Effectiveness of Monetary Policy Transmission Mechanism in an Implicit Inflation Targeting Regime: The Case of Nigeria.[‡]

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Abstract

The study examines the effectiveness of the monetary policy transmission mechanism in Nigeria by estimating a sticky-price DSGE model using the Bayesian estimation approach. This study is important given the implicit inflation targeting framework employed in the implementation of monetary policy in the country. The study employs quarterly data from 2000:1 to 2019:4 to estimate the two main categories of monetary policy frameworks, monetary aggregate and implicit inflation targeting, respectively. Data are sourced from World Development Indicator (online version). Empirical results show that the monetary policy transmission channels are effective in transmitting policy impulses to the economy within this regime. However, the monetary aggregate framework that is made explicit dampens the achievement of this framework. The study, therefore, concludes that inflation targeting should be made explicit in the country in other to reap the benefits embedded in the framework.

Keywords: Transmission Mechanism; Monetary Policy; DSGE; Inflation Targeting; Monetary Aggregates

JEL Classification Codes: C68, E58, E12

[‡] The datasets generated during and/or analyzed during the current study are available in the World Bank data repository.(https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.CD&country=)

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1. Introduction

The pursuance of price stability is a major goal of monetary policy in all economies irrespective of their level of development. As a result, monetary policy is often designed to influence the attainment of this objective. Over the years, monetary policy has been undertaken out under different regimes. However, each regime has been operated adopting different frameworks which affect the operating, intermediate, and ultimate targets. The monetary policy framework refers to the strategy monetary authority adopts in achieving its objectives. Central banks worldwide take into cognisance the continuous assessment and evaluation of policy framework as it gives room for adjustment to the changing structure and economic situation of each country. In recent years, the commonly used monetary policy regimes are monetary targeting and inflation targeting.

Monetary targeting involves targeting the growth of the money supply as a way of controlling inflation. The effectiveness of this approach depends on the extent to which the central bank of a country can control the money supply and how money growth is stably related to inflation. Shreds of evidence have shown that the use of monetary targeting recorded little success because the demand for money became unstable due to recent developments in the financial sector. Therefore, many countries embraced the use of inflation targeting. Inflation targeting entails the central bank committing to the conduct of monetary policy to achieve a publicly announced inflation target within a specified time. The regime uses the interest rate as the policy instrument to bring inflation within the bound. Inflation targeting provides a rule-like framework within which the central bank has the discretion to react to shocks. The beauty of this approach is that it combines elements of both rules and discretion in monetary policy. Inflation targeting could be explicit or implicit. It is explicit when the traditional interest rate is the only policy instrument, thereby making the interest rate channel more pronounced above all other monetary channels. In contrast, it is implicit when the interest rate is combined with another policy instrument and the interest rate channel is not pronounced (Can, Bocuoglu & Can, 2020). This concept implies interest rate works to complement the major policy instruments in achieving price stability objectives. New Zealand was the first country to adopt an inflation targeting regime in 1990. Several other countries embraced the policy afterwards. For instance, Canada started the policy in 1991, followed by the United Kingdom, Australia, and South Africa in 1992, 1993 and 2000 respectively. Also, the Central Bank of Turkey introduced implicit inflation targeting in 2002 but later implemented a full-fledged inflation targeting in 2006 (Akyurek, Kutan & Yilmazkuday, 2011).

Nigeria also adopted an inflation targeting regime in the year 2000. The country adopted this policy due to the failure of monetary targeting to stabilize the demand for money function. The instability of the demand for money function harmed the relationship between money and prices. In particular, it complicated the demand for money forecast in the country, hence the switch. The goal of this monetary policy is to maintain the inflation rate within the target of between 6 - 9 per cent (CBN, 2017). Nigeria adopted the implicit inflation targeting approach. Thus, the implementation of monetary policy in Nigeria follows both monetary targeting framework where the money supply is the policy instrument and a rule-like framework where the interest rate is the policy instrument. In this case, monetary targeting is explicit, while inflation targeting is implicit. Besides, the traditional interest rate channel is not pronounced. This approach is similar to Turkey's implicit inflation targeting of 2002. However, while Turkey experienced tremendous achievement in disinflation and policy environment, which led to the adoption of full-fledged inflation targeting in 2006; Nigeria's experience is different. Since the inception of inflation targeting in Nigeria, evidence has shown that inflation targeting arrangement still displays less achievement in keeping inflation within the target range. For instance, the inflation rate increased from 6.9 per cent in 2000 to 18.87 per cent in 2001. The figure decelerated to 17. 86 per cent in 2005. In 2012, the inflation rate in the country further declined to 12.21 per cent. The figure rose to 16.52 in 2017. As of 2019, the inflation rate was 11.39 (CBN 2019). The wide gap between the actual rate and the target bound casts serious doubts on the effectiveness of the inflation targeting monetary policy framework in Nigeria.

Akyurek *et al.* (2011) argued that an effective transmission mechanism is necessary for the inflation targeting framework to achieve its objectives. According to them, an effective channel of transmission is necessary to achieve further gains in disinflation and maintain price stability. Basically, the stronger the transmission channels and the better they are understood, the more effective the inflation targeting framework in achieving lower levels of inflation. Given the inability of the inflation targeting framework in Nigeria to achieve its objectives, it is imperative to examine the effectiveness of monetary policy transmission channels. Therefore, investigating how efficient is the monetary policy transmission mechanism, during the implicit inflation targeting regime, is the focus of this study. This is achieved using a more robust Dynamic Stochastic General Equilibrium (DSGE) method. The method is chosen based on its advantages when compared with other techniques used in policy analysis (Peiris and Saxegaard, 2007; Akinlo and Apanisile, 2018; Apanisile and Osinubi, 2020).

Giving the introductory aspect of the paper, the next section explains the findings of the existing studies on the effectiveness of the monetary policy transmission channels. Section 3 explains the methodological issues about DSGE as used in this study. Estimation of the models is implemented in section 4. Section 5 presents the findings and discusses their implications on the workings of inflation targeting in Nigeria. Section 6 concludes.

2. Literature Review

The importance of effective monetary policy transmission channels to the conduct of monetary policy cannot be overemphasized. The sound knowledge of the speed and the extent to which policy impulses are felt in an economy aid the decision of the apex bank. Several studies have examined this subject matter in the literature, and they concluded that the effectiveness of transmission channels varies under different conditions. For instance, Cevik and Teksoz (2013) examined the effectiveness of the monetary policy transmission channels in the Gulf Cooperation Council (GCC) countries using a Structural Vector Autoregressive model between 1990 and 2010. The results showed that interest rate and bank lending channels were effective in influencing output and prices. Fuddin (2014) discussed the effectiveness of the monetary transmission mechanism of monetary policy in Indonesia in the face of financial globalisation and structural changes. The study employed Vector Error Correction Model between 1961 and 2011. Results showed that the credit channel was effective in influencing output, while the interest rate was the most active channel in controlling inflation. In the same vein, Ripidian, Hayati, and Yusuf (2018) analysed the monetary mechanism effectiveness in managing inflation in Indonesia, given structural changes in the financial and banking sector using Vector Error Correction Model between 2005:1 and 2016:4. The study found that the best way to achieve price stability is by controlling people's expectations.

