

# Macroeconomic Policy Effectiveness and the Informal Economy in Nigeria: A DSGE Approach

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Received: June 7, 2020

Accepted: July 19, 2020

Online Published: October 8, 2020

doi:10.5430/rwe.v11n6p51

URL: <https://doi.org/10.5430/rwe.v11n6p51>

## Abstract

Evaluating the approach and conduct of macroeconomic policy is crucial towards the provision of effective economic policies that addresses business cycles. However, to properly evaluate the effectiveness of macroeconomic policies, there is the need to pay attention to the structure of the economy. In Nigeria, there is a particular case for the introduction of informality in macroeconomic models. Hence, this study presents a New Keynesian Dynamic Stochastic General Equilibrium (DSGE) Model featuring an informal sector in order to understand how the presence of informality affects the effectiveness of macroeconomic policies in Nigeria. The Bayesian estimation of the DSGE model provides evidence that the informal economy tends to play a buffer role or an absorbing role in reducing the effectiveness of a monetary policy shock in contracting output in comparison to an economy without informality. Therefore, this study recommends that with the aim of limiting the role of the informal economy towards absorbing some of the effects of shocks to the domestic economy, the government needs to implement market-friendly policies that would help merge the informal economy with the formal economy.

**Keywords:** DSGE, informal economy, Bayesian estimation

## 1. Introduction

Macroeconomic policy effectiveness is often tied to its ability to achieve the desired goals of sustained economic growth, price stability and balance of payments equilibrium. Furthermore, they are used as a stabilisation instruments in the advent of business cycles. In Nigeria, the negative growth rate of the Gross Domestic Product (GDP) from 2016Q1 to 2017Q1 made it the longest ever economic recession in the country since the 1980s (National Bureau of Statistics - NBS, 2018). This economic imbalance has prompted questions concerning the macroeconomic management of Nigeria in terms of the effectiveness of macroeconomic policies implemented by the Central Bank of Nigeria (CBN) and the Federal Government of Nigeria towards stabilising the economy.

In particular, when comparing the actual growth rate of the GDP to the targeted growth rate by the CBN, it can be clearly seen that monetary policy has been relatively ineffective in meeting its target in Nigeria. From 1995 to 2017, the actual growth of GDP was largely below its target by at least 200 basis points in 10 years (CBN, 2017). Bird (2001) asserts that for macroeconomic policies to be effective, there is the need for emphasis to be placed on its conduct and the approach taken by policymakers. On the one hand, the conduct of macroeconomic policy focuses on the tools of macroeconomic management, fiscal and monetary policy. On the other hand, the approach of macroeconomic policy follows the development of macroeconomic models guided by economic theory and principles (Bird, 2001). The purpose is to develop macroeconomic models that are able to reflect the complex interactions that exist between different economic agents.

According to Ahmed, Ahmed, Pasha, Khan and Rehman (2012), one notable macroeconomic model that has gained wide attention by policymakers for conducting macroeconomic policy is the New-Keynesian model, otherwise referred to as the Dynamic Stochastic General Equilibrium Model (DSGE). The New-Keynesian approach of macroeconomic policy provided an extension to the Real Business Cycle (RBC) model by including rigidity in prices and wages, nominal shocks and monopolistic competition. However, it is important to note that the application of these DSGE models for a developing economy like Nigeria requires a modification from the standard model to meet the peculiar characteristics of developing economies.

Lahcen (2014), indicates that some of these characteristics include a small open economy susceptible to external shocks; weak financial markets; weak economic and political institutions; and a large informal economy. Therefore, the development of a DSGE model without an adjustment for some of these unique characteristics can lead to misleading inferences. Among these characteristics, the case of an informal economy is important for the macroeconomic approach for Nigeria. This is because the Nigerian informal economy is acknowledged to be one of the largest in Sub-Saharan Africa, accounting for a significant share of employment in the economy. According to Internal Labour Organisation - ILO (2018), informal employment as a percentage of total employment in Nigeria was estimated at about 92.9 percent.

Based on the preceding background, it is clear that in determining the approach of macroeconomic policy in Nigeria, the structure of the economy characterised by a large informal economy should also be taken into consideration given its importance in providing employment opportunities. Hence, this paper argues that the informal economy plays a significant role in the effectiveness of macroeconomic policies in Nigeria. Therefore, it can be said that the effectiveness of macroeconomic policies in Nigeria is indirectly related to the size of the informal economy. However, majority of the studies presenting macroeconomic models for Nigeria fail to account for the role of the informal economy (CBN, 2010; CBN, 2013; and Olofin et al., 2017). This study attempts to bridge this gap by evaluating how the presence of an informal economy influences macroeconomic aggregates in a DSGE model for Nigeria. The rest of this paper is as structured as follows: Section 2 presents a review of the literature pertaining to the DSGE models and the informal economy; Section 3 discusses the methodology of the study; Section 4 presents the results and discussion of findings; and Section 5 highlights the conclusion of the study.

