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Aims and Scope

The *Economic and Financial Review (EFR)* is a quarterly publication of the Research Department of the Central Bank of Nigeria. The Review contains articles on research undertaken at the Bank, in particular, and Nigeria, in general, mainly on policy issues both at the macroeconomic and sectoral levels in the hope that the research would improve and enhance policy choices. Its main thrust is to promote studies and disseminate research findings, which could facilitate achievement of these objectives. Comments on or objective critiques of published articles are also featured in the review.

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Notes to Contributors

Information on manuscript submission is provided on the last and inside back cover of the Review.

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Global Crude Oil Price, Naira Exchange Rate and Monetary Policy Effectiveness in Nigeria

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Abstract

The study sought to assess the impact of oil price shocks on exchange rate and the effectiveness of monetary policy in Nigeria. This paper developed a structural VAR model, using quarterly data spanning 2000Q1 to 2018Q2. The relationship among oil price shocks, external reserves, exchange rate, output, price, and monetary policy instruments (policy rate, cash reserve ratio, open market operations and supply of foreign exchange), was examined using structural impulse response functions, dynamic impact analysis and forecast error variance decomposition. The result showed that: first, positive oil price shocks led to accretion of reserves and the naira appreciation against the United States dollar, which conformed to the wealth effect channel of oil price transmission mechanism for oil-exporting countries; second, oil price shocks resulted in inflationary pressures and reduction in output growth; third, response of monetary policy to oil price shocks was found to be generally restrictive; lastly, treasury-bill rate was found to be the optimal monetary policy tool in stabilising exchange rate and the macroeconomy, amidst oil price shocks.

Keywords: Oil, Structural VAR, Exchange Rate, Monetary Policy

JEL Classification Numbers: F31, Q43

I. Introduction

High volatility exhibited by global commodity prices, particularly crude oil has been a source of concern for policy makers. The distorting effects of this on oil-rich economies like Nigeria are also significant, depending on how vulnerable they are to external shocks. Specifically, the literature holds that changes in oil prices influences intra/inter temporal consumption decisions, terms of trade as well as the cost structure of firms - and through this channel has a second-round effect on domestic prices, exchange rate and output growth (Medina, 2005).

Nigeria as an oil-rich country depends majorly on crude oil as a major source of foreign exchange and revenue to the government. Crude oil constitutes about 87.0 per cent of foreign exchange earnings and 75.0 per cent of government revenue in the last four decades. Given the oligopolistic nature of the crude oil market, Nigeria has little control on both the price and output, thus becoming highly vulnerable to external shocks. With greater chunk of foreign exchange earnings coming from crude oil export, changes in crude oil price would no doubt affect the external reserve and the value of naira exchange rate. Therefore, volatility in oil price has implication on external reserve accretion and exchange rate stability. A depleted external reserve due to fall in oil receipt could dampen investors' confidence in the economy thereby leading to capital reversal and exchange rate depreciation due to demand pressure.

A depreciated naira could in turn put pressure on prices due to the import dependency nature of the economy, which could stifle growth. For instance, in 2014, crude oil price witnessed a declining trend, falling from an average of over $100.0 per barrel in June, 2014 to less than $50.0 per barrel by January 2015 but rose slightly above US$60.0 per barrel since 2016 and has been hovering around this price up to mid-2018. This has affected Nigeria,

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leading to decline in foreign exchange earnings and government revenue. With fall in foreign exchange earnings, external reserve plummeted due to high demand pressure in the foreign exchange market and capital reversal. Thus, the naira exchange rate to dollar depreciated from an average of ₦150/US$ in 2014 to ₦305/US$ in June 2016. This led to exchange rate crisis and subsequently, the economy went into recession in the second quarter of 2016. In the same vein, inflation trended upwards moving from a single digit of 8.0 per cent in 2014 to an average of 16.5 per cent in 2017. These developments made monetary policy more innovative in order to minimise the impact and help achieve the primary objective of price stability. The Central Bank had to use cocktail of policy instruments to stabilise the exchange rate and reduce inflationary pressure. The central bank, through monetary policy and other unconventional methods, endogenously react to the movements in exchange rate, inflation and output growth caused by the oil-price shocks.

The Bank, in a bid to stabilise the exchange rate due to fall in oil price and lower inflationary pressure, raised the monetary policy rate (MPR) from 12.0 per cent in 2014 to 14.0 per cent in 2016, increased the cash reserve requirement to 22.5 per cent and adopted other measures (issuance of treasury bills and open market operations) to mop up excess liquidity in the system to stem inflationary pressures. Also, unconventional approaches were adopted to curb rising demand pressure on exchange rate, which included the banning of 41 items from accessing foreign exchange form the official market; direct intervention in the foreign exchange market; the shift to a more flexible exchange rate regime in 2016; and the establishment of Investors and Exporters foreign exchange window in 2017.

Given the efforts of the Bank to stabilise exchange rate amidst oil price volatility, it is therefore, necessary to empirically investigate the effectiveness of these efforts in stabilising the economy. The objective of the study is therefore to empirically investigate the impact of crude oil price shock on the naira exchange rate and the effectiveness of monetary policy measures put in place by the monetary authority in stabilising prices (exchange rate and inflation) and stimulating economic growth. Specifically, the study would examine the optimal policy measure that would effectively stabilise exchange rate and the macroeconomy particularly during episodes of oil price shock.

The rest of the paper is structured as follows: Section 2 reviews relevant literature on how exchange rate and monetary policy respond to oil price shocks, while Section 3 examines the monetary policy framework in Nigeria. Section 4 discusses the methodology employed, while Section 5 presents the empirical findings and Section 6 concludes the paper.

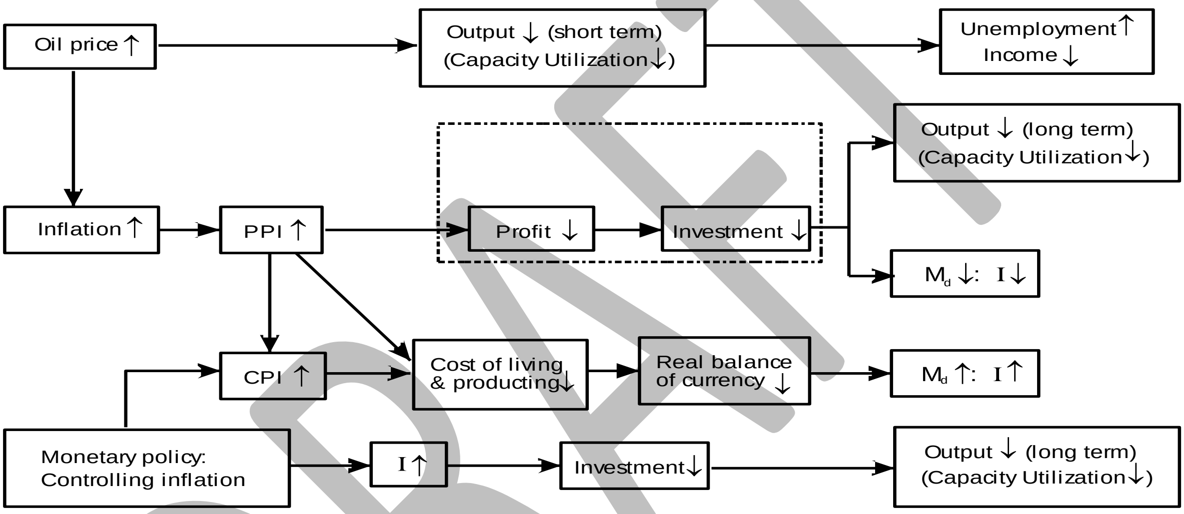
II. Review of Relevant Literature

II.1 Theoretical Landscape

The theoretical thinking on the transmission channels of oil price shock to the macroeconomy has been investigated by several studies including Brown and Yucel (2002), Tang, et al., (2010) Adenuga et al., (2012), Bodenstein et al., (2012) and Olubusoye et al., (2017). These studies have broadly categorised these channels into the supply-side and demand-side channels. Brown and Yucel (2002) proposed that a shock in oil price, from the supply side perspective, increases the marginal cost of production and decreases investment, thereby, waning capacity utilisation and causing rise in unemployment. This leads to the eventual fall in output with the attendant negative impact on real wages, causing price-wage loops.

From the demand-side perspective, Jimenez-Rodriguez and Sanchez (2005) and Adenuga, et al. (2012) noted that oil price shock influence the price of products in the market, thereby pushing up inflation and eroding the purchasing power of economic agents. Furthermore, Brown and Yucel (2002) and Tang, et al. (2010) argued that increased oil price shock contracts the demand for real balances in the face of increased real interest rate and decreased investment. This decelerates consumption through the reduction in disposable income as prices rises amidst rising cost of production. Specific to the association between commodity prices and the value of domestic currencies, De Gregorio and Wolf (1994) suggested that the currency of commodity (including oil) exporting countries tend to co-move with commodity prices. From a theoretical standpoint, Bodenstein et al., (2012) identified different channels through which an oil price shock may be transmitted to the exchange rate: the terms of trade, wealth effects and the associated trade balance and portfolio reallocation channels.

Figure 1: Transmission Channels of Oil Price Shock



Transmission channels of oil-price shocks.

Source: Adapted from Tang *et al.* (2010)

On the one hand, the terms of trade mechanism, which is considered to follow the Harrod-Balassa-Samuelson effect, works through the relative productivity differentials between traded and non-traded goods sector. Thus, positive terms of trade shock drives up the price of the non-traded goods in the domestic economy and the real exchange rate, and vice versa. On the other hand, the wealth effects channel works through the income effect where a positive oil price shock transfers wealth from oil importers to oil exporters, leading to large shifts in current account balances and portfolio reallocation (see Kilian, 2007). In order to restore the external net financial sustainability of oil importers (exporters), the real exchange rate has to depreciate (appreciate) following a positive oil price shock, in order to improve the non-oil trade balance. On the flipside, oil exporters experience real exchange rate appreciation pressures in the midst of positive oil price shocks which may lead to the Dutch disease.

Although these fundamental channels tend to suggest an inverse relationship between oil prices and exchange rate of oil-exporters, Buetzer et al (2012) noted that this might not be the case in practice given second-round effects and offsetting factors that attenuate the link between oil price shocks and the exchange rate. They further noted that the sustainability of external adjustment of economies would rely mainly on the degree of flexibility of the exchange rate and foreign reserves holdings.

II.2 Empirical Literature[1]

From an empirical perspective, a plethora of studies exists on the impact of oil price shocks on the macroeconomy of various countries. These studies majorly focus on the macroeconomic stabilisation policy put in place by monetary authorities in the aftermath of oil price shocks. Literature on the subject matter is classified broadly into two strands, namely: jurisdictional perspective (whether the country is oil-importing or oil-exporting countries); and methodology.

The first strand of literature focuses on the structure of the economy being investigated. While a great number of studies have focused on the oil-importing countries (see Hamilton, 1983, for the United States; Medina and Soto, 2005 for Chile; Kim et al., 2017 for China; and Malik, 2007 for Pakistan), others have examined it from an oil-exporting point of view (See Allerget and Benkhodja, 2015 for Algeria; Semko, 2013 and Rautava, 2002 for Russia; Bashar et al, 2013 for Canada; Farzanehan and Markwardt, 2009 for Iran; Habib and Kalamova, 2007 for Norway, Saudi Arabia and Russia; Anashasy et al, 2005, for Venezuela; and Dibooglu and Aleisa, 2004 for Saudi Arabia). Furthermore, several studies were carried out on Nigeria (see Olomola and Adejumo, 2006; Aliyu, 2009, Adebiyi and Mordi, 2010; Englama et al, 2010; Muhammad et al, 2011; Adeniyi et al, 2012; CBN, 2013; Chuku, 2015; and Olubusoye et al, 2017)[2]. Although most authors have focused on country-specific analyses, there has been appreciable number of cross-country studies that have investigated the relationship between oil price shocks and exchange rate (Buetzer et al, 2012, Nikbakht, 2009 and Basher, 2010). The findings of these studies are shown in Table 1.

The second strand of literature dwells on methodology, as a number of econometric approaches have been employed in examining the subject matter. While some studies employ the use of simple co-integration analysis (see Habib and Kalamova, 2007), others made use of volatility modeling techniques such as Generalised Autoregressive Conditional Heteroskedasticity (GARCH) and Exponential GARCH (see Muhammad et al, 2011; and Adeniyi et al, 2012). A number of studies employed multivariate time series analysis and structural modeling (see Olubusoye et al, 2017; Kim et al, 2017; Rautava, 2012, Soile and Nathaniel, 2012; Adebiyi and Mordi, 2010; Babatunde, 2015), Panel regressions (See Buetzer et al, 2012), and advanced methods such as Dynamic Stochastic General Equilibrium (DSGE) models (See Bodenstein et al, 2011; Medina and Soto, 2005; Montoro, 2010; Semko, 2013; Chuku, 2015; and CBN, 2013). The empirical findings of these studies are shown in Table 1.

In recent times, studies have focused on the effectiveness and optimality of monetary policy in catering for oil price shocks, owing to the fact that changes in oil prices influences intra/inter temporal consumption decisions as well as the cost structure of firms - and through this channel has a second-round effect on domestic prices (See Medina, 2005, Montoro, 2010; Semko, 2013, Chuku, 2015, Kim et al, 2017, Olubusoye et al, 2017). In terms of methodology, the studies have employed increasingly sophisticated approaches such as DSGE models. A clear fall-out of these studies, including in Nigeria is the need to further investigate the dynamics of the relationship, as the economy evolves and complexity of

[1] See Appendix I for the selected studies on the subject matter.
[2] See Table 1 for their findings

interactions among economic variables increases. This way, policymakers are able to better track emerging interdependencies and effectively diagnose the economic situation to guide policy.

Table 1: Selected Studies on Oil, Exchange Rate and Monetary Policy Nexus

Study	Jurisdiction(s)	Methodology	Findings
Medina and Soto (2005)	Chile (1990Q1 – 2005Q1)	DSGE	Oil price shocks have contractionary effects on the economy, which is attributed to the endogenous tightening of the monetary policy. Optimal monetary policy would be that which targets core rather than CPI inflation
Bodenstein et al (2011)	United States	2-Country DSGE	Increase in oil price occasioned by demand and supply shocks results to increased transfers to oil exporters. This wealth effect principally brings about decline in consumption, depreciation of the exchange rate and surplus in the non-oil balance of the oil-importing country
Olubusoye et al (2017)	Nigeria (1980Q1 – 2014Q3)	Structural VAR	Oil price shocks resulted to appreciation of the nominal exchange rate. Response of monetary policy was found to be expansionary
Bashar et al (2013)	Canada		Higher oil price uncertainty reduces output and price levels. The monetary policy reaction was found to be expansionary in the period of oil price shocks.
Kim et al (2017)	China (1992M04 - 2014M05)	Structural VAR TVP-Structural VAR	Oil price shocks becomes an increasingly important source in the volatility of China's interest rate
Adeniyi (2011)	Nigeria (1987Q1 – 2008Q4)	Threshold VAR	oil price shocks do not account for a significant proportion of observed movements in macroeconomic aggregates
Buetzer et al (2012)	Panel (12 advanced and 32 emerging economies) 1986Q1 - 2011Q1	Structural VAR Panel Regression	Oil shocks are not important factors in global exchange rate configuration as no evidence was found that currencies of oil exporting countries systematically appreciate after oil shocks.
Semko (2013)	Russia	DSGE	Positive oil price shocks leads to currency appreciation
Rautava (2012)	Russia 1995Q1 - 2001Q3	VAR	Oil price shocks result in appreciation of the exchange rate
Soile and Nathaniel (2015)	Nigeria	Standard VAR	Oil price shocks results to appreciation of exchange rate as well as adverse effects other macroeconomic variables
Adebiyi and Mordi (2010)	Nigeria (1999M01 – 2008M12)	Structural VAR	Positive oil price shocks results to depreciation of the domestic currency while negative oil price shocks lead to an appreciation of the currency.
Chuku (2015)	Nigeria	DSGE	Flexible exchange rate regime
Babatunde (2015)	Nigeria Jan 1997 – Dec 2012	Time Series and Structural Analysis	Positive oil price shocks were found to depreciate the exchange rate, whereas negative oil price shocks appreciate the exchange rate. In addition, the asymmetric effects of positive and negative oil price shocks on the real exchange rate were not supported by the statistical evidences.

CBN (2013)	Nigeria	DSGE	Oil Price Shocks initially resulted in depreciation of nominal exchange rate, however, it was short-lived. Thereafter appreciation of the exchange rate is observed for the rest of the horizon
Olomola and Adejumo (2006)	Nigeria (1970 -2003)	VAR	Oil price does not affect output and inflation significantly but influences exchange rate significantly. Thus, oil price shocks may give rise to wealth effect that appreciates the real exchange rate and may squeeze the tradable sector, giving rise to the "Dutch-Disease"
Englama et al (2010)	Nigeria (1999M01 to 2009M12)	VECM	Exchange rate volatility is greatly influence by the swings or volatility in oil prices at the international market both in the long-run and short-run.
Muhammad et al (2011)	Nigeria (2007 – 2010)	GARCH Exponential GARCH	Existence of a direct relationship between oil price and naira depreciation
Adeniyi et al (2012)	Nigeria	GARCH Exponential GARCH	Increase in the price of oil results in an appreciation of the naira against the US dollar. In addition, asymmetric effect with regards to the magnitude, of positive and negative oil price shocks on exchange rate instability exists.
Habib and Kalamova (2007)	Norway, Saudi Arabia and Russia	Cointegration Analysis	In case of Russia a positive long-run relationship was found between oil price and exchange rate and no impact of oil price on exchange rate was found for Norway and Saudi Arabia.