In another study conducted in Asia using eight emerging Asian economies, Jain-Chandra and Unsal (2014) employed the Generalised Dynamic Factor Model and Structural Vector Autoregression Model to investigate how large capital inflows affect the performance of the transmission mechanism of monetary policy within open economies between 2000 and 2010. Results showed that though the transmission mechanism was effective during the period under study as it worked through short-term interest rates; however, it was weaker during the periods of increase in capital inflows. Amar, Hachicha, Saadallah (2015) empirically investigated the effectiveness of the monetary transmission mechanisms in Saudi Arabia, where Islamic banking is in vogue. The study employed Structural VAR to analyze quarterly data between 1990 and 2013. It was discovered that the bank lending channel had a greater impact on non-oil private output when compared to inflation. Awad (2011) investigated the performance of Egypt's transmission mechanism of monetary policy, taking into consideration the susceptibility of the economy to external shocks. The study employed Structural VAR to analyse quarterly data between the first quarter of 1995 and the fourth quarter of 2007. The interest rate was deduced to be the dominant channel in the country. Chortareas, Magonis and Panagiotidis (2012) investigated whether the responses of inflation is asymmetric in the Euro-area economy using quantile regression. Results of the study showed that inflation response supports the hypothesis over the quantiles distribution. Patrick and Akanbi (2017) examined the relative performance of monetary mechanisms in Zambia during the inflation targeting regime using VAR and monthly data spanning between January 1993 and June 2015. The results showed that exchange rate and credit channels were the effective channels of monetary policy in the country. In Ukraine, Zholud, Lepushynskyi and Nikolaychuk (2019) analysed the effectiveness of the monetary transmission mechanisms after the Central Bank of Ukraine transitioned to an inflation-targeting regime. The study found the exchange rate channel as the most active channel of monetary transmission in the country. The interest rate channel was weak because of slow post-crisis recovery.

In Nigeria, Ogun and Akinlo (2010) discussed the effectiveness of the monetary policy transmission channels with an emphasis on the significance of the bank-credit channel given the adoption of deregulatory measures in the country. The study employed structural VAR with quarterly data spanning between Q1 of 1986 and Q4 of 2006. The study found that the bank-credit channel was ineffective during the period under review. Moreover, Otolorin and Akpan (2017) assessed the performance of the transmission mechanism of monetary policy in achieving low inflation during the period of recession using VAR. The study employed secondary data spanning from 1981 to 2015. The results showed that the interest rate was effective in controlling inflation but not output. To assess the effectiveness of monetary policy in the face of internal and external shocks, Akinlo and Apanisile (2019) decomposed total shocks into anticipated and unanticipated shocks. Four transmission channels were examined as a result of the structure of the financial system in Nigeria. The data spanned between 1986:1 and 2013:4. The DSGE results showed that unanticipated shock had short-run impacts on the transmission mechanism while anticipated had long-run impacts. Also, Apanisile and Osinubi (2020) examined the effectiveness of the monetary transmission mechanisms in the face of financial sector development in Nigeria between 2004:1 and 2016:4. The study concluded that while the credit channel was the best path in promoting output level in the country, people's expectations had the strongest ability to stabilize prices.

In conclusion, the review confirms the existence of several studies on the subject matter in the literature. Although studies have assessed the effectiveness of monetary policy transmission channels under different conditions, the performance of monetary transmission channels under implicit inflation targeting regime is missing in the literature, particularly in Nigerian. Besides, most studies on the subject matter in Nigeria employed only structural VAR. To address these gaps in the case of Nigeria, this study examines the effectiveness of the monetary policy transmission mechanisms under an implicit inflation targeting framework using DSGE methodology based on its superiority over SVAR.

3. Methodology

The New Keynesian model extends the existing framework of the neoclassical real business cycle using the basic characteristics of imperfect competition among firms and sticky prices. It promotes a framework that accounts for the relevance of monetary policy in explaining macroeconomic instability. The assumption of market imperfection is central to the workings of this framework. It also assumes that firms produce branded goods for which they set their prices. Furthermore, the workings of the model are based on sticky prices, which implies all the firms cannot adjust their prices at the same time. Key actors in the model are households that decide on the labour hours to supply, the amount of money to hold and invest in securities, business firms that hire workers' services and the government that coordinate the economic activities through policy implementation.

3.1 Household

The model starts with identical households that maximize utility function:

$$max_{C_{t,} N_t, \frac{M_t}{P_t}} E_0 \sum_{t=0}^{\infty} \beta^t \ U \left(C_{t,} N_t, \frac{M_t}{P_t}\right) \qquad (i)$$

E_o is the expectation operator condition; β represents the discount factor while $\frac{M_t}{P_t}$ represents the real money demand. The utility function is subjected to:

$$P_t C_t + Q_t B_t + M_t \leq + M_{t-1} B_{t-1} + W_t N_t + K_t \qquad (ii)$$

Where $C_t\ (i)$ is the amount of goods and services purchased by the household during the period t, $\forall\, i \in [0,1]$ and t equals 0, 1, 2, …., $P_t\ (i)$ represents the cost of good i, N_t is the labour hour supplied by household, W_t accounts for the reward of labour, B_t represents purchases of one-period bonds at a price Q_t, B_{t-1} is the lagged value of bonds purchased, M_t is money holding and K_t is a lump-sum component of income. $\in$ measures the price elasticity of demand. Obtaining the First Order Conditions of equations (i) and (ii) and re-arranging, the FOCs become:

$$1 = \beta(1 + i_t) E_t \left\{\frac{U_{c(t+1)}}{U_{c(t)}} \frac{P_t}{P_{t+1}}\right\} \qquad (iii)$$

$$- \frac{U_{N(t)}}{U_{C(t)}} = \frac{W_t}{P_t} \qquad (iv)$$

$$\frac{U_{M(t)}}{U_{C(t)}} = \frac{i_t}{1+i_t} \qquad (v)$$

The above equations $(iii, iv, and\ v)$ give the rational forward-looking household's decision. Equation (iii) is the Euler equation, equation (iv) is the labour-leisure choice and equation (v) represents the money demand.

Under the assumption of a period utility given by:

$$\mathrm{u}(C_t, N_t, M_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} + \frac{\left(\frac{M_t}{P_t}\right)^{1-v}}{1-v} \qquad (vi)$$

Additional utilities derived from an extra unit of good consumed, an extra unit of labour employed and an extra unit of money demanded become:

$$U_{Ct} = C_t^{-\sigma}$$
$$U_{Nt} = -N_t^{\varphi}$$
$$U_{Mt} = \left(\frac{M_t}{P_t}\right)^{-v}$$

By substituting the values of the additional utilities derived into equations (iii) – (iv), the equations become:

$$1 = \beta Q_t^{-1} E_t \left\{ \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\} \qquad (vii)$$

$$C_t^{\sigma} N_t^{\varphi} = \frac{W_t}{P_t} \qquad (viii)$$

$$\frac{M_t}{P_t} = C_t^{\frac{\sigma}{v}} \left(\frac{1+i_t}{i_t}\right)^{\frac{1}{v}} \qquad (ix)$$

Log- linearizing equations (vii) – (ix) give:

$$c_t = E_t c_{t+1} - \frac{1}{\sigma}(i_t - \rho - E_t \pi_{t+1}) \qquad (x)$$
$$w_t - p_t = \sigma c_t + \varphi n_t \qquad (xi)$$
$$m_t - p_t = c_t - \eta i_t \qquad (xii)$$

3.2 Firms

The economic system comprises a set of identical production units represented by $i \in [0,1]$. The production units possess a production technology represented

$$Y_{it} = A_t N_{it}^{1-\alpha} \qquad (xiii)$$

Y_{it} is the number of goods produced in the economy, A_t is the common techniques employed in the production, and N_{it} denotes the amount of labour force demanded by firms. One basic factor in the exposition of the New Keynesian model is the rigidity of prices. Firms in the model have every opportunity to review their prices, however, they are not sure of when such an opportunity will come. As a result, the probability of rigidity in price changes during a period is denoted as θ. This represents the proportion of firms that are victims of price rigidity. The rest $1-\theta$ can reset their prices as and when due. It is worthy of note that all firms operate under a similar elastic demand schedule having a price elasticity of $\in$, aggregate price level P_t and aggregate consumption index C_t. In addition, the dynamics of aggregate price function is given as:

$$\pi_t^{1-\epsilon} = \theta + (1-\theta)\left(\frac{P_t^*}{P_{t-1}}\right)^{1-\epsilon} \qquad (xiv)$$