## 2. Literature Review

This section documents relevant empirical literature across Europe, Latin America and Africa focusing on how dual labour markets in a DSGE model influences macroeconomic aggregates. In order to examine the effect monetary policy shocks, have on informal economic activities in the United Kingdom, Kolev and Morales (2005) develop a two-sector monetary business cycle model featuring a formal and an informal sector. The calibration result of the model reflected the central assumptions of their model as the informal and formal sector responds differently in the advent of monetary policy shocks. In particular, a negative monetary shock causes a fall in the level of output in the formal sector, thereby inducing loss of jobs and creating a substitution effect of labour from the formal sector to the informal sector. Similarly, Cesaroni (2017) constructs a two-sector DSGE model featuring a formal and informal sector to investigate the optimal long run rate of inflation for an economy with a considerable size of informality. The optimal level of inflation is defined as the one that maximises the household's utility. The model was calibrated with data for Lithuania and the results showed that the tax rate is an important determinant in influencing the optimal rate of inflation and that the optimal long run inflation is determined by the kind of tax rate introduced.

Antunes and Cavalcanti (2007) presented a general equilibrium model to assess whether informality hinders the growth and development of an economy. In particular, whether the variations in the informal sector and GDP per capita can be linked to regulations and enforcement costs. The model was calibrated for the United States economy and then forecasts were made based on the data for Peru. The results provided evidence regulation and enforcement costs explain the differences in the informal sector and GDP per capita. In a similar study to Antunes and Cavalcanti (2007), Charlot, Malherbet and Terra (2015), investigated how changes in regulation and fiscal policies affect informality, wage inequality and unemployment for the Brazilian economy under individual and collective bargaining. The study finds out that product market regulation represented by changes in informal sector entry costs actually reduces the level of unemployment, wage inequality and informality. Examining the results obtained from changes in fiscal policies indicated by lowering taxes to the formal sector, it was witnessed that while it reduces informality, lowering taxes actually leads to higher wages and inequality, thereby causing the level of informal sector activities to rise.

Likewise, by developing a DSGE model, Botero, Vargas, Hurtado and Franco (2014) were able to evaluate how informal employment and income distribution respond to various tax policies, such as decrease in public expenditure, increasing social security contribution by companies, and increasing taxes on capital and labour in Columbia. The simulated results of the model showed that an increase in taxes on the contribution of companies as well as on capital induces a higher degree of informality, whereas an increase in tax on labour causes the degree of informality to decrease. This implies that higher taxes levied on companies increases their cost of production which causes the size of the informal sector to increase. The results also showed that positive productivity shocks yield a positive response from firms in the formal sector, thereby reducing the degree of informality in the economy.

Recognising the need to develop business cycle models consistent with the features of developing countries, Ahmed, et al. (2012) developed an RBC model characterised by an informal sector in both the labour and product market for the Pakistan economy. The model comprised of household, firm, government and monetary agent. Three shocks were considered in the model, a technology shock, fiscal shock and an interest rate shock. Simulations with annual data were carried out and the results of the impulse response analysis provided evidence that a positive technological shock to the formal sector leads to an increase in consumption, investment and total output, while inflation is seen to decline as wages increase. Positive shocks to government spending brought about a crowding-out effect on private investment. On the other hand, positive shocks to interest rate caused output, investment, wages and labour hours to decline.

Senbeta (2013) developed a DSGE model including a formal labour market characterised by higher levels of wage rate and job search frictions, and also an informal labour market exemplified by lower wages and less frictions to answer how macroeconomic variables in a typical Sub-Saharan African country responds to both internal (domestic) and external shocks. The model was built on the work of Gali and Monacelli (2005), and the impulse response analysis showed that positive shocks to foreign income increased domestic consumption and output, but the effect fades out overtime. Foreign inflation shock was seen to have an initial positive effect on output and consumption, while employment and domestic inflation seemed to respond negatively. On the other hand, positive productivity shocks to the formal and informal sector were found to cause output in both sectors to decline contrary to the theoretical literature. However, the model designed in a simple form as it excluded the role of a fiscal agent.

Lahcen (2014) applied a DSGE model featuring informality in the labour and product market to ascertain the response of key macroeconomic aggregates under a flexible exchange rate regime system for Morocco in the advent of some domestic and external shocks. The DSGE model was estimated using quarterly data and the Bayesian technique. The major findings from the impulse response analysis showed that in the advent of monetary policy shocks, the informal sector does not alter the behaviour of key macroeconomic variables in the economy. Similar results were also obtained in the presence of a foreign demand shock and imported inflation shock. In terms of optimal monetary policy, an aggressive stance is best suited with the monetary agent placing more weight on inflation in comparison to both output and exchange rate. Overall, the results pointed out that the informal economy in Morocco does not act as a shock-absorber in the presence of business cycles. However, the study left out fiscal agents in the model which as seen from the literature has an important role in influencing the dynamics of inflation.

In summary, the studies reviewed presented general equilibrium models incorporating an informal sector. The overall findings from the study suggest that the presence of an informal sector has a role in affecting macroeconomic policies. To some extent, we find evidence that the informal sector tends to amplify and, in some cases, provides a buffer role in the advent of shocks to an economy.

### 3. Methodology

The NK-DSGE model is decomposed into four optimising agents: household, firm, government and monetary agent. The informal sector is modelled in the labour and product market, where in the labour market, the household decides on how much labour to be supplied to the informal and formal firm. In the product market, the firms are categorised into an informal firm that produces non-tradable goods, while the formal firm produces tradable goods. The decision to model the informal firm as a non-tradable goods firm is based on the study of Matthew (2011) where the findings showed that informal firms in Nigeria are linked to the non-tradable sector.