III. Perspective of Monetary Policy Framework in Nigeria

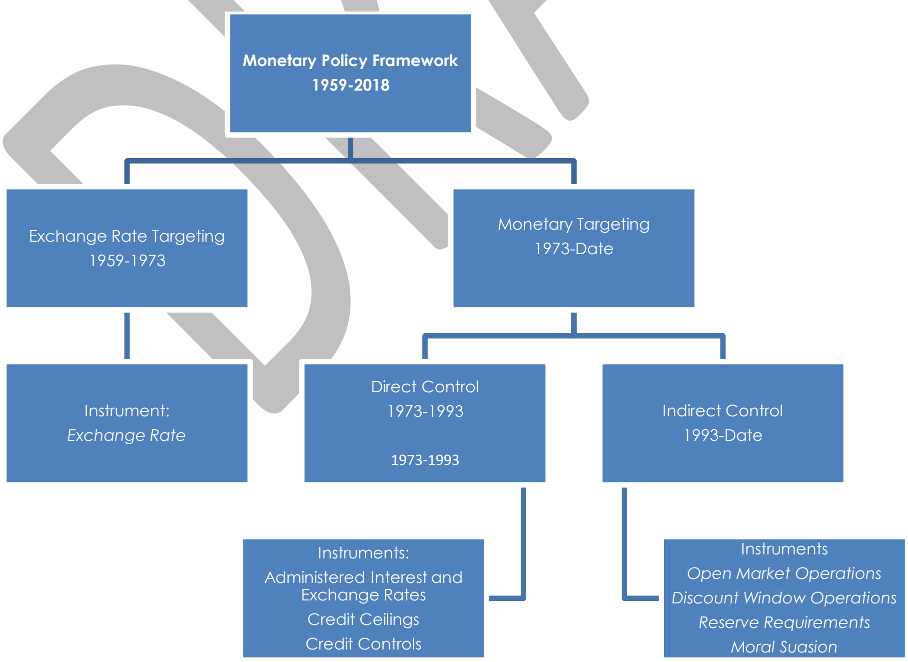
Over the years, the formulation and implementation of monetary policy framework in Nigeria conforms to the evolution of the Nigerian economy. However, the broad objectives of monetary policy in Nigeria remained the same and revolved around the maintenance of price stability and healthy balance of payments position, reduction of unemployment, and improvement of credit flow to the priority sectors of the economy (CBN 2009). In the early years of central banking, the conduct of monetary policy was by consensus between the Central Bank and the Federal Ministry of Finance. The subsequent amendments and re-enactment of the CBN Act fashioned out and vested the responsibility of monetary policy solely to the Central Bank. The Monetary Policy Committee (MPC) was established in 1999, and was charged with the responsibility of taking all monetary policy decisions.

Since inception, the central bank has practiced two policy frameworks for the conduct of monetary policy namely: exchange rate and monetary targeting frameworks. Prior to 1974, exchange rate targeting was adopted with the exchange rate as the nominal anchor. During that period, the naira was fixed at par with the British Pound Sterling and subsequently to a basket of 12 currencies. The result was stability in exchange rate, monetary aggregates and prices. However, exchange rate targeting was abandoned due to the collapse of the Bretton Woods fixed exchange rate system and the global switch to flexible exchange rate system. In addition, the monetary policy strategy shifted from supply-side management policies to demand management polices to control inflation. This also necessitated the shift to monetary targeting.

Monetary targeting as a monetary policy framework was adopted in 1974 with the Bank targeting the reserves of the deposit money banks to influence the growth of money supply in the economy. Since then, this framework has remained in operation to date. During this period, the conduct of monetary policy was carried out using a variety of instruments. The Bank implemented the direct monetary control as the instrument of monetary policy between 1974 and 1993. The underdeveloped nature of the financial markets during that period did not support the use of market-based instruments. The instruments included the use of credit ceiling, credit control, credit rationing and administered interest and exchange rates. These instruments were used to influence the rate of change in monetary aggregates with emphasis on bank credit to priority sectors of the economy in order to stem inflationary pressures. The over reliance of the direct monetary control framework on credit controls, ceilings and rigid interest rate led to monetary expansion and underdeveloped money and capital markets. In order to address these issues and improve the effectiveness of monetary policy to achieve the main objective of price and monetary stability, the use of indirect instruments for monetary policy was introduced.

The Bank adopted the use of indirect or market-based monetary policy instruments in 1993 and focused mainly on liquidity management. Open market operation is the main instrument for liquidity management, complemented by reserve requirements and discount window operations. The Bank used the Minimum Rediscount Rate (MRR) as the monetary policy anchor to influence short term interest rates in the financial market. Under this framework, the base money is the operating target used to influence monetary growth. These monetary policy frameworks implemented in Nigeria by the Bank is from inception to date is summarised in figure 2 below.

Figure 2: Monetary Policy Frameworks in Nigeria



A new monetary policy framework was introduced in 2006 to reduce interest rate volatility and improve the responsiveness of market rates to interest rate changes. The framework comprised a policy signaling rate called the monetary policy rate (MPR) which replaced the MRR as the anchor rate. In addition, an interest rate corridor was introduced with an upper and lower band around the MPR. The upper band represents the Bank's overnight lending rate (Standing Lending) while the lower band is the overnight deposit rate (Standing Deposit). Base money remained the operating target used to influence the intermediate target of money growth to ultimately achieve price stability. This framework is what guides monetary policy up to date. The new monetary policy framework is summarised in Table 2 below.

Table 2: New Monetary Policy Framework

Instruments	**Operating Target**	**Intermediate Target**	**Ultimate Target**
Main Instrument: ***Open Market Operations (OMO)*** Compliments: ***Discount Window Operations (*****MPR+ Interest Rate Corridor)** ***Reserve Requirements*** **(Cash Reserve Ratio and Liquidity Ratio)** **Moral Suasion**	Interest Rate Bank Reserves	Money Supply Bank Lending Short-Term Interest Rates Exchange Rate	Primary: Price Stability (Inflation) Secondary: Output Growth Balance of Payments Viability

In terms of monetary policy stance, the Federal government's broad macroeconomic objectives and the prevailing domestic and international economic conditions determines the direction of monetary policy in Nigeria. Over the years, eras of accommodative, restrictive and neutral policy stance were witnessed usually following the pattern of the domestic business cycle. The Bank has maintained a restrictive monetary policy stance since 2016 to date (2018), retaining the MPR rate at 14.0 per cent and asymmetric corridor of +200 and -500 basis points around the MPR; cash reserve ratio (CRR) at 22.5 per cent; and liquidity ratio at 30.0 per cent. This was in line with the economic fundamentals in the wake of economic recession and gradual recovery during the period.

Even though the Bank does not directly target exchange rate, it maintains an appropriate exchange rate policy that is consistent with its monetary policy objectives. The Bank, therefore, undertakes periodic intervention in the foreign exchange market to maintain exchange rate stability consistent with economic growth. A managed floating exchange rate regime with a band around a mid-point exchange rate was adopted to complement the new monetary policy framework. A band of ±3.0 per cent was maintained up to 2014 when it was widened to ±5.0 per cent around the mid-point exchange rate as a result of the pressure in the foreign exchange market. This system was abandoned in 2016, for a more flexible foreign exchange regime in the wake of an economic crisis triggered by the slump in crude oil prices at the international market. The shift to a more flexible exchange rate and other foreign exchange policy reforms has succeeded in stabilising the exchange rate at a level consistent with Banks monetary policy objectives.

IV. Econometric Methodology

IV.1 The SVAR Framework

Following Sims (1980)'s seminal paper, VAR models have become an increasingly powerful macroeconomic tool to gauge the dynamic response of a set of endogenous variables to exogenous shocks, and identify the magnitude of shocks on the endogenous variables. Specifically, Structural Vector Autoregressive (SVAR) models have become popular for structural and policy analysis. The idea behind these models is that structural economic shocks can be found as linear combinations of residuals of linear projection of a vector of variables with their past values.

A SVAR model has the following general form:

$$A_0 X_t = A_1(L) X_t + B\varepsilon_t \quad (1)$$

Where X_t is an n-vector relevant variable. A_0 and B are n x n matrix; and $A_1(L) = \sum_{i=1}^{q} A_{1i} L^i$ is a matrix polynomial in the lag operator; ε_t is an n-vector serially and mutually uncorrelated, zero mean structural shocks with identity contemporaneous covariance matrix, $E[\varepsilon_t \varepsilon_t^{'}] = 1$. Provided that A_0 in equation (1) is non-singular, solving for X_t yields the reduced form VAR representation:

$$X_t = A_0^{-1} A_1(L) X_t + A_0^{-1} B\varepsilon_t \quad (2)$$

or

$$X_t = C(L) X_t + u_t \quad (3)$$

Where $C(L) = A_0^{-1} A_1(L)$ and

$$A_0 u_t = B\varepsilon_t \quad (4)$$

The main technique is to estimate the reduced form of Equation (3), and recover the structural parameters, using the estimated coefficients and residuals obtained from the reduced form VAR. In general, Equation (4) is not identified unless restrictions are imposed on either A_0 or B.

IV.2 Model Specification

The study utilised a 6-variable SVAR system similar to that of Kim and Roubini (2000). While Kim and Roubini (2000) used their model to investigate the effects of monetary policy shocks on exchange rate and other macroeconomic variables, their model could be applied to examine the impact of oil price shocks on exchange rate and analyse its implications for monetary policy. This is simply because major macroeconomic variables, as well as variables relevant to oil price and monetary policy, are included in the VAR system utilised.

The VAR system is divided into several blocks as in Kim and Roubini (2000). For the domestic real sector, two variables are included to represent aggregate output and general prices while external reserves and exchange rate are incorporated to represent the external sector. For the monetary sector, the monetary policy rate is initially used, thereafter, other monetary policy indicators such as cash reserve ratio, sales of OMO bills, 3-month treasury bill rate and supply of forex to the foreign exchange rate market, are used in place of the policy rate, so as to investigate the effectiveness of these instruments individually. Finally, a measure of an exogenous oil price series has been added to represent the oil price shock.

The choice of the variables in the SVAR is motivated by a number of factors, namely: the variables are classified as endogenous variables in the theoretical sense to help in identifying structural disturbances; the assumption of small open economy is considered in modelling monetary policy in Nigeria; and a foreign set of variables are included, along with domestic variables to isolate the effects of exogenous oil price shocks on the exchange rate and monetary policy.

IV.3 Model Identification Scheme and Assumptions

Three types of structural restrictions exist in the literature namely: recursive restrictions; parametric restrictions on the diagonal matrix; and parametric restrictions on the impulse responses to shocks[3] (Ouliaris, et. al, 2016). This paper adapts the recursive short-run restriction approach, premised on the assumption that a small open economy is a price taker at the international oil market[4]. Thus, the ordering of the variables is as follows: real oil price (COP), external reserves (EXR), real exchange rate (USD), real output (RY), headline inflation (HCPI) and monetary policy indicator (MPR, CRR, OMO, SFX and TBR). The recursive structure (structural factorisation) of the contemporaneous terms is such that the reduced form error e_t, are linear combinations of the structural errors ε_t, as follows:

$$\varepsilon_t = \begin{bmatrix} \varepsilon_t^{cop} \\ \varepsilon_t^{exr} \\ \varepsilon_t^{usd} \\ \varepsilon_t^{ry} \\ \varepsilon_t^{hcpi} \\ \varepsilon_t^{mp} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & 0 & 0 & 0 & 0 & 0 \\ \alpha_{21} & \alpha_{22} & 0 & 0 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & 0 & 0 & 0 \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} & 0 & 0 \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & \alpha_{55} & 0 \\ \alpha_{61} & \alpha_{62} & \alpha_{63} & \alpha_{64} & \alpha_{65} & \alpha_{66} \end{bmatrix} \begin{bmatrix} u_t^{cop} \\ u_t^{exr} \\ u_t^{usd} \\ u_t^{ry} \\ u_t^{hcpi} \\ u_t^{mp} \end{bmatrix} \quad (5)$$

From Equation 5, oil prices are modelled to be contemporaneously exogenous, that is, oil prices do not respond contemporaneously to disturbances in other macroeconomic variables. Following a wealth effect specification, the second equation assumed that external reserve is influenced by only oil price and itself. Exchange rate is assumed to be influenced by oil price, external reserves. To capture the peculiarities of the Nigerian economy, it is assumed that real output is only influenced by exchange rate, foreign reserves and oil price. Inflation is assumed to follow an augmented-Philips curve specification, where it is influenced by oil price, foreign reserves, exchange rate and real output. The sixth equation follows an augmented monetary policy reaction function where monetary policy rate and other instruments (as mentioned earlier) are influenced by oil price, external reserves, exchange rate, real output and inflation.

IV.4 Data

Quarterly data spanning 2000:Q1 to 2018:Q2, consisting 96 observations are used in the analysis of the impact of global oil price on exchange rate and the effectiveness of monetary policy in Nigeria. The oil price series is sourced from the Reuters Eikon IV terminal. All macroeconomic data for the Nigerian economy were extracted from the CBN Statistical Database. The price, output and external reserves are seasonally-adjusted. The oil price and external reserves are deflated, using the US CPI. The choice of scope of data stems from the fact that democratic era started in 1999, thus, reflecting the emergence of monetary policy independence.

[3] See Ouliaris, Pagan and Restrepo (2016) for a detailed description of the various types of restrictions.
[4] The recursive system was first introduced by Wold (1951).

IV.5 Empirical Analysis

The next step is the estimation of the SVAR with the restrictions following Kilian (2009) recursive short-run approach. This would provide the estimation of both the impulse response (IRFs) and the forecast error variance decomposition (FEVD). The impulse response function traces the effects of a one-time shock to one of the structural errors on the current and future values of all the endogenous variables in the VAR. The variance decomposition shows the contribution of the shock to the variation in the variables in question.

V. Empirical Results

V.1 Descriptive Statistics

Table 3 showed the statistical properties of the series. Real output showed the least variability from its mean, with a standard deviation of 0.04, while all other series showed greater variability from their means with the treasury bill rate, exhibiting the greatest deviations. Furthermore, the Jarque-Bera normality tests indicated that the external reserves, real exchange rate, cash reserve ratio and supply of foreign exchange did not follow a normal distribution function.

Table 3: Descriptive Statistics (2001Q1 – 2018Q2)

	COP	EXR	USD	RY	HCPI	MPR	CRR	OMO	SFX	TBR
Mean	0.07	0.16	-0.02	0.06	0.12	-0.01	0.82	0.33	0.01	-0.16
Maximum	0.71	1.20	0.36	0.14	0.24	5.75	16.00	3.24	2.65	8.91
Minimum	-0.52	-0.31	-0.17	-0.02	0.04	-6.00	-8.50	-2.15	-3.45	-10.8
Std. Dev.	0.30	0.37	0.11	0.04	0.05	2.46	3.84	0.96	0.86	4.35
Jarque-Bera	1.21	14.44	63.31	0.39	3.39	0.93	39.40	4.16	63.48	0.38
Probability	0.55	0.00	0.00	0.82	0.18	0.63	0.00	0.12	0.00	0.83

Note: All variables are first differenced on annual basis.

Table 4 presents the ordinary correlation coefficients which showed that, in general, the chosen series exhibited linear associations, consistent with economic theory. The relationships between COP and the following variables (EXR, RY, HCPI, OMO, SFX and TBR) were found to be positive, while that between COP and the following variables (RER, MPR, and CRR) were found to be negative.

Table 4: Correlation Matrix

	COP	EXR	USD	RY	HCPI	MPR	CRR	OMO	SFX	TBR
COP	1									
EXR	0.5	1								
USD	-0.3	-0.4	1							
RY	0.2	0.1	-0.5	1						
HCPI	0.0	0.2	0.0	-0.1	1					
MPR	-0.1	-0.2	0.2	-0.2	0.1	1				
CRR	-0.3	-0.3	0.1	-0.2	-0.1	0.4	1			
OMO	0.3	0.1	0.0	-0.1	-0.1	0.4	0.1	1		
SFX	0.0	0.2	-0.5	0.3	-0.1	-0.2	-0.1	-0.1	1	
TBR	0.1	-0.2	0.3	-0.2	0.1	0.8	0.2	0.4	-0.3	1

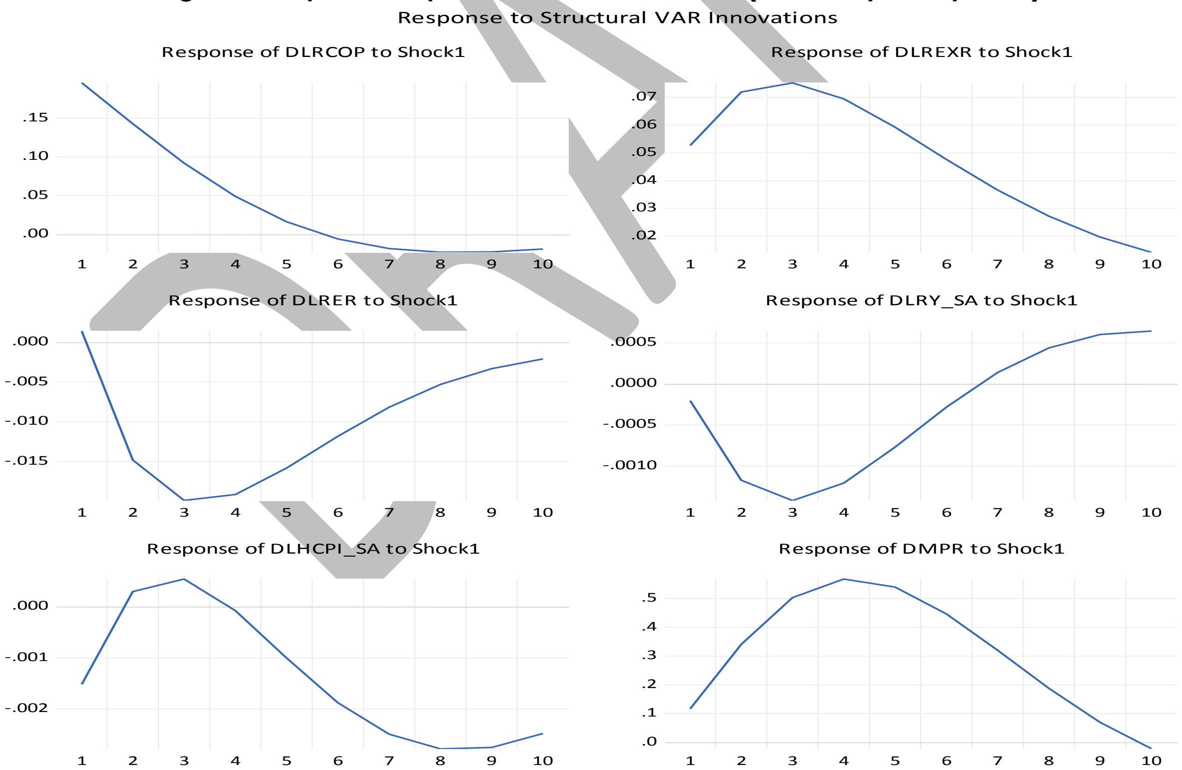
IV.2 Stability Tests

To check for the statistical adequacy and reliability of the models, a stability test was performed. A stable VAR model implies that the impact of the shocks is calculable and finite. Results from the stability tests, presented in Appendix III, show that none of the roots lie outside the unit circle and hence, the VAR satisfies the stability condition.