$\pi_t \equiv \frac{P_t}{P_{t-1}}$ denotes the total rate of inflation and P_t^* represents the price of the optimising firm during the period t. Period t is defined as the period the affected firms are re-optimising their prices. Because all firms are faced with the same problem, they choose the same price. Therefore, the steady-state condition with zero inflation becomes π = 1. At steady-state, all prices are equal i.e. $P_t^* = P_{t-1} = P_t$. Log linearising the steady-state aggregate price index with zero inflation condition gives:

$$\pi_t = (1-\theta)(P_t^* - P_{t-1}) \qquad (xv)$$

The above equation (equation xv) implies the current inflation is the difference between the price of the re-optimising firms and the lag of the economy's average price. Thus, understanding the dynamics of inflation requires analysing factors influencing a firm's decision as regards price-setting. This is achieved by examining the price P_t^* of a re-optimising firm that gives the maximum profit value in the current period when the market price remains the same. The optimization problem becomes:

$$maxP_t^* \sum_{k=0}^{\infty} \theta^k E_t \left[Q_{t,t+k}\left(P_t^* Y_{t+k/t} - \varphi_{t+k}(Y_{t+k/t})\right)\right] \qquad (xvi)$$

Subject to :

$$Y_{t+\frac{k}{t}} = \left(\frac{P_t^*}{P_{t+k}}\right)^{-\epsilon} C_{t+k} \qquad (xvii)$$

Equation *xvii* is the demand constraints faced by every re-optimizing firm. The marginal equation (FOC) becomes:

$$\sum_{k=0}^{\infty} \theta^k E_t\left(Q_{t.t+k} Y_{t+k/t}\left[P_t^* - M\omega_{t+k/t}\right]\right) = 0 \qquad (xviii)$$

∀ k = 0,1,2,…….. , $Q_{t,t+k}$ denotes the stochastic discount factor for nominal payoffs, $\varphi_t(.)$ represents the cost relation and $Y_{t+k/t}$ is the output of a forward-looking firm that changes its price in the current period, θ^k represents the likelihood of a firm being stuck with the current price during any of the periods in K and M is the expected mark-up. The optimum price P_t^* is then defined as:

$$p_t^* = \mu + (1-\theta\beta) E_t \sum_{k=0}^{\infty} \theta^k \beta^k [mr_{t+k|t}^r + p_{t+k}] \qquad (xix)$$

The equilibrium condition required for market-clearing in the goods market is stated as:

$$Y_{it} = C_{it} \qquad (xx)$$

Total output produced by firms and offered for sale in the market is given as:

$$Y_t = \left(\int_0^1 Y_{it}^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon-1}{\epsilon}} \qquad (xxi)$$

Solving for (xx) in (xx1) produces:

$$Y_t = C_t$$

The logarithm of the above equation gives:

$$y_t = c_t \qquad (xxii)$$

The overall equilibrium condition in the goods market is depicted in equation (xxii). Besides, the market-clearing condition for the demand and supply of labour is given as:

$$N_t = \int_0^1 N_{it}\, di \qquad (xxiii)$$

Solving for N_{it} in equation ($xiii$) gives:

$$N_{it} = \left(\frac{Y_{it}}{A_t}\right)^{\frac{1}{1-\alpha}}. \qquad (xxiv)$$

Solving for equations ($xxii$) and ($xxiv$) in equation ($xiii$) and taking the logarithm of the result. The new equation ($xiii$) becomes:

$$y_t = a_t + (1-\alpha)n_t \qquad (xxv)$$

3.3 Monetary Authority

The apex bank acts as the agent of the government in controlling the amount of money in circulation through the implementation of different policies that are referred to as policy rules. Given the aim of this study, two different types of policy rules are considered. They are the Taylor-type interest rate rule and monetary aggregate rule. The Taylor-type uses interest rate as the policy instrument and it is presented as:

$$i_t = \alpha_1 i_{t-1} + \alpha_2 \pi_t + \alpha_3 \hat{y} + v_t \qquad (xxvi)$$

Where:

$i_t = short\ term\ interest\ rate$
$i_{t-1} = lag\ of\ short\ term\ interest\ rate$
$\pi_t = inflation\ rate$
$y_t = output\ gap$
$v_t = is\ the\ monetary\ shock$

The monetary aggregate rule, on the other hand, uses money supply as the policy instrument. It is also presented as:

$$M_t = \omega_1 M_{t-1} + \omega_2 \pi_t + \omega_3 \hat{y} + \gamma_t \qquad (xxvii)$$

Where:

$M_t = nominal\ money\ balance$
$M_{t-1} = lag\ of\ nominal\ money\ balance$
$\pi_t = inflation\ rate$
$y_t = output\ gap$
$\gamma_t = is\ the\ monetary\ shock$

3.4 Log-linearized model

Linearizing a system of non-linear equations removes computational complexity and allows easy estimation of such equations. To this end, equations derived in this study are linearized for easy estimation and the results are presented below:

$$y_t = E_t y_{t+1} - \sigma(i_t - E_t \pi_{t+1}) \qquad (xxviii)$$
$$\pi_t = \beta E_t(\pi_{t+1}) + k\check{y}_t \qquad (xxix)$$
$$i_t = \alpha_1 i_{t-1} + \alpha_2 \pi_t + \alpha_3 \hat{y} + v_t \qquad (xxx)$$
$$M_t = \omega_1 M_{t-1} + \omega_2 \pi_t + \omega_3 \hat{y} + \omega_4 e + \gamma_t \qquad (xxxi)$$

Equation (*xxviii*) is referred to as the forward-looking IS curve. The equation states that peoples expectation plays an important role in determining the level of output in a given period. It also defines future output value and interest rate as the determinant of output in the current period. According to the equation, the current value of output is the difference between the expected inflation rate and the nominal interest rate. In addition, the equation shows the linearized version of Euler's function that links the inter-temporal marginal rate of substitution of an optimizing household with its real interest rate. Equation (*xxix*) represents the NK Philip curve that describes the most favourable behaviour of the monopolistically competitive firm that is subjected to the cost of nominal price adjustment (Rotemberg, 1982) or determine the price following the Calvo (1983) random approach. The next equation (equation *xxx*) represents the Taylor-type interest rate rule developed by Taylor (1993). The equation shows how the apex bank tinker with the interest rate as the policy instrument to maintain price stability. The fourth equation is the money growth equation. It implies the monetary authority either increase or reduce the stock of money in the economy in response to changes in the inflation rate. From the equation, the stock of money is defined as a function of its lagged value, inflation, exchange rate, and output level. The four equations involve five variables, namely nominal money balance (M_t), output gap (y_t), inflation (π_t), nominal exchange rate (e_t), and nominal interest rate (i_t).

