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REVISITING THE EFFECT OF FINANCIAL CRISIS AND BANKING REFORMS ON THE EFFECTIVENESS OF MONETARY POLICY TRANSMISSION MECHANISM IN NIGERIA

ABSTRACT: *Understanding the effect of the extent of financial intermediation on the performance of monetary policy transmission channels is crucial to the formulation of monetary policy. To this end, the paper tested the validity of the above statement in the Nigerian context using quarterly data between 2005Q1 and 2019Q4. The data was analysed using a dynamic stochastic general equilibrium approach. Results of the estimation showed that the financial crisis experienced in the country led to the depression of the Nigerian capital market and a decrease in the amount of credit provided by banks for trading in the capital market, exchange rate risk tightening of liquidity, and greater loan-loss provisioning. It was revealed that recent changes and reforms in the industry have positive impacts on all the monetary policy transmission channels (exchange rate, interest rate, expectation, and credit) considered in the study. However, the credit channel appeared to be the most active as it transmits the largest impact of shocks to the financial sector (88.06 per cent on average) to the real economy. This demonstrates that the private sector depended on the financial sector for financing their expenditures, which later induced an increase in the level of investment and increased output.*

KEY WORDS: *financial intermediation, transmission mechanism, financial crises, DSGE*

JEL CLASSIFICATION: G21; E52; G01; C11

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1. INTRODUCTION

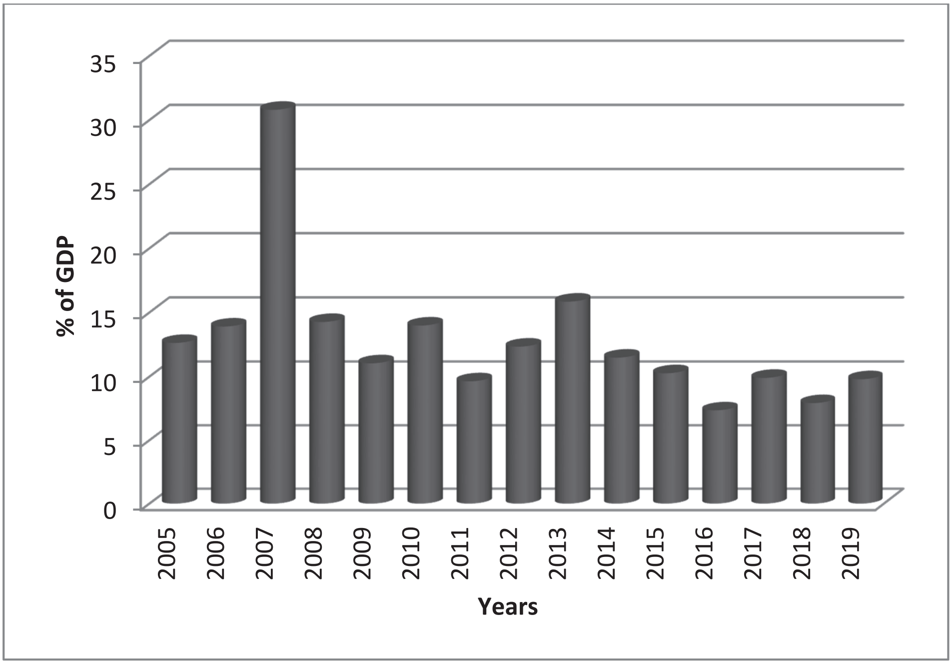
The world economy has experienced four major crises since the Great Depression of 1929: the Asian financial crisis of 1997, the Argentina financial crisis of 2001, the global financial crisis of 2007, and the Russian crisis of 2014. The global financial crises undermined banks' ability to play their developmental role. The resultant effect was a decline in the growth prospects for many economies of the world. In addition, the World Bank's global economic growth expectations also declined considerably from 2.5 to 0.9 per cent (Okonkwo & Godslove, 2015). This global financial meltdown led to a dwindling in the fortune of the once blossoming Nigerian banking industry (Okonkwo & Godslove, 2015; Ashamu & Abiola, 2012). The industry, during this period, was characterised by undercapitalisation of deposit-taking banks, weakness in the regulatory and supervisory framework, weak management practices, and tolerance of deficiencies in the corporate governance behaviour of banks. It was against these conditions that the Central Bank of Nigeria (CBN) announced a major reform in the entire banking industry in 2005. The reform included the involvement of banks in the foreign exchange market, banks were permitted to take deposits from the public sector, transaction costs were minimised, and banking rules and regulations were revised and updated to make the banking system more flexible, effective, and transparent (Okonkwo & Godslove, 2015). The primary objective of the reform initiative was to have an efficient and effective banking industry that could guarantee rapid economic growth and sustainable development. In response to this, the financial sector in Nigeria has undergone important structural and institutional changes. The restructuring exercise had a significant impact on the banking sector in that commercial banks' capital base was increased from ₦2 billion to ₦25 billion. This affected the sector to a large extent with the number of banks decreasing from 89 to 25 at first, and later further decreasing to 23 with the merger of some banks. The number of operating banks later increased to 24 with the emergence of Citibank in 2004. This radical change in market structure was to stabilise the national financial markets and consolidate the remaining banks to promote global competitiveness. The number of banks dropped to 22 in 2019. Jaiz Bank was not listed because the bank is a non-interest bank and cannot be categorised as a commercial bank.

However, the global financial crisis of 2007 presented further significant challenges to the recuperation of Nigeria's banking system. The effects of the crisis became evident in Nigeria because it happened when the country was making progress in economic performance and management. The Nigerian banking sector, after these incidents, was characterised by uncertainty and anxiety. Investors' and depositors' funds were not guaranteed, and public confidence was eroded with many of the banks becoming distressed due to capital inadequacy. These problems greatly impaired the quality of the banks' assets as non-performing assets became unbearable and became huge burdens on many of the banks. The financial intermediation role of the banks became weakened while the macroeconomic activities were seriously slowed down.

To cushion the negative effect of the global financial crisis of 2007, the CBN implemented a 2009 banking reform through which liquidity was provided for the ailing banks. The major highlights of the 2009 reform include the removal of chief executive officers (CEOs) and executive directors of banks found wanting, the injection of bailout funds (₦420 billion) to stabilise affected banks and another ₦200 billion to other banks, publication of names of outstanding debtors of affected banks, implementation of tenures for CEOs in the banking sector, and the approval of all potential CEOs by the CBN. The four pillars of the 2009 banking reform are to enhance the quality of banks, establish financial stability, enhance healthy financial sector evolution, and ensure that the financial sector contributes to the real sector.

Figure 1 shows the market capitalisation of banks as a percentage of GDP between 2005 and 2019. As can be seen from Figure 1, the banking reform of 2009 proved to be a buffer against the subsequent effects of the global financial crisis experienced in the country. The reform resulted in stronger Nigerian banks that are better able to withstand financial crisis. It had a dramatic effect on the size and health of the Nigerian banking system through improvement in banks' market capitalisation. It can be seen in Figure 1 that, after the 2009 reforms, banks' market capitalisation exhibited an upward trend, relatively speaking, throughout the period under study. This in turn increased their savings mobilisation and helped them effectively play their intermediation role. The post-recapitalisation experience in the Nigerian banking system included the injection of ₦620 billion in bailout funds to save most of the recapitalised banks, the sacking of indicted banks' CEOs and the appointment of advisers to these banks, the restructuring of banks and huge impaired shareholders' funds, huge exposure to non-performing loans, and the establishment of the Asset Management Corporation of Nigeria (AMCON).

