External Shocks and Business Cycles in Nigeria: Accounting for the Roles of Domestic Oil-Refining Alternative and Oil Price Fiscal Rule

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The paper investigates the role of oil price fiscal rule (OPFR), and functional domestic oil refineries in curtailing the effects of external shocks on the Nigerian economy. A dynamic stochastic general equilibrium (DSGE) model is developed, calibrated and estimated using Random Walk Metropolis sampling method. The model is estimated under the benchmark, OPFR-only, and refinery-only scenarios. The results reveal that building or revamping domestic oil refineries may help the economy to withstand long term shock, but in the short run, the OPFR clearly emerges as the most potent. The non-oil external shocks are not significant under the three scenarios. However, oil-related external shocks have significant implications for business cycles in Nigeria, reinforcing the demand- and supply-side shocks. Furthermore, it is found that there is a need for functional domestic oil refineries in insulating the economy against external shocks, however, there is a huge welfare loss associated with refinery development alone. Thus, policymakers should consider instituting the OPFR to stem external shocks in the short run, while building oil refineries to tackle external shocks in the long run.

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1. Introduction

The Oil Price Fiscal Rule (OPFR) was first introduced in Nigeria in 2006 following its success stories in other countries such as Norway. The Norwegian oil revenue-based sovereign wealth fund (SWF) has protected the economy from vagaries of the international oil market. The Canadian province of Alberta has also explored the rule. Even Saudi Arabia has been exploring ways to isolate its fiscal balance from the vulnerability imposed by oil price swings. In a similar vein, Chile has implemented a structural balance rule that seeks to mitigate the volatility of copper prices. The

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success of the Nigerian OPFR, however, is muted by a number of factors including lack of fiscal discipline and monitoring. Thus, despite the early success of the rule in Nigeria, the economy has since been exposed to fluctuations in crude oil markets and hence to external shocks.

This paper hypothesizes that the combination of the OPFR and the development of refinery capacity in Nigeria can strategically insulate the economy against the external shocks. While the OPFR seems to offer a shorter-term relief from external shocks by robustifying the fiscal balance, building refineries offers a more prospective and hence longer-term guidance against external shocks. The decision between implementing the OPFR and building refineries hinges on several critical factors. The OPFR offers a mechanism to stabilize government revenue in the face of volatile oil prices, facilitating effective budgeting and resource allocation. This in effect will help to reduce the fluctuations in the economy as government spending constitutes a huge bulk of the total spending in Nigeria. In 2022, the ratio of government spending to the GDP stands at 14.39%. The impact of the government spending on the household could be hugely enormous as the government is the highest employer of workers. Although constructing refineries may expose the economy to fluctuations in refined product prices, which emphasizes the need for careful consideration, building refining capacity will lessen the stress on foreign reserves and thereby safeguard against exchange rate volatility. The importance of revenue diversification also becomes evident as reliance solely on crude oil exports poses risks due to price volatility. Like building robust refinery capacity, the OPFR encourages diversification by managing and saving oil revenues during periods of high prices, enabling the accumulation of financial reserves to offset revenue shortfalls during low-price periods. This approach will enhance fiscal resilience and provide a strategic tool for long-term economic planning.

Building refineries also brings about strategic infrastructure development, creating jobs during construction and supporting downstream industries like petrochemicals and manufacturing. The technology transfer and skill development associated with refinery construction will contribute to a more knowledge-intensive economy, which is a crucial aspect for developing nations aiming to build technical capacity. Furthermore, refineries contribute to reduced dependency on imported products, enhancing energy security and potentially leading to cost savings. Both the OPFR and refinery development will contribute to long-term economic resilience, with the OPFR providing fiscal discipline and refineries laying the foundation for sustained economic growth through value addition to the oil sector.

As important as the OPFR and refinery development may be in strategic planning, the cost profiles for the two are not likely the same. As the OPFR is a government policy aimed at stabilizing fiscal budgets in response to volatile oil prices, the setup costs for this rule involve the development, implementation, and monitoring of the policy. This includes expenses for economic modelling, data collection and analysis, legislative adjustments, and the establishment of mechanisms to adapt government spending or taxation in accordance with oil price fluctuations. While initial setup costs are significant, ongoing expenses for monitoring and potential rule adjustments may also be incurred. In contrast, building refineries involves the construction of industrial facilities that process crude oil into refined products. The setup costs for refineries include land acquisition, engineering and design, construction labour and materials, permits, regulatory compliance, and the purchase of refining equipment. These costs are incurred upfront during the construction phase. Refinery setup costs are substantial, but once the facility is operational, ongoing operational and maintenance costs, as well as variable costs related to crude oil prices, become prominent. When comparing the two, the nature of setup fixed costs differs, with OPFR costs associated with policy development, and refinery setup costs related to physical infrastructure construction. Both endeavours involve varying degrees of risk and uncertainty, with OPFR addressing fiscal risks associated with oil price volatility, and refinery projects facing risks related to construction delays, cost overruns, and market fluctuations in refined product prices. Furthermore, refinery setup costs represent a one-time investment, while the costs associated with the OPFR may evolve over time based on changing economic conditions and policy requirements.

The strategies of implementing the OPFR and developing refining capacity in the oil industry are not mutually exclusive but rather complementary approaches to enhancing resilience. The OPFR serves as a valuable short-term solution, offering a cost-effective means to stabilize government revenues in response to the unpredictable nature of oil price. It functions as a flexible tool to manage immediate economic impacts, providing a transitional measure while more permanent solutions, such as the development of refining capacity, are being built. On the other hand, the development of refining capacity is a long-term strategy that involves constructing infrastructure for processing crude oil into refined products. While it requires significant investment and time, it addresses the broader goal of energy security by reducing dependence on external sources for refined products. The integration of both strategies can create a more robust and comprehensive resilience framework. The OPFR can act as a buffer against short-term shocks, ensuring stability during market volatility, while the establishment of refining capacity contributes to sustained resilience by addressing long-term supply chain and production capacity challenges. In essence, the two strategies, when strategically integrated, offer a balanced and adaptable approach to enhance the overall resilience of the oil industry and the overall protection of the economy against external shocks.

Although some of the studies employing DSGE models have stylized some facts about the external shocks and the behaviour of the macroeconomic aggregates, none has examined these important features of the economy. Some of the studies in this regard include, Olayeni (2009), Alege (2008), Adebiyi and Mordi (2012), Rasaki (2017), Zubair (2019), Oladunni (2019), Omotosho (2020), and Oje-yinka and Yinusa (2021). As crucial as the viable refineries are to the functioning of the Nigerian macroeconomy and in staving off the full impact of external shocks, all the studies in this category conspicuously overlook their importance. Functioning refineries would have insulated the economy against volatile imported refined oil prices, an important pass-through channel in Nigeria, and safeguarded the economy from external shocks. Therefore, neglecting this phenomenal channel of transmission would undoubtedly understate the impact of external shocks in the Nigerian economy. Yet another feature worth including in our model is the oil price fiscal rule (OPFR). It lent credence to the efficacy of the rule in stemming the impact of external shocks (Okonjo-Iweala & Osofo-Kwaako, 2007). Thus, like the viability of domestic oil-refining alternative, OPFR would give an oil-dependent economy an extra stability to neutralize external shocks. These two features are critical, and this paper infuses them into the standard

DSGE model to make it more bespoke for Nigeria's experience.

The rest of the paper is as follows. Section 2 gives a brief literature review; Section 3 summarizes the model schematically; and Section 4 reports and discusses the results, while Section 5 concludes.

2. Literature Review

The main subject of macroeconomics has remained intact, which is the study of fluctuations around the trend and how to smooth them, though the approach deployed to study it has continually evolved. The clampdown of the new perspective on the modelling of macroeconomic relations and the Keynesian macroeconometrics rests on Lucas critique, to provide micro foundations for macroeconomics. Lucas (1976) noted that the practice of macroeconomics that is based on reduced-form equations will not be invariant to policy changes. Such were the macroeconometric models that were not founded on microeconomics. Although often massive in number of equations, these models were hardly useful for policy considerations because they were just the reduced-form models whose constituent parameters are summative of the underlying structural time-invariant parameters. This implies that the model needed must be micro-founded and based on deep structural parameters.

A DSGE model, being based on the first-order conditions derived from the optimized choices of the agents, possesses deep structurally invariant parameters. This feature is the point of attraction of the DSGE model (Hoover, 2010; Hurtado, 2014). Hein (2023) provided a review of post-Keynesian macroeconomics that substantiates the central importance of the Critique. The idea is to reemphasize the individualism and self-interest of the invisible hand paradigm first captured in the Classical work of Adam Smith. Behind the aggregates of the macroeconomy are the individual choices of economic agents driven by expectations and tastes and limited by available resources but forward-looking. Expectations are no longer formed mechanically but through a sophisticated process as would by a rational economic planner. Thus, surprises are not possible and cannot be systematic. This thought is expressed in the DSGE model. The orientation of the DSGE model is to infuse the theoretical microfoundation into the empirical fluidity, thereby making it possible to analyze economic issues grounded in theoretical constructs that can be used to replicate empirical implications. In other words, empirics meets theory in DSGE modelling.