IV.3 Structural Impulse Response Analysis

Figures 3 to 8 reveal the impulse response of impact of oil prices shocks on external reserves, exchange rate, output, price, and monetary policy indicators in a standard SVAR. From Figure 3, a shock to oil price leads to external reserves accretion and exchange rate appreciation. In addition, real output is found to decline for 6 quarters before returning to equilibrium. Thereafter, it expands for the rest of the horizon. Oil price shocks is also found to bring about non-monotonic movements in price levels, however, declines in price levels are dominant over the horizon analysed. The monetary policy rate rises in response to oil price shocks indicating a tight monetary stance to curb inflationary pressures. A possible explanation to the fall in output would be the effect of the Dutch disease, while decline in prices could be traced to the proactive nature of the monetary authority towards achieving the price stability objective.

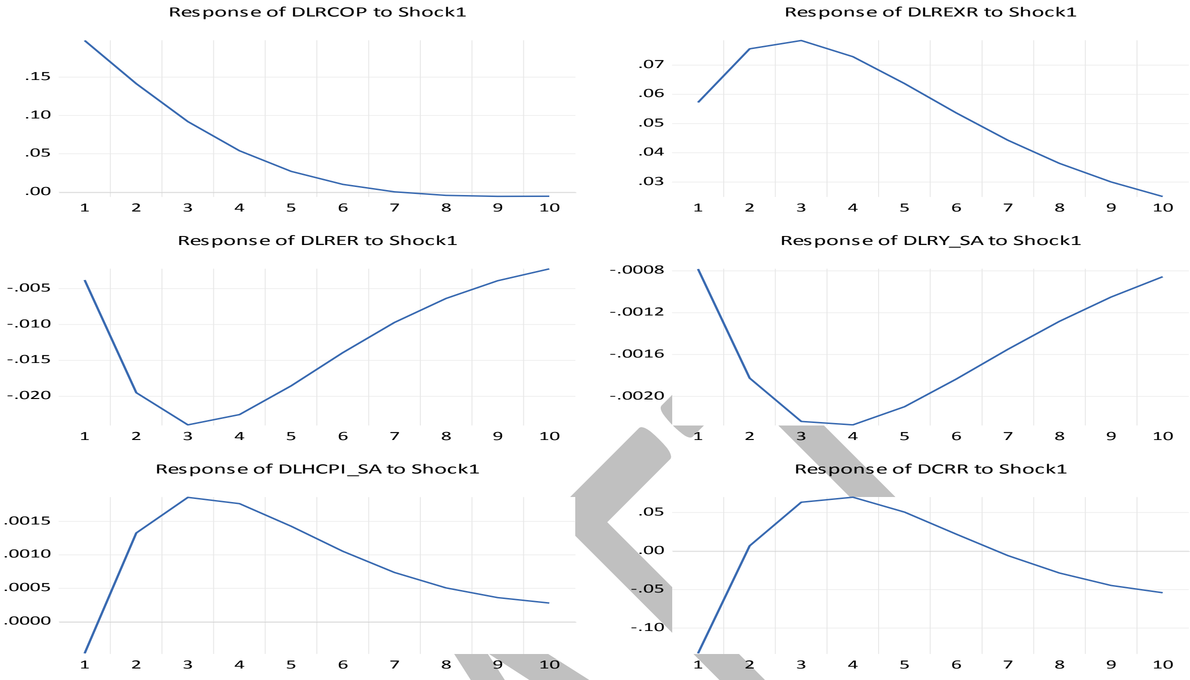
Figure 3: Impulse Response to Oil Price Shock (Monetary Policy Rate)



From Figure 4, variables in the external block (external reserves and exchange rate) exhibit similar movements, relative to previous analysis; however, their magnitudes are seen to vary. Real output is found to decline instantaneously and throughout the horizon. Inflationary pressures are seen to mount for the most part of the horizon and remain asymptotic. Cash reserves ratio, the monetary policy indicator, is seen to exhibit non-monotonic movements. After instantaneously declining, in response to oil price shocks, and returning to equilibrium after about 2 quarters, it increases for about 4 quarters, thereafter declines for the rest of the horizon.

Figure 4: Impulse Response to Oil Price Shock (Cash Reserves Ratio)

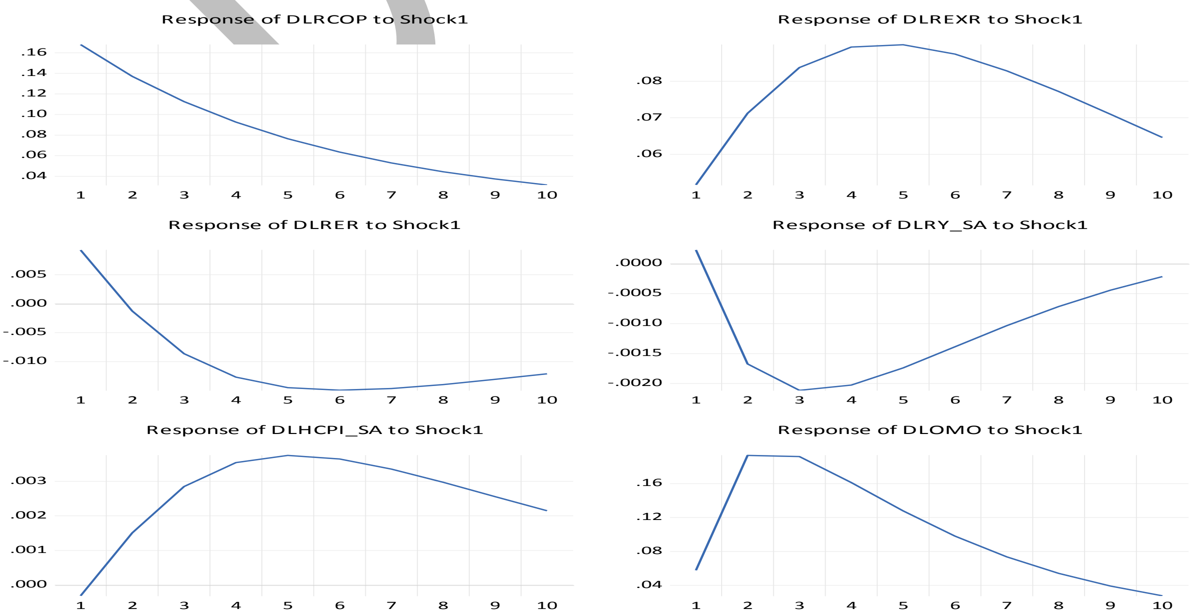
Response to Structural VAR Innovations



In Figure 5, we present the estimated impulse responses of real exchange rate and other macroeconomic variables due to a standard deviation shock to oil price. The response of external reserves to shocks in oil price is positive throughout the 10-period horizon while that of exchange rate is an appreciation of the naira, relative to the United States dollar. Shock to oil price is found to impede economic activity as well as induce inflationary pressures on the economy. Sales of OMO bills are seen to increase throughout the horizon, peaking in the second quarter. This may due to liquidity management operations in response to the inflationary pressure observed as result of the shocks.

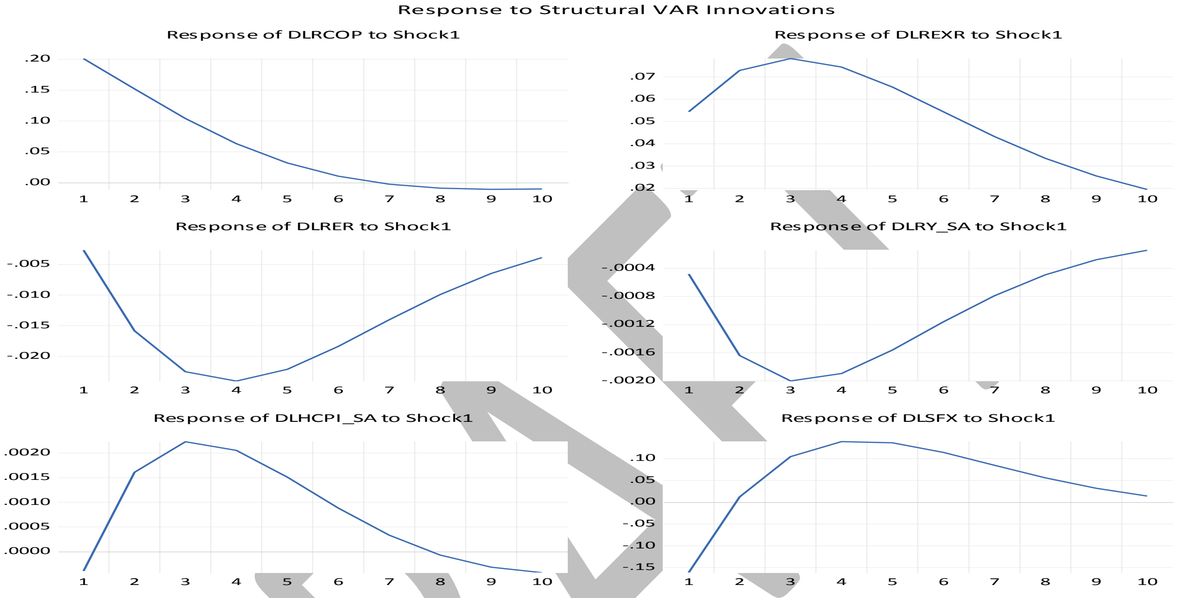
Figure 5: Impulse Response to Oil Price Shock (Open Market Operations)

Response to Structural VAR Innovations



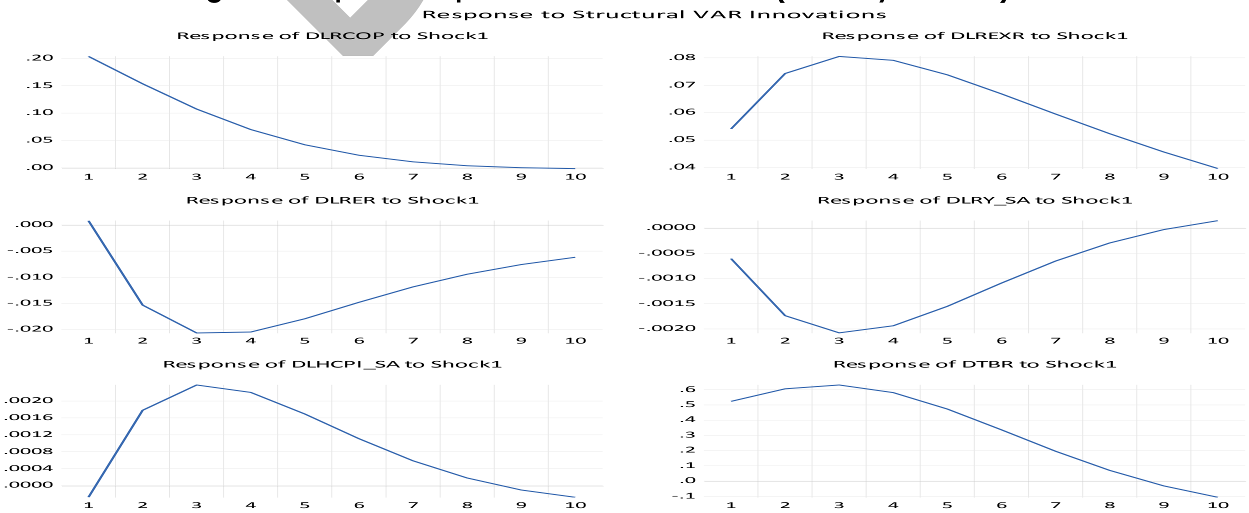
From Figure 6, the responses of external reserves, exchange rate, output and inflation to unanticipated structural innovations to global oil price is found to be similar, to a large extent, to that observed in Figure 4. However, modest disparity in magnitude is observed. Specifically, the interventions of the monetary authorities, proxied by supply of foreign exchange are found to decline contemporaneously in response to shocks to oil price. This may be due to economic agents sourcing foreign exchange from autonomous sources or dampen demand pressure arising from the availability of foreign exchange. This decline is, however, short lived, as the supply of foreign exchange seems to increase after the first quarter and this lasts till the tenth quarter.

Figure 6: Impulse Response to Oil Price Shock (Supply of Forex)



From the results presented in Figure 7, an unanticipated shock to oil price leads to rise in external reserves and exchange rate appreciation. In addition, real output is found to decline for 9 quarters before returning to equilibrium. Thereafter, it expands for the rest of the horizon. Oil price shocks are also found to bring about rise in price levels for 9 quarters before returning to steady state. The 3-month Treasury bill rate rises instantaneously in response to oil price shocks, thus, reflecting the proactive nature of the monetary policy authorities towards achieving the price stability objective.

Figure 7: Impulse Response to Oil Price Shock (Treasury Bill Rate)



IV.4 Dynamic Impact and Optimum Policy Instrument

The dynamic multiplier of oil price shocks is reported in Figure 8 and Table 4. From the result, oil price shocks had the highest impact on external reserves, implying that a one standard deviation shock to oil price would lead to external reserves accretion of about 16.0 per cent. The dynamic impact on exchange rate was found to be negative, as innovations to oil price would result to about 10.0 per cent appreciation in the exchange rate on the average.

Also, output was seen to contract due to oil price shocks, owing to the Dutch disease syndrome and the low contribution of the sector to output growth. Furthermore, oil price pass-through to inflation was found to be positive (2 per cent) and incomplete. Monetary policy indicators, generally, were found to be restrictive amidst oil price shocks, except for cash reserve ratio. In summary, structural innovations to global oil price resulted in reserve accretion, exchange rate appreciation, output contraction and high inflationary pressures. In addition, oil price innovation, generally, necessitate the use of restrictive monetary policy. This is in line with the impulse response functions discussed earlier.

Figure 8: Dynamic Impact of Oil Price Shocks

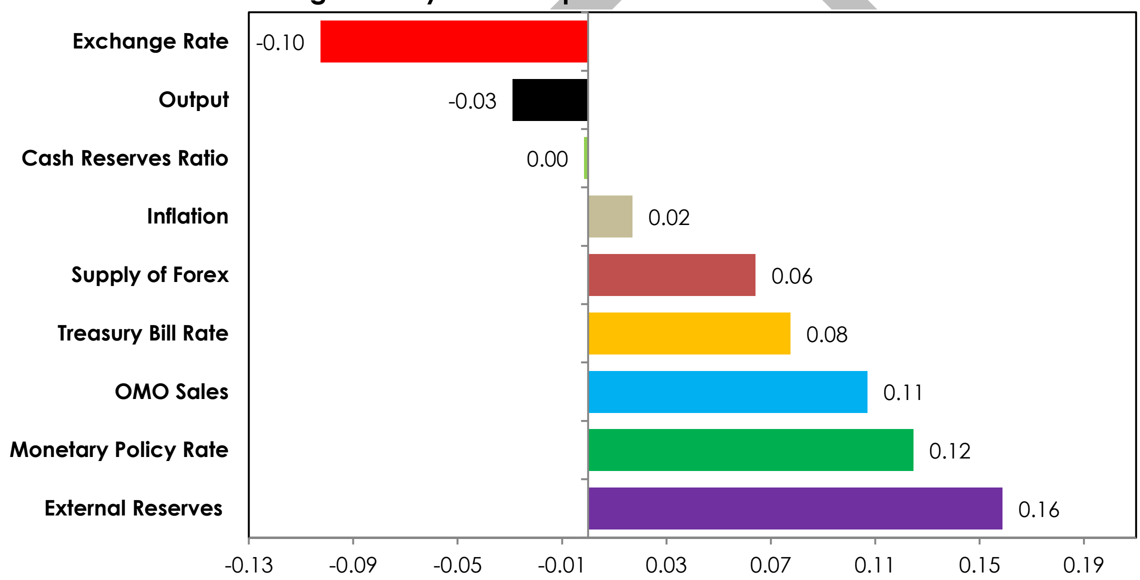


Table 4: Dynamic Impact of Oil Price Shocks (Indicator- Specific Models)

Models	Real oil Price	External Reserves	Exchange Rate	Output	Inflation	Monetary Policy Indicator
MPR	0.132	0.128	-0.087	-0.009	-0.032	0.125
CRR	0.165	0.146	-0.110	**-0.045**	0.020	-0.001
OMO	**0.265**	**0.208**	-0.085	-0.032	**0.059**	0.107
SFX	0.172	0.141	**-0.123**	-0.030	0.017	0.064
TBR	0.199	0.170	-0.109	-0.028	0.021	0.078

Furthermore, the relative volatilities of exchange rate, output and inflation were computed to depict a simple loss function as regards monetary policy. This was done using the standard deviation of the impulse responses over the forecast horizon as denoted below:

$$L = \sigma_z + \sigma_y + \sigma_\pi \qquad (6)$$

Where: '*L*' indicates macroeconomic volatility as a result of oil price shock; 'σ_z' is the standard deviation of the real exchange rate response; 'σ_y' is the standard deviation of the real output response; and 'σ_π' is the standard deviation of inflation response.

The results as presented in Table 5 reveal that exchange rate volatility is least under the treasury bill model, thus, suggesting treasury-bill rate as the most potent monetary policy tool in stabilising the exchange rate amidst oil price shocks. Likewise, output and inflation volatility were found to be least under the cash reserve ratio model, implying that cash reserve ratio is most potent in stabilising output and inflation amidst an oil price shock. Finally, the sum of standard deviations which depicts macroeconomic volatility was found to be least under the Treasury bill rate model. This suggests that treasury-bill rate is the optimal monetary policy tool to employ in stabilising the macroeconomy amidst an oil price shock.