Figure 1: Banks' Market Capitalisation as a percentage of GDP in Nigeria 2005–2019.



However, towards the end of 2019, there was the outbreak of the COVID-19 pandemic. This affected all the economies of the world, with Nigeria being no exception. COVID-19 threatened the economy of Nigeria through forced lockdown of economic activities and disruption to the workings of the financial system. These led to gross economic loss and withdrawal of funds by portfolio investors from the stock market. The resultant effect was another financial crisis that wiped out the benefits of banking reforms in the country.

The developmental roles of banks are felt in the economy through monetary policy transmission channels. These define the various channels through which policy-induced changes in the nominal money stock or the short-term nominal interest rate affect prices and output in the economy. Not only do the transmission mechanism of monetary policy work through various channels, but their functioning and effectiveness vary across countries due to differences in the extent of financial intermediation, the development of domestic capital markets, and structural economic conditions (Cevik & Teksoz, 2012). During the period under investigation, the Central Bank of Nigeria used short-term interest rates, open market operations, and short-term liquidity tools as the instruments of monetary policy. Furthermore, the monetary policy transmission channels included interest rate, exchange rate, and credit channels. It was also observed that there wm jere certain changes in the implementation of monetary policy during this period. These included the extension of the repayment of loans under a federal government scheme by one year, interest rate reduction on all intervention loan facilities from 9% to 5%, an offer of a ₦50 billion (US$131.6m) targeted credit facility to the service sector, strengthening of the loan to deposit ratio (LDR) policy, which allowed banks to extend more credit to the economy, and provision of credit support to the healthcare industry to meet the increasing demand for healthcare services during the outbreak. In addition, the Central Bank of Nigeria implemented the Central Bank Digital Currency (CBDC), also known as eNaira. The eNaira provides the Nigerian monetary authority with a new and more effective means of monetary policy transmission.

Several authors (Cecchetti, 1999; Dabla-Norris & Floerkemeier, 2006; Kovanen, 2011; Cevik & Teksoz, 2012) have argued that the extent of financial intermediation affects the performance of monetary policy transmission channels across countries. Their main point of contention is that the size and the structure of financial intermediation play a critical role in the performance of transmission channels. Following several major developments in financial intermediation in Nigeria as a result of the 2009 reforms, it is therefore important to examine the effect of improved financial intermediation on the performance of these channels in Nigeria. The research questions are: (1) Did the financial crisis affect the performance of the Nigerian financial system?; (2) What were the effects of improved financial intermediation on the performance of the monetary policy transmission channels in Nigeria? To achieve this objective, our study uses the small open economy version of the dynamic stochastic general equilibrium (DSGE) in the analysis of the four transmission channels (exchange rate, interest rate, expectation, and credit) in Nigeria. The use of the DSGE models provided several advantages over all other approaches to analysing macroeconomic policy in the literature. This was explained by Peiris and Saxegaard (2007), Apanisile and

Osinubi (2020), Akinlo and Apanisile (2019), and Apanisile and Akinlo (2022). First, DSGE models contain structural equations that can be explained using economic interpretations. The effect of macroeconomic policy and its transmission channels are traceable, thereby enabling the use of another policy to achieve the same objective if the other one is not forthcoming. Second, DSGE models are formulated on the basis of the interaction of microeconomic agents. This implies the models describe the activities of microeconomic agents using structural parameters that will remain the same as economic policies change. This property validates the use of alternative policies. Third, the models explain, in detail, how random shocks such as monetary and fiscal policy shocks are transmitted to the economy. Last, the models predict and explain the future performance of the economy based on the interactions among the economic agents.

This study is similar to Apanisile and Akinlo (2022) because they both use DSGE and quarterly data in estimating the effectiveness of monetary policy transmission channels in Nigeria. However, this study is different from Apanisile and Akinlo (2022) in various ways. First, it considers an inflation targeting framework in a small open economy using DSGE as against Apanisile and Akinlo (2022), which employed a DSGE for a closed economy with two different policy frameworks (inflation targeting and monetary aggregates). Second, while Apanisile and Akinlo (2022) examined the effectiveness of monetary policy transmission channels using two monetary policy frameworks, this study differs by explaining the response of monetary policy channels to the financial crisis and reforms after the crisis in Nigeria. Third, the scope of the two studies is not the same. While Apanisile and Akinlo (2022) covered the period 2000Q1 and 2019Q4, our study employs quarterly data on macroeconomics and financial variables between 2005:1 and 2019:4 to achieve the objectives of the paper. The choice of 2005 is informed by the financial crisis experienced in Nigeria in the same year.

Our results are in line with the finding of Ashamu and Abiola (2012) that the financial crisis affected "the quality of part of the credit extended by banks for trading in the capital market, exchange rate risk tightening of liquidity, greater loan-loss provisioning, slower growth rate of banks' balance sheet in response to the crisis and higher provisioning leading to lower profitability among others" (Ashamu & Abiola, 2012, p. 251). Furthermore, it was discovered that recent changes and reforms have positive impacts on exchange rates, interest rates, expectations, and credit channels. However, the credit channel appears to be the most active channel as it transmits the largest impact of shocks to the financial sector (88.06 per cent on average) to the real economy.

The paper contains six sections. Section one, the introduction, explains the objective of the paper. Section two presents the extant literature on the subject matter and the need for this study. Section three discusses the fundamentals of the methodology used and section four explains data employed for the analysis, the technique of data estimation, and the description of the variables. In section five, the estimation technique is employed to examine the effect of the financial crisis on the channels of transmission of the monetary policy in Nigeria. The last section, section six, concludes the study.

2. LITERATURE REVIEW

There is a body of literature on banking reforms and the performance of transmission channels of monetary policy. Of the studies in the literature, the paper of Ogun and Akinlo (2010) investigated the effect of the newly adopted deregulation measures on the performance of the bank credit channels of monetary policy in Nigeria. The study employed quarterly data between 1986Q1 and 2006Q4. The data were analysed using a structural vector autoregressive model (SVAR). It was discovered that during the period under study, financial assets such as bank deposits, total loans, and advances were rigid in their response to monetary policy shock. Furthermore, the results showed that the effect of monetary policy shock on the forecast error of bank balance sheet variables is independent. It was concluded that the bank credit channel is not effective in Nigeria.

In the same vein, Butkiewicz and Ozdogan (2013) examined the role of reforms on the performance of Turkish monetary policy transmission channels using monthly data spanning between 1996:07 and 2007:06. The sample period was divided into two because of the presence of a structural break in the year 2001 and the two models were estimated separately. The first sample represented the pre-crisis period and contained 42 observations. The period ran between 1996:07 and 1999:12. The results showed that the structural break of 2001 boosted the strength of the monetary policy transmission channels in the country in the postcrisis period. It was also revealed through the estimation of the baseline model that an unanticipated increase in the interest rate has a significant impact on economic activities before and during the crisis in an unusual manner.