The precursor to the DSGE model is the Structural Vector Autoregressive (SVAR) model. Both DSGE and SVAR models impose restrictions on the economic structure and relationships; however, while SVAR model is used to interpret the hypotheses and restrictions wilfully and subjectively imposed by the researchers (Cuestas & Tang, 2021), DSGE model derives its own set of restrictions from the first order describing the optimal choices of the economic agents (Adolfson *et al.*, 2008). In this sense, DSGE model can be seen as SVAR model where the theoretical cross-equation restrictions are not from the researcher's worldview but from the interactions among economic agents, and the optimal choices made by these agents. Thus, due to its theoretical orientation, DSGE model is seen as the standard. A lucid discussion juxtaposing the contents of these competing approaches can be found in Pagan and Robinson (2016), Liu *et al.* (2018), and Lippi (2021).

The DSGE model is versatile with applications spreading across all subfields in economics. As long as a model can be conceived and solved (not all models can be solved – some lead to indeterminacy) either nonlinearly or after approximation to the first or second order, it can be deployed. In Nigeria, a number of DSGE studies have been conducted. Among the early studies are Olayeni (2009, 2012), Alege (2008), and Adebiyi and Mordi (2012). These studies examine the implications of external and monetary policy shocks for business cycle and exchange-rate pass-through in Nigeria. Olayeni (2012) in particular built a much larger model of Nigerian economy with a focus on the oil price shocks. Lately, Rasaki (2017), Zubair (2019), Oladunni (2019) and Omotosho (2020) investigated the implications of external shocks including those emanating from external debt, exchange rate, oil price shocks and fuel subsidies using small open economy (SOE) versions of DSGE model. In Ojeyinka and Yinusa (2021), the objective was to investigate the compositional shocks to output with a view to ascertaining the key external drivers behind the movement in output.

In the light of the objectives of this paper, it would be illuminating to examine the literature on the connection between oil refinery and external shocks. However, it seems this is a lonely road as no study has investigated this connection to the best of my knowledge. Nevertheless, we are led to examine the evidence of external shocks in a set of oil-producing countries with below average oil refinery capacities. In effect, we draw the correlation between the evidence of adequate refinery capacities and the published evidence of external shocks. In Africa, the seven highest oil producing countries are Angola, Algeria, Libya, Nigeria, Egypt, Republic of Congo and Gabon. With a daily oil production of 1,316,415 barrels per day (bpd), Nigeria is the highest, while Gabon is the lowest producer in African. Nigeria has the installed capacity of about 473,000 bpd from six refineries. Of interest is the fact that these refineries are at varying stages of decay and abandonment. The daily oil production in Angola is 1,165,993, while the refining capacity is 72,000 bpd from two refineries. Although Egypt is the fifth largest oil producer in Africa with production of about 567,652 bpd, it has the largest refining capacity of 883,000 bpd. Algeria has the refining capacity of 677,000 bpd and producing 1,211,863 bpd. For Libya, the refining capacity is 380,000 bpd while its production stands at 1,057,890 bpd. The daily oil productions in Congo and Gabon are 272,928 and 195,808 bpd with a refining capacity of 15,000 and 25,000 bpd respectively. Of all these seven top oil producers in Africa, only Egypt has the refining capacity beyond its production volume.

As noted above, the role of oil refining capacity in managing external shocks has not been explicitly studied in the literature. We rely on some anecdotal evidence here. First, the auspicious benefits of having higher refining capacity pays off for Egypt in terms of the extent that oil price shocks impact on its macroeconomy. Omoshoro-Jones and Bonga-Bonga (2019) observed that less than 0.5% variability in output can be attributed to oil price shocks. The study further classified Egypt as an investment-driven economy, whose main driver of output volatility is fiscal policy. This is not the case in other oil-producing countries. Investigating the role of external shocks in Nigeria, Oyelami and Olomola (2016) provided the evidence that Nigeria's economy is subjected to external shocks, which is substantiated by the findings of Olayeni (2012), Oladunni (2019) and Omotosho (2020). Estimating a multisector DSGE model, Alleget and Benkhodja (2015) documented the experience of Algeria and noted that Algerian economy has been impacted by external shocks including oil price, real exchange rate, international interest rate, and inflation and that monetary policy plays a significant role in stemming this impact. The study also highlighted the welfare implications, noting that the oil price shocks induce higher welfare than does exchange rate. The important point to note here is that external shocks matter and that the existence of oil refining capacity can be a latent factor in the intensity of external shocks.

In this study, our goal is to use the DSGE model to shed light on external shocks and contagion risks in Nigeria. While most empirical studies using the DSGE models adapted their models, we are going to adopt the model developed by Olayeni (2012) which mainly focuses on peculiarities to Nigeria.

3. The Model

3.1 Structure of the Model

The structure of the model developed in Olayeni (2012) is depicted in Figure 1. Several studies have developed models that explicitly address the open economy problem. Galí and Monacelli's (2005) version is one of the most widely used. But this version does not address the role of oil in the model economy. The version we follow in this study, which is a modified version of the New Area Wide Model (NAWM) developed by the European Central Bank, has been discussed by Christoffel et al., (2008). These models share some features regarding the households, firms, and institutions. Firstly, they are both based on micro-foundation of macroeconomics, thereby obviating the pitfalls highlighted by the Lucas critique. Furthermore, they both assume homogeneous households and intermediate firms, the assumption that allows them to use the representativeness of a single household and a single intermediate firm as a stand-in for the remaining households and intermediate firms respectively.

Additionally, they both spell out the frictions or imperfections characteristic of the New Keynesianism: price-stickiness, wage-stickiness and adjustment cost in investment, which are preconditions for government interventions. However, unlike the Galí-Monacelli model, the NAWM is more detailed as it makes distinction between the final and intermediate goods producers and guarantees more dynamism in the economy. However, both models relegate the role of oil to the background, though the NAWN allows for integration of oil. Thus, our model extends the NAWM in this direction by explicitly integrating the production, importation, exportation, and marketing of oil into the basic NAWM model. Apart from the introduction of the role of oil in the economy, ours is a DSGE model with the usual blocs: the production bloc that deals with the behaviour of various firms in the economy, the consumption bloc that deals with the behaviour of the households, and the policy bloc that spells out the rules governing the exchange of goods and services in the economy. Unlike the NAWM, we also extend the model to incorporate the Ricardian and non-Ricardian households. This extension is important because a large percentage of the Nigerian households is financially constrained and lacks access to financial resources. The two-agent New Keynesian (TANK) model allows us to achieve this feature. A useful way to conceptualize the structure of this model is the open economy schema presented in Figure 1.

This schematization depicts many households each of which can be described by its preference and the resources – labour and capital – it owns. In the pure-market economy, such as the one described in this work, all resources are ultimately owned by the households. The households' preferences are defined over consumption goods and labour effort/skill supplied to the intermediate goods producing firms. The Ricardian households also accumulate capital, which they supply to the intermediate goods producing firms. It is assumed that oil production is highly capital-intensive with oil-specific capital sourced abroad. Thus, households are only allowed to supply their labour efforts and capital to the intermediate goods producing firms and not to the oil producing unit. This gives a treatment of the fact that the oil-producing sector does not directly generate much employment. Oil output is divided between domestic demand and exports. At the same time, the shortfall between what is required and what is available is made up by oil imports. The final goods, that is, the consumption goods, the private investment goods, the public goods and the export goods are all produced from combining domestically produced intermediate goods and foreign intermediate goods representing the imports. Thus, the addition of these four components plus the exports of oil less imports of oil and intermediate goods should give the real gross domestic product inclusive of oil output. It should be noted that the public goods are sold to the government while consumption goods and private investment goods are sold to the households.

Government affects the economic system by conducting both monetary and fiscal policies. For example, government is allowed to participate in the domestic bonds market and to also levy series of distortionary and lump-sum taxes. In addition, the government is allowed to use strategies such as the oil price fiscal rule (OPFR) to help assuage the effects of the exogenous fluctuations in the international oil price. Households also have access to the foreign bonds. For their *shareholding* in various firms, households receive dividends and pay taxes.