Table 5: Relative Volatilities under Model-Specific Policy Indicators

	σ_Z	σ_Y	σ_π	*L*
MPR	0.0075	0.0008	0.0013	0.00956
CRR	0.0083	0.0006	0.0007	0.00959
OMO	0.0078	0.0008	0.0012	0.00988
SFX	0.0079	0.0007	0.0010	0.00969
TBR	0.0069	0.0008	0.0010	0.00872
Minimum	0.0069	0.0006	0.0007	0.00872

IV.5 Forecast Error Variance Decomposition (FEVD)

To examine the role of oil price shocks in the volatility of exchange rates and monetary policy instruments, a forecast error variance decomposition (FEVD) analysis is conducted. Tables 6 to 10 reports the FEVD results for the various models estimated. A cursory look at Table 6 reveals that, in the short-run, oil price contributes modestly in explaining the volatility in exchange rate (9.69 per cent) and monetary policy rate (15.34 per cent). In the medium term (10 quarters after the shock), global oil price explains 11.62 per cent and 21.19 per cent of the volatility in the exchange rate and monetary policy rate, respectively. Other than its own shocks, the volatility in exchange rate is influenced by shocks to output (14.77 per cent) and external reserves (9.11 per cent). Monetary policy rate shocks are seen to contribute marginally to the variation in exchange rate over the horizon.

The results from the variance decomposition analysis of the CRR model indicates that oil price contributes modestly in explaining the volatility in exchange rate (14.38 per cent) and cash reserve ratio (0.20 per cent) in the short-run. In the medium term (10 quarters after the shock), global oil price explains 16.79 per cent and 0.24 per cent of the volatility in the exchange rate and cash reserve ratio, respectively. Other than its own shocks and that of oil price, the volatility in exchange rate is influenced by shock to output (14.62 per cent) and external reserves (7.10 per cent). Shocks to the cash reserve ratio are found to contribute 4.45 per cent to the variations in exchange rate 10 quarters after the shocks.

Table 6: Forecast Error Variance Decomposition (MPR Model)

Shocks / Responses	Steps	COP	EXR	USD	RY	HCPI	MPR
Oil Price (COP)	**4**	86.56	0.12	5.02	2.63	0.31	5.36
	8	73.93	0.17	7.07	9.82	1.56	7.44
	10	71.75	0.32	6.79	11.73	2.26	7.14
External Reserves (EXR)	**4**	26.18	62.29	10.80	0.14	0.03	0.55
	8	23.71	52.72	20.70	0.58	0.56	1.73
	10	22.24	51.37	22.76	0.73	0.91	1.99
Exchange Rate (USD)	**4**	9.69	8.27	77.07	2.82	1.99	0.16
	8	12.14	8.89	64.96	11.60	2.00	0.41
	10	11.62	9.11	61.59	14.77	2.51	0.40
Output (RY)	**4**	0.67	0.26	9.48	84.72	3.84	1.03
	8	0.49	0.29	11.94	76.40	9.08	1.80
	10	0.51	0.31	12.12	74.58	10.69	1.79
Inflation (HCPI)	**4**	0.16	1.50	4.31	1.06	90.54	2.44
	8	1.09	1.35	6.01	2.45	83.91	5.18
	10	1.77	1.34	6.39	2.86	82.30	5.33
Monetary Policy Rate (MPR)	**4**	15.34	0.28	5.76	7.56	4.87	66.20
	8	22.00	1.87	5.04	15.85	4.06	51.18
	10	21.19	2.49	5.47	16.74	4.22	49.90

Table 7: Forecast Error Variance Decomposition (CRR Model)

Shocks / Responses	Steps	COP	EXR	USD	RY	HCPI	CRR
Oil Price (COP)	**4**	84.60	0.03	1.72	2.67	0.32	10.65
	8	72.00	0.20	1.62	5.80	2.77	17.62
	10	70.11	0.37	1.59	6.35	3.75	17.83
External Reserves (EXR)	**4**	28.51	61.22	9.75	0.24	0.04	0.25
	8	27.50	53.13	15.30	0.39	0.81	2.87
	10	26.41	51.74	16.16	0.37	1.33	3.99
Exchange Rate (USD)	**4**	14.38	6.53	69.19	3.84	1.31	4.75
	8	17.48	6.92	57.83	12.04	1.41	4.32
	10	16.79	7.10	55.03	14.62	2.00	4.45
Output (RY)	**4**	1.97	0.22	9.87	84.39	3.53	0.01
	8	2.28	0.33	11.00	78.64	7.62	0.12
	10	2.22	0.42	11.02	77.35	8.85	0.14
Inflation (HCPI)	**4**	0.49	1.67	5.03	0.94	91.27	0.60
	8	0.65	1.54	4.94	3.75	87.18	1.94
	10	0.64	1.51	5.06	5.08	85.52	2.18
Cash Reserve Ratio (CRR)	**4**	0.20	0.92	2.59	1.52	0.60	94.18
	8	0.21	2.50	2.45	2.38	1.78	90.67
	10	0.24	2.96	2.48	2.49	2.10	89.73

Oil price shocks are seen to contribute significantly to the variations in open market operations both in the short-run (12.35 per cent) and the long-run (15.79 per cent). Furthermore, shocks to open market operations record marginal contribution to the variation in exchange rate, particularly, 3.70 and 5.66 per cent in quarters 4 and 10, after the shock, respectively.

Table 8: Forecast Error Variance Decomposition (OMO Model)

Shocks / Responses	Steps	COP	EXR	USD	RY	HCPI	OMO
	4	96.51	0.08	0.13	1.36	1.45	0.48
Oil Price (COP)	**8**	90.74	0.18	0.12	3.26	4.66	1.05
	10	88.84	0.20	0.13	3.80	5.81	1.22
	4	30.58	62.21	5.34	0.22	0.48	1.16
External Reserves (EXR)	**8**	41.98	46.67	6.98	0.31	2.97	1.09
	10	44.38	43.07	7.02	0.32	4.17	1.05
	4	3.08	13.19	74.77	2.69	2.56	3.70
Exchange Rate (USD)	**8**	9.09	13.83	61.77	7.57	2.42	5.31
	10	10.85	13.55	57.95	9.20	2.78	5.66
	4	1.45	0.39	6.39	80.19	2.97	8.61
Output (RY)	**8**	1.42	0.29	9.07	72.52	5.93	10.76
	10	1.32	0.29	9.65	70.94	6.70	11.10
	4	1.13	2.24	4.59	1.10	90.85	0.09
Inflation (HCPI)	**8**	3.07	2.03	4.38	4.25	85.80	0.47
	10	3.47	1.99	4.53	5.45	83.85	0.72
	4	12.35	1.49	3.96	2.09	0.78	79.33
Open Market Operations (OMO)	**8**	15.59	2.05	4.00	2.20	0.88	75.27
	10	15.79	2.12	4.01	2.20	0.88	75.00

Results from the variance decomposition analysis of the SFX model indicates that oil price shocks contribute 13.36 per cent and 8.25 per cent in explaining the volatility in exchange rate and supply of foreign exchange, respectively. In the medium term (10 quarters after the shocks), global oil price explains 18.96 per cent and 12.79 per cent of the volatility in the exchange rate and supply of foreign exchange, respectively. Other than its own shocks and that of oil price, the volatility in exchange rate is influenced by shocks from output (12.67 per cent) and external reserves 5.91 per cent. Shocks to the supply of foreign exchange are found to contribute 6.60 per cent to the variations in exchange rate 10 quarters after the shock.

Table 9: Forecast Error Variance Decomposition (SFX Model)

Shocks / Responses	Steps	COP	EXR	USD	RY	HCPI	SFX
	4	88.13	0.09	2.35	3.78	0.80	4.85
Oil Price (COP)	**8**	77.78	0.34	2.28	8.69	2.80	8.11
	10	76.22	0.40	2.41	9.69	3.27	8.01
	4	27.43	62.54	9.12	0.27	0.09	0.55
External Reserves (EXR)	**8**	25.85	55.13	13.27	0.69	0.94	4.12
	10	24.59	54.52	13.56	0.74	1.28	5.32
	4	13.36	5.34	68.73	2.85	2.09	7.63
Exchange Rate (USD)	**8**	19.59	5.61	55.42	10.22	2.40	6.76
	10	18.96	5.91	52.50	12.67	3.37	6.60
	4	1.49	0.39	7.45	85.78	3.45	1.43
Output (RY)	**8**	1.36	0.26	7.66	79.64	8.31	2.77
	10	1.25	0.26	7.46	78.12	10.06	2.85
	4	0.67	1.79	5.18	0.68	90.91	0.77
Inflation (HCPI)	**8**	0.77	1.79	4.82	2.77	87.21	2.63
	10	0.78	1.77	4.78	3.79	85.91	2.97
	4	8.25	0.42	4.56	0.62	2.19	83.96
Supply of Foreign Exchange (SFX)	**8**	12.86	0.49	5.21	1.96	3.03	76.44
	10	12.79	0.60	5.18	2.44	3.63	75.37

The results obtained from the Treasury bill rate model indicate that oil price shocks are seen to contribute to the variations in Treasury bill rate both in the short-run (9.46 per cent) and the long-run (10.01 per cent). Furthermore, shocks to open market operations explain only 0.10 and 1.18 per cent in quarters 4 and 10 quarters, respectively, after the shocks.

Table 10: Forecast Error Variance Decomposition (TBR Model)

Shocks / Responses	Steps	COP	EXR	USD	RY	HCPI	TBR
	4	91.79	0.07	4.12	3.15	0.76	0.12
Oil Price (COP)	**8**	83.19	0.06	4.70	7.92	3.99	0.13
	10	81.21	0.07	4.60	8.84	5.12	0.17
	4	29.02	59.61	9.98	0.54	0.07	0.77
External Reserves (EXR)	**8**	31.78	48.46	16.55	0.76	1.13	1.31
	10	31.92	46.37	17.90	0.71	1.74	1.36
	4	10.53	8.07	75.96	3.38	1.96	0.10
Exchange Rate (USD)	**8**	14.78	8.20	62.31	11.90	1.98	0.83
	10	14.71	8.15	59.00	14.34	2.61	1.18
	4	1.51	0.36	9.37	83.71	3.22	1.84
Output (RY)	**8**	1.28	0.25	11.36	76.69	7.02	3.39
	10	1.18	0.24	11.58	75.16	8.16	3.67
	4	0.78	1.63	4.13	1.01	91.82	0.63
Inflation (HCPI)	**8**	0.93	1.51	4.86	3.26	87.86	1.59
	10	0.91	1.48	5.15	4.13	86.50	1.83
	4	9.46	4.26	1.16	5.23	0.72	79.17
Treasury Bill Rate (TBR)	**8**	10.32	8.52	1.05	11.09	0.77	68.25
	10	10.01	9.56	1.01	12.32	1.02	66.09

V. Summary and Conclusions

This paper developed a structural VAR model to examine the impact of global oil price shocks on exchange rate and monetary policy in Nigeria, using quarterly data spanning 2000Q1 to 2018Q2. The study identified assumptions that were consistent with Nigeria's economic structure and confirmed by the estimated dynamic responses to mimic movements of macroeconomic variables in the country. The relationship among oil price shocks, external reserves, exchange rate, output, price, and monetary policy indicators (policy rate, cash reserve ratio, open market operations and supply of foreign exchange) were examined and the empirical results revealed the following:

First, oil price shocks are associated with rise in external reserves and appreciation in the naira. This outcome conformed to theory regarding oil-exporting countries, like Nigeria. This is also in line with findings of Olomola and Adejumo (2006), Adeniyi et al, (2012), Soile and Nathaniel (2015), and Olubusoye et al. (2017). In addition, the oil-dependent nature of the economy supports this outcome.

Second, oil price shocks generally result to inflationary pressures and reduction in output growth. The inflationary impact may be ascribed to the wealth effect, and effect of fiscal injections. The decline in output may not be unconnected to the marginal contribution of oil to total output, which on average is about 10 per cent relative to that of non-oil output which accounts for about 90 per cent. Furthermore, the Dutch disease may also be used to explain this phenomenon due to underdevelopment of other sectors of the economy. In addition, appreciation of the exchange rate would also discourage non-oil exports in the international market.

Third, monetary policy response to positive oil price shocks was found to be generally restrictive as in the case of the monetary policy rate, open market operations, treasury bill rate and foreign exchange interventions. On the contrary, monetary policy was found to be loosen in the case of cash reserve ratio, albeit, this was short-lived as tightening was embarked on after 2 quarters. This may be attributed to the fact that cash reserve ratio is a complementary tool for monetary policy, with a view of ensuring financial stability and not price stability.

The result showed that for all the scenarios, monetary policy has been effective in improving accretion to external reserve and naira appreciation against the US dollar. The result for output and inflation was mixed. Under the monetary policy rate, output witnessed initial decline up to the 6th quarter before recovering for the rest of the horizon. For prices, oil price shock initially led to increase but maintained a declining trend for most part of the period. Under treasury-bill rate scenario, output decline for nine consecutive quarters before recovering, while oil price shock led to increase in price up to 9th quarter. For cash reserve ratio, open market operation and foreign exchange intervention by the Bank led to decline in output and increase in prices throughout the horizon. The mixed result could be attributed to applying different monetary policy instrument simultaneously.

Finally, Treasury-bill rate was found to be optimal monetary policy tool to employ in stabilising exchange rate and the macroeconomy amidst an oil price shock. However, the monetary authority in Nigeria should realise that there are trade-offs in policy outcomes and should choose which indicator is best suit the achievement of their mandate. Trying to achieve external and internal balance at the same time might be difficult as observed in the faster stability of the external sector and the slow recovery of the real sector. Output and price recovery has been slow compared to the stability in the foreign exchange market. Therefore, proactive policies should be put in place to continuously monitor the movement in crude oil prices for informed monetary policy decisions to achieve price and exchange rate stability.

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Appendices

Appendix I: Structural Parameter Estimates of SVAR Models

(a) .MPR model

$$\begin{bmatrix} 0.19* & 0 & 0 & 0 & 0 \\ 0.05* & 0.12* & 0 & 0 & 0 \\ 0.00 & -0.02* & 0.07* & 0 & 0 \\ -0.00 & -0.001 & -0.003* & 0.01* & 0 \\ -0.00 & 0.004 & -0.007* & 0.016 & 0.03* \\ 0.12 & 0.06 & 0.07 & 0.10 & 0.15 \end{bmatrix}$$

(b).CRR model

$$\begin{bmatrix} 0.19* & 0 & 0 & 0 & 0 & 0 \\ 0.05* & 0.12* & 0 & 0 & 0 & 0 \\ -0.00 & -0.02* & 0.07* & 0 & 0 & 0 \\ -0.00 & -0.001 & -0.003* & 0.01* & 0 & 0 \\ -0.00 & 0.004 & -0.008* & 0.00 & 0.03* & 0 \\ -0.13 & 0.06 & 0.50 & 0.12 & 0.11 & 2.76* \end{bmatrix}$$

(c).OMO Model

$$\begin{bmatrix} 0.18* & 0 & 0 & 0 & 0 \\ 0.05* & 0.13* & 0 & 0 & 0 \\ 0.00 & -0.02* & 0.08* & 0 & 0 \\ 0.00 & -0.001 & -0.003* & 0.01* & 0 \\ -0.00 & 0.004 & -0.009* & 0.001 & 0.03* \\ 0.06 & 0.02 & 0.11 & 0.032 & -0.07 \end{bmatrix}$$

(d).SFX Model

$$\begin{bmatrix} 0.20* & 0 & 0 & 0 & 0 & 0 \\ 0.05* & 0.12* & 0 & 0 & 0 & 0 \\ -0.00 & -0.02* & 0.07* & 0 & 0 & 0 \\ -0.00 & -0.001 & -0.003* & 0.01* & 0 & 0 \\ -0.00 & 0.004 & -0.008* & 0.001 & 0.03* & 0 \\ -0.16* & -0.038 & -0.16* & 0.030 & -0.09 & 0.53* \end{bmatrix}$$

(e).TBR Model

$$\begin{bmatrix} 0.20* & 0 & 0 & 0 & 0 \\ 0.05* & 0.13* & 0 & 0 & 0 \\ 0.00 & -0.02* & 0.07* & 0 & 0 \\ -0.00 & -0.001 & -0.003* & 0.01* & 0 \\ -0.00 & 0.004 & -0.007* & 0.001 & 0.03* \\ 0.52 & -0.283 & 0.297 & 0.65* & 0.03 \end{bmatrix}$$

Note: * denotes significance at 1% levels of significance.

Appendix II: VAR Stability Tests

MPR model

Root	Modulus
0.879790 - 0.020601i	0.880031
0.879790 + 0.020601i	0.880031
0.749294 - 0.275017i	0.798170
0.749294 + 0.275017i	0.798170
0.741918	0.741918
0.642227	0.642227

CRR model

Root	Modulus
0.890578 - 0.032734i	0.891179
0.890578 + 0.032734i	0.891179
0.785695	0.785695
0.664928 - 0.197603i	0.693669
0.664928 + 0.197603i	0.693669
0.562538	0.562538

OMO model

Root	Modulus
0.884077	0.884077
0.841643 - 0.028998i	0.842143
0.841643 + 0.028998i	0.842143
0.678306 - 0.064161i	0.681333
0.678306 + 0.064161i	0.681333
0.221446	0.221446

SFX model

Root	Modulus
0.869652 - 0.015891i	0.869797
0.869652 + 0.015891i	0.869797
0.796005	0.796005
0.697046 - 0.247389i	0.739645
0.697046 + 0.247389i	0.739645
0.566662	0.566662

TBR model

Root	Modulus
0.874133	0.874133
0.820417 - 0.063882i	0.822900
0.820417 + 0.063882i	0.822900
0.714569	0.714569
0.665562 - 0.189798i	0.692095
0.665562 + 0.189798i	0.692095

Note: No root lies outside the unit circle thus, the VAR satisfies the stability condition
.