Mohanty and Rishabh (2016) reviewed the implications of three key post-2008 crisis developments in financial intermediation – the role of banks, the globalisation of debt markets, and the sustained decline in global long-term interest rates – for various transmission channels of monetary policy in emerging market economies using quarterly data from 1996Q2 to 2014Q4 and a structural vector autoregressive framework. The paper argued that the globalisation of debt markets means that monetary policy can no longer be conducted through the short-term interest rate alone. The study concluded by requiring the central bank to use other instruments (such as foreign exchange intervention, bond market operations, and macro-prudential tools) to reduce risks to price and financial stability.

In the same vein, the paper by Abdel-Baki (2010) investigated the significance of the role of the Egyptian monetary policy agent in mitigating the negative impact of the multifaceted financial crisis on the interest rate and exchange rate channels in the country. The objective of the study was achieved by using structural VAR to examine the effect of the crisis on the economy and on the ability of the agents to mitigate the effect of the economic meltdown caused by the financial crisis. The study differs from existing studies by introducing an expectation channel to the analysis of the effectiveness of monetary policy transmission channels in the country. Data on the expectation channel were obtained from a field survey administered for 21 months. This inclusion was necessary given the failure to consider future inflation and the effect of the proposed removal of subsidies in the country. The results showed that the Central Bank of Egypt did not respond appropriately to the negative effect of the shocks inflicted by the inflation expectation. In addition, it was discovered that the apex bank needed to improve on the implementation of policy to combat the effect of negative shocks on the economy.

Furthermore, following the collapse of Lehman Brothers in late 2008, Islam and Rajan (2009) investigated the effectiveness of bank lending channels in India given the global financial crisis of 2007–2009. The results of the study contradicted the outcome of studies in the United States and popular perceptions. While other studies found a negative effect of the global financial crisis on bank lending channels, this study found that bank credit in India maintained stable growth even in the face of the financial crisis. This was due to an aggressive effort by the Reserve Bank of India to ease monetary measures in the country. The study, however, differentiated between public and private banks' behaviour towards lending and confirmed that the bank lending channel is an important channel for transmitting monetary policy actions to the economy of India.

Kubo (2013) investigated whether reforms established a transmission channel of exchange rates from the formal to parallel markets in Myanmar. To investigate the question, the study examined the relationship between the Central Bank reference rate and the informal broker selling price of the US dollar banknote in the parallel market. The sample period of daily exchange rates spanned from 2 April 2012 through 13 March 2013. The empirical results of a VAR analysis with the daily exchange rates indicate that the Central Bank had been following the parallel rate rather than guiding it, implying that a transmission channel had yet to be established.

Furthermore, Chileshe (2018) explored the effect of changes in banking structure on the monetary policy channel of transmission with emphasis on the bank lending channel in Zambia. Using panel data that spanned between 2005:1 and 2016:4 and the dynamic one-step GMM proposed by Arellano and Bond (1991), the study showed that larger banks with more market power and liquidity respond less to monetary policy tightening. In addition, Jannsen et al. (2019) investigated the claim that the effects of monetary policy on output and inflation during the financial crisis differ significantly from those in normal times. The study employed panel data from 20 developed countries and the VAR model. The results showed that monetary policy has larger and quicker effects on inflation and output during financial crises and that the effects of monetary policy on output and inflation depend on the state of the economy.

To examine the effect of anticipated and unanticipated monetary policy shocks on the effectiveness of the transmission mechanism in Nigeria, Akinlo and Apanisile (2019) generated two policy shocks from the policy reaction function. The study covered the period between 1986Q1 and 2013Q4 and, using DSGE, discovered that unanticipated monetary policy shocks had a short-run impact on transmission channels while anticipated ones had a long-run impact on them. Based on its findings, the study concluded that the government should announce its policy at the beginning of every year to reduce unanticipated policies in the economy.

Apanisile and Osinubi (2020) also investigated the effects of the recent development in the financial system of Nigeria on the effectiveness of the transmission mechanism in the country. The study employed a sticky-price DSGE model and estimated the model using the Bayesian approach. Their results showed that financial development had positive effects on all the transmission channels considered within the period 2004Q1 to 2016Q4. The credit channel was found to be the most active channel in stimulating output while the expectation channel was determined to be the most active channel in stabilising prices in the economy.

Furthermore, Apanisile and Akinlo (2022) examined the effectiveness of the monetary policy transmission mechanism in Nigeria within the frameworks of inflation targeting and monetary aggregate using a closed economy DSGE. The monetary aggregate uses money supply as the policy instrument while the interest rate is used as a nominal anchor under the inflation targeting framework. The study was necessitated by the implicit nature of inflation targeting in the country, where the interest rate is augmented by the use of money supply. The study employed quarterly data between 2000Q1 and 2019Q4 and discovered that the monetary aggregate framework dampens the achievement of the inflation-targeting framework in the country.

Based on the reviewed literature, it can be seen that ample studies on this subject matter exist. However, most of the studies failed to include expectation channels. Furthermore, vector autoregressive (VAR) and structural vector autoregressive (SVAR) models were most commonly used. This study contributes to the extant literature by including the expectation channel and using a more robust approach to the study of the effectiveness of the transmission mechanism of monetary policy in Nigeria. This is because the implementation of monetary policy is a major determinant in formulating expectations and expectation plays an important role in transmitting policy impulses to the real sector of the country.

3. METHODOLOGY

The New Keynesian model was derived by extending the standard real business cycle framework. The model is employed for a small open economy such as the Nigerian economy. One of the attributes of the standard framework is the neutrality of money, which is a result of flexible prices and wages. However, the New Keynesian model introduces such Keynesian features as imperfect competition and sticky prices. These, therefore, provide a platform that enables monetary policy to be at the centre of discussions on macroeconomic fluctuations. The New Keynesian model assumes that there is a goods market characterised by imperfect competition and that firms in the market produce differentiated goods for which they set their prices. Furthermore, the model assumes the majority of firms in the market find it difficult to adjust their prices at any given point in time. This forms the major constraint of the model. Lastly, key players in the set-up of the model include an individual household that consumes goods produced and renders labour services. It also demands money and bonds. Others are firms that hire labour for production and the government, which implements policy.

3.1 Households

The model contains a set of identical and long-lived households that seek to optimise the utility function:

$$max_{C_t, N_t, \frac{M_t}{P_t}} E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, N_t, \frac{M_t}{P_t} \right) \tag{1}$$

The constraints are $C_t \leq Y_t ; B_{t+j} \leq 0; N_t \leq \int_{t=0}^{1} N_{it} d_t$; and the no-Ponzi game. E_0 is the conditional operator of expectation given the level of information in time 0, β represents the factor that discounts the model, and $\frac{M_t}{P_t}$ represents the real money demand. The utility function is subject to:

$$P_t C_t + Q_t B_t + M_t \leq M_{t-1} B_{t-1} + W_t N_t + J_t \tag{2}$$

where $C_t(i)$ is the quantity of household consumption of commodity *i* in time *t* for *i* $\forall[0,1]$ and *t* = 0, 1, 2, …., $P_t(i)$ represents the commodity of good *i*, N_t represents the number of hours worked, W_t represents nominal wage, B_t is the amount of bond purchased in one period at a price Q_t, B_{t-1} is the amount of bond bought the previous year, M_t represents demand for money, and J_t is the component of income held as a lump sum. $\in$ captures the intertemporal elasticity of substitution that differentiates the goods. This is equal to the degree of responsiveness of change in consumption to change in price. To optimise the utility function subject to its constraint, we use the Kuhn-Tucker approach to derive the FOC conditions from equations (1) and (2).