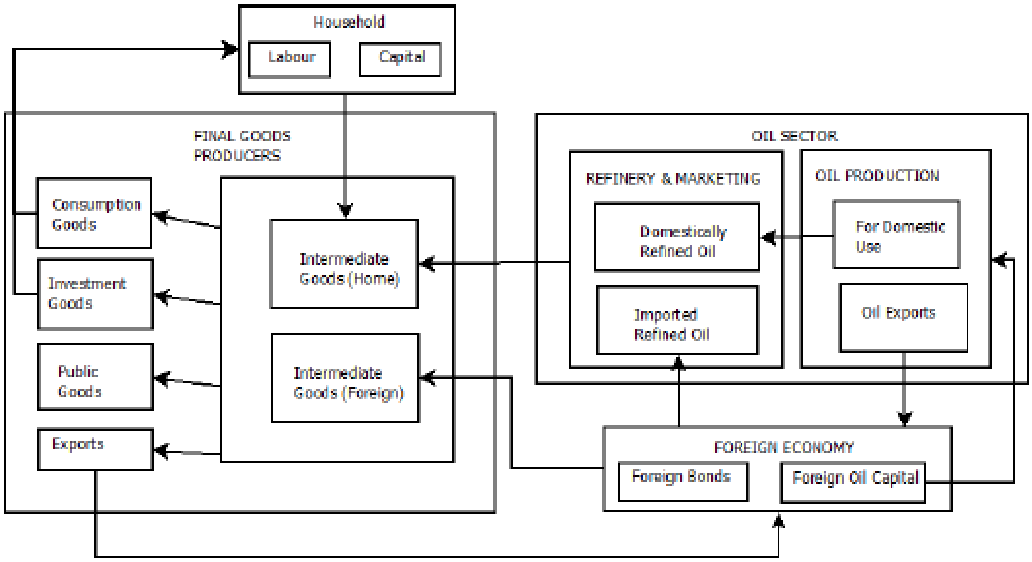

Figure 1: The structure of DSGE model

3.2 External sector

This section details the behaviour of the external sector, given its relevance to the objective of the paper. Thus, following the practice in the literature the foreign (global) economy is approximated by a *closed* economy, and the dynamics of the foreign variables are modelled by an estimated structural VAR(p) model, the parameters of which will be kept at the estimated values throughout the estimation. The structural shocks are non-recursively identified by means of non-Cholesky identification scheme imposed on the contemporaneous matrix. Specifically, we assume the ordering given by the vector $\Upsilon_t^* = (\hat{y}_t^*,\ \widehat{\pi}_t^*, r_t^*)'$, where $\hat{y}_t^*$ is the foreign output gap, $\widehat{\pi}_t^*$ is the foreign inflation and r_t^* is the foreign interest rate. The estimated SVAR(p) model is given by

$$\Phi_0 \Upsilon_t^* = \Phi(L)\,\Upsilon_{t-1}^* + \varepsilon_t^* \qquad (1)$$

where $\varepsilon_t^* = \Lambda\zeta_t^*$, $\zeta_t^* \sim N(0,I)$ and $\varepsilon_t^* \sim N(0,\Lambda\Lambda')$ and the impact matrix, Φ_0, has the following structure

$$\Phi_0 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ \phi_1 & -\phi_2 & 1 \end{bmatrix}$$

while Λ is defined as

$$\Lambda = \begin{bmatrix} \sigma_1 & 0 & 0 \\ 0 & \sigma_2 & 0 \\ 0 & 0 & \sigma_3 \end{bmatrix}$$

The maintained SVAR model implies that output gap does have contemporaneous effects on inflation, whereas inflation does not have contemporaneous effects on output gap. That is, there is a delayed effect from inflation to output gap, perhaps due to structural adjustment that will need to be made, while inflation is more reactionary because it is subject to announcement effect.

3.3 Oil Refinery

In this sub-section, we explain the refinery process. First, a refinery is a sunk capital, which, once installed, cannot be recovered at least in the short run. That means we do not need to be concerned about the installation cost. Secondly, the technological process is best characterized as a fixed-coefficient technology, where a constant relation exists between output (refined oil), $O_{H,t}$, and input (crude oil), $O_{Z,t}$. If we let the output-input ratio at the steady state be represented by μ, then the refinery technology is given by

$$O_{H,t} = \mu O_{Z,t}, \tag{2}$$

and a unit of crude oil yields μ unit of refined oil products. We will calibrate μ as 1.063 since the refinery process is such that the volume of output is larger than the volume of input as the products from the refinery process have a lower density than the crude oil. A typical refinery process has the processing gain of about 6.3%, which according to the Energy Information Agency (EIA), is the average processing gain in the US. This standard cannot be applied to other countries such as Nigeria with inefficiencies in the refinery process. Years of dilapidation in the refineries imply existence of operational cost. We thus allow for the adjustment cost to capture this feature. Thus, the adjustment cost function of the form

$$AdjCost_t = S(\eta_t)\,\varepsilon_{\eta.t}, \tag{3}$$

is formulated, where, at the steady state output-input ratio μ, $S(\mu) = S'(\mu) = 0$, $S''(\mu) > 0$, and

$$\varepsilon_{\eta.t} = \left(\frac{d\left[S(\eta_t)\right]}{d\eta_t}\right)\left(\frac{\eta_t}{S(\eta_t)}\right), \tag{4}$$

is the output-input ratio elasticity of adjustment cost. Two important considerations inform this formulation. First, for technical reason, the adjustment cost with its first derivative adopted here vanishes when evaluated at the steady state and drops out of the model. This is not helpful to think about the implication of the inefficiencies experienced in refinery process in Nigeria. The second derivative, however, is strictly positive. We circumvent this problem with the adjustment cost formulation in Eq. (3), which accounts for inefficiencies after log-linearizing the refinery technology function. Second, empirically, the adjustment cost is exacerbated or assuaged by ease of adjustment, which also points to the technical responsiveness. A more adjustable refinery technology will be more pliable to process crude oil of different densities and sulfur contents. It follows that the refinery technology with the adjustment cost is given by

$$O_{H,t} = \mu\left[1 - \frac{d[S(\eta_t)]\eta_t}{d\eta_t}\right] O_{Z,t} = \mu\left[1 - S(\eta_t) - S'(\eta_t)\,\eta_t\right] O_{Z,t}.$$

If $\eta_t = \mu$, then this equation reduces to Eq. (2). Substituting $\eta_t = \frac{O_{H,t}}{O_{Z,t}}$, we have

$$O_{H,t} = \mu\left[1 - S\left(\frac{O_{H,t}}{O_{Z,t}}\right) - S'\left(\frac{O_{H,t}}{O_{Z,t}}\right)\frac{O_{H,t}}{O_{Z,t}}\right] O_{Z,t}.$$

The log-linearization of the stationarized refinery production technology yields the following:

$$o_{H,t} = -\mu^2 S''(\mu)(o_{H,t} - o_{Z,t}) + \mu o_{Z,t}.$$

Substituting $S''(\mu) = \psi > 0$ into the above expression and assuming a quadratic adjustment cost function $S(\eta_t) = \frac{\psi}{2}(\eta_t - \mu)^2$, we have:

$$o_{H,t} = -\mu^2 \psi (o_{H,t} - o_{Z,t}) + \mu o_{Z,t}. \tag{5}$$

The term $-\mu^2 \psi (o_{H,t} - o_{Z,t})$ captures inefficiency due to adjustment cost. If the adjustment parameter is zero, that is, $\psi = 0$, then, the fixed-coefficient technology results.

3.4 Oil Price Fiscal Rule

Using part of the oil fund reserves is a norm in Nigeria, and it has regularly been used in the form of the windfall sharing between state and the federal governments. Indeed, this is one reason that efficacy of the OPFR has been questioned, not only in the case of Nigeria but also in the case of Botswana and Norway where the rule has also been used. In Nigeria, sharing of oil fund reserves has generated controversies among scholars and in the political circle, and the rationale behind such withdrawals has likewise been questioned. Most arguments hinge on the destabilizing effects that they may have on the economy and on the corruption and rent-seeking they may provoke. In this thesis, we will be concerned with the destabilizing effects on the Nigerian macroeconomy.

The oil price fiscal rule (OPFR) used by the government is given by the following equations, with Eq. (6) describing the actual oil revenue that is allowed to enter the budget and Eq. (7) giving the evolution of oil fund reserves:

$$R^G_{O,t} = \rho_G \varpi_S S_t + (1 - \rho_G)\varpi_\Delta D^G_{O,t}, \tag{6}$$

$$S_{t+1} = S_t + (1 - \varpi_\Delta) D^G_{O,t}, \tag{7}$$

where $\rho_G \in (0,1)$ and $\varpi_\Delta \in (0,1)$ are the oil revenue smoothing and the OPFR parameters, respectively. $\varpi_S \in (0,1)$ is the fraction of the oil fund reserves that can be spent. Eq. (6) states that government can spend part of its reserves and part of the current oil revenue. That is, oil revenue is a weighted average of these two sources. Eq. (7) states the law of motion for reserve accumulation: at any given time, total oil fund reserves in the next period is the current period oil funds reserve plus the fraction of oil revenue in the current period.

The thought process leading to the previous equations is as follows. As the government is concerned about the variability of oil revenue, it divides oil revenue into two parts: $(1-\varpi_\Delta)\,D^G_{O,t}$ which is saved as oil fund reserves and $\varpi_\Delta D^G_{O,t}$ which is meant to be spent at almost the time of receipt. Thus, the *stock* of oil fund reserves increases each period by the amount of flow that equals $(1-\varpi_\Delta)\,D^G_{O,t}$, giving a difference equation in Eq. (7). The amount that the government finally spends each period out of the oil revenue $R^G_{O,t}$ comes from $\varpi_S S_t$, withdrawn from the oil fund reserves, and from $\varpi_\Delta D^G_{O,t}$, which is the oil revenue meant to be spent contemporaneously. This is given by Eq. (6), with ρ_G controlling the amount that comes from each of these two sources.