#### A. Household

The Nigerian economy is inhabited by a representative household deriving utility from the consumption of goods and services; and leisure. The total time endowment of the representative household is normalised to one, such that the inter-temporal utility function is given as follows:

$$U(C_t, N_t) = E_t \sum_{t=0}^{\infty} \beta^t [U(\bar{C}_t, 1 - N_t)] \quad (1)$$

Where  $\beta^t \in [0,1]$  denotes the inter-temporal discount factor that reflects the household's choice overtime,  $E_t$  is the rational expectation operator,  $\bar{C}_t$  represents the household's consumption bundle of goods and services, and leisure is denoted by  $1 - N_t$ . Expressing Equation (1) further to account for the structural parameters, which is given as:

$$U(C_t, N_t) = E_t \sum_{t=0}^{\infty} \beta^t \left[ \frac{\bar{C}_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right] \quad (2)$$

Where  $\sigma$  indicates the inverse elasticity of substitution or the coefficient of the relative risk aversion of the household and  $\varphi$  denotes the inverse elasticity of labour supply. Furthermore, the household's consumption decision is a composite good comprising of tradable goods ( $C_{T,t}$ ) and non-tradable goods ( $C_{N,t}$ ). This implies that the resources of the household are shared towards consuming tradable and non-tradable goods defined by Dixit and Stiglitz (1977) Constant Elasticity of Substitution index shown as follows.

$$C_t = \left[ (1 - \gamma)^{\frac{1}{\alpha}} C_{T,t}^{\frac{\alpha-1}{\alpha}} + (\gamma)^{\frac{1}{\alpha}} C_{N,t}^{\frac{\alpha-1}{\alpha}} \right]^{\frac{\alpha}{\alpha-1}} \tag{3}$$

The household's share of tradable goods is defined by  $(1 - \gamma)$  and non-tradable goods is represented by  $(\gamma)$ . The elasticity of substitution between both goods is denoted by  $(\alpha)$ . The household is also assumed to have access to the financial market, such that the budget constraint of the household is defined by the wages received from labour ( $W_t N_t$ ), capital returns from investment ( $r_t^k K_t$ ), the profit earned from owning a firm ( $\Pi_t$ ), transfer payment received from the government ( $TP_t$ ) and the earnings from investing in a government bond ( $B_t$ ). This is represented as follows:

$$P_t C_t + P_t I_t + E_t(Q_{t,t+1} B_{t+1}) \leq W_t N_t + r_t^k K_t + \Pi_t + B_t + TP_t \tag{4}$$

Therefore, the optimisation problem of the household is to maximise his lifetime utility in equation (2) subject to the budget constraint in equation (4).

**The labour Supply Decision of the Household**

The labour supply decision of the household,  $N_t$ , is a combination of formal labour,  $N_t^F$ , and informal labour,  $N_t^I$ . A proportion of the household ( $\varsigma$ ) provides labour services to the formal firms (tradable) and the others  $(1 - \varsigma)$  offer their services to the informal firms (non-tradable). Therefore, the aggregate labour supply expressed as a CES index is given as:

$$N_t = \left[ \varsigma^{-\kappa} (N_t^F)^{1+\kappa} + (1 - \varsigma)^{-\kappa} (N_t^I)^{1+\kappa} \right]^{\frac{1}{1+\kappa}} \tag{5}$$

**B. Firms**

The firms are categorised into formal and informal firms. The formal firms produce tradable goods and services, while the informal firm produces only non-tradable goods and services.

**The Formal Sector: Tradable Firms**

Following Ahmed, et al. (2012), the representative tradable sector firm  $j \in [0,1]$  operating in the formal sector is assumed to be a monopolistic competitive firm using a Constant Returns to Scale (CRS) technology with labour and capital as the factor inputs. The production function of the firm is given as:

$$Y_{T,t}(j) = A_{T,t} N_{T,t}^{1-\beta}(j) K_{T,t}^{\beta}(j) \tag{6}$$

Where  $A_{T,t}$  denotes the total factor productivity of the firm,  $N_{T,t}(j)$  represents the labour input of the firm and  $K_{T,t}(j)$  indicates the capital input of the firm. Equation (6) is log-linearised as follows:

$$y_{T,t}(j) = a_{T,t} + (1 - \beta)n_{T,t}(j) + \beta k_{T,t}(j) \tag{7}$$

The total factor productivity ( $a_{T,t}$ ) is assumed to follow an AR(1) process, such that:

$$a_{T,t} = \rho_{a_T} a_{T,t-1} + \varepsilon_{T,t}^a \tag{8}$$

Where  $\varepsilon_{T,t}^a$  denotes the technological shock to the production process in the economy which is assumed to be normally distributed, has a mean value of zero and has a constant variance. The optimisation process of the firm is in two stages. The first stage is to minimise cost by determining the amount of labour and capital required to attain a certain level of output. This is given as:

$$Min C_t = \frac{W_{F,t} N_{T,t}}{P_{T,t}} + \frac{r_{T,t}^k K_{T,t}}{P_t} \tag{9}$$