Following Akinlo and Apanisile (2019), Apanisile and Osinubi (2020), and Apanisile and Akinlo (2022), the marginal utility derived from the optimisation of equations (1) and (2) is log-linearised. Representing the log-linearised variables with small letters, the equations become:

$$c_t = E_t c_{t+1} - \frac{1}{\sigma}\left(i_t - \rho - E_t \pi_{t+1}\right) \tag{3}$$

$$w_t - p_t = \sigma c_t + \varphi n_t \tag{4}$$

$$m_t - p_t = c_t - \eta i_t \tag{5}$$

Equation (3) is the first-order Taylor expansion of the Euler equation around the steady state. Equation (4) is the log-linearised version of the labour supply equation while equation (5) is the log-linearised version of the money demand equation. η in equation (5) is defined as interest rate elasticity in the money demand equation and is defined as $\frac{1}{v}\frac{1}{(1+i)i}$.

3.2 Firms

The model contains a set of individual firms that produce different goods using the same technology. The production function of the firms is given by:

$$Y_{it} = A_t N_{it}^{1-\alpha} \tag{6}$$

Y_{it} represents the output of each of the firms in time *t*, A_t represents the level of technical input available to all the firms, and N_{it} captures the amount of labour supply employed by each firm. The major feature of this model is the rigidity of price level. The rigidity of a firm's prices implies that although firms could freely set their prices, they are not sure when the next opportunity to change the prices will arise. The likelihood of not knowing when it is the right time to change their prices is given by θ. This represents the proportion of firms that are unable to change their last year's price. The rest, 1 – θ, can reset their prices. The firms in the market have similar demand schedules with an elasticity of price ϵ and the total level of price P_t. In addition, the total consumption index C_t is as given above. Finally, the total dynamics of price are given by:

$$\pi_t^{1-\epsilon} = \theta + (1-\theta)\left(\frac{P_t^*}{P_{t-1}}\right)^{1-\epsilon} \tag{7}$$

where $\pi_t \equiv \frac{P_t}{P_{t-1}}$ represents the gross price level and P_t^* represents the price set by firms in time *t*. The firms optimise their prices during this period,. Also, within this period, all firms will choose the same price because they have an identical problem. Therefore, the steady-state value with zero inflation becomes π = 1. Given this, P_t^* = $P_{t-1} = P_t$. Linearising this yields:

$$\pi_t = (1-\theta)\left(P_t^* - P_{t-1}\right) \tag{8}$$

Equation (8) explains that the value of inflation of a re-optimising firm in the current period is due to the fact that such firms select a price that varies from the average price of the economy in the past period. Therefore, to understand the evolution of inflation over a period, analysing the factors underlying a firm's price-setting decision is important. This is achieved by examining a re-optimising firm in period t that chooses a P_t^* that satisfies the condition for attaining the current market value of the profits generated when the price is still effective. The optimisation problem is solved subject to the constraints posed by the ordering of demand as presented by Akinlo and Apanisile (2019), Apanisile and Osinubi

(2020), and Apanisile and Akinlo (2022). The optimal price P_t^* , derived from the optimisation problem becomes:

$$p_t^* = \mu + (1-\theta\beta) E_t \sum_{k=0}^{\infty} \theta^k \beta^k [mr_{t+k|t}^r + p_{t+k}] \tag{9}$$

Solving for equilibrium in the goods market, the equilibrium condition becomes:

$$Y_{it} = C_{it} \tag{10}$$

The total output level is given as:

$$Y_t = \left(\int_0^1 Y_{it}^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon-1}{\epsilon}} \tag{11}$$

Substituting equation (10) into (11) and taking the logarithm of the result yields:

$$y_t = c_t \tag{12}$$

Equation (12) is the market-clearing condition for the entire market. In the same vein, the market-clearing condition in the labour market is:

$$N_t = \int_0^1 N_{it} di \tag{13}$$

From equation 6, we have N_{it} , the subject of the formula. Thus,

$$N_{it} = \left(\frac{Y_{it}}{A_t} \right)^{\frac{1}{1-\alpha}}. \tag{14}$$

By substituting (12) and (14) into (13) and log-linearising, equation (13) becomes:

$$y_t = a_t + (1-\alpha) n_t \tag{15}$$

3.3 Monetary Authority

The central bank employs the rate of interest as the monetary instrument in the short run. A decrease in the rate of interest increases the demand for consumption goods. An increase in demand will increase the firms' marginal cost and, consequently, their prices. The outcome of this action is inflation. The reverse is the case when there is an increase in the rate of interest. Therefore, the use of interest rates follows the Taylor rule type. Taylor's rule model is given as:

$$i_t = \beta_r i_{t-1} + (1-\beta_r)(1+\beta_\pi)\pi_t + \alpha_x(\hat{y}) + \varepsilon_t \tag{16}$$

where

$i_t = rate\ of interest\ in\ the\ short\ run$

$i_{t-1} = rate\ of\ interest\ in\ the\ previous\ period$

$\pi_t = consumer\ price\ index$

$y_t = output\ gap$

$\varepsilon_t = shock\ to\ the\ monetary\ policy$

3.4 The World Economy

The world economy, which is defined as the foreign economy in the model, is very large. It is represented by an unrestricted VAR (1) of output, inflation, and the nominal interest rate. This follows the approach of Jääskelä and McKibbin (2010). The VAR model is presented as follows:

$$\begin{pmatrix} Y_t^* \\ \pi_t^* \\ r_t^* \end{pmatrix} = M \begin{pmatrix} Y_{t-1}^* \\ \pi_{t-1}^* \\ r_{t-1}^* \end{pmatrix} + \varepsilon_t^* \tag{17}$$

ε_t^* captures the vector of the external shock and Y_t^*, π_t^*, and r_t^* are foreign output, foreign inflation, and foreign nominal interest rates, respectively. The variables are proxied by the output, inflation, and nominal interest rate of the United States of America. They are expressed as the percentage deviations from their sample means. The world economy is treated as exogenous to the domestic economy. Therefore, the coefficients of matrix M are estimated separately. They enter the system of equations through an autoregressive model of order one (AR (1)).

3.5 Log-linearised Model

Log-linearisation is a process of linearising the system of complex equations in terms of the log deviation around their steady state. Linearising Euler equations and substituting them into the goods clearing condition under the resource constraints, the dynamic IS curve (equation 18) is obtained. Also, by log-linearising intermediate goods firms' first-order conditions, using the aggregate law of motion for prices stated, and substituting in the household intra-temporal condition and the market-clearing conditions, the forward-looking Phillips curve (equation 18) is obtained.

$$y_t = E_t y_{t+1} - \sigma\left(i_t - E_t \pi_{t+1}\right) \tag{18}$$

$$\pi_t = \beta E_t\left(\pi_{t+1}\right) + k \check{y}_t \tag{19}$$

$$i_t = \beta_r i_{t-1} + \left(1 - \beta_r\right)\left(1 + \beta_\pi\right)\pi_t + \alpha_x\left(\hat{y}\right) + \varepsilon_t \tag{20}$$

Equation (18) is the expectational IS curve. The equation presents the current output as a function of the expected value together with its prior rate of interest. The prior interest rate is achieved by deducting the future interest rate from the nominal interest rate. The mathematical expression represents a logarithm version of the Euler equation. This equation links the optimising household's inter-temporal rate of marginal substitution to the real rate of interest. The second equation is referred to as the New Keynesian Phillips curve. The mathematical expression shows a log-linearised FOC that explains the optimum behaviour of monopolistically competitive firms that are affected by explicit costs of nominal price adjustment as explained by Rotemberg (1982), or set the random prices in a staggered fashion as suggested by Calvo (1993). The third equation follows the monetary policy rate of interest rule as explained by Taylor (1993). Following this equation, the central bank uses interest rates as the policy instrument to control changes in the value of inflation and the output gap. The three equations have three important variables. These are the output gap (y_t), inflation (π_t), and the short-term rate of interest measured in nominal terms (r_t).