The log-linearized OPFR equations after stationarizing them are given by

$$r^G_{O,t} = \frac{1}{r^G_{O,S}}\left(\rho_G\varpi_S\frac{s_S}{\mu_A\pi_S}\left(s_t-\mu_{A,t}-\pi_t\right)\right)+(1-\rho_G)\,\varpi_\Delta d^G_{O.S}d^G_{O,t}\Bigg), \tag{8}$$

$$s_{t+1} = \frac{s_t-\mu_{A,t}-\pi_t}{\mu_{A,S}\pi_S}+\frac{(1-\varpi_\Delta)\,d^G_{O.S}}{s_S}d^G_{O,t}, \tag{9}$$

where the lower cases refer to the log-linearized versions of their upper cases.

The countercyclical property of the OPFR can be stated as follows:

$$s_t = \rho_S s_{t-1}+(1-\rho_S)\,\omega_Y\,(y_t-y_S)+\omega_O\left(p^X_{O,t}-p^X_{O,S}\right)+\omega_G(g_t-g_S) \tag{10}$$

This OPFR countercyclicality property states how s_t adjusts to fluctuations of y_t, the international price of crude oil $p^X_{O,t}$ and government spending g_t around their steady state values. The countercyclical adjustment in the OPFR is achieved when $\omega_Y > 0$, meaning that when output is above its steady state, the OPFR must adjusts upwards as more oil revenue is saved. Similarly, when crude oil price goes beyond the benchmark, savings from oil revenue must increase, which means that $\omega_O > 0$. Again, the rule is designed to adjust to the changes in government spending. When government spending is higher than its steady state level, the funds adjust downwards, that is, $\omega_G < 0$, counteracting the excessive spending of the government.

Table 1: Observed variables for estimation

Oil exports	Oil price
Oil imports	Gross Domestic Product
Oil output	GDP Deflator
Government consumption	Real interest rate
Non-oil exports	Nominal exchange rate
Non- oil imports	Foreign price level
Oil revenue	Foreign real interest rate
CPI inflation	Foreign output

4. Empirical results

The model presented above has been calibrated using data on macroeconomic variables as well as the foreign macroeconomic variables for the period between January 2010 and September 2022. The data used are as listed in Table 1, while Table 2 gives the list of shocks and their groups. We employed the Bayesian econometric method to estimate the model, simulating it using the Random Walk Metropolis sampling method. The model outlined in this paper has been estimated using the Bayesian econometrics. The Monte Carlo Markov Chain (MCMC) algorithm has been used. The estimations are based on two Markov chains. We sample 20,000 draws and expunged 10,000 initial draws as burn-ins. Consequently, the posterior densities of the model parameters are based on 10,000 draws. The posterior mode estimation needed for the initialization of the Dynare's Metropolis Hastings (MH) and for the jumping distribution was done using a Monte-Carlo based optimization routine. This choice saves us the burden of obtaining the posterior mode. Rather, we simply need to start randomly in the parameter space with a high posterior density value. In what follows, we discuss some stylized facts about the sources of real GDP growth before proceeding to analyse the impulse responses.

Table 2: Shock blocks in the model

	Definition	Symbol	Process*
	(A) Supply-side shock bloc		
1	Permanent technology shock	$\zeta_{\mu_A,t}$	RW
2	Transitory technology shock	$\zeta_{Y,t}$	RW
3	Transitory oil technology shock	$\zeta_{O,t}$	RW
4	Shock to technological differential	$\zeta_{a,t}$	RW
	(B) Demand-side shock bloc		
5	Investment specific shock	$\zeta_{I,t}$	ARAR(1)
6	External premium shock	$\zeta_{B^*,t}$	ARAR(1)
7	Domestic premium shock	$\zeta_{B,t}$	ARAR(1)
8	Shock to inflation target	$\zeta_{\pi,t}$	RW
9	Monetary policy shock	ζ_t^R	RW
10	Shock to consumption	$\zeta_{C,t}$	ARAR(1)
11	Shock to labour effort	$\zeta_{L,t}$	AR(1)
	(C) Foreign shock bloc		
12	Shock to foreign inflation	$\zeta_{\pi^*,t}$	RW
13	Shock to foreign price	ζ_t	RW
14	Shock to foreign income	$\zeta_{Y^*,t}$	RW
15	Shock to foreign interest rate	$\zeta_{r^*,t}$	RW
	(D) Refinery specific shock bloc		
16	Shock to refinery maintenance fund	$\zeta_{gO,t}$	RW
17	Oil refinery shock	$\zeta_{z,t}$	RW
	(E) Oil price shock bloc		
18	Shock to the international price of refined oil	$\zeta_{O^*,t}$	RW
19	Shock to the international price of crude oil	$\zeta_{O,t}^X$	RW
20	Shock to the price of domestically sourced refined oil	$\zeta_{O,t}^H$	RW
21	Shock to the domestic price of imported refined oil	$\zeta_{O,t}^M$	RW

*Notes: AR(1): autoregressive (AR) process of order one (1);RW: Random walk.

4.1 Some stylized facts about sources of real GDP contractions in Nigeria

To understand the roles of oil price and non-oil price external shocks in the system, we start by decomposing the real GDP growth historically and attribute the sources of fluctuations accordingly. The results are presented for the four groups of shocks. The figure presented here closely represents the reality as obtained presently in Nigeria. Figures 2-5 respectively present the historical contributions of oil price shocks, non-oil external shock, the demand-side and the supply-side shocks. The shaded periods are recessionary periods of consecutive negative growth rates of two quarters. The results show that real GDP growth is dominated by two sources of shocks, namely, the supply-side and the oil price shocks. The demand side shocks and non-oil related external shocks are not significant contributors. In terms of the timing of the shocks, we notice that the contractions experienced during the study period coincide mostly with the periods of negative oil price shock, suggesting that negative oil price shock is a major driver of economic recessions in Nigeria. Significant periods of recessions can also be attributed to the supply-side as can be seen in Figure 3.

