that this real appreciation suppresses the competitiveness of the traded sector, thereby encouraging factor re-allocations in capital (panel 13), investments (panel 11) and employment (panel 14), from the traded to the non-traded sectors. In addition, it is the appreciation of the nominal exchange rate that drives the deflation in traded prices (see panel 12), which partly offsets the inflation observed in the non-traded sector, so that aggregate CPI inflation (panel 6 in Figure 1) increases in the short-run and triggers expenditure switching by the private sector which helps to reduce aggregate demand pressures.

Monetary policy follows a contractionary approach in response to higher inflation, hence interest rates rise in the short-term (see panel 5 in Figure 1). Further, because the central bank's reserve policy allows the domestic economy to fully absorb the increased spending by government, this leads to higher overall private sector consumption (panel 2 in Figure 1) and investments (panel 11 in Figure 2). Finally, the observed persistence in the increased GDP

in the medium term, could be explained by the accumulation of public infrastructure in the economy resulting from the fact that government devotes a portion of its windfall spending to investments in public infrastructure.

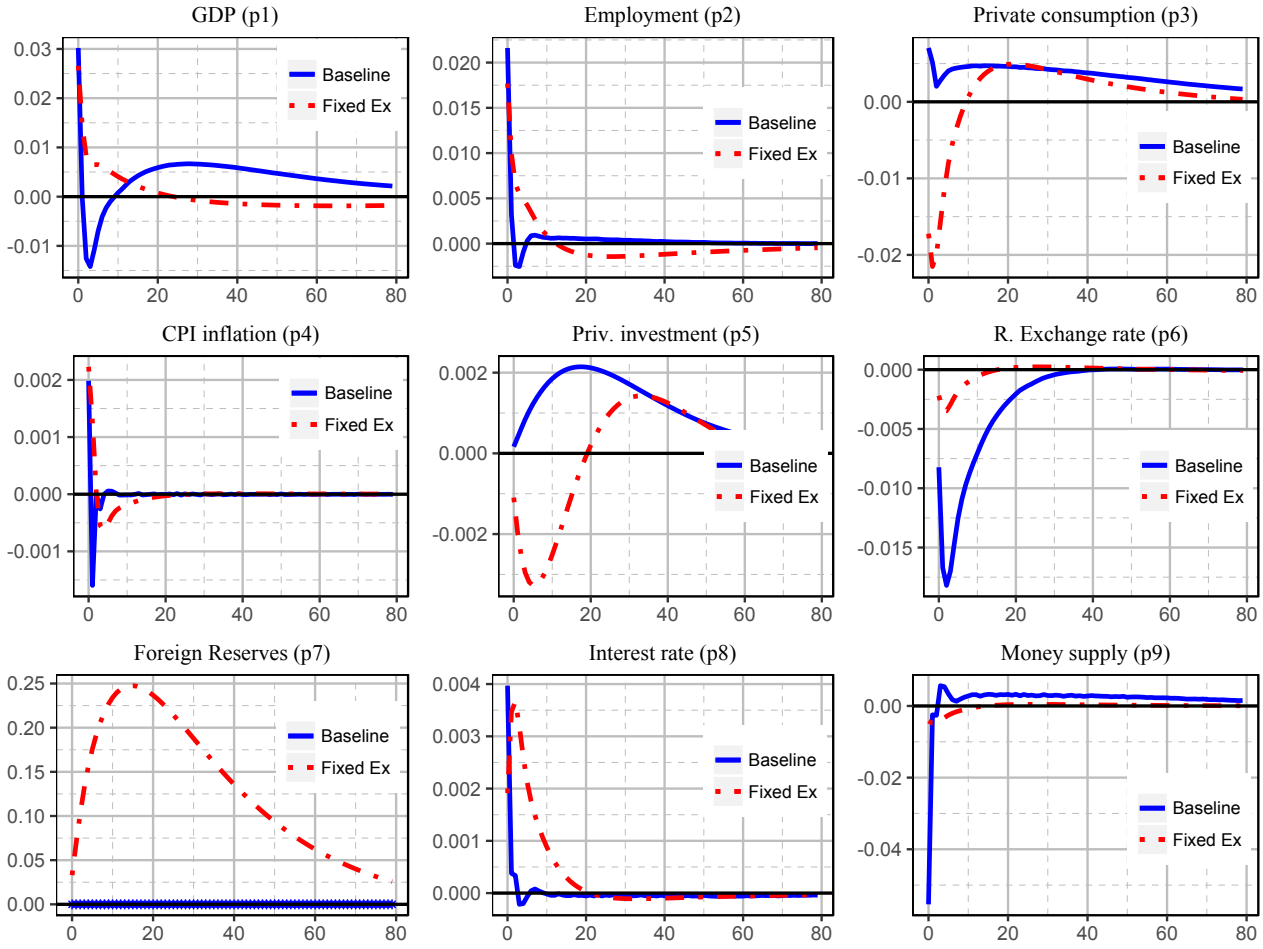
4.2 A crawling peg with partial domestic absorption