Considering the New Keynesian model, the operation of monetary policy follows the old rate of interest channel. A contractionary monetary policy increases the nominal rate of interest in the short term and yields an increase in the real rate of interest when the nominal price is rigid as a result of a random price setting. The increase in the rate of interest thereby leads to a decrease in spending patterns as explained by the IS curve. Finally, the decrease in output through the Phillips curve puts downward pressure on inflation. This adjusts sluggishly after the shock. In addition, the expectation terms in the equation imply that the actions of monetary policy are not the same quantitatively. Their effects depend on whether the actions are anticipated or unanticipated.

4. TECHNIQUES OF ESTIMATION, DATA DESCRIPTION, AND VARIABLE MEASUREMENT

The literature contains different approaches for estimating the DSGE model. Some of these approaches include the full-information likelihood-based, minimum distance generalised method of moments (GMM), on the one hand, and the Bayesian, on the other. The Bayesian approach has been found superior to all other available techniques (Adjemian, 2013; Akinlo & Apanisile, 2019; Apanisile & Osinubi, 2020; Apanisile & Akinlo, 2022). The major reason for this is that there exists an identification problem which is due to the non-informative nature of data when the maximum likelihood method is used. Furthermore, the use of maximum likelihood and other approaches lead to a lack of precision in estimating the DSGE model. The Bayesian approach, however, makes the comparison of models possible. Therefore, we employ the Bayesian approach to estimate our model.

The use of the Bayesian estimation technique calls for the calibration of the parameters of interest. This is important because it resolves the identification problem that is associated with the estimation of the DSGE models. The process of calibrating the parameters in the Bayesian tradition involves fixing the initial value of the parameters. This process is known as the imposition of prior. The advantages of this exercise are that it enables the steady-state equilibrium to be established and provides the basis for determining how best the data fits the economy. The selected prior is informed by the theoretical knowledge of the researcher and the likelihood function that must be included in the Bayesian method. The posterior distribution needed for generating the outcomes of the estimation is obtained by combining the prior and the likelihood function.

4.1 Data

Quarterly data on the eight macroeconomic variables were employed. The data cover the period between 2005:1 and 2019:4. The macroeconomic variables include the output gap, nominal interest rate, domestic inflation rate, nominal exchange rate, commercial bank credit to the private sector, anticipated monetary policy, unanticipated monetary policy, and terms of trade. If the real variables are used with domestic inflation as one of the independent variables, then there is a likelihood of collinearity among the independent variables. This will in turn produce spurious results since inflation is an important variable in the DSGE estimation and it cannot be eliminated. The New Keynesian Phillips curve in the DSGE estimation is proxied by inflation. Therefore, to avoid this problem, the nominal values of all the variables were used. This approach follows the work of Akinlo and Apanisile (2019), Apanisile and Osinubi (2020), and Apanisile (2021). The foreign economy was proxied by the output, inflation, and nominal interest rate of the USA. The output gap is the natural log of the ratio of the trend of output to real output. (Ajilore & Ikhide, 2013; Apanisile & Ajilore, 2013). The Hodrick-Prescott filter was used to extract the trend of real output from the output data. We generated anticipated and unanticipated monetary policies by estimating the monetary policy function. The predictive component of the model represents the anticipated monetary policy while the residual represents the unanticipated monetary policy. Outliers, trends, and non-stationarity of the selected variables were filtered. This was done to ensure the stability of the model. As a robustness check, two periods were considered, 2007:1–2019:4 and 2011:1–2019:4. The first period was considered to establish the effect of the financial crisis that started in the USA in 2007. The latter sample was considered as a post-consolidation era. Following Li and Liu (2017), the study considered four observable variables so that the model could be free from a stochastic singularity.

4.2 Methodology

This study employs the Bayesian approach in estimating the DSGE models. We simulated the posterior kernel for each model specification using the random-walk Metropolis-Hastings (MH) algorithm. This simulation method is commonly used in the current literature of Bayesian estimation of DSGE models. The popular Matlab package and Dynare, version 4.3.3, were used to estimate our model.

4.3 Calibration

The choice of priors was based on the observations and facts emanating from the extant literature. Therefore, factors such as the validity of the economic theory, stylised facts about the economy, observation, and the literature were considered in the selection of priors for the parameters to be estimated. This study benefited from such studies as Adebiyi and Mordi (2011), Mordi et. al. (2013), Akinlo and Apanisile (2019), Apanisile and Osinubi (2020), and Apanisile and Akinlo (2022). The initial values (priors) and the standard errors selected are shown in Table 1.

Table 1: Priors of the Estimated Parameters

Parameter	Description	Density	Mean	Std Deviation
α_3	Measures impact of inflation expectation on the output gap	beta	0.300	0.050
α_4	Measures impact of anticipated monetary policy on the output gap	beta	0.670	0.050
α_5	Measures impact of unanticipated monetary policy on the output gap	beta	0.320	0.050
α_7	Measures impact of interest rate on the output gap	beta	0.200	0.049
α_8	Measures impact of bank loans on the output gap.	beta	0.300	0.050
β_1	Intercept	beta	0.990	0.051
β_2	Measures output persistence	beta	0.125	0.050
β_4	Measures impact of anticipated monetary policy on inflation	beta	0.300	0.050

β_5	Measures impact of unanticipated monetary policy on inflation	beta	0.250	0.050
β_7	Measures impact of interest rate on inflation	beta	0.260	0.050
β_8	Measures impact of bank loan on inflation	beta	0.310	0.050
φ_1	Measures policy persistence	gamma	0.220	0.050
φ_2	Measures weight put on inflation by policymakers	gamma	0.240	0.051
φ_3	Measures weight put on output gap by policymakers	gamma	0.300	0.050
eps_v	Measures unanticipated monetary policy shocks	invg	0.063	0.0267
eps_k	Measures shock to commercial bank credit to the private sector	invg	0.035	0.0301
eps_x	Measures output gap shocks	invg	0.488	0.0426
eps_u	Measures inflation shocks	invg	0.060	0.0098
eps_a	Measures anticipated monetary policy shocks	invg	0.500	0.0455

Our study went further to simulate the model to confirm the existence of the steady-state and obtain the steady-state values of the endogenous variables. To achieve this, we calibrated the stochastic shocks of the model. The calibration shocks are presented in Table 1. Based on the simulation result, the steady state, its values, and responses of the variables to orthogonal shocks were derived. The results show that the steady-state exists and the model has a unique solution.