The Effectiveness of Monetary Policy Corridor in Anchoring the Behaviour of Money Market Inter-bank Rate in Nigeria

Nwosu, C., Sunday B. A. and Opiah D. C. [*]

Abstract

The adoption and implementation of the new framework for monetary policy in December 2006, was with the ultimate goal of achieving a stable value for the naira through the stability in short-term interest rates. The operationalisation of the policy rate was to serve as an indicative rate for transactions in the money market within a corridor (lower and upper) around the rate. The study investigated how effective the monetary policy corridor is in driving market interest rates in Nigeria. It employed the structural vector autoregressive (SVAR) impulse responses functions and the forecast error variance decomposition in isolating shocks to monetary policy rate and traced their impact on the money market rates. The research findings revealed that, although both the interbank rate and the 91-day Treasury bill rate are sensitive to increases in the upper and lower corridors than they are to reductions, they tend to be lower and more stable with an asymmetric expansion of the lower band. The findings are important to policymakers considering the role played by the short-term interest rates in the economy.

Keywords: Monetary Policy Stance, Monetary Policy Shocks, Vector Auto-regression
JEL Classification: *E43, E47, E52*

I. Introduction

Central banks, all over the world, seek to achieve price stability, output growth, low level of unemployment, among other objectives. In attaining these objectives, the stability of the financial system is a sine qua non. This is because a sound financial system is a key driver of economic growth and development. To this end, adverse developments in the financial system would resonate in the whole economy and impede economic growth.

The importance of banks in the financial landscape, especially in a developing country like Nigeria, cannot be overemphasised. The banking sector dominates the Nigerian financial system, accounting for about 90 per cent of total assets in the system and 65 per cent of market capitalisation in the Nigerian stock exchange (Soludo,2009a). For this reason, it is important for banks to have adequate liquidity to enable them perform their intermediation role in the economy, effectively. The CBN, in its bid to ensure stability (adequate liquidity) in the banking system and financial system stability, in general, introduced the monetary policy rate (MPR) in 2006, due to the inability of the pre-existing minimum rediscount rate (MRR) to effectively drive other money market rates.

The new monetary policy framework was to serve as an anchor for other rates in the economy by smoothening interest rate volatilities; ensuring the reaction of overnight rate to changes in the policy rate; and attaining monetary targets (Alade, 2015). The framework entails averaging of reserve requirements over a maintenance period and employing Standing Facilities (Lending and Deposit) within an interest rate corridor to guide short-term rates in the money market. As such, changes in the MPR should expectedly, transmit to short-term money market rates, credit growth and development in

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prices in the economy. Whereas the Central Bank of Nigeria (CBN) typically expects the short-term rates target (Inter-bank call and OBB rates) to be within the MPR corridor, there have been recurring periods of liquidity surfeits or shortages that prompted the market rate to deviate from the band, particularly in 2010 and early 2012 (Tule, 2014). This questions the efficacy of the asymmetric corridor framework and its capacity to influence other short-term rates in the economy. Consequently, this study seeks to assess the effectiveness of the monetary policy corridor in anchoring money market rates in Nigeria with a view to ascertaining if the corridor system effectively transmits the policy decisions of the monetary authority in Nigeria. The study would also attempt to show if the current asymmetric corridor of +200 and -500 basis points around the MPR is optimal for effective monetary policy transmission and at what cost to the Bank?

Following the introduction, Section 2 reviews the theoretical and empirical literature. Section 3 discusses monetary policy framework in Nigeria (presents the trend analysis on the asymmetric corridor around the MPR in Nigeria). The methodology and data are discussed in Section 4, while Section 5 undertakes the estimation and presentation of results. Section 6 provides a summary, policy implications and conclusion.

II. Literature Review

II.1 Theoretical Literature

To gauge the effectiveness of the corridor framework of monetary policy transmission in anchoring short-term rates, it is important to understand the theories that explain the phenomenon. For instance, the monetary theorists assume that monetary tightening would lead to an increase in the short-term nominal interest rates, resulting in higher longer-term nominal interest rates. This is because investors would try to assess the differences in risk-adjusted anticipated returns on debt instruments of various maturities and take a decision that would maximise return on investment. As nominal prices gradually correct themselves; changes in nominal interest rates are transferred into movements in real interest rates.

The interest rate channel in the monetary policy transmission provides the basis for the ability of central banks to set the policy rate, and thus, influence money market rates. The interest-rate channel assumes that an expansionary monetary policy, causes real interest rates in the money market to fall (assuming constant money demand). This development creates changes in medium-term interest rates on loans, with effects on the level of investment, as well as, aggregate expenditure in the economy (Mishkin, 1995).

The theoretical foundation for monetary policy implementation under the corridor system is premised on the ability of the monetary authority to generate and eliminate balances in the system, by considering the price stability objective of the Bank. If the overnight rate represents the price of balances and what could be earned on it daily, the monetary authority could fix the overnight rate at the level that is commensurate to price stability and ready to purchase and sell as much balances as needed at that rate, thus, becoming the market maker for the whole system[1].

[1] Disyatat (2008). Also, Bowman et al. (2010) assumed that the demand for balances depends inversely on the opportunity cost of holding balances. The opportunity cost is represented as the interest rate that could be earned on lending balances in the market minus the interest rate paid by the monetary authority on balances. When the spread between the market rate and the interest rate paid by the monetary authority on balances, decreases, earnings opportunities in the market decline, relative to those at the central bank, and demand for

Disyatat (2008) observed that this framework could be captured under the policy implementation reaction function, (PIRF) which pronounces how the monetary authority would react to variations in the reference market rate from its policy rate. He noted that in PIRF, balances traded by the monetary authority were changed, at varying degrees conditional on the country's economic conditions, to attain an overnight target rate. In corridor systems, the PIRF is well described by the automatic responses built in through standing facilities that establish the upper band and lower band on overnight rates (Disyatat, 2008). He also argued that the ability of the market to understand and discern the PIRF is a key determinant of the level of interest rate that would prevail with a specific announced benchmark for interest rates. If the market believes that the monetary authority would act instructively to counterbalance substantial variations from that rate, then trading would be anchored near the target[2].

II.2 Empirical Literature

Few studies[3] have attempted to assess the effectiveness of the corridor system in anchoring money market rates in the literature. More so, these studies tend to concentrate on countries around the OECD. Also, most studies tend to separate the implementation of the corridor, i.e., the lower band (floor) from the upper band (ceiling) of the corridor. For instance, Keister *et al*., (2008) and Goodfriend (2002) analysed the floor system. The emphasis of policy operations (at least for managing the day-to-day market rate) shifted from fine-tuning operations that influence the supply of balances to that of ensuring that the supply is large enough to keep the interbank rate at the floor rate of the corridor.

Additionally, several central banks[4] have for long operated variants of the corridor system. During the Global financial crisis of 2008, the European Central Bank (ECB), Bank of Japan (BoJ), Bank of England (BoE), Bank of Canada (BoC) and the Norges Bank migrated to a floor system. Kahn (2010) observed that the corridor system had been potent in taming variations in overnight rates and in affording monetary authorities the opportunity to provide significant liquidity to the banking system, especially during the financial crisis. Agreeing with Kahn (2010), Bowman, *et al.,* (2010) reviewed the experiences of major foreign central banks[5] with policy interest rates comparable to the interest rate on excess reserves paid by the central banks, over the past decade. They noted that policy rate floors could be effective at lower bands for market rates, albeit incomplete access to central bank accounts and the interest accrued on them, queries this result.

Their findings[6], however, revealed that the policy rate floors seemed to contain downward movements in money market rates if the central bank balances were surplus and the overnight rate was close to the policy rate (floor of the overnight rate). Binici *et al*., (2016)

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balances rises. Thus, as the spread approaches zero, the opportunity cost of holding balances diminishes, and banks become willing to absorb considerable increases in balances at only slightly lower opportunity costs.

[2]Gedikli, (2017), highlighted that factors such as: formal interventions by the monetary authority; pricing system; structure of the financial system; maturity structure of financial contracts; and capital flows have been identified to affect the performance of monetary policy transmission mechanism.

[3]Earlier studies include Poole (1968) and Woodford (2003).

[4] These includes BoE, BoC, BoJ, ECB, Reserve Bank of Australia, Reserve bank of New Zealand, Norges Bank and the Riksbank; See Kahn (2010).

[5] These are the same central banks considered in (Kahn 2010) above.

[6] Bowman et al., (2010) also believed that the interest paid on surplus reserve balances could be utilised by the monetary authority to contract monetary policy thereby reducing the dependence on reserve balances.

employed a panel estimation technique on bank-level flow data to examine the relationship between bank deposit rates and multiple policy rates and found overnight inter-bank rates very vital in the pricing of loans and deposits.

Beindseil and Jablecki (2011a) considered how the width of the central bank standing facilities corridor impacted on daily liquidity and the volatility of the overnight rate, using a simple stochastic model. Their findings showed that a market-oriented central bank, would under a normal situation, choose a width of 175 basis points (bps)- wide corridor as optimal, while a risk-averse central bank would settle for 150 bps-corridor. For a neutral and volatility-averse monetary authority, the optimal width is a narrow corridor of 25 bps, apiece.

Berentsen and Monnet (2008) examined monetary policy under a corridor system and found that a symmetric increase of the corridor was welfare reducing and led to policy tightening by the central bank[7]. However, Dell'Ariccia et al., (2017) and Lee et al., (2017) held an alternative view and opined that a symmetric widening of the corridor would positively influence both output and welfare, as well as, restrain the reduction in the short-term interest rate. Khayat (2017) also found that symmetrically increasing the width of the corridor would enhance output and welfare and reduce the monetary policy's risk exposure to the economy.

The experience of Turkey in the implementation of an asymmetric corridor to guide its short-term rates is quite instructive for Nigeria. Kucuk et al., (2014) showed that a change in the ceiling of the corridor impacted on the spread in the same direction; thus, the upper band proved to be more effective than the lower band. Also, Beindseil and Jablecki (2011b) established a correlation between the width of the corridor and the monetary policy stance during the Global financial crisis and found that the narrower the standing facilities window, the higher the intermediation volume of the monetary authorities, and the lower the inter-bank lending volume.

Studies on monetary policy transmission in Nigeria, including Nwosa and Saibu (2012) and Ishioro (2013), considered the impact of interest rate channels on the productive sector and on the banking system. Only Bello et al., (2017) attempted to examine the effectiveness of MPR on short-and long-term rates in Nigeria. Their findings revealed that the policy rate exerted a significant impact on the 3-month Treasury bill rate, followed by the inter-bank call rate. Evidence on the efficacy of the corridor system is mixed. To the best of our knowledge, it appears no study had been undertaken on the effectiveness of the corridor framework in Nigeria. This study is, therefore, appears to be novel in contributing to the literature on the corridor system, as an anchor of short-term rates.

III. Monetary Policy Management in Nigeria

Monetary policy is the deliberate use of monetary instruments at the disposal of the monetary authorities to regulate credit supply in the economy, with a view to achieving predetermined macroeconomic goals. In Nigeria, monetary policy management has evolved over the years in consonance with the economic situation of the country. This

[7] Their findings also demonstrated that it was optimal to have a positive spread between the interest rates of the central bank's lending and deposit facilities if the opportunity cost of holding the collateral needed to borrow liquidity from the central bank was positive.

could be grouped into two policy-eras: the pre-SAP period (before 1986) which is considered as a period of financial repression; and the post SAP period (from 1986 to date).

The pre-SAP period was characterised by a highly regulated monetary policy environment in which policies of selective credit controls, interest rate ceiling and restrictive monetary expansion were the rules rather than the exception (Soyibo and Olayiwola, 2000). These measures were directed to manage excess liquidity in the system. The monetary control framework, which relied heavily on credit ceilings and selective credit controls, and the non-harmonisation of fiscal and monetary policies, however, failed to achieve the set monetary targets, as their implementation became less-effective with time. Also, compliance by banks with credit guidelines was less than satisfactory. Hence, most of the macroeconomic variables moved in undesirable directions. The low-interest rates on government debt instruments did not satisfactorily attract savings from the private sector, and since the CBN was required by law to absorb the unsubscribed portion of government debt instruments, large amounts of high-powered money were injected into the economy (CBN, 2007).

Following the adoption of the Structural Adjustment Program (SAP) in 1986, the Bank introduced a market-based interest rate policy in August 1987. Interest rates were determined by market forces, and the rates increased as envisaged. Other policies adopted included the management of excess liquidity through the withdrawal of public sector funds from banks and the ban on foreign currency deposits, as collaterals for naira loan facilities. The Minimum Rediscount Rate (MRR) was a major monetary policy tool for the Central Bank of Nigeria at that time. The rate was designed to give direction to interest rates and monetary policy. However, the policy failed to achieve these objectives despite several adjustments made to it between 1999 and 2005 by the Monetary Policy Committee (MPC) to align it with the prevailing monetary conditions (CBN, 2016).

In a bid to reduce the volatility in interest rates and ensure that money market rates, especially the overnight inter-bank rates, are more responsive to the policy rates, the Bank introduced a 'new' monetary policy implementation framework in December 11, 2006 (CBN, 2006). The introduction of the Monetary Policy Rate (MPR) was on the assumption that better monetary policy result would be achieved. Thus, the adoption of the MPR served as a replacement for the MRR, as the anchor rate. The operating principle of the MPR is to facilitate inter-bank trading and transfer of balances at the CBN by managing the supply of settlement balances of banks and motivating the banking system to achieve zero balances at the CBN. An interest rate corridor was also introduced with the upper band representing the CBN overnight lending rate to the DMBs under the Standing Lending Facility (SLF), and the lower band representing the over-night rate at which the CBN was ready to accept deposits from DMBs under (SDF).

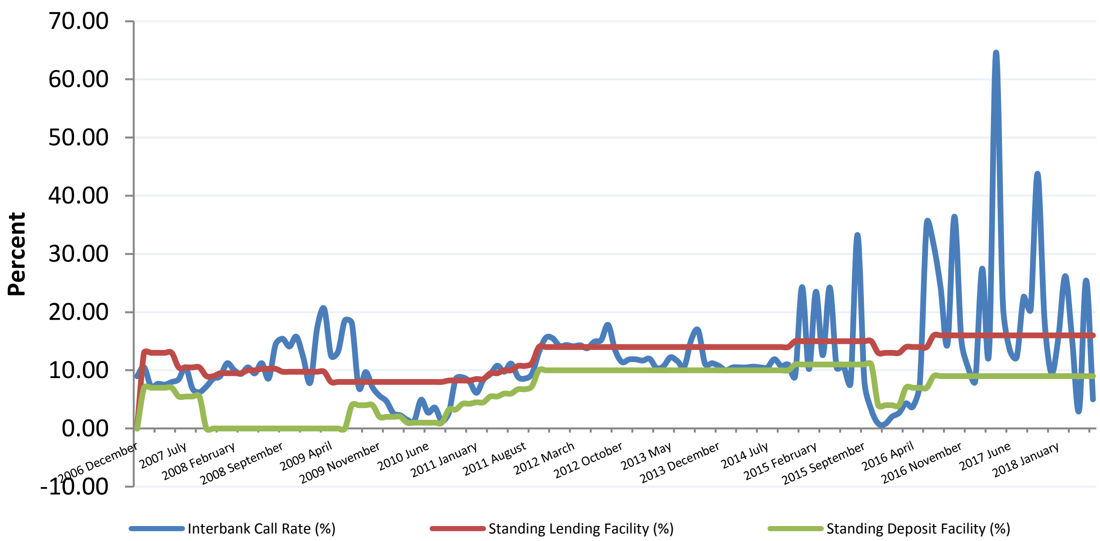
III.1 Trend Analysis of Movements in MPR and its Corridor

The adoption and implementation of the 'new' framework for monetary policy was with the ultimate goal of achieving a stable value of the naira through stability in short-term interest rates. The MPR, which was to serve as an indicative rate for transactions in the interbank money market, as well as, other interest rates in the money market, was set at 10 per cent in 2006, with a spread of 600 basis points around the it, (i.e. 300 basis points above the MPR and 300 basis points below). This translated to an upper limit of 13 per cent (SLF) and a lower limit of 7 per cent (SDF). At that time, the interbank call and OBB rates stood at 8.98 and 9.55 per cent, respectively.

An analysis of the movement of the MPR and its corridor in 2006 revealed that the operationalisation of the MPR and other related policy reforms was successful at managing the rates. The volatility in the inter-bank rates was subdued with rates hovering within the MPR corridor, with improved transmission of monetary policy actions. Responding to the anticipated changes in economic and financial conditions, the Bank adjusted the MPR thrice in 2007. It was first adjusted in June 2007 from 10.0 per cent to 8.0 per cent, and the width of the interest rate corridor reduced from +/- 300 to +/- 250 basis points. The second was in October 2007, when the MPR was raised by 100 basis points, from 8.0 to 9.0 per cent, while, the last was in December 2007 when it was increased from 9.0 to 9.5 per cent. In 2008, the MPR was increased to 10.0 and 10.25 per cent in April and June, respectively.

In the wake of the 2007/2008 Global financial crisis (GFC), the money market was largely affected by trade and capital flows. The tightening of liquidity as a result of net forex outflow and lower monetisation of oil earnings made it difficult for banks to carry out their intermediation function (Nakorji *et al*., 2017). To address the problem of liquidity shortages in the banking system, as a result of the effect of the GFC, the Bank adopted the policy of monetary easing from September 2008 to September 2010. The cash reserve and the liquidity ratios were reduced from 4.0 to 2.0 per cent and from 40.0 to 30.0 per cent, respectively, while the policy rate was gradually reduced from 10.25 per cent to 6.00 per cent. Consequently, interbank and open-buy back (OBB) rates declined from 15.42 and 10.56 per cent in September 2008 to 7.91 and 5.08 per cent, respectively, before increasing to 18.10 and 7.52 per cent, in July 2009. The Treasury bill rate declined consistently in the same period. The 2009 banking crisis saw the money market rates falling significantly to almost below the SDF.

Figure 1: Movements in Average SDF, SLF and the Interbank Call Rate.



Source: CBN Statistical Database

The monetary policy easing measures, during the GFC coupled with huge fiscal expansion, put much pressure on inflation, exchange rate, and external reserves. Hence, to curtail these threats, the stance of monetary policy changed from monetary easing to monetary tightening. The policy rate was increased gradually from 6.00 per cent (September 2010) to 12.00 per cent (October 2011). The SDF and SLF also increased from 4.25 and 8.25 per cent to 10.00 and 12.00 per cent, respectively. This resulted in the increase of the inter-bank call and OBB rates from 8.50 and 7.48 per cent to 13.07 and 13.70 per cent, respectively, within the same period.