An alternative policy experiment compared to the baseline is a situation where the central bank strictly targets an exchange rate band, with the level of foreign reserve accumulation determined endogenously, given the level of commitment to maintaining the band. Here, the private sector in the domestic economy is allowed to partially absorb (half of) the increase in government spending from the windfall. The results for this monetary policy regime are presented in Figure 3. It is easy to see that the results under a controlled exchange rate regime are quite different from those of a flexible exchange rate regime. Focusing on the exchange rate mechanism, we observe from panel (6) in Figure 3, that the appreciation of the real exchange rate with full windfall spending is well contained (minuscule impact), hence, the competitiveness of the traded sector is not significantly compromised. This therefore contains the extent of resource reallocation activities from the traded to the non-traded sectors of the domestic economy, so that the non-traded sector does not have the capacity to respond as elastically as it would to the demand-driven windfall spending under a flexible exchange rate regime. The outcome is that real GDP under a crawling peg does not increase by as much as it does under a flexible exchange rate regime (see panel 1 in Figure 3).

Further, because there is very little deflation in the traded goods sector, added with nominal rigidities, CPI inflation under a crawling exchange rate regime is higher mainly because of the absence of the dampening effect from exchange rate appreciation, and hence traded goods deflation (see panel 4 in Figure 3). To maintain the predetermined exchange rate band, the central bank would have to decide how much of the foreign currency windfall spending to sell in order to achieve the nominal exchange rate target band, the balance of which would be stashed away in foreign reserves. This is the sense in which the domestic absorption of the foreign currency is endogenously determined by a crawling exchange rate regime.

In a crawling exchange rate regime, foreign reserves are positive, (see panel 7 in Figure 3), when compared with a flexible exchange rate regime. However, there is a crowding-out effect of government spending on the private sector as can be noticed by the decline in private sector investments (see panel 5 in Figure 3), and private consumption (see panel 3 Figure 3). This crowding-out effect works simultaneously to contain the high levels of trade deficits (private consumption and investment of tradables), observed in the flexible exchange rate regime (not shown). Again, monetary policy here is contractionary as interest rates increase moderately to keep inflation expectations anchored (see panel 8 in Figure 3).

Figure 3: Macroeconomic responses to full windfall spending with a crawling peg regime