Subject to the firm’s production function in Equation (6). The real wages and real rent on capital are denoted by  $w_t n_t$  and  $r_{T,t}^k k_t$ , respectively. The lagrangian function is represented as:

$$L = w_{T,t} n_{T,t} + r_{T,t}^k k_{T,t} + \lambda_t [Y_{T,t} - A_{T,t} N_{T,t}^{1-\beta} K_{T,t}^\beta] \tag{10}$$

The second stage of the firm is concerned with determining the optimal price for their goods and services that maximises profit. To do this, the firms are assumed to follow a Calvo (1983) staggered price-setting mechanism, where at each period of time, only  $1 - \theta_T$  fraction of randomly selected firms set optimally new prices, while the remaining fractions of firms leave the price unchanged. The profit maximisation process for a representative firm adjusting their price ( $P_{T,t}^*$ ) is shown as:

$$\pi = \text{Max } E_t \sum_{k=0}^{\infty} \theta_T^k E_t [Q_{t,t+k} Y_{T,t+k} (P_{T,t}^* - MC_{T,t+k})] \tag{11}$$

Subject to the firm’s demand function for their goods:

$$Y_{T,t+k} = \left( \frac{P_{T,t}^*}{P_{T,t+k}} \right)^{-\varepsilon} Y_{T,t+k} \tag{12}$$

**The Informal Sector: Non-Tradable Firms**

The non-tradable informal firm operates in a perfectly competitive market where labour is the only factor input and there is no capital and technology (total factor productivity). The production function of the firm is given as:

$$Y_{IG,t}(j) = \xi N_{IG,t}(j) \tag{13}$$

Where ( $\xi$ ) provides information on the productivity of informal labour. The profit maximisation problem of a representative informal firm is defined as:

$$L = w_{IG,t} n_{IG,t} + \lambda_t [Y_{IG,t} - \xi N_{IG,t}] \tag{14}$$

Where  $w_{IG,t} n_{IG,t}$  denotes real wages and the FOC with respect to labour gives:

$$\frac{\partial L}{\partial n_{IG,t}}: w_{IG,t} - \lambda_t [\xi] = 0 \tag{15}$$

$$\lambda_t = \frac{w_{IG,t}}{\xi} \tag{16}$$

The real marginal cost of the non-tradable informal firm is represented in equation (16).

**C. Monetary Authority**

The monetary authority, CBN, is assumed to adopt an interest rate feedback policy guided by the Taylor rule principle. Taylor (1993) opined that central banks should respond to deviations in inflation and output from their respective targets by altering the interest rate. The monetary policy for Nigeria adapts the Taylor rule and is given as:

$$\frac{R_t}{R} = \left[ \frac{R_{t-1}}{R} \right]^{\rho_R} \left[ \left( \frac{Y_t}{Y} \right)^{\theta_Y} \left( \frac{\pi_t}{\pi} \right)^{\phi_\pi} \right]^{1-\rho_R} \varepsilon_t^R \tag{17}$$

Where  $R_t$  and  $R_{t-1}$  denotes the nominal interest rate and the lagged nominal interest rate,  $Y_t$  represents output,  $\pi_t$  and  $\varepsilon_t^R$  denotes the inflation rate and innovation to monetary policy, respectively. Log-linearising equation (17) gives:

$$sr_t = \rho_r r_{t-1} + (1 - \rho_r) [\theta_y y_t + \phi_\pi \Delta \pi_t] + \varepsilon_t^r \tag{18}$$

Where  $\theta_y$  and  $\phi_\pi$  are the parameters measuring how the CBN responds to output and inflation.  $\rho_r$  measures the degree of interest rate smoothing, a higher value reduces the responsiveness to output and inflation.

**D. Fiscal Agent**

The fiscal agent, the Federal Government of Nigeria, is assumed to follow a rule governed by expenditure and taxation. The government earns revenue from issuing bonds ( $B_t$ ) and receiving taxes ( $TX_t$ ). The revenue earned is used to finance the purchase of goods ( $G_t$ ) and making transfer payments to households (Alege, Oye, Adu and Jolaade, 2019). The real flow budget constraint for the government is given as:

$$TX_t + B_t = G_t + TP_t + B_{t-1} \tag{19}$$

Government spending, tax revenue and bonds are all assumed to follow an AR(1) process given as:

$$g_t = \rho_g g_{t-1} + \varepsilon_t^g \quad (20)$$

$$tx_t = \rho_{tx} tx_{t-1} + \varepsilon_t^{tx} \quad (21)$$

$$b_t = \rho_b b_{t-1} + \varepsilon_t^b \quad (22)$$

## E. General Equilibrium

### Aggregate Demand: Goods Market

The market clearing condition for each good produced in the goods market by the formal (tradable goods) and informal (non-tradable goods) requires that the total output equals aggregate domestic demand (formal and informal), investment and government spending. The aggregate resource in the formal (tradable) sector is given as:

$$Y_{T,t} = C_{T,t} + I_t + G_t \quad (23)$$

The informal (non-tradable) sector's aggregate resource constraint is represented as:

$$Y_{N,t} = C_{N,t} \quad (24)$$

Therefore, the overall economy constraint incorporating the formal and informal output is defined in equation (25) as shown as:

$$Y_t = C_{T,t} + C_{N,t} + I_t + G_t \quad (25)$$

### Aggregate Supply: The New Keynesian Philips Curve (NKPC)

The New Keynesian Philips Curve for the formal tradable goods sector is represented as follows (Lahcen, 2014):

$$\pi_{T,t} = \beta E_t(\pi_{T,t+1}) + \lambda^T (mc_{T,t} - mc_T) \quad (26)$$

Where  $\lambda^T = \frac{(1-\theta_T)(1-\beta\theta_T)}{\theta_T}$

### Aggregation Rules

The aggregate output produced in the economy is a combination of tradable and non-tradable output. This is given as follows:

$$Y_t = (1 - \lambda)Y_{T,t} + \lambda Y_{N,t} \quad (27)$$

Similarly, the aggregate consumption is defined as a combination of formal (tradable) and informal (non-tradable) goods represented as follows:

$$C_t = (1 - \varpi)C_{N,t} + \varpi C_{T,t} \quad (28)$$

The aggregate formal labour market condition is defined as a combination of labour in the formal tradable sector and informal non-tradable workers. This is given as follows:

$$N_t = (1 - \chi)N_{T,t} + \chi N_{N,t} \quad (29)$$

## F. Exogenous Shocks Processes

This study considers three sources of exogenous shocks namely: a tradable formal firm productivity shock, monetary policy rate shock, and fiscal policy shock. The respective equation of these shocks are as follows:

$$\text{Tradable firm productivity shock: } a_{T,t} = \rho_{a_T} a_{T,t-1} + \varepsilon_{T,t}^a \quad (30)$$

$$\text{Monetary policy shock: } r_t = \rho_r r_{t-1} + \varepsilon_t^r \quad (31)$$

$$\text{Government spending shock: } g_t = \rho_g g_{t-1} + \varepsilon_t^g \quad (32)$$

### 3.1 Model Calibration

The parameters of the model are derived from empirical evidence concerning the estimation of DSGE models with a similar economic structure with Nigeria (Ahmed, et al., 2012; CBN, 2013; Lahcen, 2014; Oye, Alege and Olomola, 2018).

Table 1. The NK-DSGE prior values of the parameters

Symbol	Parameter Description	Distribution	Mean	Std.Dev
$\sigma$	Inverse elasticity of substitution	Normal	3.00	1.00
$\varphi$	Inverse elasticity of labour supply	Normal	1.50	0.10
$\alpha$	The share of capital in output	Normal	0.60	0.10
$\mu$	Elasticity of substitution between formal and informal goods	Normal	0.70	0.10
$\kappa$	Inverse elasticity of substitution between formal and informal labour	Normal	2.00	0.50
$\theta_T$	Calvo price stickiness for tradable firms	Beta	0.75	0.05
$\rho_{a_T}$	Productivity persistence for tradable firms	Beta	0.70	0.10
$\rho_r$	Productivity persistence for interest rate	Beta	0.70	0.10
$\rho_{tx}$	Productivity persistence for government bond	Beta	0.70	0.10
$\rho_g$	Productivity persistence for government spending	Beta	0.70	0.10
$\theta_y$	Taylor rule weight on output	Gamma	0.50	0.05
$\phi_\pi$	Taylor rule weight on inflation	Gamma	1.50	0.05
$\rho_r$	Interest rate smoothing	Beta	0.20	0.05
$\varepsilon_t^{aT}$	Productivity shock for tradable firms	Inverse Gamma	0.10	2.00
$\varepsilon_t^{r*}$	Productivity shock for interest rate	Inverse Gamma	0.10	2.00
$\varepsilon_t^{g*}$	Productivity shock for government spending	Inverse Gamma	0.10	2.00

Note: Std.Dev denotes standard deviation

The study considers three observable variables over the period 1991Q1 to 2018Q4: real GDP, informal GDP and inflation. The data for Real GDP and inflation are both sourced from CBN Statistical bulletin, while the informal GDP data is sourced from Dell'Anno and Adu (2020).

#### 4. Bayesian Estimation of the DSGE Model

##### 4.1 Estimation of the Parameters of the NK-DSGE Model

The study estimated thirteen parameters which are categorised into: five structural parameters; three policy parameters; two persistent parameters; and three shock parameters. The results are presented in Table 2 and from the structural parameters,  $\sigma$ , the estimated elasticity of intertemporal substitution between consumption and interest rate is estimated as 0.47. This parameter reflects the willingness of an individual to give up future consumption in anticipation for higher real interest rates. Given the estimated value for Nigeria at 0.47, it implies that the consumption pattern of individuals is less sensitive to changes in the real interest rate. In comparison to other studies, the result is similar to the study of Oye, Alege and Olomola (2018) where it was also discovered consumption is less sensitive to changes in the real interest rate in Nigeria.

The elasticity of substitution between formal and informal labour ( $\kappa$ ) represents the degree to which formal labour can be substituted for informal labour in the production process for goods and services. The posterior mean estimated value is given as 0.32, indicates that formal and informal labour are not good substitutes for each other. The result obtained is similar to the study of Lahcen (2014) for Morocco, in which the study noted that the formal and informal labour are hardly substitutable. Examining the estimated Calvo parameter ( $\theta_T$ ) at about 0.21, it indicates that about 21 percent of firms do not re-optimize their prices in a given quarter. This value is lower than the estimated value of Oye, Alege and Olomola (2018) given as 0.49, but slightly close to the 0.38 value derived by CBN (2013) for Nigeria.