4. Empirical Analysis

Estimating the DSGE model could be a herculean task if the appropriate technique is not used. Several authors (Ajemian, 2013; Akinlo and Apanisile, 2019; Apanisile and Osinubi, 2020) have favoured Bayesian estimation techniques over all other available techniques. The preference for the Bayesian approach arises because of the identification problem and lack of precision that may be encountered when other techniques are used. The use of the Bayesian approach calls for choosing the initial values for some or all the coefficients to be estimated in the model. the approach is significant in resolving the problem of identification that is usually emanated in estimating DSGE equations. This process is called calibration. It involves the selection of fixed values which are seen as a way of enforcing a strict value called prior. More importantly, initial values are selected for parameters that define the equilibrium condition. This is because they become the basis for determining how informative the data is in the process of estimating the equations. This implies the coefficients (also known as the parameters) to be calibrated are those that are germane to attaining the equilibrium conditions. Furthermore, they must show the equilibrium condition for all the key parameters in the model, whether their reliable estimates already exist or not. This process allows the inclusion of priors, that is based on the theoretical knowledge, and the probability function through the priors selected for each coefficient in the model. the inclusion of both the prior and the probability function generate the posterior distribution that provides the basis for judging the suitability of the selected priors.

4.1 Data

The models were estimated using quarterly data between 2000Q1 to 2019Q4. The estimation involved eight variables such as output gap, nominal interest rate, domestic inflation rate, nominal exchange rate, nominal money balance, domestic credit to the private sector, and terms of trade. The output gap was obtained by detrending output using the Hodrick-Prescott filter and taking the natural logarithm (Ajilore and Ikhide, 2013; Apanisile and Ajilore, 2013; Akinlo and Apanisile, 2019; Apanisile and Osinubi, 2020). All other sources of noise are removed from the data. This is because the exercise is important for the stability of the model. To check the robustness of the model, the study considers periods 1995Q1 – 2019Q4 and 2005Q1 – 2019Q4. The two samples were considered because they covered the post-liberalization and the consolidation in the banking sector period in Nigeria.

4.2 Estimation Technique

The posterior density is defined by the Bayes' theorem as:

$$p(\emptyset|M_{1,}^{T}, Y_i) = \frac{L(\emptyset|M_1^T, Y_i)p(\emptyset|Y_i)}{p(M_1^T|Y_i)}\ , for\ i\ ranges\ from\ 1\ to\ 2$$

$\emptyset\ and\ M_1^T$ represent the entire coefficients of the model and the set of data respectively. L is the probability function. $p(\emptyset|Y_1)$ and $p(M_1^T|Y_1)$ represents the "prior density" and the "marginal data density conditional" on M_i. i represents the two models. Model 1 is for the monetary aggregate rule, while model 2 is for the inflation targeting rule. We constructed and evaluated $L(\emptyset|M_1^T, Y_i)$ using the Kalman filter and simulate the posterior kernel, $L(\emptyset|M_1^T, Y_i)p(\emptyset|Y_1)$, for the two models by "random-walk Metropolis-Hastings(MH) algorithm". This approach is a "Markov chain Monte Carlo (MCMC) method" commonly used in simulating DSGE models. The models are estimated using Dynare 4.3.3 and Matlab software.

To achieve the main purpose, which is investigating the performance of the channels of monetary policy actions during the implicit inflation targeting regime in Nigeria, the study developed and compared the Bayesian model for the two frameworks and the most favourable model was selected based on the Bayes factor. The Bayes factor is obtained by finding the ratio of the marginal densities of the two models. In addition, the impulse-response of the selected channels for the two models were generated. We also estimated $\log[p(M_1^T|Y_i)]$ using Geweke's (1999) approach, following Lubik and Schorfheide (2004), An and Schorfheide (2007), Traum and Yang (2011), and Li and Liu (2013).

4.3 Calibration

The calibration of coefficients to be estimated in a DSGE analysis is called priors. This reflects the understanding of economic theories by the researcher. It also reveals the belief of the researcher about the position of the structural parameters in the model. it is worthy of note that in reality, initial values (priors) of parameters are selected based on the theoretical knowledge and past values from the extant literature. Based on this, initial values are chosen based on economic theory, stylised facts and extant literature. in addition, facts from published studies with Bayesian estimation techniques are important in choosing initial values. Therefore, initial values for this study were selected from the works of Adebiyi and Mordi (2011), Mordi et. al (2013), Akinlo and Apanisile (2019), and Apanisile and Osinubi (2020). The selected initial values are depicted in tables 1and 2.

Table 1: Priors of the Estimated Parameters for Money Growth Rule (Model 1)

Parameter	Description	Density	Mean	Std Deviation
α_1	Parameter of Inflation expectation in the output gap equation.	beta	0.300	0.050
α_2	Parameter of nominal money balance in the output gap equation	beta	0.200	0.049
α_3	Parameter of the exchange rate in the output gap equation	beta	0.100	0.050
β_1	Constant	beta	0.990	0.060
β_2	Parameter of the output gap in the Philips curve equation	beta	0.125	0.052
β_3	Parameter of expected Inflation in the Philips curve equation	beta	0.230	0.050
β_4	Parameter of nominal money balance in the Philips curve equation	beta	0.260	0.051
β_5	Parameter of the exchange rate in the Philips curve equation	beta	0.150	0.050
φ_1	Parameter of the lag of money supply in the money supply equation	gamma	0.310	0.050
φ_2	Parameter of the output gap in the money supply equation	gamma	0.300	0.054
φ_3	Parameter of inflation the money supply equation	gamma	0.240	0.053
φ_4	Parameter of nominal money balance in the money supply equation	gamma	0.220	0.056
φ_5	Parameter of the exchange rate in the money supply equation	gamma	0.310	0.050
eps_w	Parameter of a shock to terms of trade	invg	0.063	0.0221
eps_x	Parameter of shock to aggregate demand	invg	0.488	0.0689
eps_u	Parameter of a shock to aggregate supply	invg	0.060	0.0110

Table 2: Priors of the Estimated Parameters for Inflation Targeting (Model 2)

Parameter	Description	Density	Mean	Std Deviation
α_1	Parameter of Inflation expectation in the output gap equation	beta	0.300	0.050
α_2	Parameter of interest rate in the output gap equation	beta	0.200	0.049
α_3	Parameter of the exchange rate in the output gap equation	beta	0.320	0.050
α_4	Parameter of domestic credit in the output gap equation	beta	0.300	0.050
β_1	Constant	beta	0.990	0.042
β_2	Parameter of the output gap in the Philips curve equation	beta	0.125	0.050
β_3	Parameter of interest rate in the Philips curve equation	beta	0.260	0.050
β_4	Parameter of the exchange rate in the Philips curve equation	beta	0.250	0.050
β_5	Parameter of domestic credit in the Philips curve equation	beta	0.310	0.050
φ_1	Parameter of the output gap in the Taylor's equation	gamma	0.300	0.050
φ_2	Parameter of inflation in the Taylor's equation	gamma	0.240	0.050
φ_3	Parameter of interest rate in the Taylor's equation	gamma	0.220	0.056
φ_4	Parameter of the exchange rate in Taylor's equation	gamma	0.300	0.050
eps_x	Parameter of shock to aggregate demand	invg	0.488	0.2032
eps_u	Parameter of a shock to aggregate supply	invg	0.060	0.0113
eps_w	Parameter of shock to terms of trade	invg	0.063	0.0934

The two models were simulated based on the calibration of the stochastic shocks. This process allows calibrating the identified shock processes in the model for simulation to take place. This becomes necessary because the simulation result is used to verify the existence of a unique solution for the model and also to simulate values for the dependent variables. The initial values selected for the shock processes are depicted in tables 1 and 2 for the two models. The estimated models are presented in appendix A. These values are presented in the .mod file for execution. We deduce from the simulation results that the solution exists and the values of the dependent variables were recorded. In addition, the simulation results are presented in Appendix B.