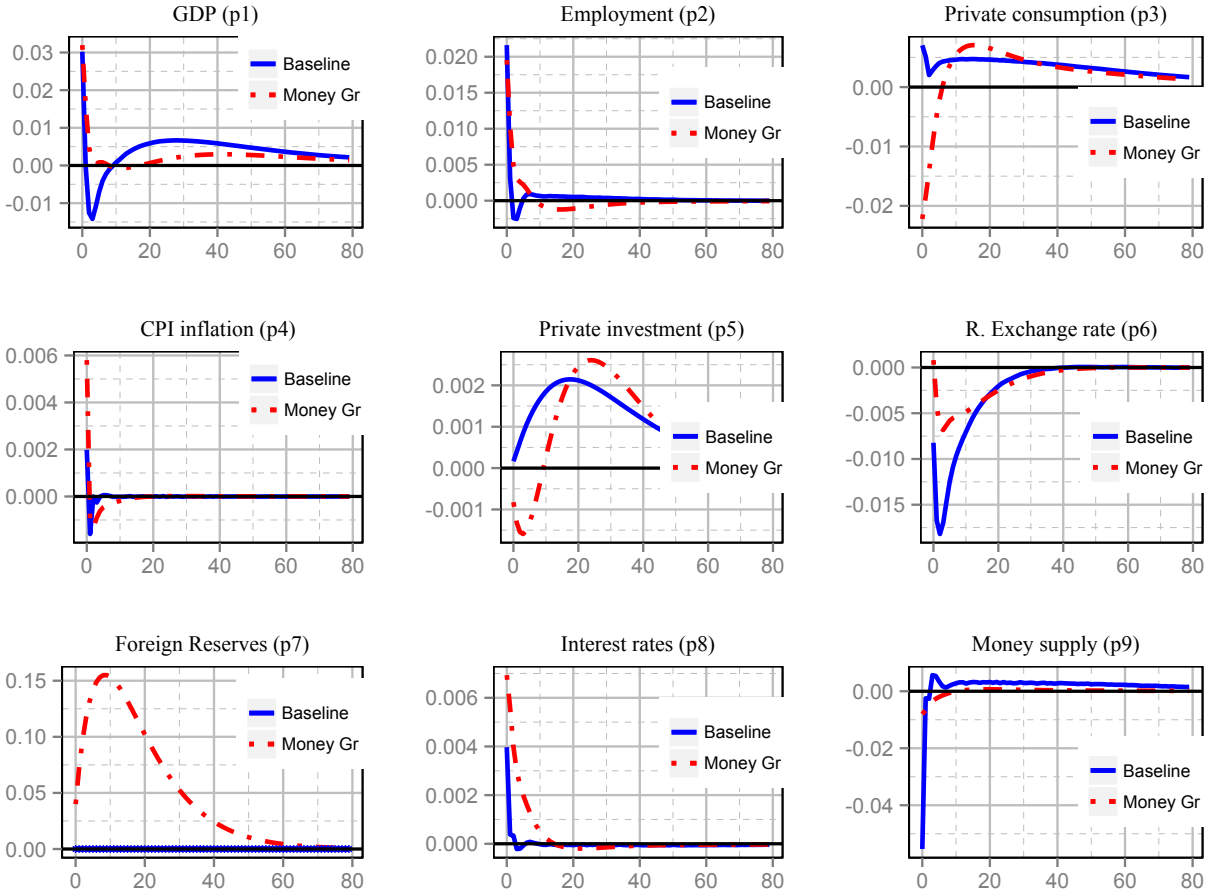


Source: Author's illustration based on impulse responses from DSGE model

4.3 Money growth target with full sterilization

In the money growth target with full sterilization regime, the central bank uses open market operations to sterilize, and hence prevent the expansion of the money supply that would have been caused by increased government spending of the domestic currency equivalence of windfall revenue. Here, the central bank follows a flexible exchange rate regime, there is full sterilization of windfall spending by government, and the domestic absorption rate is endogenously determined. The results for this policy experiment are presented in Figure 4. In this case, open market operations are used to keep the money supply growing at a relatively constant rate (see panel 9 in Figure 4). However, the overall monetary stance is much tighter, with interest rates increasing by much more than in the baseline, with more persistence than usual. Although this helps to control the higher CPI inflation (see panel 4), it also leads to significant crowding out of the private sector, as private investments and consumption declines in the short term (see panels 3 and 5 in Figure 4). The main implication of crowding-out the private sector is the reduction of the medium-term impact of windfall spending on real GDP (see panel 1 in Figure 4). A probable explanation of the mechanism that leads to the crowding-out effect is as follows; the crowding-out of the private sector results from the fact

Figure 4: Macroeconomic responses to full windfall spending with money growth target