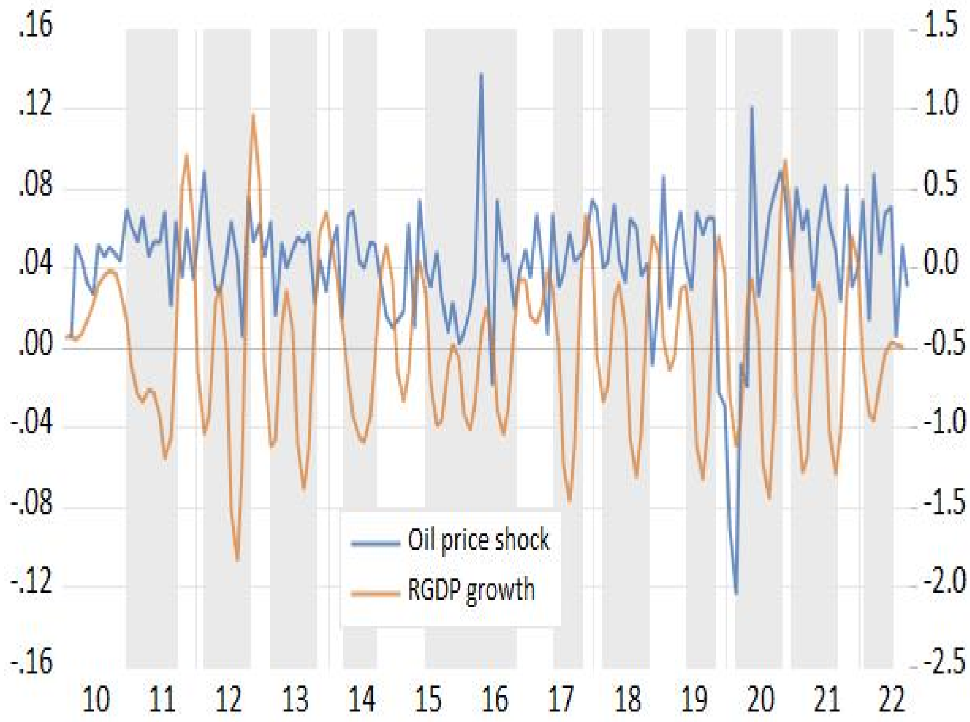

Figure 2: Historical decomposition of real GDP: Oil price shock

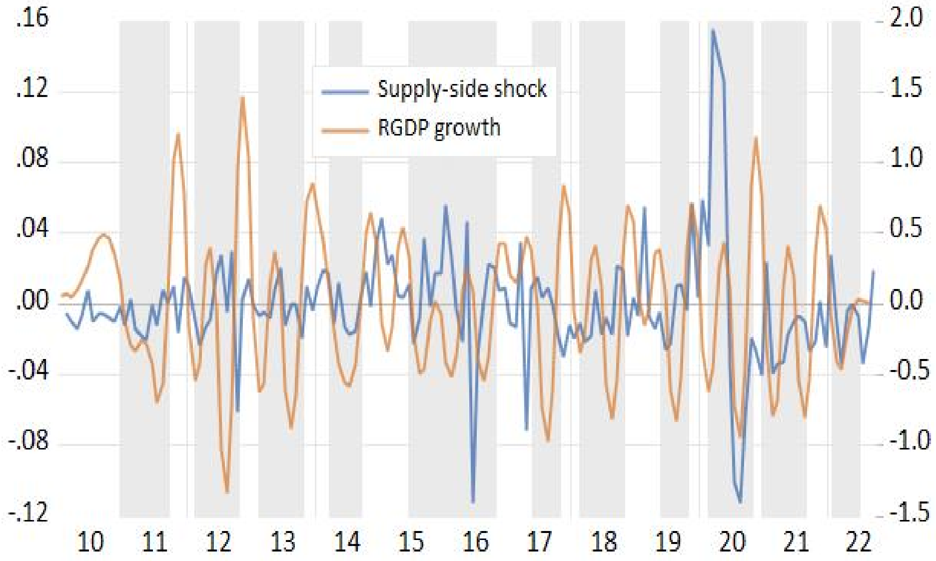

Figure 3: Historical decomposition of real GDP: Supply-side shock

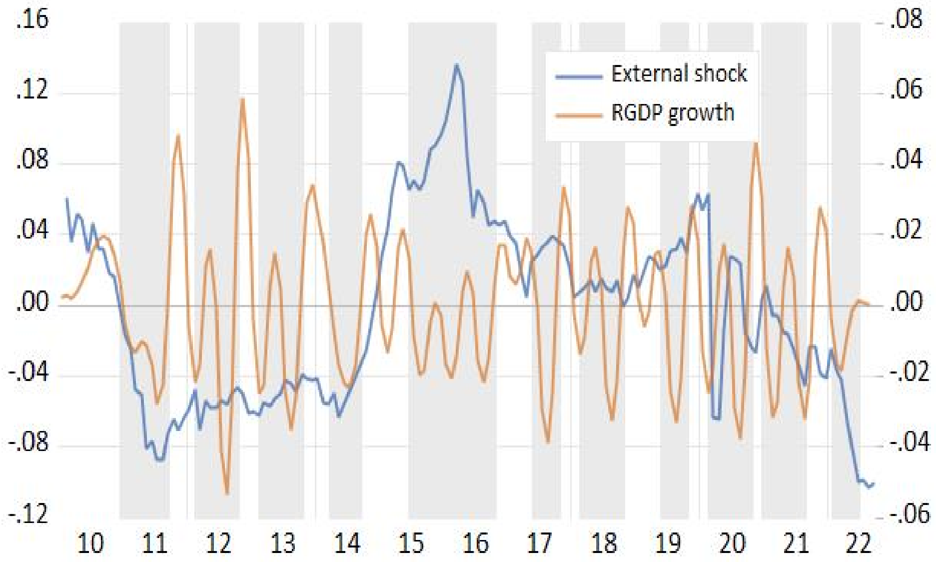

Figure 4: Historical decomposition of real GDP: External shock

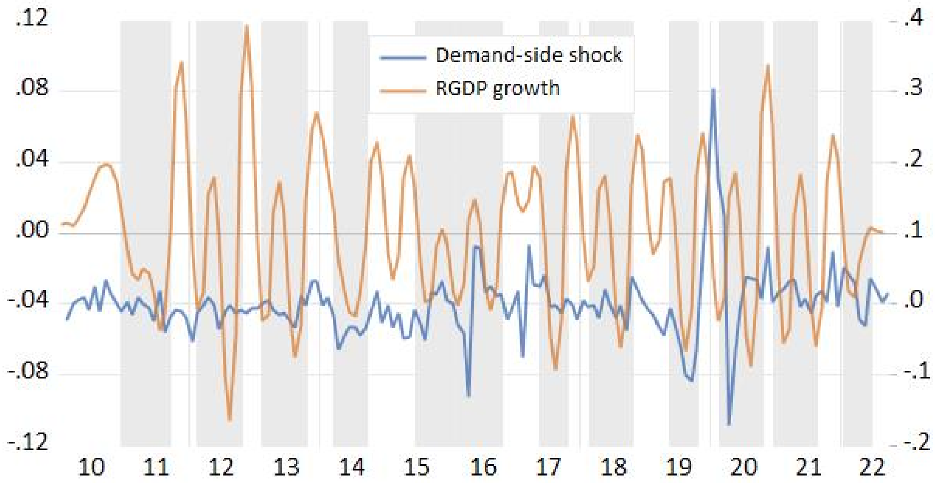

Figure 5: Historical decomposition of real GDP: Demand-side shock

Although the demand-side shocks are not quantitatively as important as those of the oil price and supply-side factors, in terms of the timing of the recessions, their downward swings appear to coincide with negative movements in real GDP growth and could be a source of business cycle (Figure 4). There is no clear-cut pattern in the movement of the external shocks as shown in Figure 5, and it appears they are more of decadal movements than being reckoned as business cycles. While they are important, their slow and gradual evolutions indicate they do not impose urgency that the oil-price, demand-side and supply-side shocks impose on the economy. Overall, the findings indicate the supply-side shocks as the most important factors driving the economy, followed by the oil price shock and consequently by the demand-side factors.

4.2 Transmission mechanism of the oil price shocks

In this section, we present the channels of transition of the oil price shocks. The analysis depicts a complex interrelationship among these macroeconomic variables. Figure 6 displays the impulse responses of these variables after the oil price shocks. Following the shock, there is an initial depreciation of the exchange rate, reflecting the Dutch Disease hypothesis. The central bank shows concerns by adjusting the interest rate downwards to potentially prevent excessive currency appreciation.

Domestic output shows a positive response, likely driven by increased government spending from higher oil revenues, showing the Keynesian principles at work.

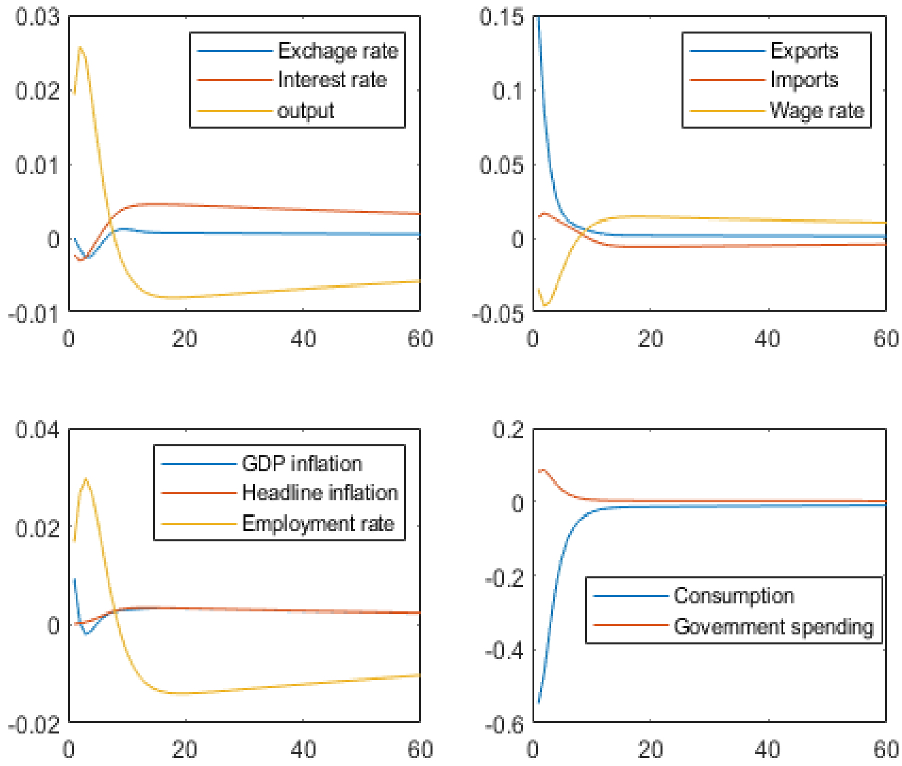

Figure 6: Impulse response functions of macroeconomic variables

With a positive response in exports and a negative response in imports, trade balances adjust reflecting the impact of currency fluctuations. The decrease in the nominal wages clearly indicates the challenges in the labor market. These dynamics also align with the principle of the Dutch Disease. GDP deflator increases due to expanded government spending and potential supply-side constraints, and the headline inflation, also rising in tandem with the GDP deflator, reflects upward pressure on overall price levels. Employment experiences a negative response after the initial rise on impact, indicating potential job losses due to currency appreciation and sectoral shifts. Consumption shows a substantial negative response on impact, indicating the dominance of the financially constrained households, the so-called non-Ricardian households, who could not smooth their consumption intertemporally. Meanwhile the frictions between the increase in government spending and private consumption clearly indicates a well-known trade-off under the crowding-out effect of government spending.

The channels of transmission are a complex interplay among the macroeconomic variables. These channels in Nigeria explain the intricate interactions between exchange rates, monetary policy, government spending, and various sectors. In line with the objective of this paper, oil price shocks are potentially influential on the Nigerian macroeconomic environment and can affect the standard of living of the people. Finding a more fundamental approach of counteracting their sphere of influences will go a long way in protecting the economy and the people at large. Our goal in this paper is to examine two of the ways this can be done.