Monetary policy, however, continued to contribute significantly to the robust performance of the economy after the GFC in 2008 on the one hand, and the domestic banking crisis of 2009, on the other. In response to a rise in inflation and the rapidly depreciating naira, the MPR was increased by 100 basis points to 13.00 per cent in November 2014. Nonetheless, the symmetric corridor of +/-200 basis points, around the MPR, was retained, complemented by repurchase transactions, reserve requirements, discount window operations, and foreign exchange market interventions. These measures moderated the banking system liquidity, contained the inflationary threats and pressures in the foreign exchange market, and further stabilised the interbank interest rates.

Towards the end of 2015, however, the MPR was slashed by 200 basis points to 11.0 per cent, and the corridor around the MPR changed to an asymmetric corridor of +200/-700 basis points, to ease the pressure on external imbalances, arising from dwindling forex earnings due to fall in oil price. This reduced the cost of borrowing for the government and the private sector. In addition, the lower band indicated the Bank's desire to spur lending to the real sector by discouraging commercial banks from placing funds with it. Resultantly, the average interbank call and OBB rates moved in tandem with the measures, falling within the MPR bands. These were, however, short-lived as the Bank changed its monetary policy stance in 2016 to mitigate the adverse effect of global factors, which affected domestic, foreign exchange receipts and foreign reserves. Consequently, the monetary policy rate was raised from 11.0 to 14.0 per cent and the asymmetric interest rate corridor on standing facilities was narrowed to +200/-500 basis points around the MPR, from +200/-700 basis points. The treasury bills rate was also reduced. The monetary policy measures eased the pressure on the exchange rate and moderated the upward trend in domestic prices. However, money market activities responded to the trends in liquidity in the banking system. Between 2016 and 2017, the average interbank call and OBB rates rose above the upper band of the MPR, most of the time, ranging from 2.77 to 58.73 per cent and from 2.90 to 46.07, respectively. This could be attributed to the commencement of the new flexible foreign exchange policy in June 2016, as foreign exchange transactions drained liquidity in the money market.

IV. Methodology

In line with the objective of tracing the dynamic responses of market interest rates to exogenous monetary policy shocks, this section presents the data, methodological framework, and specifies the SVAR model to be estimated.

IV.1 Methodological Framework

IV.1.1 The Structural Vector Autoregressions (SVAR) Model

Structural Vector Autoregressions (SVARs), originally introduced by Sims (1980) as a large-scale macroeconomic model, was used to capture unanticipated shocks in the economy. Basically, the estimation of an SVAR begins with the specification of the reduced form VAR, after which contemporaneous or short-run restrictions are imposed.

Equation 1 is a typical SVAR:

$$AX_t = B_0 + B_1X_{t-1} + \mu_t \tag{1}$$

Where A is an nxn matrix of contemporaneous coefficients; X_t is an $nx1$ matrix of a two-variable vector, $y \; and \; r$; $B_1 \; and \; B_0$ are nx1 and nxn matrixes of unknown parameters; and μ_t is an $nx1$ matrixes of independent structural shocks with zero mean and constant variance.

In the case of a 2-variable VAR, Equation 1 could be expressed as:

$$\begin{bmatrix} 1 & a_{12}^0 \\ a_{21}^0 & 1 \end{bmatrix} * \begin{bmatrix} y_t \\ r_t \end{bmatrix} = \begin{bmatrix} \beta_{10} \\ \beta_{20} \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} * \begin{bmatrix} y_{t-1} \\ r_{t-1} \end{bmatrix} + \begin{bmatrix} \mu_{yt} \\ \mu_{rt} \end{bmatrix} \tag{2}$$

Where a_{21}^0 and $a_{12}^0$are the contemporaneous parameters.

Multiplying Equation 1 by the inverse matrix A, the reduced form VAR is obtained as shown:

$$AA^{-1}X_t = A^{-1}B_0 + A^{-1}B_1X_{t-1} + A^{-1}\mu_t \tag{3}$$

This gives the reduced form VAR as:

$$X_t = G_0 + G_1X_{t-1} + e_t \tag{4}$$

$$AA^{-1} = I, \; A^{-1}B_0 = B_0; \; A^{-1}B_1X_{t-1} = G_1; \; A^{-1}\mu_t = e_t \tag{5}$$

e_t is the linear combinations of the structural shock μ_t, and $Ae_t = \mu_t$

Let $E(\mu_t\mu_t') = D$ be a diagonal covariance matrix of structural disturbances and $E(e_te_t') = \varphi$, the covariance matrix of the reduced form structural disturbances. Based on the order condition, the structural parameters could be recovered from the reduced form. By using the Cholesky decomposition of the reduced form innovations (e), as prescribed by Sims (1980), the rank condition is satisfied, and the result of the model is a recursive VAR structure. In other methods, such as the structural approach (SVAR), the VAR structure is non-recursive with the imposition of restrictions on the contemporaneous relationships among the variables. The imposition of the restrictions is based on economic theory, knowledge of the economy or intuition. Following these definitions:

$$\varphi = E(e_te_t') = E[A^{-1}\mu_t, (A^{-1})'\mu_t'] = A^{-1}E(\mu_t\mu_t')(A^{-1})' = A^{-1}D(A^{-1})' \tag{6}$$

To estimate the structural parameters, it is necessary for the model to be either exactly-identified or over-identified. This requires that the number of parameters in matrixes A and D is the same as in φ. Since φ is symmetric, it has $\frac{n(n+1)}{2}$ parameters. The matrix of the structural disturbances, D, is a diagonal matrix with n parameters. Therefore, matrix A should not have more than $\frac{n(n-1)}{2}$ restrictions to be exactly- identified.

IV.1.2 Specification of the SVAR Model

While the selection of variables in the models is underlined by the Keynesian ISLM framework, which highlights the interaction between the money and goods markets, their ordering is inspired by the portfolio choice theory. In this case, the monetary authority exogenously and systematically chooses between the goals of interest stabilisation and liquidity management, with inherent trade-offs. The possibility of realising the set policy objective represents the returns on its policy choice. With these frameworks in mind, the following five-variable SVAR equations were specified:

$$mpr_t \rightarrow spr_t \rightarrow ibr_t \rightarrow cpi_t \rightarrow gdp_t \quad (7)$$

$$mpr_t \rightarrow spr_t \rightarrow plr_t \rightarrow cpi_t \rightarrow gdp_t \quad (8)$$

$$mpr_t \rightarrow spr_t \rightarrow 91\_tbr_t \rightarrow cpi_t \rightarrow gdp_t \quad (9)$$

$$mpr_t \rightarrow spr_t \rightarrow mlr_t \rightarrow cpi_t \rightarrow gdp_t \quad (10)$$

In each of the specifications, the interest rate variable is substituted. Although the interbank rate could sufficiently proxy market interest rate, as argued by Grenville (1997), other market rates, including the prime and maximum lending rates and the 91-day treasury bill rate, were incorporated for robustness purposes.

IV.1.3 Structural Identification

The proper identification of the SVAR equations is important for tracing the dynamic impact of purely exogenous shocks on endogenous variables. As earlier noted, these restrictions may be informed by theory, knowledge of the economy or intuition. The maximum number of restrictions to be imposed is guided by the formula: $\frac{n^2-n}{2}$ where n equals the number of variables in the VAR model. Specifically, the sum of parameters in the covariance matrix of structural shocks and the matrix of contemporaneous coefficients (A) should not exceed the number of parameters in the reduced form covariance matrix of the error term. In the model, n=5. The maximum number of restrictions on matrix A is $\frac{5^2-5}{2} = 10 \text{ restrictions}$. Thus, with 13 restrictions, the VAR structure is 'over identified. In the case of an over identified model, the full information maximum likelihood (FIML) estimation of the SVAR model are still consistent and efficient.

The identification scheme in matrix A is given as:

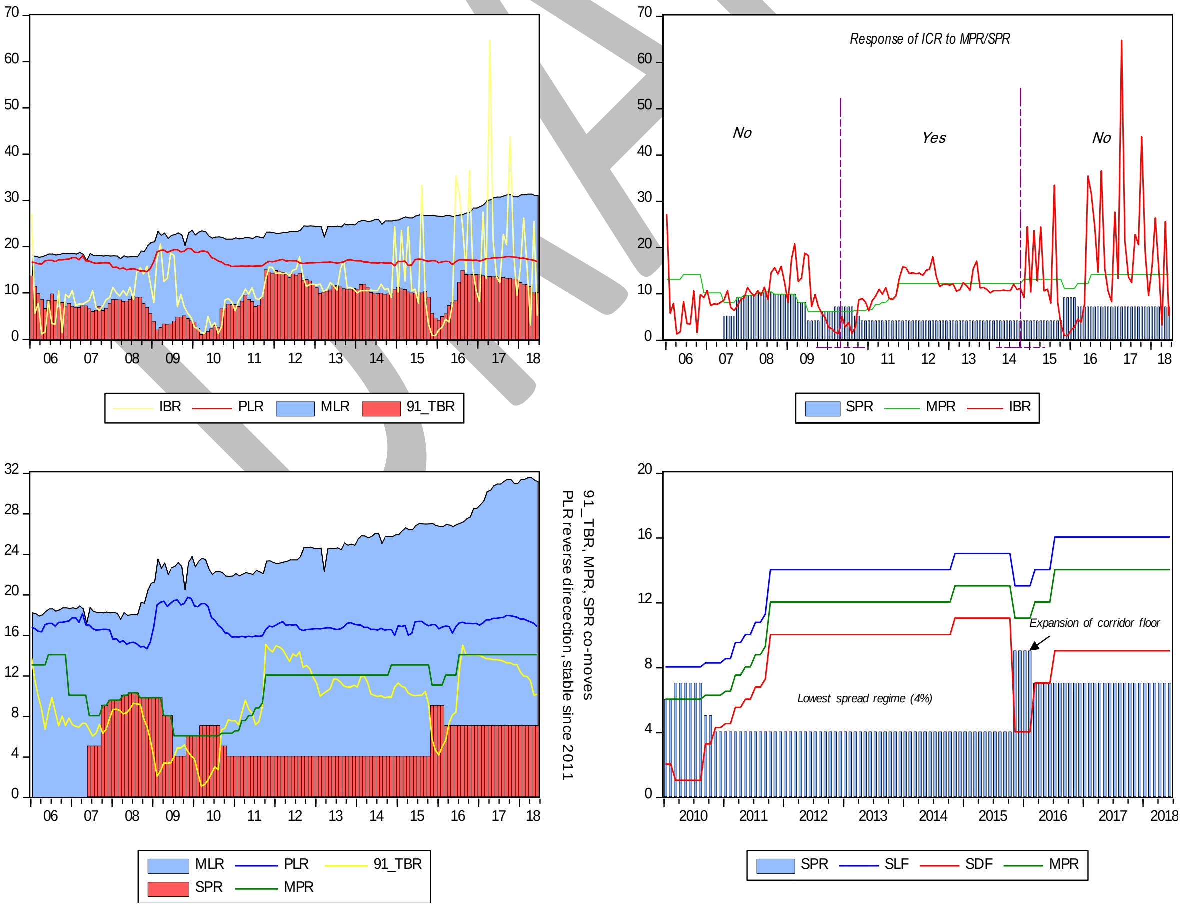
$$AX_t = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ b_{21}^0 & 1 & 0 & 0 & 0 \\ b_{31}^0 & b_{32}^0 & 1 & 0 & 0 \\ 0 & 0 & b_{43}^0 & 1 & b_{45}^0 \\ 0 & 0 & b_{53}^0 & b_{54}^0 & 1 \end{pmatrix} \begin{pmatrix} mpr_t \\ spr_t \\ ibr_t \\ cpi_t \\ gdp_t \end{pmatrix}$$

The MPR enters the SVAR framework as a 'rule' in which case the policymaker acts systematically. This presumes that the monetary policy rate is exogenously determined. Behavioural restrictions were also imposed on some variables, given that some of the endogenous variables respond slowly to movements in short-term interest rates. For instance, output (GDP) does not respond contemporaneously to monetary policy changes, based on the money neutrality argument. Besides, real economic activities, respond to financial signals with a lag, owing to the inherent high cost of adjustment in production. We also restricted the parameters b^0_{41}, b^0_{42}, b^0_{51}, b^0_{52} to zero, indicating that GDP is not contemporaneously impacted by the MPR and the asymmetric corridor, owing to the money neutrality argument. Also, the data also shows that changes in the policy rates are not immediately transmitted to inflation. This is in addition to the restrictions imposed by the VAR recursive structure ($b^0_{12}\ to\ b^0_{15} = b^0_{23} = b^0_{24} = b^0_{25} = b^0_{34} = b^0_{35} = 0$).

IV.2 Data Overview

This study employed monthly frequency time series data for the sample period, spanning December 2006 to June 2018. The variables were categorised as endogenous and exogenous based on their interactions in the SVAR system. The endogenous variables include interest rates (Open-Buy-Back rate (OBB), Interbank call rate (ICR), monetary policy rate (MPR), standing lending facility (SLF), standing deposit facility (SDF), 91-day treasury bills rate (91_TBR), prime lending rate (PLR), maximum lending rate (MLR), corridor spread (SPR)), consumer price index (CPI), and gross domestic product (GDP)[8]. The endogenisation of CPI and GDP in the models is underscored by the basic Keynesian ISLM framework, which captures interactions between the money and goods markets.

Figure 2: Trends in Policy Rate and Market Interest Rates



[8] Measured by the Index of Industrial Production (IIP), available in the CBN statistical database

The exogenous variables in the system include inter-bank nominal exchange rate (ER), credit to the private sector (CPS), bank reserves (BR), money stock (M_2), monetary policy regime change (REG_M). BR was included because, by intuition, the level of banks' reserves affects their lending and borrowing behaviour, and by extension, the market interest rates. All the variables were derived from the Central Bank of Nigeria (CBN) database, except the CPI, which was sourced from the National Bureau of Statistics (NBS). Some of the variables used in the estimation were 'derived.' For instance, the *corridor-width or spread* is measured by the difference between the corridor ceiling and floor (SLF minus SDF); the *Upper and Lower Bands* of the MPR were derived by subtracting the MPR from the SLF (SLF minus MPR), and the SDF from the MPR (i.e., MPR minus SDF), respectively. Also, the dummy variable, *Regime change,* measures periods before a specific monetary policy regime (0), and after (1). The introduction of the dummy is to capture the structural breaks and step-wise movements, particularly in the policy variables, over the period of analysis.

The key variables in this study are the policy rates and the market interest rates. Figure 2 describes the interactions among these rates. In Panel a, the prime lending rate is expected to be stable over the horizon and co-moved with the maximum lending rate. The interbank rate and the 91-day Treasury bill rates also co-moved with other rates for the most part of the analysis period. However, from the 4th quarter of 2014 up to June 2018, the interbank rate was significantly volatile despite relative stability in the policy rates over that period. Observing the trends in the interbank market, the interbank rate dipped sharply from 33.3 per cent in August 2015 to 3.2 per cent in October 2015. In the same month, MPR was reduced by 200 percentage basis points from 13 to 11 per cent, and this was followed by a steady decline in the interbank rate, averaging 1.6 per cent between November 2015 and February 2016. This decline in both the MPR (including SLF and SDF) and IBR could be attributed to the initial momentum of the economic recession in Nigeria.

Table 1: Correlation among Interest Rates

	91-Day TBR	MPR	MLR	SDF	SLF	PLR	ICR
91-Day Treasury Bill Rate	1						
Monetary Policy Rate	0.8	1					
Maximum Lending Rate	0.4	0.5	1				
Standing Deposit Facility	0.7	0.5	0.7	1			
Standing Lending Facility	0.5	0.4	0.8	0.8	1		
Prime Lending Rate	-0.3	-0.2	0.3	-0.1	-0.1	1	
Interbank Rate	0.5	0.4	0.4	0.3	0.4	0.0	1

The correlation matrix provides insights on the relationships between the policy and retail rates in the economy. The standing facilities (SDF and SLF) appear to be positively correlated with both the MPR and the MLR. However, the association is stronger between the standing facilities and the MLR. Compared with other market rates, the 91-day Treasury bill rate exhibited the strongest association with the MPR, and this association is also shown in Panel c of Figure 2. The interbank rate (IBR) is moderately correlated with the 91-day Treasury bill rate, but weakly correlated with the rates at the discount windows. Similarly, the prime lending rate (PLR) was negatively and weakly associated with other market rates, except with the maximum lending rate where the relationship was both weak, but positive. The Jaque-Bera statistic indicates normality in most of the series (see Appendix A).