5. DISCUSSION OF RESULTS

Table 2: Correlation Matrix

	Anticipated	Credit	Exchange	Inflation	Interest	Output	Trade	Unanticipated
Anticipated	1.00							
Credit	0.22	1.00						
Exchange	0.15	-0.30	1.00					
Inflation	-0.18	0.13	-0.50	1.00				
Interest rate	0.02	-0.21	0.42	-0.81	1.00			
Output	0.15	0.99	-0.35	0.14	-0.21	1.00		
Trade	-0.04	0.55	0.38	-0.08	-0.12	0.53	1.00	
Unanticipated	0.22	-0.54	0.43	-0.53	0.48	-0.55	-0.06	1.00

Table 2 presents the degree of relationship between the variables. The purpose of this analysis is to show the correlation between the independent variables used in the study. This analysis is a way of detecting the existence of collinearity among the independent variables. The rule of thumb is that the degree of correlation must not be greater than 0.6. A correlation coefficient that is greater than 0.6 signifies a strong relationship between the two variables; therefore, they must not be included in the same model. The independent variables in Table 2 include credit to the private sector, exchange rate, terms of trade, anticipated monetary policy, and unanticipated monetary policy. Looking at the results in Table 2, it can be seen that there is no evidence of collinearity as the degree of relationship between the independent variables is less than 0.6.

Furthermore, the posterior density of the estimation was derived from the calibration process using a random walk MH algorithm-generated posterior density of 10,000 draws. 94 out of the available 112 data points were used in generating the posterior density. The logarithm of the data used in generating the posterior density is -215.036470. The result is presented in Table 3, which shows the values of the prior mean, posterior mean, prior standard deviations, and confidence interval. The values are for the estimated parameters and shocks.

Table 3: Priors and Posteriors of the Estimated Parameters

Parameter	Density	Prior Mean	Posterior Mean	Standard Deviation	Confidence Interval at 90%
α_3	beta	0.300	0.3025	0.050	0.2940 0.3108
α_4	beta	0.670	0.6705	0.050	0.6619 0.6785
α_5	beta	0.320	0.3206	0.050	0.3118 0.3286
α_7	beta	0.200	0.1955	0.049	0.1875 0.2029
α_8	beta	0.300	0.3006	0.050	0.2928 0.3081
β_1	beta	0.990	0.9880	0.051	0.9791 0.9974
β_2	beta	0.125	0.1263	0.050	0.1177 0.1352
β_4	beta	0.300	0.2996	0.050	0.2919 0.3080
β_5	beta	0.250	0.2500	0.050	0.2418 0.2587
β_7	beta	0.260	0.2603	0.050	0.2527 0.2682
β_8	beta	0.310	0.3116	0.050	0.3036 0.3204
φ_1	gamma	0.220	0.2300	0.050	0.2218 0.2385
φ_2	gamma	0.240	0.2442	0.051	0.2361 0.2524
φ_3	gamma	0.300	0.3115	0.050	0.3029 0.3208
eps_v	invg	0.063	0.3441	0.267	0.2986 0.3857
eps_k	invg	0.035	0.4176	0.301	0.3665 0.4687
eps_x	invg	0.488	0.5910	0.426	0.5185 0.6648
eps_u	invg	0.060	0.0385	0.098	0.0140 0.0651
eps_a	invg	0.500	0.2042	0.455	0.1108 0.2905

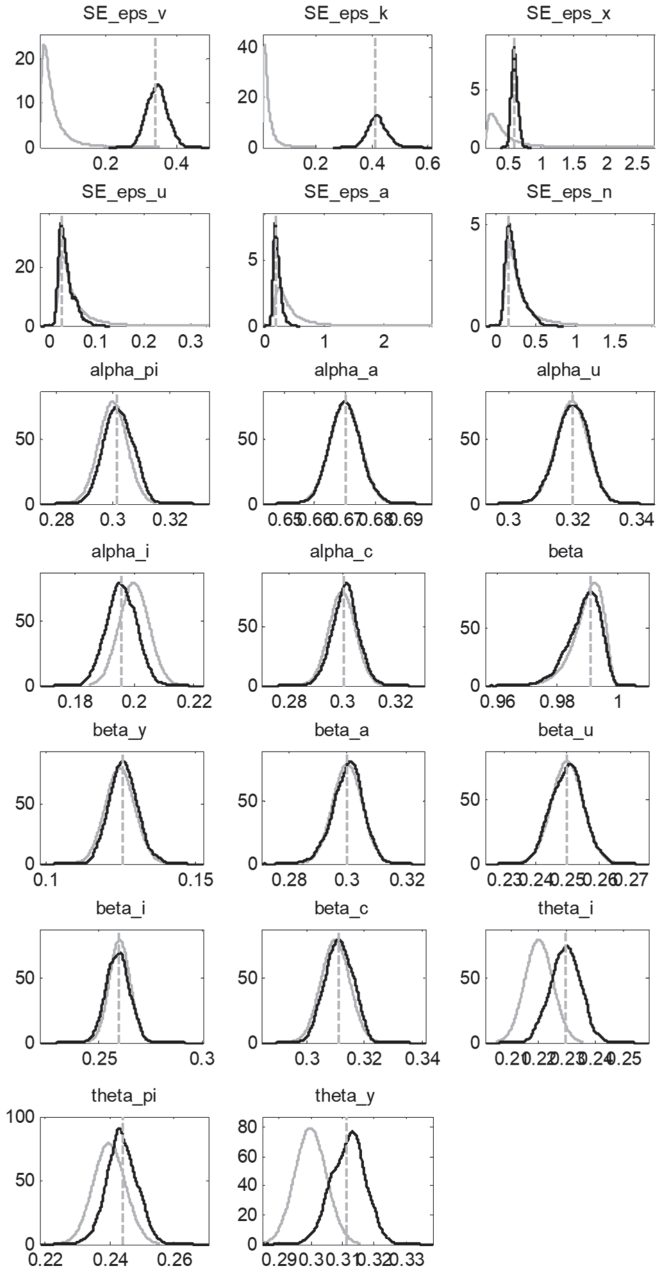
It can be seen from the results in Table 3 that the posterior means and the prior means are not the same. This implies the available data does indeed provide information about the Nigerian economy. Looking at the output gap equation, one can see the consistency in Nigeria's household consumption and that the posteriors are higher than the priors. These results corroborate the findings of Adebiyi and Mordi (2011) and Mordi et. al. (2013)

Furthermore, the results of the Phillips curve equation reveal basic information about the pattern of inflation in Nigeria as evident in the results of the prior and posterior estimation of this equation. Measures of output gap expectation (β_2), anticipated monetary policy (β_4), unanticipated monetary policy (β_5), and measures of interest rate (β_7) determine the behaviour of the economy. The posterior value of β_4 (0.2996) shows that 29 per cent of the firms in the economy failed to re-optimise their prices in the quarter under consideration. The posterior value of β_5 (0.2500) reveals that 25 per cent of the available firms re-optimised their prices in quarter two. This result implies that firms in the country have the average price re-optimisation within the second quarter. This supports the studies of Adebiyi and Mordi (2010), Mordi et. al. (2013), and Garcia (2010). The effect of monetary policy on inflation is measured by the posterior value of output and exchange rate parameters, which must be greater than zero. The output gap (β_2 = 0.1263) and exchange rate (β_6 = 0.15) satisfy this condition. This implies that the Central Bank of Nigeria has effective tools for the output gap and exchange rate to control inflation. The estimates of the reaction function of the monetary policy provide adequate information about the design of monetary policy in the country in the period under investigation. Following the estimation of the Taylor-type reaction function, monetary policy is active and shows a strong effect on the output gap. This shows the operation of monetary policy is in tandem with the Taylor-type. In addition, the operation of the Central Bank is concerned with output stabilisation as against price stability in the long run.