5. Discussion of Results

The Bayesian approach to estimating DSGE models produces an intractable posterior density. This density merges the prior and the likelihood in one result. For this study, the posterior density was produced using 10,000 draws from the random walk MH algorithm. Overall, a 77 data point was used from the total 80 available data point. This spanned through 2000Q4 to 2019Q4 for both models. For model 1, the money growth model, the log data density is -74.983519, while the log data density for model 2 (interest rate model) is -1.086288. Estimation results were reported in tables 3 and 4. The tables revealed other information about the results generated such as the distribution employed, the prior and the posterior means, standard deviation and the confidence interval for both the parameters and the shocks.

Table 3: Priors and Posterior of the Estimated Parameters for Model 1

Parameter	Density	Prior Mean	Posterior Mean	Standard Deviation	Confidence Interval at 90%	
α_1	beta	0.300	0.3004	0.050	0.2917	0.3094
α_2	beta	0.200	0.2006	0.050	0.1916	0.2094
α_3	beta	0.100	0.1000	0.050	0.0918	0.1077
β_1	beta	0.990	0.9906	0.050	0.9836	0.9975
β_2	beta	0.125	0.1248	0.050	0.1267	0.1334
β_3	beta	0.230	0.2297	0.050	0.2215	0.2386
β_4	beta	0.260	0.2587	0.050	0.2506	0.2677
β_5	beta	0.150	0.1499	0.050	0.1419	0.1686
φ_1	gamma	0.310	0.3052	0.050	0.2972	0.3136
φ_2	gamma	0.300	0.2989	0.050	0.2901	0.3064
φ_3	gamma	0.240	0.2361	0.050	0.2284	0.2438
φ_4	gamma	0.220	0.2097	0.050	0.2012	0.2180
φ_5	gamma	0.310	0.3106	0.050	0.3024	0.3190
eps_w	invg	0.063	0.0425	inf	0.0178	0.0682
eps_x	invg	0.488	1.4033	inf	1.2098	1.6003
eps_u	invg	0.060	0.0491	inf	0.0156	0.0861

Table 4: Priors and Posterior of the Estimated Parameters for Model 2

Parameter	Density	Prior Mean	Posterior Mean	Standard Deviation	Confidence Interval at 90%	
α_1	beta	0.300	0.2950	0.050	0.2860	0.3040
α_2	beta	0.200	0.1985	0.050	0.1904	0.2064
α_3	beta	0.320	0.3194	0.050	0.3104	0.3286
α_4	beta	0.300	0.3008	0.050	0.2917	0.3092
β_1	beta	0.990	0.9900	0.050	0.9825	0.9982
β_2	beta	0.125	0.1255	0.050	0.1170	0.1339
β_3	beta	0.260	0.2591	0.050	0.2508	0.2679
β_4	beta	0.250	0.2499	0.050	0.2413	0.2588
β_5	beta	0.310	0.3103	0.050	0.3021	0.3189
φ_1	gamma	0.300	0.2983	0.050	0.2903	0.3068
φ_2	gamma	0.240	0.2375	0.050	0.2293	0.2456
φ_3	gamma	0.220	0.2208	0.050	0.2126	0.2286
φ_4	gamma	0.300	0.3003	0.050	0.2918	0.3088
eps_x	invg	0.488	0.3205	inf	0.2769	0.3655
eps_u	invg	0.060	0.0468	inf	0.0122	0.0844
eps_w	invg	0.063	0.0481	inf	0.0166	0.0850

Results from tables 3 and 4 showed how informative the Nigerian data is given the fact that the shapes of the prior and posterior means were not the same. Looking at the first equation, the output gap equation, the estimated value of α_1 (0.3004) is greater than its initial mean value selected (0.300). However, in table 4, the initial mean value of the same parameter (0.300) performed better than its posterior mean value (0.2950). Furthermore, the estimated value of α_2 (0.2006) performed better than its initial value (0,200) while the prior and posterior means of the exchange rate (α_3) are the same (0.100). In table 4, the values of interest rate (0.1985) and exchange rate (0.3194) performed less than the initial value means (0.200 and 0.320). Based on these results, one could conclude that the performance of the estimated values (posteriors) are data-driven, implying higher persistence of household consumptions in Nigeria under model 1 and relatively low persistence of households in model 2. The estimated values of the coefficients of output gap equations are clearly different from the selected initial values, showing that the Nigerian data are very informative.

The New Keynesian Philips curve equation explains the efficiency of the monetary policy towards achieving the price stability objective. It is worthy of note that the macroeconomic performance of the country rests on the values of the parameters β_2, β_4, and β_5. The estimated value for the nominal money balance parameter (β_4= 0.2587) indicates the number of firms whose prices could not be re-optimized in a given period. Moreover, the value of β_4 reveals that firms that fall within this category could only change their set prices every second quarter. This implies the mean period of price adjustment in the second quarter. This finding is supported by the works of Adebiyi and Mordi (2010) and Mordi et. al (2013). In addition, the effectiveness of the monetary policy in achieving price stability objective is measured using the value of parameters β_2 and β_5. The rule of thumb is that the values of the two coefficients must be greater than zero. Given that β_2= 0.1248 and β_5= 0.1499, we can conclude that the implementation of monetary policy is effective in achieving price stability objectives through output gap and exchange rate pass-through. Furthermore, the performance of the economy under the inflation targeting framework also depends on the value of β_2, β_3, and β_4. The estimated value of β_3 accounts for the fraction of firms within the country that find it difficult to adjust their prices within a given period. Also, the value of β_3 (0.2591) implies firms within the economy could only adjust their prices in the second quarter. The values of β_2 (0.1255) and β_4 (0.2499), as presented in table 4, are greater than zero. This also indicates that monetary authority could achieve price stability objectives using exchange rate pass-through and output gap under inflation targeting framework.

The monetary authority's reaction function estimates revealed the design of the monetary policy implemented during the period under investigation. The design is tailored towards achieving price stability as its main objective. The estimates of Taylor's rule equation demonstrated this. Looking at the coefficient of inflation in Taylor's rule equation, Looking at the persistence of the estimated standard deviations of all the shocks considered in the two models, a shock to the aggregate demand (0.14033 for model 1 and 0.3025 for model 2) is considered the most volatile while a shock to the terms of trade (0.0425) and a shock to the aggregate supply (0.0468) are the least volatile in the two models respectively. Overall, it can be deduced from the results of the estimation that the estimates are data-driven.