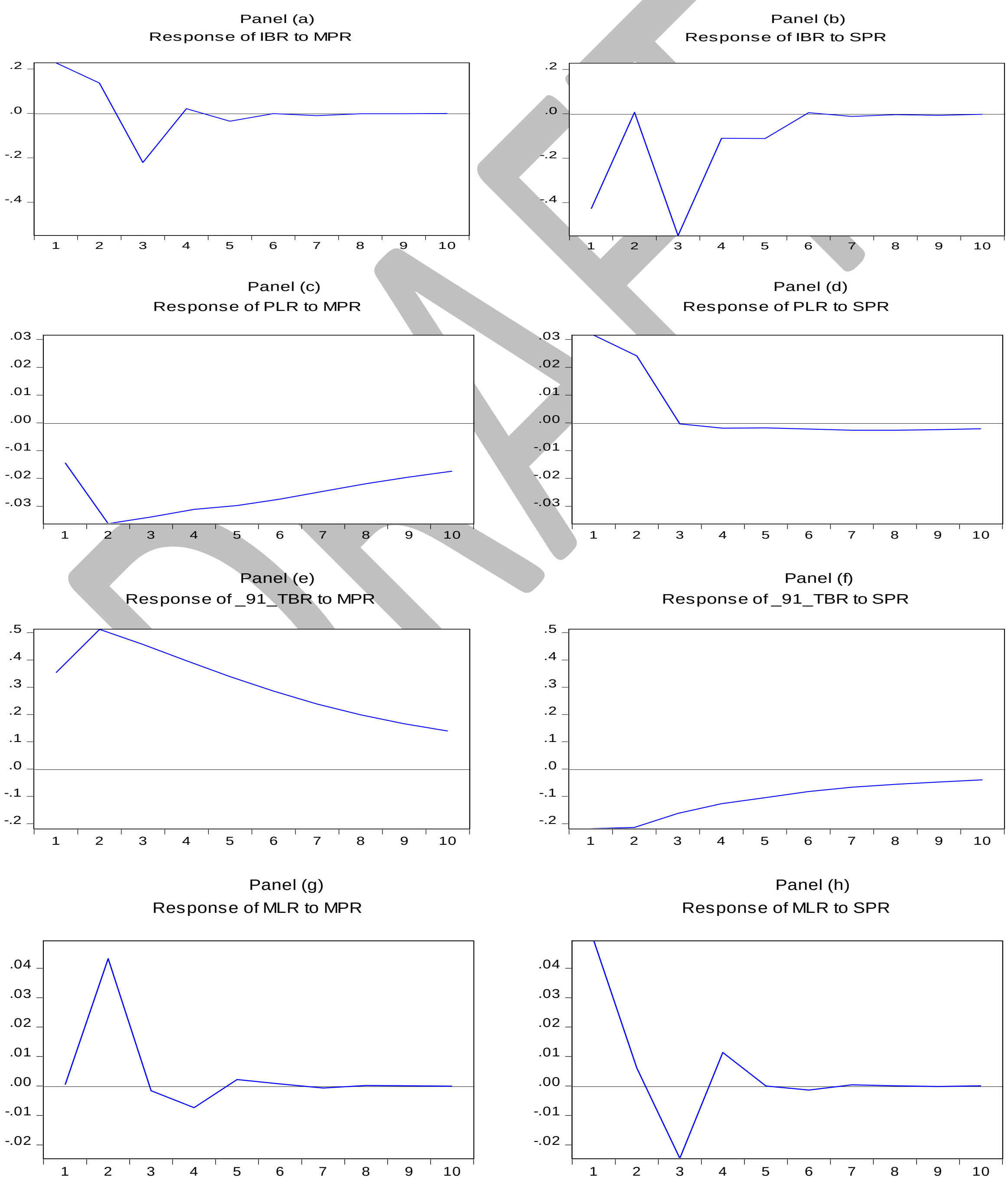
V. Estimation and Results

V.1 Impulse Response Functions and Forecast Errors Variance Decomposition

The impulse response of an unanticipated contractionary monetary policy shock resulted in a large and immediate increase in the interbank rate, which dies out in the 4th month. As shown in Panel (a), this impact is only significant up to the 2nd month. In response to a one-time shock to the corridor (SPR), which connotes an expansion of the corridor, the interbank rate contemporaneously declines with the effect fizzling out in the 6th month (see Panel (b)).

Figure 3: Market Rates Impulse Responses to Monetary Policy Shocks

Impulse Responses



Similar to IBR's response to a sudden change in the MPR, the significance of the impact is short-lived, expiring in the 2nd month. The observed contemporaneous response of the interbank rate (IBR) to shocks emanating from the MPR and SPR, offers credence to the perspective of the existing monetary policy framework being an effective signal to the interbank market.

The negative response of the interbank rate is pre-empted given that an expansion of the asymmetric corridor implies either a reduction in the corridor floor or an expansion of the corridor ceiling, which increase, the penalty for banks' participation in the discount windows. This compels banks to transact among themselves at the interbank market, increasing liquidity, and possibly driving down the interbank rate. This explanation may, however, have oversimplified the operating channels by taking for granted alternative investible windows available to banks, such as foreign currency holdings and other longer-term maturity assets.

Panels (a) and (b) are the impulse responses of the prime lending rate to innovations in the MPR and the asymmetric corridor. Shocks to MPR and SPR are associated with a decline and an increase in the PLR, respectively. The effect is however more long-lasting in the case of an MPR shock compared to impulses from the SPR where the impact fizzles in the 3rd month. Regardless, the beta coefficients reveals that the responses of the PLR to these shocks are insignificant.

Panel (e) shows that shocks to the MPR induces a positive contemporaneous impact on the 91-day TBR, with the effect outlasting the forecast horizon. This is expected given that treasury bills are issued, by the monetary authority, on behalf of the government, and the rates are often benchmarked closely against the policy rate. On the other hand, Panel (f) indicates that positive shocks to the asymmetric corridor (SPR) result in a reduction in the 91-day_TBR in the 2nd month with persistence over the 10-month horizon. This effect is, however, not significant.

Panels (g) and (h) show the reaction of the maximum lending rate (MLR) to unanticipated shocks to monetary policy (MPR and SPR). The impact of the MPR shocks on MLR is positive, with the rates spiking in the 2nd months before converging at zero in the 3rd month. In response to impulses from the SPR, the maximum lending rates jumped in the first month and gradually drifted to zero in the 2nd month before eventually dying out in the 5th. However, the responses of the MLR to MPR and SPR impulses are not significant.

The impulse response results tend to suggest that the inter-bank rate and the 91-day Treasury bill rate are reactive to shocks to the monetary policy rate and the asymmetric corridor; while the prime and maximum lending rates, responded imperceptibly to monetary policy shocks. This was corroborated by the FEVD analysis in Table 2, which indicates that monetary policy shocks induce the greatest variation in the 91-day TBR, compared, with other rates. In addition to this, the FEVD analysis revealed that shocks to the monetary policy rate (MPR) feature largely in the market rates when compared with shocks in the asymmetric corridor. It was also observed that shocks to the MPR and the asymmetric corridor, tend to have identical but opposite effects on the market interest rates. This underscores the view that, unlike the MPR that has a positive relationship with the market interest rates, the widening of the asymmetric corridor, discourages the participation of banks in the discount windows, thus encouraging interbank trading, with a tendency for market forces to drive down the rates.

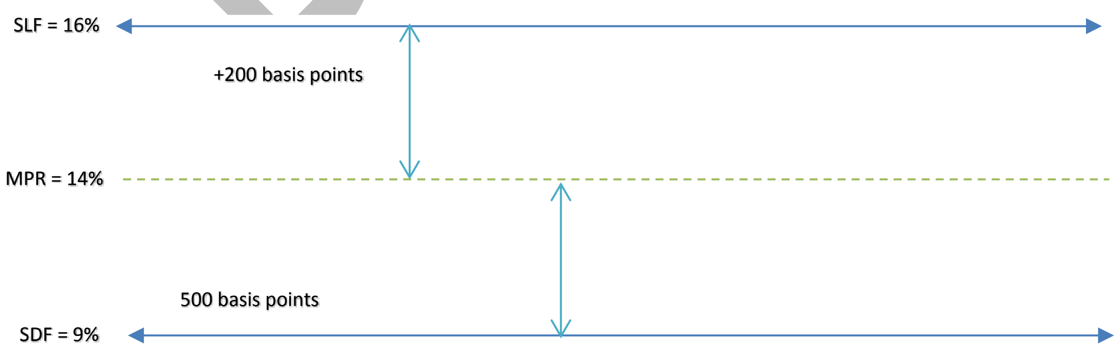
V.2 Simulations: What if Analysis

Simulations were performed on the key policy variables to examine the responses of the other variables in the system. The relevance of such simulations to policy depends on the forecasting power of the model. To ascertain the model's forecast reliability, in-sample and out-sample forecasts were carried out, using the Theil's inequality statistic, as the main decision criterion. Theil's statistics for the models were considerably less than 1 (see Appendix). In addition, the relatively low Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) produced by the forecasts reinforced the reliability of the models and their suitability for forecasting. Notably, the variables, MLR and PLR, were dropped to enhance the predictability of the model. This was done, in consideration too, the earlier results of the SVAR impulse responses, which noted their insensitivity to shocks to monetary policy. Although, exogenous in the system, money supply (M_2) was included to enhance the model's performance.

Table 3: Simulation Sequence, Scenarios and Assumptions

Policy	Action	Scenarios	Description
Policy Option 1	Maintain Corridor	Baseline	+ 200/-500 bps, relative to the MPR
Policy Option 2	Adjust bands but retain width	1	100 bps increase in the upper and lower band
		2	100 percentage basis reduction in the upper and lower bands
Policy Option 3	Adjust both bands and width	3	Increase corridor ceiling by 100 bps and reduce corridor floor by 100 bps
		4	Decrease corridor ceiling by 100 bps and increase corridor floor by 100 bps
Policy Option 4	Adjust lower band and width	5	Increase the corridor floor by 100 bps with the ceiling unchanged
	Adjust upper band and width	6	Increase the corridor floor by 100 bps with the ceiling unchanged

Figure 4: Existing Operating Corridor for Baseline Scenario



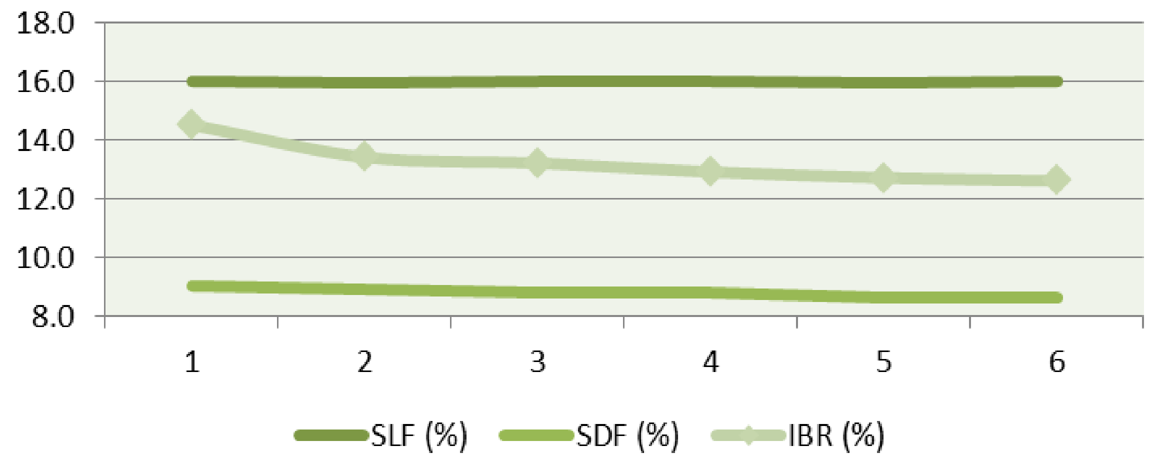
Assumptions regarding changes in the asymmetric corridor were deliberately restricted to plus or minus 100 percentage basis points, owing to the presumed sensitivity of the financial market to large adjustments in the monetary policy corridor. For each of the scenarios, these assumptions are imposed on the policy variable, and the reactions in the target variables are evaluated. The scenarios, in each case, assume, ceteris paribus, that changes in the target financial and macroeconomic variables are induced by adjustments in the policy variables. The scenarios are based on a 6-month out-of-sample forecast (July 2018 to December 2018). The forecast period was limited to 6 months, owing to the sensitivity of monetary policy and financial variables to short-run dynamics.

Table 4: Scenarios for Simulation

Baseline									
Period	**MPR**	**MPR_Upper Band**	**MPR_Lower Band**	**IBR**	**91-Day TBR**	**M2 (%)**	**ER**	**CPI (%)**	**GDP**
1	13.9	2.1	4.9	14.5	10.0	13.94	310.3	10.67	116.5
2	13.8	2.1	4.9	13.4	9.9	15.92	311.3	10.65	116.5
3	13.8	2.2	5.0	13.2	9.8	17.72	312.1	10.78	116.5
4	13.8	2.2	5.0	12.9	9.7	19.52	313.0	10.93	116.8
5	13.7	2.2	5.1	12.7	9.6	21.39	313.9	11.05	117.0
6	13.7	2.3	5.1	12.6	9.6	23.31	314.8	11.41	117.2

The baseline scenario is the model forecast with the assumption of no policy action. With respect to the policy rates, the baseline forecast deviates slightly from the observed but suffices for simulation. Results of scenarios 1 to 6 are presented in Appendix F.

Figure 5: Baseline Graph

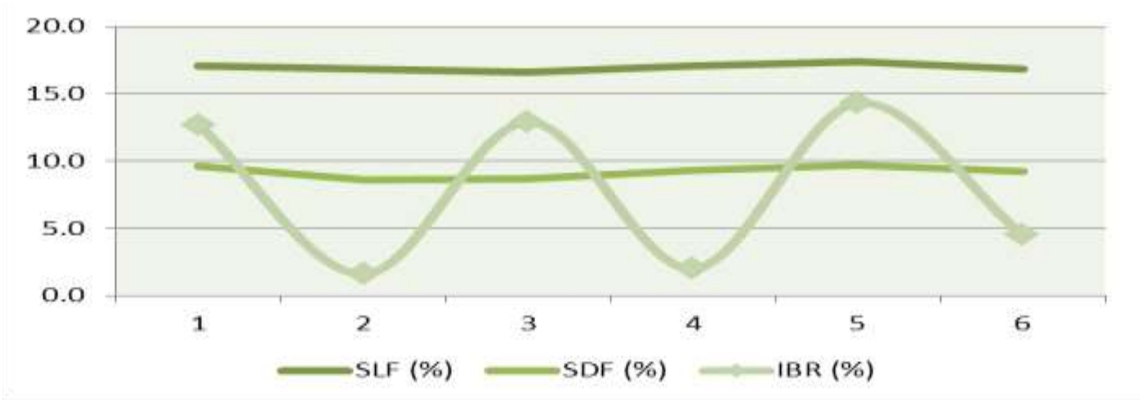


V.2.1 Simulation Outcomes

V.2.1.1 Scenario 1: 100 percentage basis points increase in the upper and lower bands

This results in an immediate decline in the IBR from 14.5 per cent in the baseline scenario to 12.7 per cent. The IBR, however, increased to 14.3 per cent in period 5. On average, the interbank rate fell by 39.3 per cent in the forecast horizon. The 91-day TBR also declined by 52.8 per cent over the 6-month forecast period, relative to the baseline scenario. With regards to the response of other macroeconomic variables, the exchange rate appreciated by 1.4 per cent, on average. This was also associated with a 0.7 per cent fall in the general price level and a 3.1 per cent reduction in output.

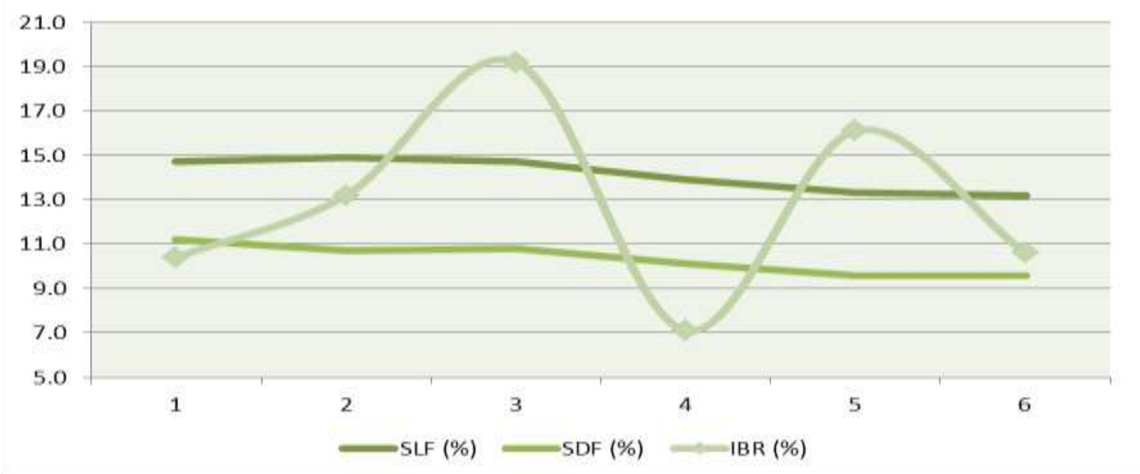
Figure 6: Scenario 1



V.2.1.2 Scenario 2: 100 percentage basis points reduction in the upper and lower bands

The IBR fell by 3.4 per cent on average, compared with 61.0 per cent reduction in the 91-day TBR. Although the IBR fell from 14.5 per cent in the baseline scenario to 10.4 per cent in the period one, it increased significantly to 19.2 per cent in the 3rd period before declining to 7.1 per cent in the 4th month. The 91-day TBR, on the other hand, declined sharply to 2.9 per cent in the 1st month from 10.0 per cent in the baseline. While the exchange rate depreciated by 6.1 per cent on average, the GDP and the price level, increased by 4.1 and 0.6 per cent, respectively.

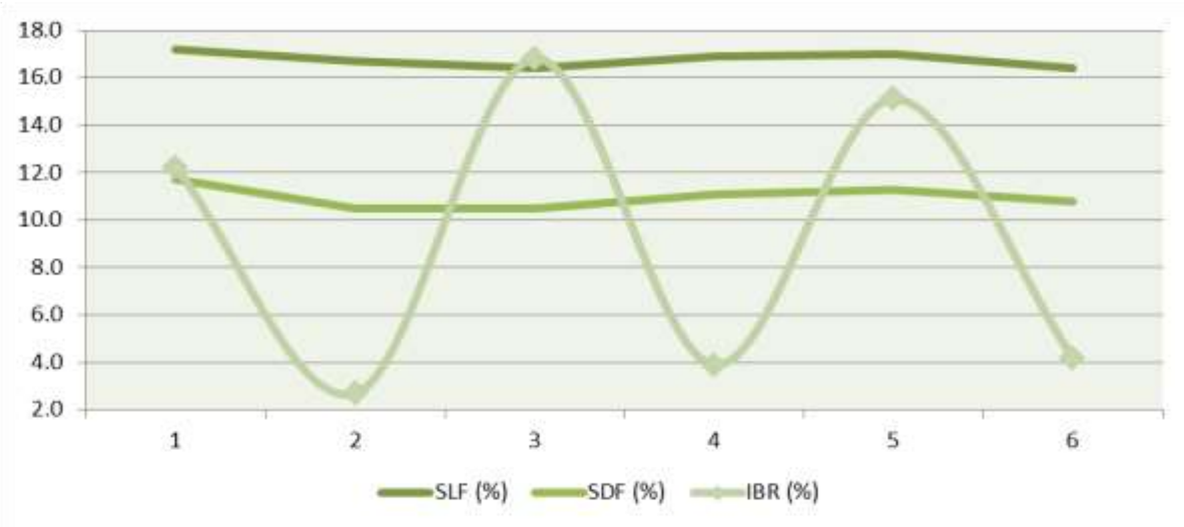
Figure 7: Scenario 2



V.2.1.3 Scenario 3: Increase upper band by 100 bps and reduce lower band by 100 bps

This triggered a 30.8 per cent reduction in the IBR on average and induced volatility in the monthly IBR. Similarly, over the 6-month forecast period, the 91-day TBR declined by 57.7 per cent, when compared with the baseline. Also, on average, exchange rate depreciated by 0.2 per cent, while the economy experienced a non-inflationary growth with GDP rising by 0.6 per cent and the price level shrinking by 3.5 per cent.