The posterior value of the lag of interest rate (φ_1 = 0.2300) is greater than its prior value (0.2200). This indicates that the short-term interest rate follows a smoothing path. The result of this estimate differs from that of Adebiyi and Mordi (2010), 0.623, and that of Mordi et. al (2013), 0.43. The policy reaction function results reveal that monetary policy design is effective in achieving the primary objective of price stability and economic growth as its supporting objective. Examining the posterior estimate of the standard deviations, the output gap shock is the most volatile shock (0.5910) and the shock to the commercial bank credit to the private sector (0.4176) is the least volatile. The results of these parameters indicate that they are driven by the data.

The diagram of the prior and the posterior of the parameters is presented in Figure 2. Grey represents the prior while black represents the posterior. The green line in each chart is the posterior mode generated from the numerical optimisation of the simulations. It can be observed from the result that both the prior and the posterior estimates are the same except in a few cases. This result validates the likelihood of our estimation. In addition, the posterior values are close to normality. The implication is that our model accurately models the Nigerian economy.

Figure 2: Prior and Posterior Distributions



5.1 Estimating the Viability of the Model

Our study employed a set of diagnostic tests to examine the statistical integrity of the whole estimation process. The diagrams in the results of our sensitivity analysis contain the historical and smoothed graphs of the estimated parameters. In each diagram, the length of the period in each sample is plotted on the horizontal axis. In addition, the study used the univariate and the multivariate MCMC test to verify how sensitive the Metropolis-Hastings algorithm is. The sensitivity level of the MH algorithm calls for the similarity of the simulation's result both within and across the chain. The lines are expected to vary for a while and later converge at the end of the process (Griffoli, 2007; Mordi et. al., 2013). The diagrams show that the lines of all the estimated parameters satisfy the conditions.

The results of the multivariate MCMC test are summarised in three graphs. Each graph represents two different lines that show the within and between-chain results. The results explain the analysis of parameters mean (interval), variance (m2), and third moment (m3). The condition requires that both lines converge to their steady state at the same time. The results affirmed the stability and convergence of all the models.

5.2 Result Sensitivity

The sensitivity of the selected priors was confirmed by changing the prior means and standard deviation by one per cent and re-estimating the model. The results of the re-estimated model are shown in Table 4. The results, when compared with the benchmark result in Table 3, show that the changes noticed in the re-estimated model were not significant.

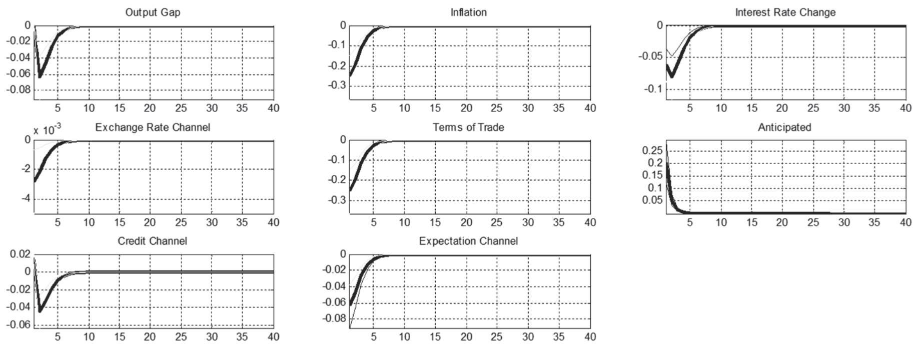
Table 4 Sensitivity Result with 1% Increase in Prior Mean and Standard Deviation

Parameter	Density	Prior Mean	Posterior Mean	Standard Deviation	Confidence Interval at 90%	
α_3	beta	0.303	0.2990	0.0505	0.2897	0.3078
α_4	beta	0.6767	0.6704	0.0505	0.6617	0.6783
α_5	beta	0.3232	0.3204	0.0505	0.3127	0.3291
α_7	beta	0.202	0.1967	0.04949	0.1879	0.2044
β_1	beta	0.9999	0.9905	0.05151	0.9838	0.9977
β_2	beta	0.12625	0.1284	0.0505	0.1206	0.1370
β_4	beta	0.303	0.3003	0.0505	0.2918	0.3084
β_5	beta	0.2525	0.2502	0.0505	0.2417	0.2572
β_7	beta	0.2626	0.2604	0.0505	0.2518	0.2692
φ_1	gamma	0.2222	0.2215	0.0505	0.2129	0.2292
φ_2	gamma	0.2424	0.2334	0.05151	0.2261	0.2412
φ_3	gamma	0.303	0.3013	0.0505	0.2936	0.3098
eps_v	invg	0.063125	0.0239	0.26967	0.0142	0.0334
eps_k	invg	0.035754	0.1579	0.304011	0.1382	0.1787
eps_x	invg	0.49288	0.3334	0.43026	0.2880	0.3779
eps_u	invg	0.0606	0.2773	0.09898	0.0158	0.0394
eps_a	invg	0.505	0.1414	0.45955	0.0977	0.1821

5.3 Impulse Response Results

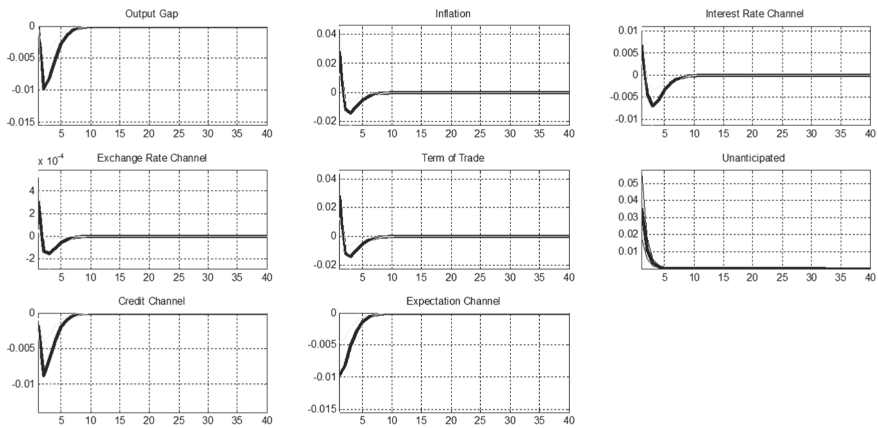
The impulse response of the estimated model reveals the propagation of the steady-state shocks within the economy. The results of the impulse response are presented in Figures 3 to 6.