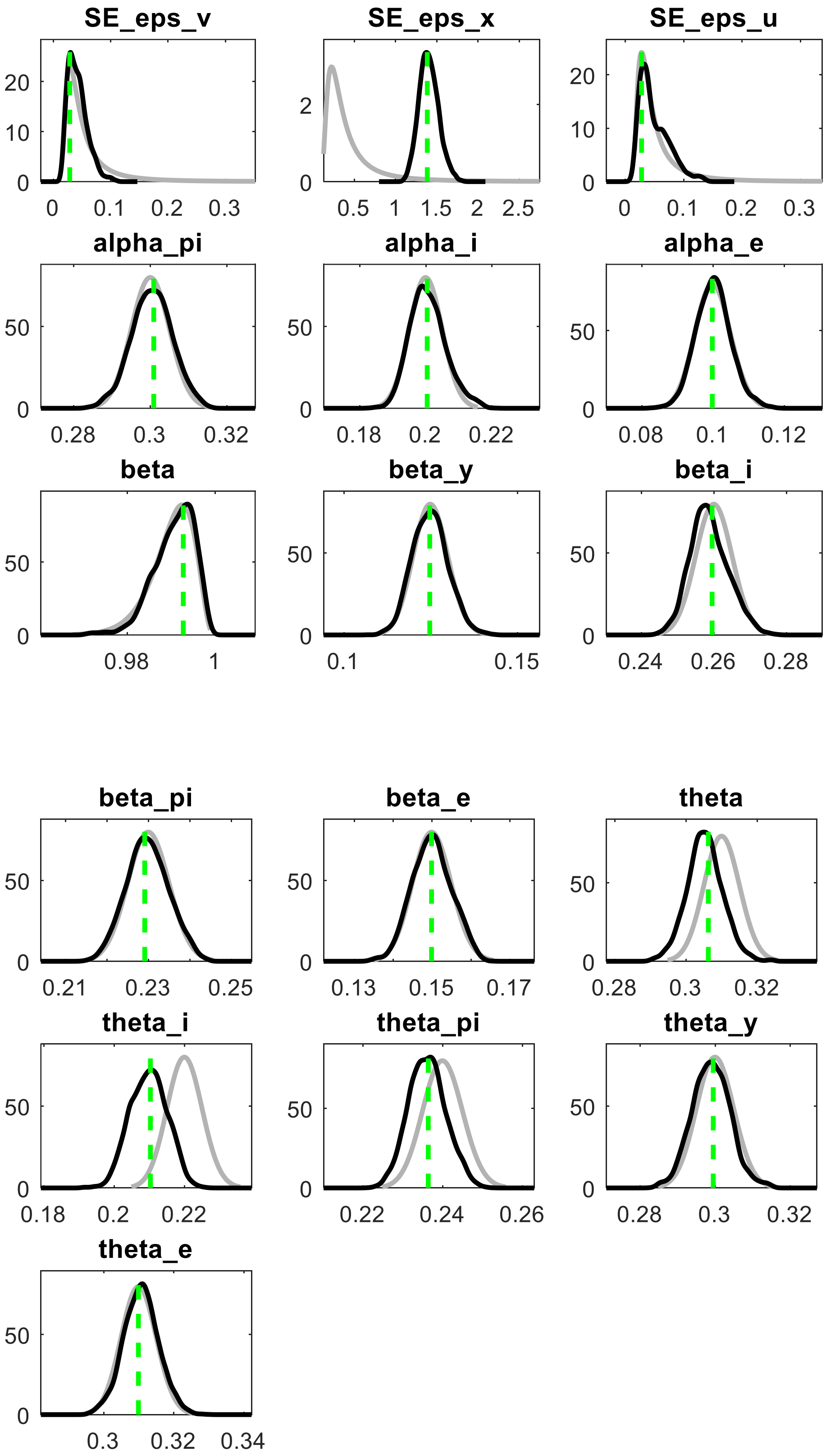

Figure 1: Prior and Posterior Distribution for Model 1

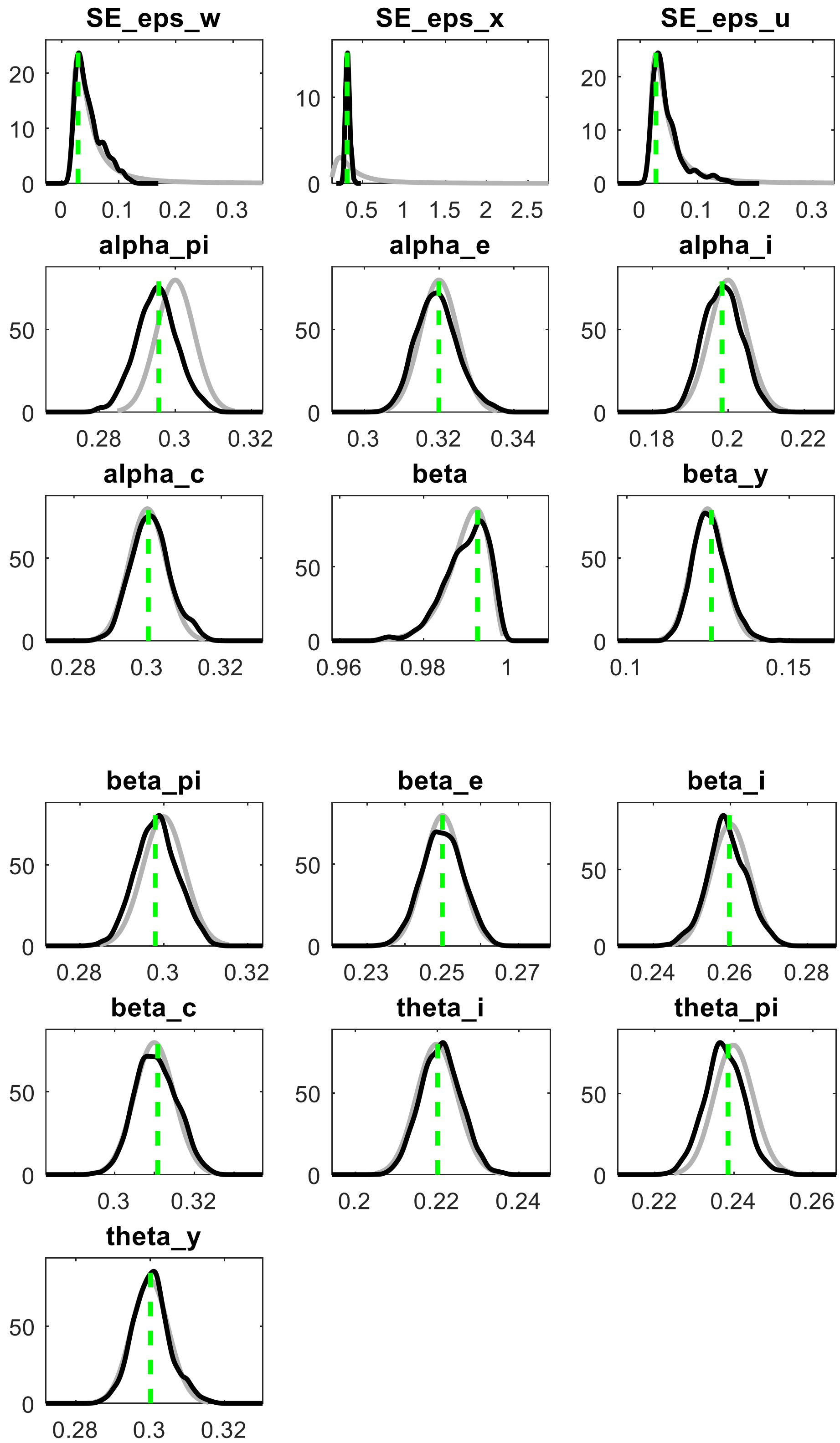

Figure 2: Prior and Posterior Distribution for Model 2

5.1 Viability of the Estimation

It is important to test the integrity of the estimation technique used in this study to justify the robustness of the entire estimation process. This was done using a visual diagnostic test for model 1 and model 2. In line with the extant literature, the study investigated the sensitivity of the Metropolis-Hastings simulations with the use of both univariate and multivariate MCMC diagnostic tests. The rule of thumb is that the shape of the simulations for the within and across chain must be identical. There should be little variation between the two lines and that the lines must converge in the long run (Griffoli, 2007; Modi et al. 2013). The results of the simulation revealed that the generated moments for the two models were stable and smoothly converged. Results of this test are available on request.

Furthermore, the overall convergence was diagnosed using the MH sampling algorithm. The results were summarized using three graphs. The within and between chain results were presented in each graph using two different lines. The measures analyzed the interval, second moment and third moment of the entire parameters. The condition is that the two lines that measure the convergence for each of the three graphs must be constant and converged. The study generated the three graphs and the results confirm that the stability and convergence conditions were satisfied. The results are also available on request.