The estimated policy parameters of the study focus on CBN's reaction to changes in output and inflation. A Taylor rule monetary policy function was estimated and the results indicate that the weight on output ( $\theta_y$ ) and inflation ( $\theta_\pi$ ) are 0.51 and 1.48, respectively. These estimated values imply that the CBN places more priority on price stability than on pursuing economic growth. This result is in line with some of the recent monetary policy actions of the CBN. In 2016, when the Nigerian economy contracted by about 1.6 percent and inflation rose to 18.5 percent, the CBN responded by raising its policy rate by 300 basis points to 14 percent in order to combat inflationary pressures at the

expense of stimulating economic growth. The finding obtained is similar to the results of Adebisi and Mordi (2016), where the CBN was found to be primarily concerned with price stability. The estimated interest rate smoothing parameter is given as 0.84 and suggests the persistence, where the previous interest rate is a determinant for the current or future interest rate.

The persistent parameters of the study are assumed to follow an autoregressive model of order one, and are also expected to fall within the range of zero to one. A parameter value closer to zero indicates non-persistence, while a value closer to one is interpreted as a persistent parameter. From the estimated results, the findings show that the posterior mean value for productivity shocks in the tradable formal sector and government spending is about 0.81 and 0.72, respectively. These values are similar to the result of Oye, Alege and Olomola (2018) in Nigeria; Ahmed et al., (2013) in Pakistan; and Lahcen (2014) for Morocco. Therefore, the results suggest that the Nigerian economy takes a longer time to return to its equilibrium state in the advent of an unexpected shock.

The posterior estimates of the shock parameters provide an indication of the extent of volatility of the shocks. Three shocks were considered in the model: a tradable formal firm productivity shock; a monetary policy shock; and a fiscal policy shock. The estimated posterior values are given as 0.02 for each of the shocks, which is slightly above the specified prior values by about 100 percent.

Table 2. Parameter estimates

Parameter		Prior	Prior	Posterior	90%	Confidence
Symbol	Description	Distribution	Mean	Mean	Interval	
$\sigma$	Inverse elasticity of intertemporal substitution	Normal	3.00	2.11	1.70	2.48
$\beta$	Share of capital in output	Beta	0.60	0.51	0.38	0.64
$\kappa$	Inverse elasticity of substitution between formal and informal labour	Normal	2.00	3.10	2.75	3.44
$\omega$	Fraction of households consuming formal goods	Normal	2.00	0.32	0.27	0.36
$\theta_r$	Calvo price parameter	Beta	0.50	0.21	0.13	0.26
$\theta_y$	Taylor rule weight on output	Gamma	0.50	0.51	0.31	0.65
$\phi_\pi$	Taylor rule weight on inflation	Gamma	1.50	1.48	1.41	1.55
$\rho_r$	Interest rate smoothing	Beta	0.80	0.84	0.78	0.89
$\rho_{aT}$	Productivity persistence for tradable/formal firms	Beta	0.70	0.81	0.74	0.87
$\rho_g$	Productivity persistence for government spending	Beta	0.70	0.72	0.72	0.74
$\varepsilon_t^{aT}$	Productivity shock for tradable/formal firms	Inverse Gamma	0.01	0.02	0.02	0.03
$\varepsilon_t^g$	Productivity shock for government spending	Inverse Gamma	0.01	0.02	0.01	0.02
$\varepsilon_t^r$	Productivity shock for interest rate	Inverse Gamma	0.01	0.02	0.02	0.03

Source: Researcher's estimation from MATLAB

#### 4.2 Bayesian Impulse Response Analysis

The main aim of this section is to assess whether the informal sector acts as a shock absorber or plays the role of a buffer in the advent of shocks to the Nigerian economy, which is central to the main argument of the study. Two models are estimated, a baseline model with informality and another model without informality. To neutralise the



presence of the informal sector and compare how the various shocks affects the economy without an informal sector, the share of the informality in the goods and labour market are set to zero. The evaluation of these models is based on the intuition that, if the informal economy acts a buffer in the advent of shocks to the economy, then it weakens the transmission mechanism of monetary policies (Castillo and Montoro, 2010; Lahcen, 2014). Hence, the CBN would have to pursue more aggressive policies in order to achieve the set targets.

As seen in Figure A1, the response of aggregate output to a contractionary monetary policy shock, an increase in the interest rate, is more evident in the economy with only formal markets (Figure A2). In the economy with dual labour markets, the presence of an informal sector reduces the impact of a monetary policy shock by about 33.33 percent. Hence, aggregate output contracts more in the economy with only formal markets. A key explanation for this finding is that in economies where a larger proportion of the economy is formal, the transmission mechanism of monetary policy shocks is much quicker and broadly felt across the economy. Therefore, in the case of a monetary policy shock, the study finds evidence that the informal economy plays a buffer role in reducing its effectiveness.