Figure 3: Response to 1% Anticipated Monetary Policy Shock



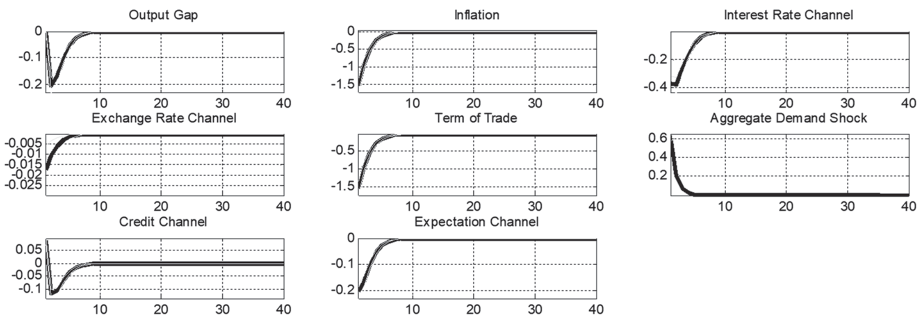
Anticipated monetary policy harmed transmission channels such as the interest rate, exchange rate, expectation, and credit channels. It impacted negatively on the interest rate, exchange rate, and credit to the private sector. It reduced the rate of interest from 0.06 per cent in quarter one to 0.009 in quarter eight. The credit channel also demonstrated a negative response to the anticipated shock, though the effect is insignificant over the periods. This confirmed the argument of rational expectation theory that the anticipated shock would increase the price at the expense of other macroeconomic objectives. It could also be observed that the variables return to a steady state after their responses to shock.

Figure 4: Response to 1% Unanticipated Monetary Policy Shock



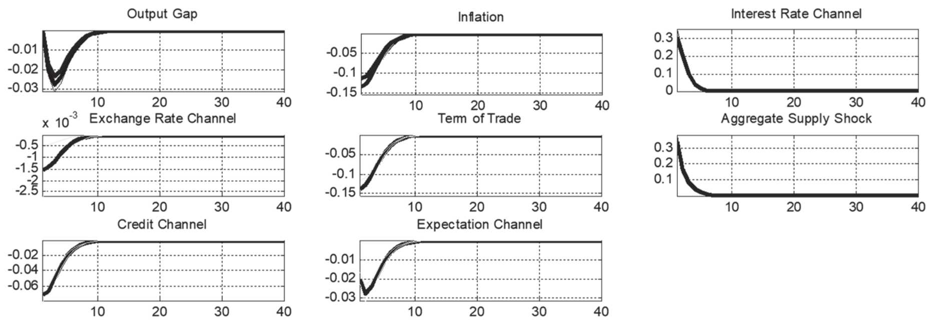
The interest rate responded positively to the unanticipated monetary policy shock while the exchange rate, credit, and expectation channels responded negatively. The interest rate channel transmitted 0.31 per cent in quarter one and this decreased to 0.004 per cent in quarter eight. Pressure from the unanticipated monetary policy shock subdued the performance of the exchange rate as the percentage of shock transmitted by the channel decreased from 0.002 in quarter one to zero in quarter eight. The same trend is noticed in the performance of the credit channel as the percentage of shock transmitted decreased from 0.07 per cent in quarter one to 0.003 per cent in quarter eight. Finally, the expectation channel performance followed the same trend. This result showed the pro-cyclicality of monetary policy in Nigeria. These results reasonably captured the effectiveness of monetary policy as it showed how to achieve its basic objectives, with some nominal tradeoffs, in terms of output decline and exchange rate appreciation. In the medium to long run, all the variables converged to their equilibrium levels.

Figure 5: Response to 1% Aggregate Demand Shock



A shock to aggregate demand could either be positive or negative. The interest rate, exchange rate, credit, and expectation channels responded negatively to a one per cent positive aggregate demand shock. Although the response of the exchange rate to a positive demand shock is negative, the results are different both in the long-run and short-run periods. In the short run, the response is negative and significant. However, in the long run, it is negative and insignificant. The percentage of shock transmitted by interest rate and exchange rate channels fell from 0.36 per cent and 0.08 per cent in quarter one to 0.009 per cent and 0.003 per cent in quarter eight, respectively. The expectation channel also decreased from 0.20 per cent in quarter one to 0.002 per cent in quarter eight. For the exchange rate, the percentage of shock fell from 0.01 per cent in quarter one to zero in the last quarter. All the variables converged to a steady state in the long run.

Figure 6: Response to Aggregate Supply Shock



The transmission channels differ in their responses to an aggregate supply shock. The credit and expectation channels responded negatively to the shock while interest rate and exchange rate responded positively both in the long- and short-run periods. The overall results showed that the supply shock produced short-term effects as against the demand shock. Given that the supply shock led to temporal supply adjustment problems, it pushed credit to the private sector upward from 0.001 per cent in the first quarter to 0.003 per cent in the fourth quarter. The interest rate and expectation channels responded negatively and the percentage of shocks transmitted fell from 0.06 per cent and 0.09 per cent in quarter four to 0.004 per cent and 0.002 per cent in quarter eight, respectively. The exchange rate produced an insignificant result as its values fizzled out over the entire period. The variables eventually converged to their steady state in the long run.

5.4 Robustness Check

Following Li and Liu (2013), the robustness of our empirical results was checked in the following two ways. First, we slightly altered the beginning and ending quarters of the samples, in addition to trying samples other than the baseline samples. For instance, 2007:1 to 2019:4 was taken as the longest sample instead of

2005:1 to 2019:4. Furthermore, the samples were extended to a more recent quarter i.e. 2011:1 to 2019:4. Second, some of the observable variables were changed and different measures for the existing observable variables were also used. For example, one of the observable variables was replaced by credit to the private sector as a measure of the credit channel. Furthermore, the short-term interest rate was used to represent the nominal interest rate against the treasury bill. The official exchange rate was also used to represent the exchange rate channel against the fixed effective exchange rate. It turns out that our baseline results do not change qualitatively in this robustness check.[1]

6. CONCLUSION

Our study examines the financial crisis, banking reforms, and effectiveness of monetary policy transmission channels in Nigeria by estimating a sticky-price dynamic stochastic general equilibrium model using quarterly data from 2005:1 to 2019:4. Our results are in line with the finding of Ashamu and Abiola (2012) and showed that the financial crisis "caused a drop in the quality of part of the credit extended by banks for trading in the capital market, exchange rate risk tightening of liquidity, greater loan-loss provisioning, slower growth rate of banks' balance sheet in response to the crisis and higher provisioning leading to lower profitability among others" (Ashamu & Abiola, 2012, p. 251). Furthermore, it was discovered that recent changes and reforms have positive impacts on all the monetary policy transmission channels considered in the study (exchange rate, interest rate, expectation, and credit). However, the credit channel (proxied by credit to the private sector) appears to be the most active channel as it transmits the largest impact of shocks to the financial sector (88.06 per cent on average) to the real economy. This demonstrates that the private sector depended on the financial sector for financing its expenditures which later induced an increase in the level of investment and increased output. Mengesha and Holmes (2013) argued that the effectiveness of credit channels, however, is an empirical issue that varies from one country to another. In line with their argument, most of the findings in the literature indicate the ineffectiveness of the credit channel through the private sector. Their argument is based on the fact that the effectiveness of the credit channel comes from credit issued to the government sector and not the

1 The results of the robustness check are available upon request.

private sector (Mengesha & Holmes, 2013; Ravn, 2014; Gambacorta & Signoretti, 2014; Badarau & Popescu, 2014).

In addition, the data were found to be informative as the posterior means are different from the prior means. Furthermore, the prior and posterior estimations of the hybrid Phillips equation show that the data provide useful information in explaining inflation behaviour in Nigeria. Our study concluded that structural weaknesses such as a weak legal framework, poor governance, and insufficient infrastructure, which have contributed to inadequate financial intermediation and heightened risks, must be eliminated because they hamper the transmission mechanism of monetary policy.

Data Availability Statement

The datasets generated during and/or analysed 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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