5.2: Model Comparisons

Table 5: Model Comparisons

Sample	Specification	$\log[p(Y_1^T \vert M_i)]$	Bayes Factor Versus M2
1995:1 - 2019:4	M1	-110	exp(98)
	M2	-12	1
2000:1 - 2014:4	M1	-74	exp(66)
	M2	-8	1
2005:1 – 2014:4.	M1	-13	exp(8)
	M2	-5	1

Table 5 presents the baseline Bayes factor for model 1 against model 2 and their log densities. Apart from the baseline model, two other periods were considered for robustness check. The results favoured model 2 as the best framework for the Nigerian economy in achieving price stability objectives. The other two periods considered also aligned with the result of the baseline model. we conclude that an inflation-targeting framework is a more reasonable choice for the implementation of monetary policy in Nigeria.

5.3: Bayesian Impulse Response

The transmission channels of the monetary policy respond to shocks differently. This study analyzed the effects of a shock to the aggregate demand, aggregate supply, and terms of trade on the efficiency of the monetary policy channels of transmission in Nigeria. Therefore, this section presents the responses of the transmission channels considered in this study to the estimated shocks under the monetary aggregate framework (M1) and the implicit inflation targeting framework in Nigeria. The graphical Bayesian impulse responses are illustrated in Figures 3 - 8.

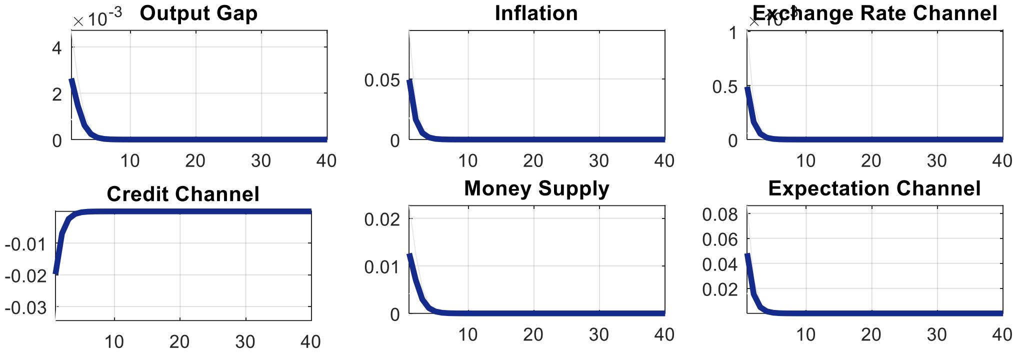

Figure 3: Response to 1% aggregate supply shock for model 1

Figure 3 shows the responses of different monetary policy channels of transmission to 1% aggregate supply shock. Exchange rate channel, expectation channel, and money supply responded negatively to the aggregate supply shock. This is evident in the diagram given that their values decreased throughout the periods. Output and inflation also responded in the same manner as their values fell. By implication, aggregate supply shock reduces both output and inflation. However, the credit channel responded positively as the value of impulse transmission increased. The effect of aggregate supply shock produces temporary supply adjustment problems thereby reducing output, inflation, and people's expectation throughout the periods. The results also revealed that all the variables return to their steady-state.

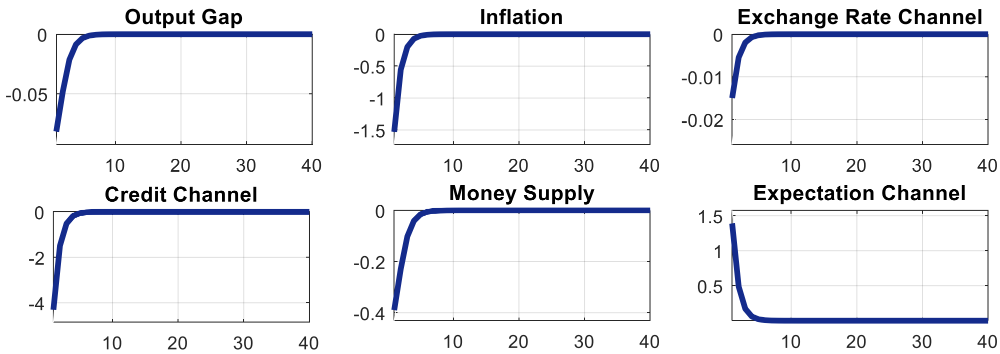

Figure 4: Response to 1% aggregate demand shock for model 1

A shock to the aggregate demand could be a result of a rise in government expenses or a reduction in taxes. This concept is called positive aggregate demand shock. However, a shock to the aggregate demand could also be due to a decrease in government expenses or a tax increase. Figure 4 presents the effect of a 1% shock to the aggregate demand on the channels of transmission of the monetary policy. The results showed that the effect of a 1% aggregate demand shock is positive for all the variables except the expectation channel. This finding shows that aggregate demand shock increases output, exchange rate, credit, money supply and inflation. The steady-state condition is satisfied by all the variables.

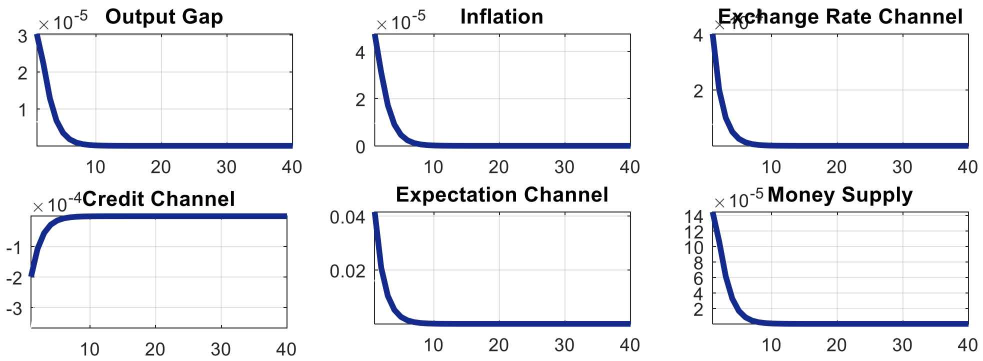

Figure 5: Response to 1% terms of trade shock for model 1

The effect of a shock to the terms of trade under the monetary targeting framework is similar to that of an aggregate supply shock. A 1% terms of trade shock negatively impacted all the variables, as evident in figure 5, except the credit channel. It reduces output and enhances price stability in the country in all the quarters under investigation. However, the credit channel responded positively as the magnitude of shock transmitted increased throughout the period. The results remained the same in all the periods.

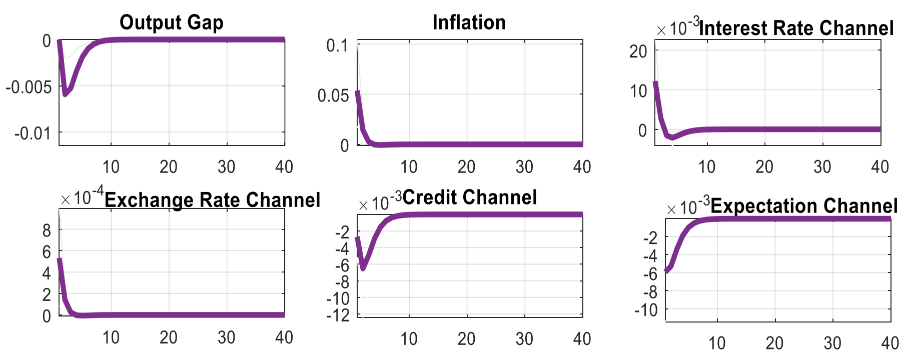

Figure 6: Response to 1% aggregate supply shock for model 2

The response of variables to aggregate supply shock under implicit inflation targeting is quite different from that of the monetary targeting framework. Under implicit inflation targeting, a 1% aggregate supply shock increases output, credit, and expectation channels. However, it reduces inflation, interest rate, and exchange rate in all quarters. All the variables satisfied the steady-state conditions in the long run.