4.3 Counterfactuals of OPFR and Refinery Development Project

We now present some counterfactuals of the two policy interventions underpinning the objectives of this study. Figure 7 presents the effects of terms of trade shocks on GDP under four hypothetical scenarios. The analysis of the impulse responses of GDP to terms of trade shocks under different scenarios reveals insights into the potential impacts of policy interventions on economic resilience. When oil refinery development and the oil price fiscal rule (OPFR) are jointly implemented, the immediate negative effects on GDP are mitigated to some extent. This underscores the importance of a comprehensive strategy that combines fiscal measures with long-term infrastructure projects. The sustained positive effects over time suggest that the synergistic approach of having both policies in place contributes to the economy's recovery and resilience against shocks.

On the other hand, when neither the oil refinery development project nor the OPFR is implemented, we observe prolonged negative effects, demonstrating the vulnerability of the economy to the terms of trade shocks. The absence of active policies leaves the economy less equipped to adapt and recover from terms of trade shocks. The counterfactual analysis further reveals that, with the implementation of the OPFR alone, the initial impact on GDP is less severe than when both are implemented, highlighting the moderating effect of the fiscal rule.

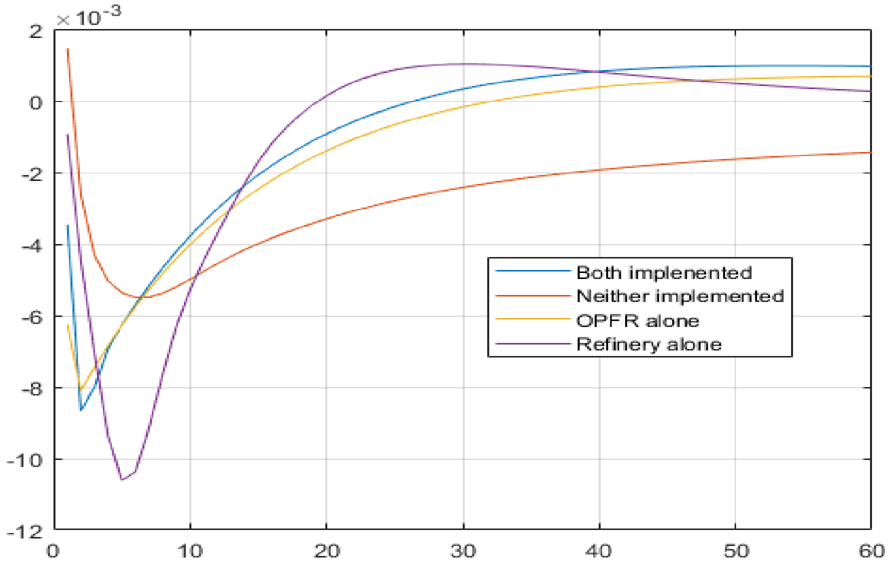

Figure 7: Effects of terms of trade shocks on GDP under four hypothetical cases

While the long-term effects indicate a stabilization and recovery, they also underscore the importance of combining fiscal measures with broader development initiatives for comprehensive economic resilience.

Similar to the cases of both or neither of the strategic policy interventions, focusing on oil refinery development alone exhibits a negative initial impact on GDP. However, the long-term effects reveal that infrastructure development contributes to economic recovery over time. This emphasizes the significance of diversification through strategic investments in key sectors. The findings collectively suggest that a phased approach, prioritizing immediate stabilization measures while planning for sustained infrastructure development project, such as the development of oil refineries, could offer a balanced strategy for safeguarding the economy from disruptive effects of shocks.

In examining the impulse responses of consumption to terms of trade shocks in different scenarios for Nigeria, several key findings emerge (Figure 8). Firstly, the scenario where oil refinery development and the oil price fiscal rule (OPFR) are implemented demonstrates the potential for a comprehensive strategy to mitigate the immediate negative effects on consumption.

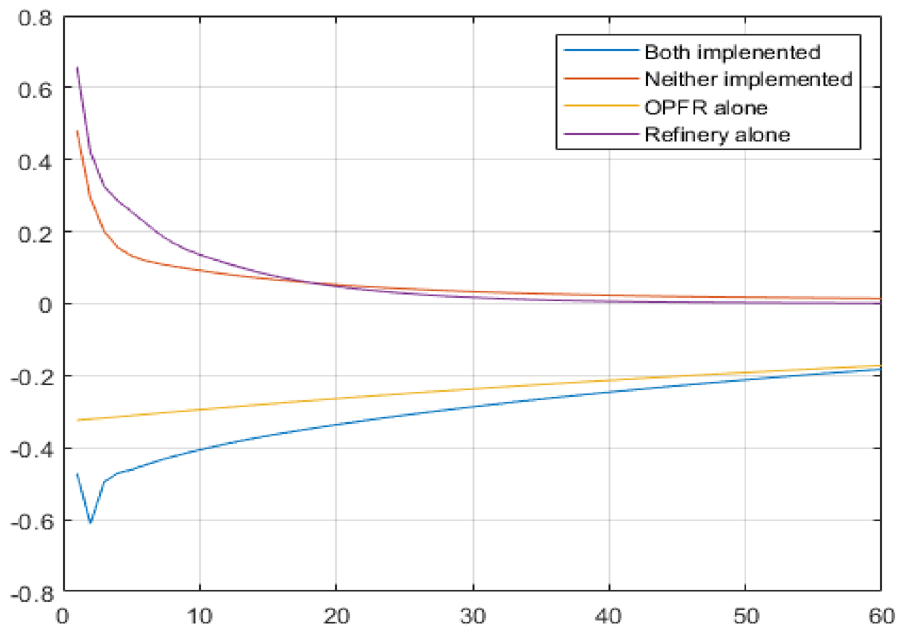

Figure 8: Effects of terms of trade shocks on consumption under four hypothetical cases

This aligns with the country's ongoing efforts to diversify its economy, particularly through investments in the oil and gas sector. The simultaneous implementation of the OPFR and oil refinery development would reflect the government's commitment to enhancing economic resilience by reducing dependence on oil exports and fostering domestic industries. The positive long-term effects emphasize the importance of sustained infrastructure development for economic diversification and consumption stability.

When neither the oil refinery development nor the OPFR is an option, we find the vulnerability of consumption to prolonged negative effects. This finding underscores the risks associated with a lack of proactive policy interventions, especially in a country like Nigeria that is heavily reliant on oil exports. Nigeria's historical economic challenges, marked by susceptibility to oil price fluctuations, support the notion that a passive stance on policy could lead to prolonged adverse effects on consumption. The absence of a comprehensive strategy is antithetical to nation's current economic diversification agenda, which aims to reduce vulnerability to external shocks.

With only the OPFR implemented, we are presented with mixed findings depending on the horizons. While the immediate negative effects on consumption are moderated compared to the other first two scenarios, the long-term recovery is slower. In Nigeria's context, this finding points to the fact that the OPFR, while effective in stabilizing short-term fiscal dynamics, may not be sufficient on its own to address the structural challenges hindering sustained economic growth. Nigeria's experience suggests that a singular focus on fiscal rules, without concurrent investments in critical infrastructure and economic diversification, may not yield optimal results in the long-run.

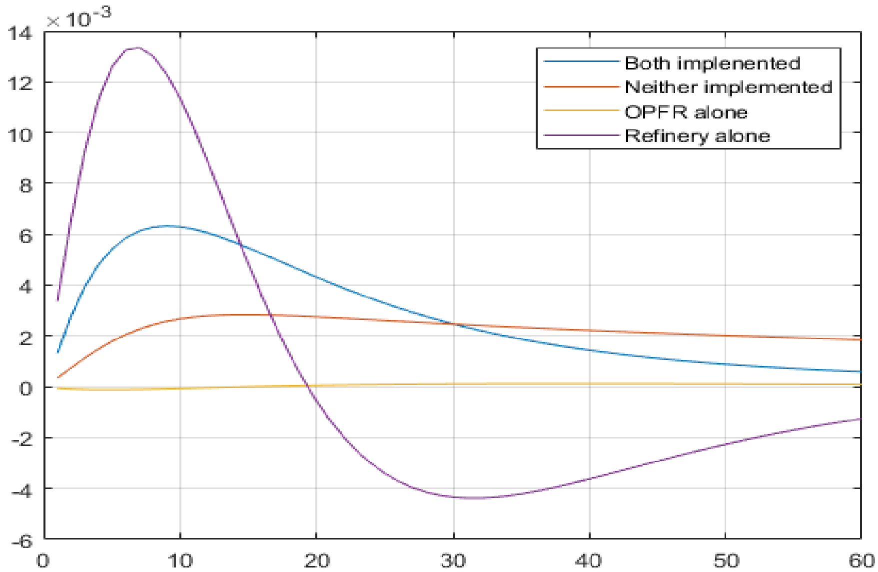

Figure 9: Effects of terms of trade shocks on investment under four hypothetical cases

Focusing on oil refinery development alone, we observe that both immediate and long-term positive effects on consumption. This aligns with Nigeria's ongoing efforts to boost local refining capacity and reduce dependency on imported petroleum products. The positive long-term effects may be attributed to the potential job creation, increased industrial activity, and reduced reliance on foreign markets. However, the negative immediate impact suggests that the benefits of oil refinery development may take time to materialize. Marked by the need for industrialization and reduced reliance on imports, the peculiarity of Nigeria supports the rationale for prioritizing oil refinery development as part of a broader economic transformation agenda.