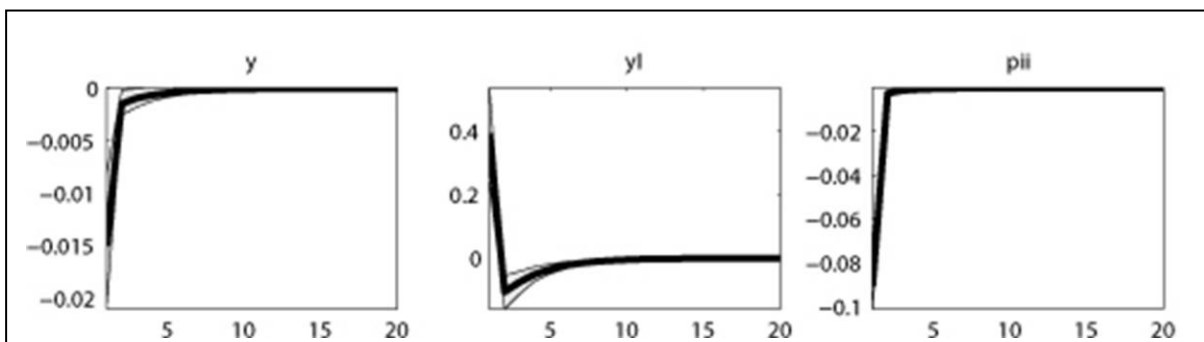


Figure A1. Impulse Response to Monetary Policy Shock (With Informality)

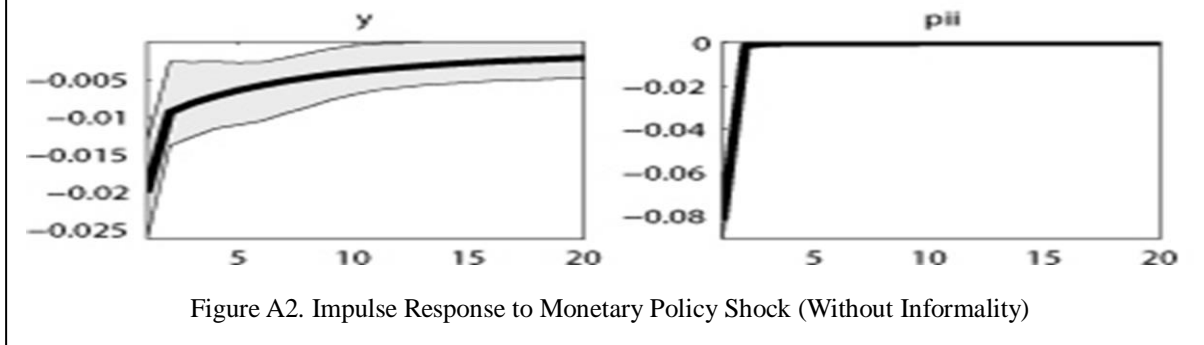


Figure A2. Impulse Response to Monetary Policy Shock (Without Informality)

Source: Researcher’s computation from MATLAB

Comparing Figure B1 to Figure B2, it can be seen that the response of output to a productivity shock is much higher in the economy with dual labour markets (formal and informal sector) in comparison to the economy without informality. This suggests that the presence of an informal economy amplifies the impact of a formal productivity shock on output. Castillo and Montoro (2010) explain that because of the availability of informal labour markets, formal firms are offered more flexibility when employing workers, such that they are able to offer more informal contracts to individuals seeking employment opportunities rather than offering formal contracts. This is because informal contracts are cheaper and reduce the cost of production of the formal firm, hence allowing them to maximising output at the minimum cost level. This assertion is evident in Nigeria where over a 10-year period, the growth in employment has come from the increase in part-time employment, rather than full-time employment (NBS, 2017). For a fiscal policy shock (Figure C1 and C2), an increase in government spending, the results indicate that the presence of an informal economy also amplifies the effect on aggregate output in comparison to the economy without informality.

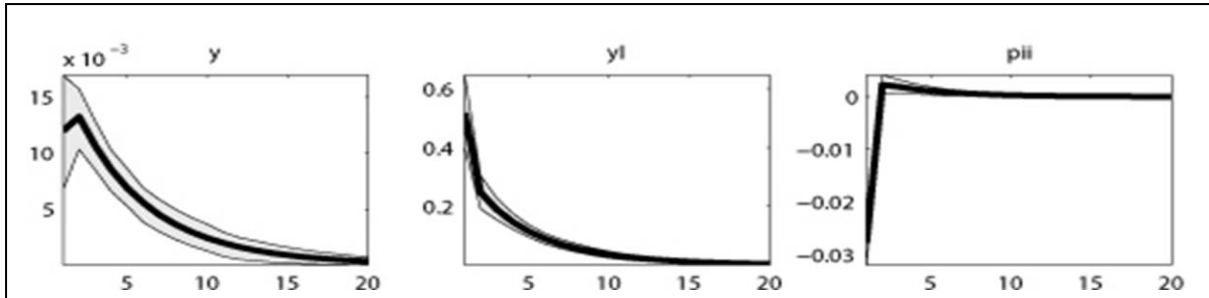


Figure B1. Impulse Response to Formal Productivity Shock (With Informality)