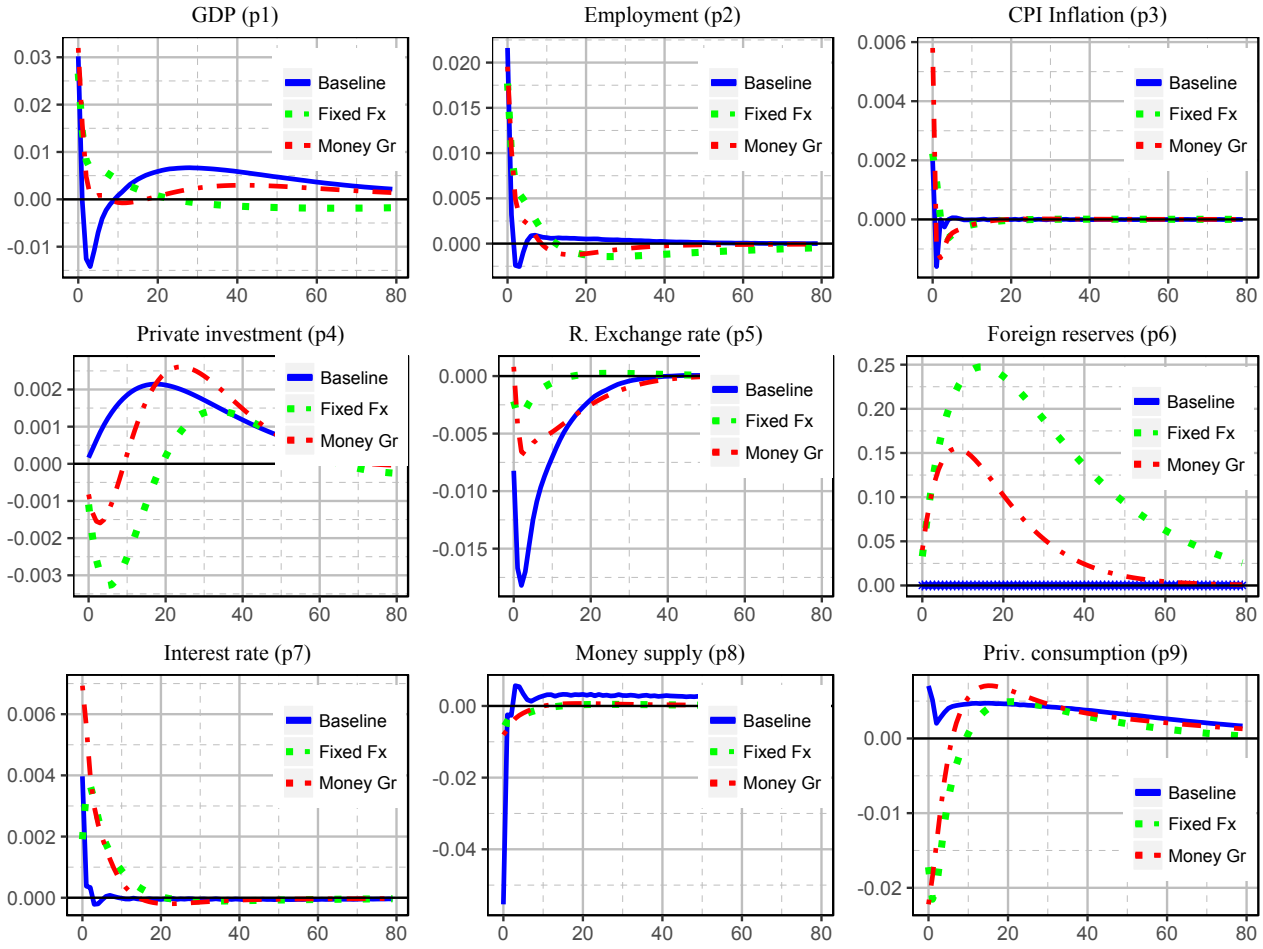


Source: Author's illustration based on impulse responses from DSGE model

that the public sector is attempting to use the resource revenue twice: first as government spending, and also as foreign reserves, however, because it is not technically possible to achieve this simultaneously, the private sector has to reduce its investments and consumption spending, which is made possible by the increase in interest rates (see Dagher et al., 2012).

In Figure 5, we plot and compare the responses of the macroeconomic variables to full resource windfall spending under the three alternative monetary policy regimes. By eye-balling the plots, it is difficult to tell which policy option dominates the others, especially because policy makers may attach different weights of importance to different macroeconomic targets and aggregates. Overall, economic agents generally prefer less uncertainty and variability of macroeconomic aggregates to more of it. However, the weight of importance attached to the macroeconomic variables may differ, and hence, aggregate variability is not often a popular method for evaluating alternative monetary policy options. A more systematic way to look at it is to consider the welfare cost, in terms of lost consumption, that would be suffered by individuals as a result of not implementing policy regimes that are not able to eliminate as much as possible, all macroeconomic instability in a given economy. This is the subject of the next subsection.

Figure 5: Responses to flexible exchange rate, fixed exchage rate and money growth reimes.



Source: Author's illustration based on impulse responses from DSGE model

4.4 Second moments and welfare rankings

We now focus on policy evaluation based on the welfare implications of the alternative monetary policy regimes relative to the time-invariant equilibrium process associated with the non-stochastic steady state. The welfare implications of alternative policies are evaluated using the popular framework set up by Lucas (1987, 2003), with related applications in Schmitt-Grohé and Uribe (2001, 2007), and Gali and Monacelli (2005). In particular, the welfare cost of business cycles associated with a particular policy regime, is the fraction of non-stochastic steady state consumption that households are willing to give up in order to be indifferent between the choice of the constant non-stochastic steady state values of consumption and work, and the fluctuating equilibrium stochastic sequences for consumption and work, associated with the policy regime under consideration.