In Figure 9, we present the responses of private investment to the terms of trade shocks under the four hypothetical cases under consideration, offering valuable intuitions into the potential effects of policy interventions in Nigeria. The simultaneous implementation of oil refinery development and the OPFR generates an initial positive response, indicative of the initial short-term confidence. However, the diminishing positive impact over time raises questions about the sustainability of these policies in the long run. While the OPFR may provide immediate stability, the long-term effects may require additional measures. The absence of specific interventions results in a gradual and sustained increase in investment over time. This scenario highlights the resilience of the economy in responding positively to terms of trade shocks without the need for immediate policy interventions. It suggests that a hands-off approach could lead to steady economic growth, but policymakers must carefully monitor potential vulnerabilities. The implementation of the OPFR alone is suggestive of a pattern similar to engaging both strategies, with an initial positive response followed by a gradual decline. This finding underscores the importance of comprehensive policies that go beyond fiscal rules. While the OPFR can contribute to short-term stability, its effectiveness in driving long-term investment may be limited. Policymakers need to assess the need for complementary measures to sustain positive economic trends.

The finding that oil refinery development exhibits a positive short-term effect but turns negative in the long run suggests a complex dynamic between the immediate benefits of such a development and the potential challenges it may pose over time. In the short term, the positive impulse response can be attributed to the initial boost in economic activity associated with the implementation of the oil refinery development project. This may involve increased employment, infrastructure development, and overall economic stimulation. However, the subsequent long-term negative impulse response indicates that, as the oil refinery development progresses, it may introduce challenges or vulnerabilities that outweigh the initial positive impact. Several factors could contribute to this reversal. For instance, the construction phase of the refinery might boost short-term investment and economic activity, but once completed, the refinery's operation could lead to increased dependence on a specific sector. If global oil prices or demand for oil products decline, the economy could face challenges, resulting in a negative long-term impulse. The tendency for Nigeria to focus on one sector is perennial and this needs to be tackled. This is in addition to the burden of corruption that has pervaded the Nigerian oil industry. This too can cause a monstrous setback for the development of refinery projects.

These findings highlight the importance of a balanced and phased approach to policy implementation in Nigeria. While comprehensive strategies combining the OPFR, infrastructure development, and economic diversification yield the most immediate and sustained positive effects on consumption, the intricacies in individual scenarios provide valuable insights.

4.4 Historical decomposition of the real GDP growth

By decomposing the real GDP growth, we are poised to learn the evolution of drivers and contributors to business cycles in Nigeria. In Figure 10, we present the counterfactual case of both implementing the OPFR along with development of refinery capacity. It shows what the economy would have experienced had this been the case; and it is clearly shown that under this scenario, supply-side shocks would have dominated coupled with brief occasions of the external and oil price shocks. The hypothetical case illustrates the potency of the policy as largely demand-driven filtering out the oil price shocks.

The results shown in Figure 11 for the real GDP growth decomposition when only the OPFR is implemented indicate that only supply-side shock would have affected the economy had the policy been implemented. This finding indicates that the OPFR alone is strong enough to insulate the economy from external, demand-side and oil price shocks but not against the supply-side shocks. This calls for the need to understand that the infrastructural development towards the longer-term sectoral diversification can run independently of the short-term objective of isolating the economy from fluctuations as the OPFR alone can secure the economy against those that can impinge on the short-term demand-side disruptions.

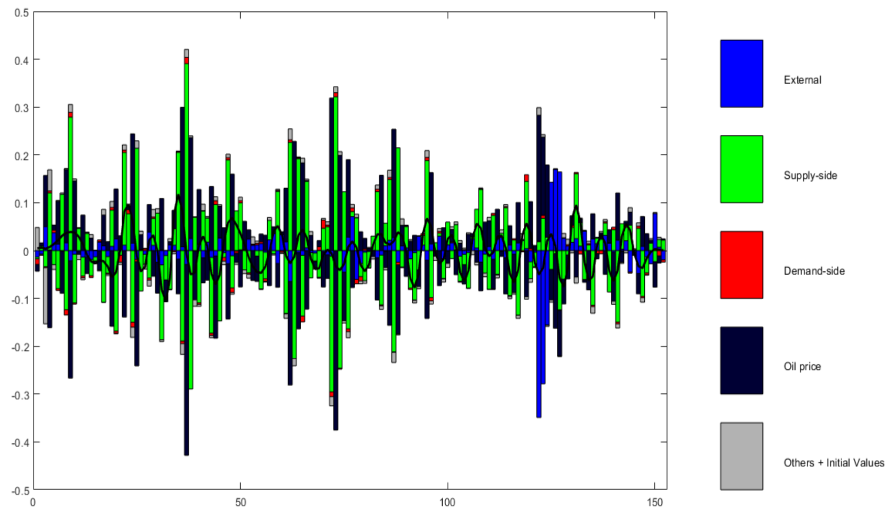

Figure 10: Historical decomposition of real GDP (both OPFR and Refinery Development)

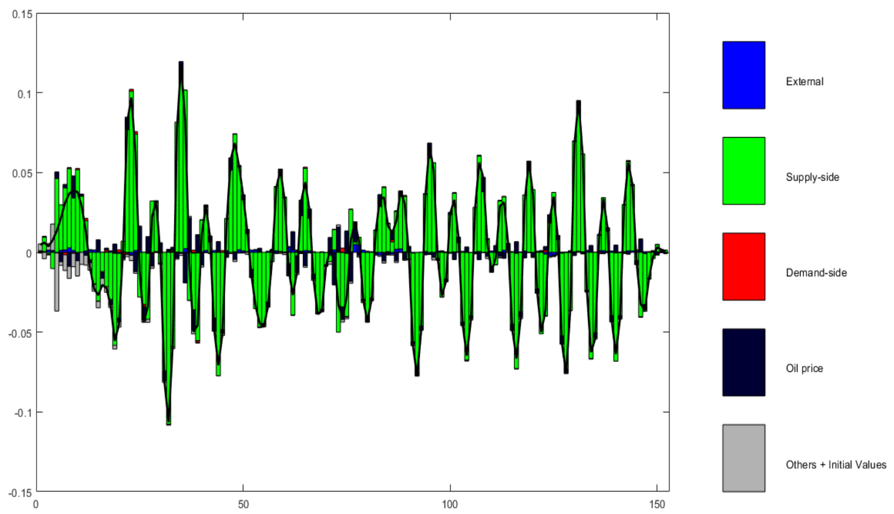

Figure 11: Historical decomposition of real GDP (under OPFR)

The same is not observed when only the refinery development project is implemented without paying attention to the short-term fluctuations in the demand. As can be seen from Figure 12, developing the refinery alone, which is a long-term infrastructural project, is unable to cater for the short-term fluctuations. Indeed, under this counterfactual, the economy is at the mercy of all the shocks and even the demand shock that spirals out of control in the early period. Again, this finding is indicative that the refinery development is a long-term objective and should not be taken as a solution to protecting the economy from the fluctuations especially in the short-term. These scenarios illustrate the need for policy coordination between policies that aim at the short-term gains and those that aim at long-term gains. While the development of oil refinery capacity is a strategic goal for securing the independence, particularly oil price related, it must be borne in mind that it may come at a greater short-run cost.

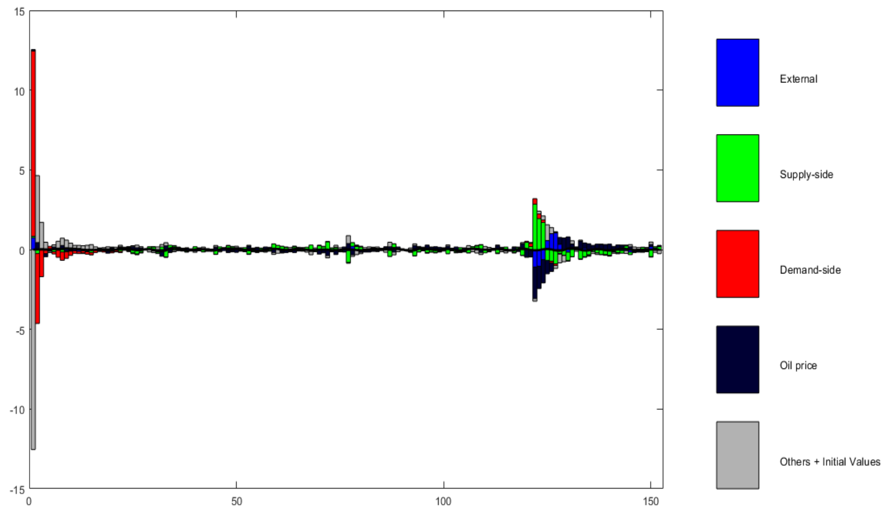

Figure 12: Historical decomposition of real GDP (under refinery development)

4.5 Welfare Implication of the OPFR and Refinery Development

The welfare losses in consumption under three scenarios against the no intervention baseline are presented in Table 3. In the computation, W^* represents the baseline welfare of no intervention. The computation reveals that developing oil refinery alone without combining it with the fiscal policy that stems the short-term impact of the policy will result in a huge welfare loss. As can be seen in the table, compared with the benchmark of no intervention at all, the implementation of refinery development can really devastate the welfare of the people. On the other hand, the OPFR alone without coupling it with refinery development results in welfare gain even though it is marginal (0.04 percent gain) while the combined strategy of the OPFR and refinery development results in welfare gain of around 0.04 percent as well. This analysis ensures that there must be phased implementation in implementing strategic diversification of the economy particularly when large-scale capital-intensive programmes are involved. Policy coordination is imperative to safeguard the people. In particular, pursuing the long-term project should not be at the detriments of the short-term pro-poor policies and all efforts are needed to control the short-term disruptions

Table 3: Welfare Loss of Each of the Programmes Against No Intervention

Both Interventions	OPFR Only	Refinery Development Only
-0.042 percent	-0.04 percent	56 percent

The welfare loss is computed as consumption loss κ given by $\kappa = (\exp((1-\beta)(W^* - W)) - 1) \times 100$.