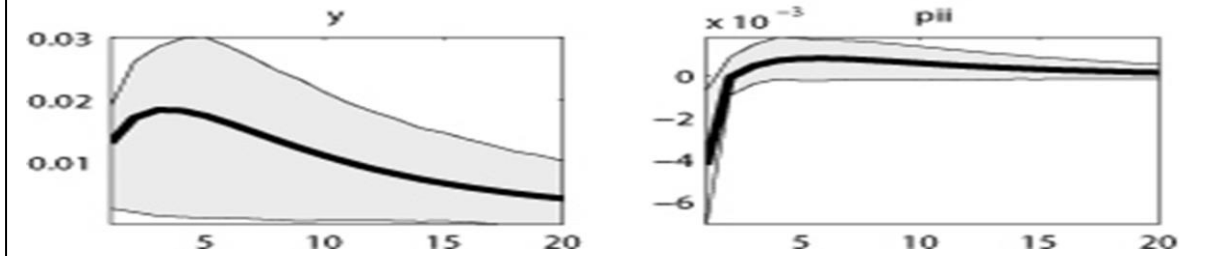


Figure B2. Impulse Response to Formal Productivity Shock (Without Informality)

Source: Researcher's computation from MATLAB

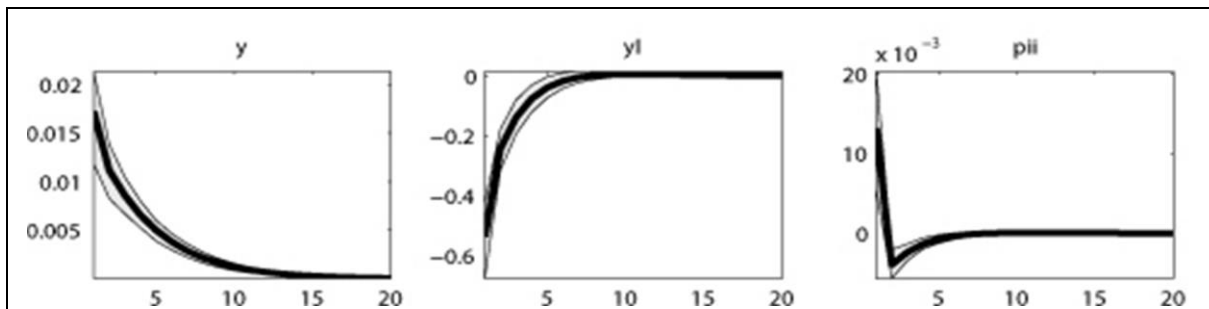


Figure C1. Impulse Response to Fiscal Policy Shock (With Informality)

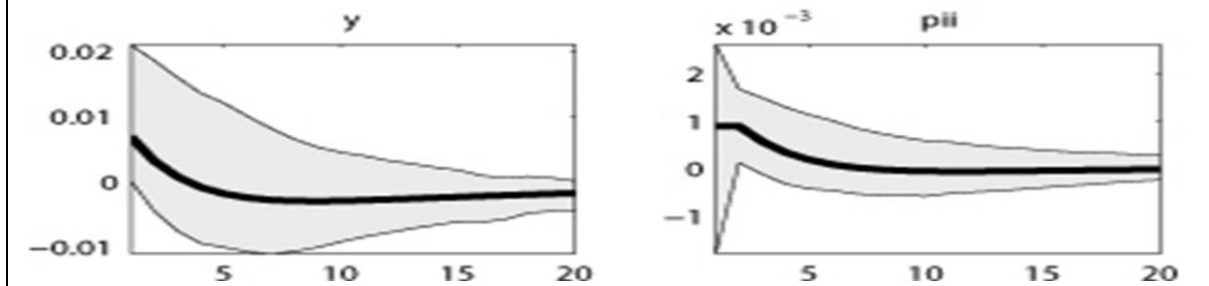


Figure C2. Impulse Response to Fiscal Policy Shock (Without Informality)

Source: Researcher's computation from MATLAB

## 5. Conclusion

The role of the informal economy in influencing macroeconomic policy decisions and key aggregates in the Nigerian economy has received little attention in the literature (CBN, 2010; CBN, 2013; Olofin et al., 2017; Oye, Alege and Olomola, 2018). This study attempted to bridge this gap by explicitly modelling the behaviour of the informal economy in the labour market and the market for goods and services in a NK-DSGE model. To the best of the researchers' knowledge, this is the first study that attempted to incorporate informality in a macroeconomic model for Nigeria

The results from the Bayesian estimation of the NK-DSGE model, in particular the Bayesian impulse response analysis has been able to show that macroeconomic policy tends to be relatively ineffective in an economy with a substantial degree of the informal economy in comparison to an economy without informality. The results showed that in Nigeria, the informal sector reduces the impact of a contractionary monetary policy shock by about 33.33 percent in comparison to an economy without an informal sector. This implies that for an economy with the presence of an informal sector, monetary authorities may have to pursue a more aggressive policy stance to achieve intended targets which might be at the detriment of the welfare position of the citizens.

Therefore, this study recommends that in order to limit the role of the informal economy in absorbing some of the effects of policy shocks to the domestic economy, the government needs to implement market-friendly policies that would help integrate the informal economy with the formal economy. These market-friendly policies are intended to encourage informal enterprises to register their businesses and pay taxes in the long run which will help boost the revenue of the government.

## Acknowledgements

The researchers will like to thank Covenant University Centre for Research, Innovation and Discovery (CUCRID) for her financial support.

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