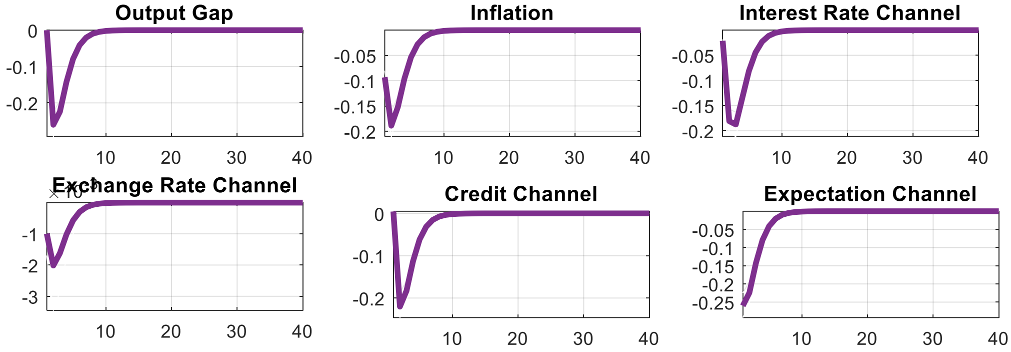

Figure 7: Response to 1% aggregate demand shock for model 2

A positive 1% aggregate demand shock enhances all the variables. The effect of the shock is negative in the short run, however, it is positive in the remaining periods under investigation. The steady-state conditions for all the variables are satisfied. This implies that aggregate demand shock reduced output, inflation, interest rate, exchange rate, and credit to the private sector in the short-run and later increased. However, the case of people's expectations is different. It increased throughout the periods.

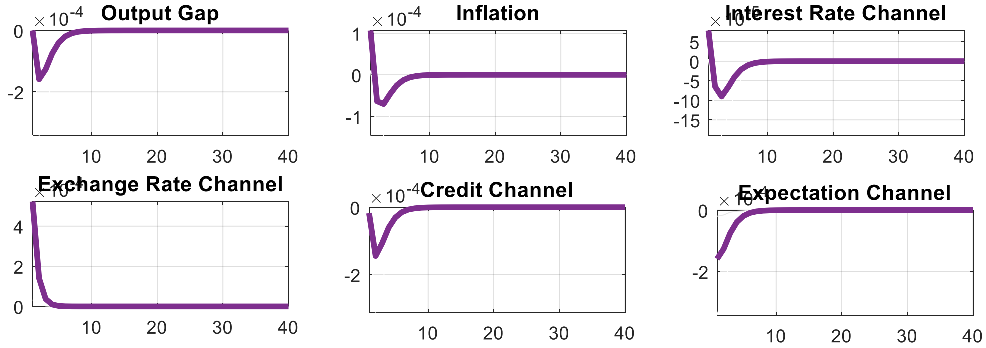

Figure 8: Response to 1% terms of trade shock for model 2

A 1 % positive term of trade shock influences all the variables positively except the exchange rate. The pattern of its impact differs among the variables. For example, people's expectations responded positively in all periods. However, the terms of trade harm the output gap, inflation, interest rate, and credit to the private sector in the short run. The reverse is the case in the long run. However, the exchange rate responded negatively to terms of trade shock both in the short and long run. The variables satisfied the steady-state conditions.

In sum, comparing the responses of the four transmission channels considered in the study for both models, one can say that the channels performed better under the implicit inflation targeting regime than the monetary targeting regime. However, the responses of the transmission channels to aggregate demand shock for the two regimes are similar. This implies that the effects of aggregate demand shock are persistent under the two models. The results show that monetary policy transmission channels are more active and perform better under implicit inflation targeting. The only obstacle to its operation is the implicit nature of its implementation in the country.

6.0 Conclusion

The focus of this study is to investigate the performance of the transmission mechanism of the monetary policy in the country in the face of implicit inflation targeting regime using quarterly data from 2000:1 to 2019:4. Specifically, the study estimated the DSGE model that is characterized with a sticky-price and estimated using the Bayesian technique. This became imperative because a sound understanding of the extent to which monetary policy impulses are transmitted to the economy is a critical factor in investigating the efficacy of monetary policy in the achievement of the set macroeconomic objectives. The results show that the inflation-targeting framework is strongly favoured by the data relative to the monetary targeting framework. Besides, the transmission mechanism performs better in the face of implicit inflation targeting regime. However, its impact was dampened by the effect of monetary targeting that was made explicit. By implication, the country might not benefit from the opportunities provided by the inflation targeting regime in achieving price stability if the framework is not explicit. The study concluded that for the country to achieve the primary objective of price stability, inflation targeting should be made explicit and that the Central Bank of Nigeria should stick to one policy framework rather than the hybrid that is in place.

Declarations

- **Conflicts of Interest**: We declare that there are neither conflicts of interest nor competing interest between the authors.

- **Funding**
  The authors received no funding for this research

- **Ethical Approval**
  The researchers adhered to the accepted ethical standards of a genuine research study.
- **Consent to Participate**
  All Authors gave their consent to participate in this research work.
- **Consent to Publish**
  The authors gave their consent towards publishing this work

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Appendix A

Model 1 (Monetary Aggregate Rule)

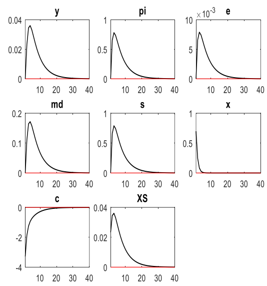
```
y = XS+alpha_pi*pi(+1)+alpha_e*e+alpha_i*md+alpha_c*c+x;
pi = beta+beta_y*y(+1)+beta_pi*pi(+1)+beta_i*md+beta_e*e+beta_c*c+u;
md = theta+theta_i*md(-1)+theta_pi*pi+theta_y*y+theta_e*e;
e = (1-beta)*s;
y - theta_i*md;
m = y-XS(-1);
s = e+pi+v;
v = rho_v*v(-1)+eps_v;
x = rho_x*x(-1)+eps_x;
u = rho_u*u(-1)+eps_u;
```

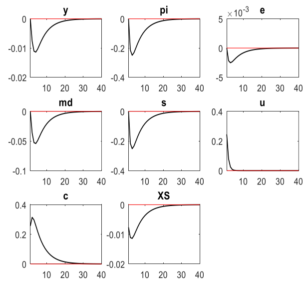
Model 2 (Inflation Targeting Rule)

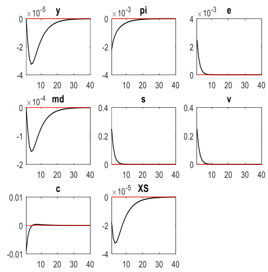
```
y = alpha_y*y(+1)+alpha_pi*pi(+1)+alpha_e*e+alpha_i*i+alpha_c*c+x;
pi = beta+beta_y*y(+1)+beta_pi*pi(+1)+beta_i*i+beta_c*c+beta_e*e+u;
i = theta_i*i(-1)+theta_pi*pi+theta_y*y+theta_e*e+theta_c*c;
c = y - theta_i*i;
e = (1-beta)*s;
s = e+pi+w;
x = rho_x*x(-1)+eps_x;
w = rho_w*w(-1)+eps_w;
u = rho_u*u(-1)+eps_u;
```

Appendix B

Simulation Results for Model 1







Simulation Results for Model 2