If we compare this result with the historical decomposition findings, it is immediately clear that the OPFR alone is able to stem all other shocks except the supply side. The supply-side shock alone drives the economy. This result is suggestive of the efficacy of OPFR not only as a potent strategy to ameliorate the effects associated with demand, external and oil price shocks.

Who then bears this welfare loss most? While this is hard to tell, our guess is that the Ricardian family with the exposure to credit and financial resources to stave off shocks is able to gain from the implementing full scale refinery project as it is able to smooth out or take advantage of the prevailing economic condition to consume more rather than less. They save more when prosperity benefits them and consume more when the economy is in lull. This contrasts with the response of the non-Ricardian family whose consumption either fluctuates wildly or allowed to decline drastically on impact.

5. Conclusion

The study investigated the roles played by the oil price fiscal rule and the development of domestic oil refineries as alternative strategies to curtail the effects of external shocks on the Nigerian economy. To carry out this objective, a DSGE model has been built which accounts for different sectors of the Nigerian economy. The model is calibrated using data on macroeconomic variables as well as the variables for the foreign economy between the period January 2010 and September 2022. We compared the impulse response functions of these macroeconomic variables to different shocks including those attributable to external sources under three scenarios. This exercise revealed the importance of building or revamping domestic oil refineries as this has implications for the ability of the economy to withstand the shocks especially those emanating from external sources.

To further investigate the roles of the oil price fiscal rule and the need for having functional oil refineries, the shock decomposition through the historical decomposition technique was carried out. This enables us to measure the sources of business cycles in Nigeria. We isolated the shocks into blocs: external shock, oil price shock, supply shock and the demand shock groups. The sources of business cycle in Nigeria are time-varying over the study period. But more importantly, the non-oil external sources of shocks are not significantly important under all the scenarios investigated. However, the oil-related external shocks have important implications for business cycles in Nigeria. Again, it was found that the need for functional domestic oil refineries is pronounced. The welfare loss in consumption equivalence indicates that huge loss can be incurred in pursuing infrastructural development alone without accommodating short to intermediate factors. In particular, the efficacy of the OPFR is clearly demonstrated as the strategy to smooth out fluctuations due to short run factors. Completing the refinery development, the OPFR leads to a drastic reduction in welfare loss, again illustrating the importance of temporal policy coordination.

References

Adebiyi, A., & Mordi, C., (2012). A dynamic stochastic general equilibrium (DSGE) model of oil price shocks and exchange rate pass-through to domestic inflation in Nigeria. EcoMod (no 3715).

Adolfson, M., Laséen S., Lindé J., & Villani M. (2008). Evaluating an estimated new Keynesian small open economy model. *Journal of Economic Dynamics and Control* 32(8) 2690-2721.

Alege, P.O. (2008). Macroeconomic policies and business cycles in Nigeria: 1970-2004. Ph.D. Thesis, Covenant University.

Allegret J.P. & Benkhodja M.T. (2015). External shocks and monetary policy in an oil exporting economy (Algeria), *Journal of Policy Modelling*, 37, 652-667.

Anderson, G., and Moore G. (1985). A linear algebraic procedure for solving linear perfect foresight models, *Economics Letters*, 17(3), 247-252.

Blanchard, O., & Khan, C. (1980). The solution of linear difference models with rational expectations, *Econometrica*, 48, 1305-1311.

Christoffel, K., Coenen G., & Warne A. (2008). The new area-wide model in the euro area: Specification and estimation results. Mimeo, ECB.

Cooper, J.C.B. (2003). Price elasticity of demand for crude oil: Estimates for 23 countries. *OPEC Review*, 27(1), 1-8.

Cuestas, J.C., & Tang, B., (2021). A Markov switching SVAR analysis on the relationship between exchange rate changes and stock returns in China, *International Journal of Emerging Markets*, 16(3) 625-642.

Galí, J., & Monacelli T. (2005). Monetary policy and exchange rate volatility in a small open economy, *Review of Economic Studies*, 72, 1165-1192.

Hein, E. (2023). Macroeconomics after Kalecki and Keynes: Post-Keynesian foundations, Edward Elgar Publishing Inc.

Hoover, K.D. (2010). Idealizing reduction: The micro foundations of macroeconomics. Erkenntnis 73, 329– 347 https://doi.org/10.1007/s10670-010-9235-1.

Klein, P. (2000). Using the generalized Schur form to solve a multivariate linear rational expectations model, *Journal of Economic Dynamics and Control*, 24, 1405-1423.

Lippi, M. (2021). Validating DSGE models with SVARs and high-dimensional dynamic factor models. *Econometric Theory*, 1st View, 1-19.

Liu X., Pagan A. R., & Robinson T. (2018). Critically assessing estimated DSGE models: A case study of a multi- sector model, *Economic Record*, 94(307), 349-371.

Loutia, A., Mellios C., & Andriosopoulos K. (2016). Do OPEC announcements influence oil prices? *Energy Policy*, 90, 262-272.

Lubik, T.A., & Schorfheide, F. (2005). A Bayesian look at new open economy macroeconomics. In: Mark, G., Rogoff, K., eds. NBER Macroeconomics Annual 2005. Cambridge, MA: MIT Press, 313-366.

Lucas, R.E. Jr. (1976). Econometric policy evaluation: A critique, Carnegie-Rochester Conference Series on *Public Policy*, 1, 19-46.

Oaikhenan, H.E., & Aigheyisi O.S. (2015). Factors explaining exchange rate volatility in Nigeria: Theory and empirical evidence. *Economic and Financial Review*, 53(2), 47-77.

Ojeyinka, T.A., & Yinusa D.O. (2021). External shocks and their transmission channels in Nigeria: A dynamic stochastic general equilibrium approach, *Global Journal of Emerging Market Economies* 15(1) https://doi.org/10.1177/09749101211067311.

Okonjo-Iweala, N., & Osofo-Kwaako, P. (2007). Nigeria's economic reform: progress and challenge, Working paper No 6, Brookings Global Economy and Development.

Oladunni S. (2019). External shocks and business cycle fluctuations in oil-exporting small open economies: The case of Nigeria, *CBN Journal of Applied Statistics*, 10(2) 38-70

Olayeni, O.R. (2009). A small open economy model for Nigeria: A BVARDSGE approach. Tech. rept. University Library of Munich, Germany.

Olayeni, O.R. (2012). Oil price shocks and Nigerian macroeconomy (1970-2008), Ph.D. Thesis, Obafemi Awolowo University, Ile-Ife.

Olayungbo, D.O. (2019). Effects of oil export revenue on economic growth in Nigeria: A time varying analysis of resource curse, *Resources Policy* 64, https://doi.org/10.1016/j.resourpol.2019.101469.

Omoshoro-Jones O.S. & Bonga-Bonga L. (2019). The emergence of regional business cycle in Africa—a reality or myth? A Bayesian dynamic factor model analysis, *The World Economy*, 43, 239-273.

Omotosho, B.S. (2020). Oil price shocks, fuel subsidies and macroeconomic (in)stability in Nigeria. http://dx.doi.org/10.2139/ssrn.3771007.

Omotosho, B.S. (2022). Oil price shocks and monetary policy in resource-rich economies: Does capital matter? *Journal of Economic Dynamics and Control*, 143, https://doi.org/10.1016/j.jedc.2022.104479.

Oyelami, L.O. & Olomola P. A. (2016). External shocks and macroeconomic responses in Nigeria: A global VAR approach, Cogent Economics and Finance 4: 1239317 http://dx.doi.org/10.1080/23322039.2016.1239317.

Pagan, A., & Robinson T. (2016). Investigating the relationship between DSGE and SVAR models. *NCER Working Paper Series*, Working Paper No 112.

Pagan, A.R., and Robinson T. (2014). Methods for assessing the impact of financial effects on business cycles in macroeconometric models, *Journal of Macroeconomics*, 41, 94-106.

Rasaki, M.G. (2017). A Bayesian estimation of DSGE model for the Nigerian economy. *Euro Economica* 36(2), 145-158.

Sims, C. (2002). Solving linear rational expectations models, *Computational Economics*, 20, 1-20.

Zubair, A. (2019). Multisector small open economy DSGE model for oil exporting countries: The case of Nigeria. PhD Thesis, Cardiff University.