Formally, let c^* and l^* denote the non-stochastic steady state values of consumption and labour hours, and $\{c_t^a, l_t^a\}$, their corresponding equilibrium stochastic processes for an alternative monetary policy regime, then, the cost of business cycle fluctuations under the

alternative monetary policy is given as λ^a, such that;

$$U((1-\lambda^a)c^*, l^*) = \mathbb{E}\{U(c_t^a, l_t^a)\}, \tag{22}$$

where $\mathbb{E}$ is the unconditional mathematical expectation. The welfare cost of a certain policy λ^a, in terms of non-stochastic steady state consumption, is approximated by a second-order Taylor expansion of (4) with respect to $(\ln c_t^a, \ln l_t^a)$, around the Ramsey plan $(\ln c_t^*, \ln l_t^*)$. By using the approximation $\mathbb{E}\ln(y_t^a/y^*) = 0$ for $y = \{c, l\}$, and defining $x_t = c_t^{\vartheta}(1-l_t)^{1-\eta}$, the welfare cost λ^a is given by;

$$\lambda^a = 1 - \left[1 + \frac{(1-\eta)^2}{2}\mathrm{Var}(\hat{x}_t)\right]^{\frac{1}{\vartheta(1-\eta)}}, \tag{23}$$

where $\hat{x}_t$ denotes the non-stochastic deviation of a variable from its steady state value, and $\mathrm{Var}(\hat{x}_t)$ is the unconditional variance of $\hat{x}_t$. Table 4 contains the standard deviations of several key variables, and the welfare costs under alternative monetary policy regimes. The welfare costs are comparable across board, because the policy regimes are set up in such a way that they give rise to the same non-stochastic steady state values. The second moments and standard deviations confirm some of the results that were already observed by visual inspection of the impulse response functions.

Table 4: Cyclical and welfare properties of alternative policy regimes

	A: Baseline s.d in %	**B**: Crawling peg s.d in %	**C**:Money growth s.d in %
Consumption	4.2	4.3	5.4
GDP	6.2	5.1	4.5
Interest rate	0.4	0.7	1.1
CPI inflation	0.3	0.7	0.8
Real exchange rate	5	3.1	0.26
Employment	2.1	2.4	2.7
Aggregate cyclicality	3.03	2.71	2.46
Conditional welfare cost (λ^a)	0.16	0.17	0.26

Welfare cost (λ^a) entries are percentage units of steady state consumption, and s.d denotes standard deviations in percentage terms. Policy regime **A**: Baseline, corresponds to an inflation targeting regime, with a floating exchange rate policy, no sterilization, an endogenously determined rate of windfall absorption, and limited capital mobility. Regime **B**: Crawling peg, is characterized by a tightly controlled exchange rate regime, partial domestic absorption and endogenously determined reserve accumulation; finally, **C**: Money growth, is the money growth target regime with full sterilization.

Source: Author's computation based on DSGE model.

The main insight arising from the policy evaluation exercise presented in Table 4 is that a flexible exchange rate with an inflation target (regime A: Baseline), is welfare superior to a crawling-peg with partial private sector absorption policy, and a money growth target with full

sterilization, in that order. In particular, under a flexible exchange rate regime with inflation targeting, households are willing to give up about 0.16 percent of their non-stochastic steady state consumption to have a sequence of consumption streams that are equivalent to what the efficient Ramsey policy would deliver, this is compared to the higher costs of 0.17 percent under a crawling peg, and 0.26 percent under a money growth target. As is usually the case in welfare exercises of this nature, the implied welfare losses are however quantitatively small for all the policy regimes.

5 Conclusion

The present paper develops a three sector dynamic stochastic general equilibrium model for a resource-rich developing economy, featuring unique characteristics such as the Dutch disease, limited international capital mobility, credit constrained consumers and learning by doing effects. The model is calibrated to match the Nigerian economy, a typical resource-rich developing economy with a lot of political pressure on fiscal spending of resource revenues. The macroeconomic and welfare effects of alternative monetary policy regimes are considered; (a) a flexible exchange rate regime with inflation targeting, (b) a crawling peg with partial domestic absorption, and (c) a money growth regime with full sterilization.

Our analysis consistently points to the effect of a booming non-traded sector, following a windfall spending, in line with the Dutch disease syndrome. The policy evaluation exercise indicates that a flexible exchange rate with inflation targeting regime ranks best among the policy options considered, as it implies a 0.16 percent loss in welfare terms compared to higher levels of welfare losses associated with a crawling peg with partial domestic absorption (0.17 percent), and a money growth regime with full sterilization (0.26 percent).

The framework adopted here could be extended in several dimensions, one way would be to add sticky wages to the sticky price rigidity, which as noted in Erceg et al. (2000) introduces an additional trade-off which renders (strict) inflation targeting suboptimal, it may be interesting to see how the introduction of this feature would alter the policy rankings. Secondly, it may also be interesting to go beyond the complete exchange rate pass-through (to prices of imports and exports of goods) assumption, and consider the implications of partial exchange rate pass-through on the relative performance of alternative monetary policy regimes. These potentially interesting extensions are left for future endeavours

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