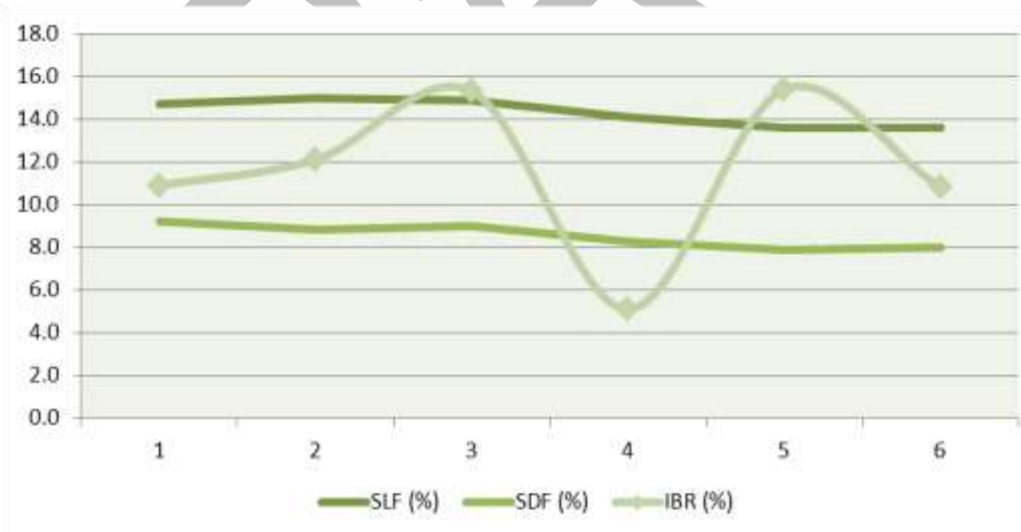
Figure 8: Scenario 3



V.2.1.4 Scenario 4: Reduce the upper band by 100 bps and increase lower band by 100 bps

On average, reductions in both the IBR and the 91-day TBR from the baseline values are 11.9 and 56.1 per cent, respectively. The decline is more prominent in the first two months, except for IBR where it persisted up to the 4th month.

Figure 9: Scenario 4

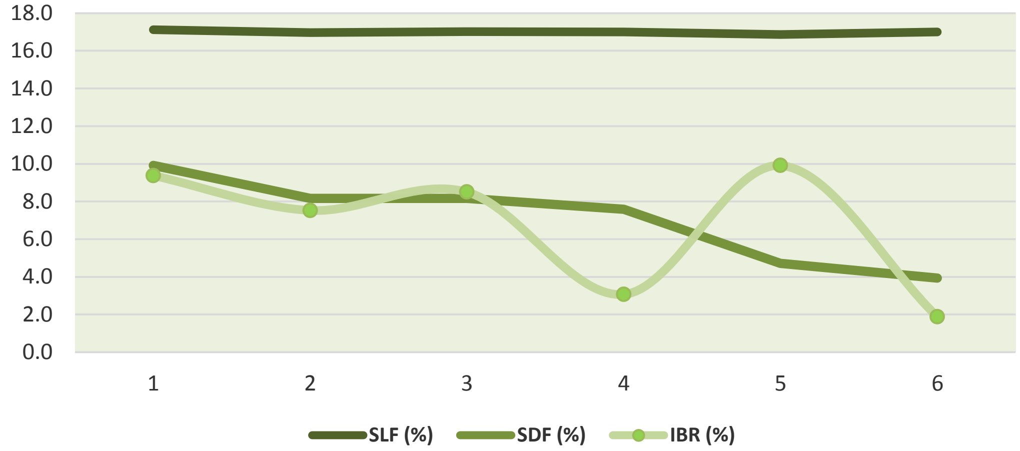


Overall, the simulation output suggests that the 91-day TBR responds more significantly to monetary policy shocks, compared with the IBR, and this sensitivity is biased towards a reduction in the corridors (Scenario 2) than it is to an expansion of the corridor (Scenario 1). The IBR is more sensitive to a reduction in the ceiling and expansion in the floor (Scenario 4) than an expansion in the ceiling and a reduction in the floor (Scenario 3). From the policy standpoint, Policy Option 3 (Scenario 4) appears to be the preferred optimal policy choice, given that the IBR and 91-Day TBR were relatively lower and less-volatile, compared with the policy options 1 and 2.

V.2.1.5 Scenario 5: 100 bps increase in the Lower band with the upper band unchanged

IBR averaged 6.7 per cent, lower by about 49.2 per cent relative to the baseline. It is also the lowest among the scenarios. In addition, the rates stayed well below the SLF for the most part of the forecast horizon compared to other scenarios. Whether or not the bias in the SDF as shown in figure 11 is corrected, does not upturn the relatively low level of the IBR under this scenario. Inflation moderated by 3.0 per cent in addition to a 3.6 per cent reduction in output.

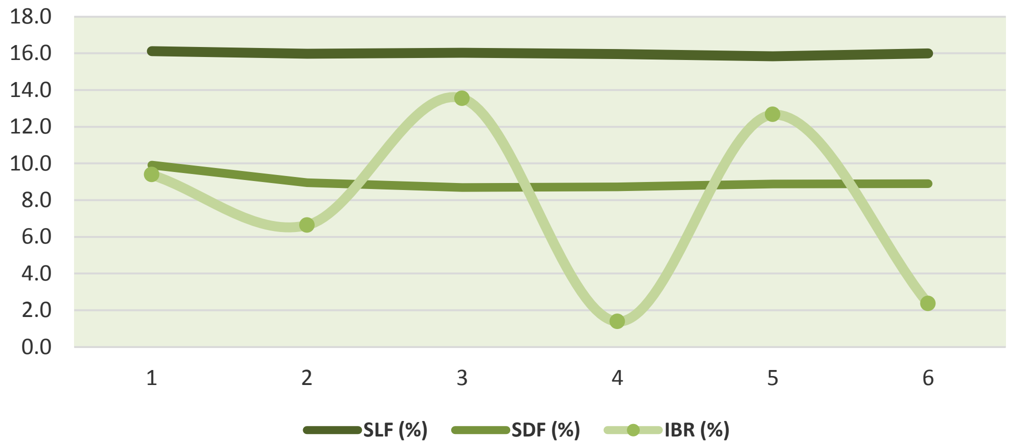
Figure 10: Scenario 5



V.2.1.6 Scenario 6: 100 bps increase in the upper band with the lower band unchanged

On average, IBR and the 91-Day TBR remain relatively low, averaging 7.7 and 3.6 per cent, respectively. IBR stayed below the SLF over the forecast period with moderate undulations. With regards to the behaviour of other macroeconomic indicators, the exchange rate was relatively stable, appreciating, on average, by 0.6 per cent; while inflation and output moderated by 1.6 and 1.3 per cent, respectively.

Figure 11: Scenario 6



VI. Summary, Policy Implications and Conclusion

This study investigated the effectiveness of the asymmetric corridor and the prevailing policy rate in driving market interest rates in Nigeria. It employed the SVAR impulse responses functions and the forecast error variance decomposition in isolating shocks to monetary policy and traced their impact on the market rates. The paper also carried out simulations based on four scenarios, to predict the reactions of these rates to varying monetary policy surprises. Among the major findings from the research are, that:

- Shocks to the MPR and the asymmetric corridor induce significant variations in both the interbank interest rate and the 91-day Treasury bill rate compared to other market rates. Consequently, the maximum and prime lending rates appear to be disconnected from the interest rate transmission channel, as both are insensitive to monetary policy shocks;
- The interbank rate is more sensitive to expansions in the corridor (Scenario 1) than they are to reductions (Scenario 2) The reverse effect, is however observed for the 91-day Treasury bill rates;
- Reductions in either the upper or lower bands (Scenarios 3 and 4) produced high and volatile interbank rates;
- Scenario 5 appears to be a more optimal policy choice in the policy menu, given that the market interest rates under this scenario, are relatively low and stable over the forecast horizon.

These findings have significant implications for the conduct of monetary policy in Nigeria. Firstly, the significant responses of the interbank rate and the 91-day TBR to shocks to monetary policy rate and the asymmetric corridor reinforce the importance of the overnight interest rate as the most appropriate indicator of monetary policy stance (Grenvile, 1997).

Regarding the finding of the MPR and its corridor, being ineffective in anchoring the maximum and prime lending rate, the explanations are relatively proximate. Although, the policy rate features in banks' determination of their lending rates, other considerations, including, overhead costs[9], risk factors, cost of fund vis-à-vis the prevailing reserve requirements, among others, appear to be more prominent and substantive, thereby reducing the relative importance of the policy rate and its corridor. Consequently, to enhance the effectiveness of monetary policy, the Bank needs to address the factors that increase their lending costs. For example, the reduction of the CRR can create more space for bank lending and assert downward pressure on market rates. Ongoing sectoral intervention in the credit market, in forms of risk-sharing and guarantees on commercial loans, appears not to have the desired impact on the effective lending rates by banks. Thus, credit market interventions should be focused more aggressively on the productive sectors of the economy, and banks should also be closely monitored to ensure compliance.

On whether or not the asymmetric corridor is effective; the existing asymmetric corridor is effective in influencing variations in the interbank and Treasury bill rates. However, there are substantial deviations in the rates, despite the relative stability of the asymmetric corridor over the years, particularly in the inter-bank market. From the observed data, the

[9] In forms of contributions to the Asset Management Corporation of Nigeria (AMCON) sinking fund, premium to the Nigerian Deposit Insurance Corporation (NDIC), in addition to their operating costs.

interbank rate fluctuated between a minimum of 1 per cent and a maximum of 68 per cent in a period where the average rate was 12 per cent (See Appendix A). This, therefore, suggests the need to adjust the bands to enhance its transmission to the interbank market.

Our simulation output prescribes a 100 bps increase in the lower corridor (-600 bps). Based on our analysis, this is projected to induce, on average, a 42.0 per cent reduction in the interbank rate, with relative stability in the rates over a 6-month horizon. Although this policy action has the possibility of enhancing the effectiveness of monetary policy transmission, reduce CBN's interest payments obligations on banks' deposits, and compel banks to transact among themselves; it comes at a cost. Although the reduction of the SDF to 8 per cent clearly reduces the incentive for banks to deposit with the Bank at overnight rates, there is no guarantee that banks would preferably transact more among themselves. Possible investment windows, including the foreign exchange market, capital market or other assets with longer term maturity, could be other considerations. The Bank should rely on prudential guidelines to ensure that banks maintain the right proportion of their liquid asset within the banking system, while sustaining its on-going interventions in the foreign exchange market.

While this paper does not undermine the effectiveness of the current asymmetric corridor, it concludes that it is sub-optimal if the primary objective is to maintain a low and stable interbank rate.

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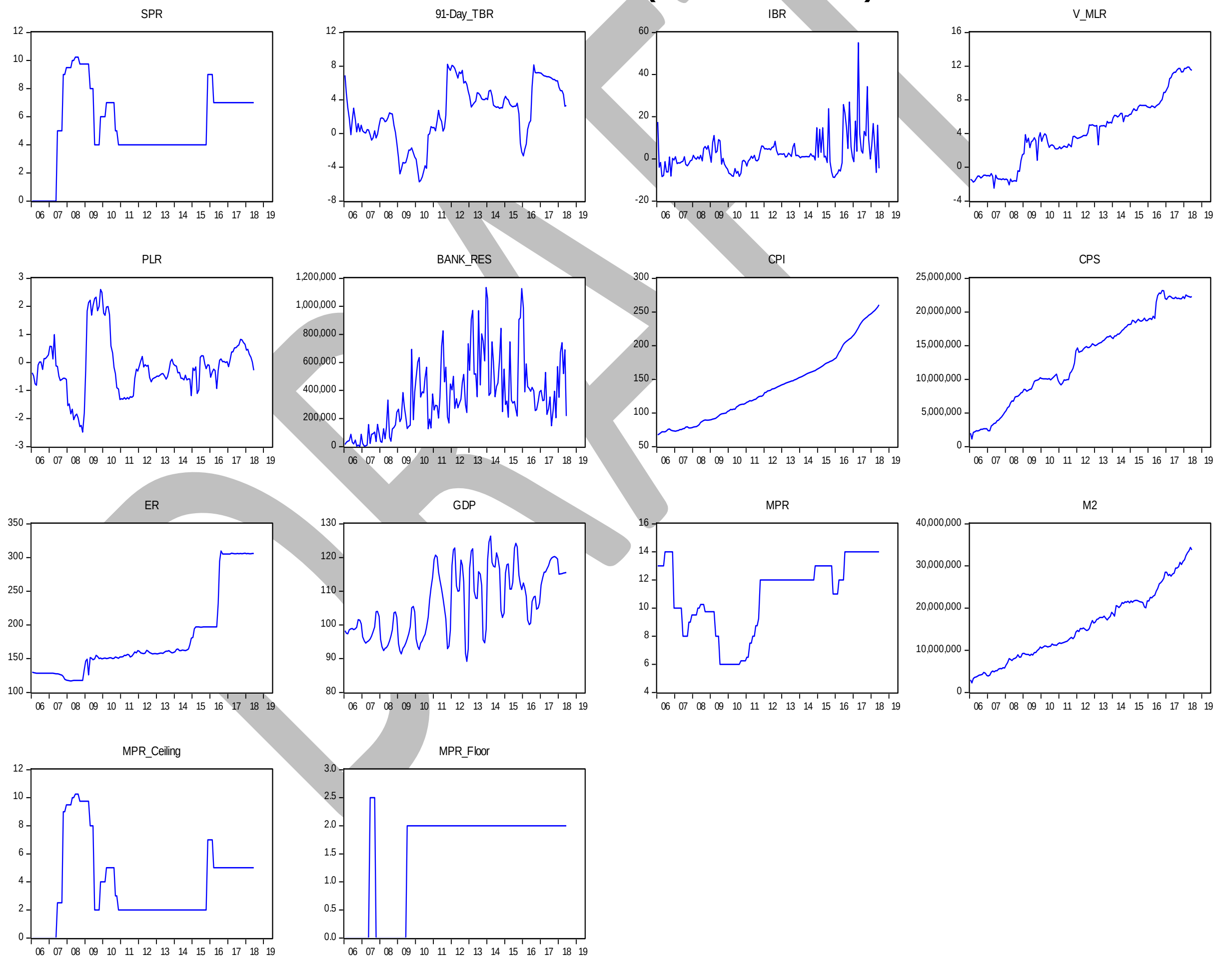
Appendix 1
Summary Statistics of the Original Variables

	MPR	SPR	GDP	CPI	ICR	ER	BANK_RES	91-Day TBR	M2	RG_M	CPS
Observations	150	150	150	150	150	150	150	150	150	150	150
Mean	11	5	107	139	12	178	358316	9	15607540	0	13065354
Median	12	4	105	133	11	158	325694	10	14725198	0	14332606
Maximum	14	10	126	260	65	310	1133873	15	34422668	1	23180458
Minimum	6	0	89	67	1	117	3	1	2227473	0	1113896
Std. Dev.	3	3	10	54	8	60	262251	3	8351129	1	6509573
Skewness	-1	0	0	1	2	1	1	0	0	0	0
Kurtosis	2	3	2	2	13	3	3	2	2	1	2
Jarque-Bera	14	1	11	11	822	48	19	5	8	25	9

Trends in Observed Series (2006 – Jun. 2018)



Appendix B

Stationarity and Unit Root Tests

Variables	Test Techniques			Remarks	Variable Augmentation
	ADF	PP	KPSS		
MPR	I(1)	I(1)	I(1)	Non-Stationary	Differenced in Model
SDF	I(1)	I(1)	I(1)	Non-Stationary	Differenced in Model
SLF	I(1)	I(1)	I(1)	Non-Stationary	Differenced in Model
SPR	I(1)	I(1)	I(1)	Non-Stationary	Differenced in Model
IBR	I(0)	I(0)	I(1)	Stationary	Incorporated at Levels
91_TBR	I(1)	I(1)	I(1)	Non-Stationary	Differenced in Model
MLR	I(1)	I(1)	I(1)	Non-Stationary	Differenced in Model
PLR	I(0)	I(0)	I(0)	Stationary	Incorporated at Levels
GDP	I(1)	I(0)	I(1)	Non-Stationary	Differenced in Model
CPI	I(1)	I(1)	I(1)	Non-Stationary	Differenced in Model
B_RES	I(0)	I(0)	I(0)	Stationary	Incorporated at Levels
REG_M	I(0)	I(0)	I(0)	Stationary	Incorporated at Levels
ER	I(1)	I(1)	I(1)	Non-Stationary	Differenced in Model
CPS	I(1)	I(1)	I(1)	Non-Stationary	Differenced in Model
M2	I(1)	I(1)	I(1)	Non-Stationary	Differenced in Model

Note: Unit root was not accepted at 5% level of significance

Appendix C

Statistical Significance of Impulse Response Functions

Results

Impulse from MPR												
Period	91-Day TBR			IBR			PLR			MLR		
	$\breve{\beta}$	se	$\frac{\tilde{\beta}}{2}$	$\breve{\beta}$	se	$\frac{\tilde{\beta}}{2}$	$\breve{\beta}$	se	$\frac{\tilde{\beta}}{2}$	$\breve{\beta}$	se	$\frac{\tilde{\beta}}{2}$
1	0.337	-0.079	0.168*	0.131	-0.056	0.065*	-0.005	-0.031	-0.003	-0.001	-0.002	0.000
3	0.464	-0.163	0.232*	-0.044	-0.063	0.022*	0.023	-0.061	0.011	0.000	-0.003	0.000
5	0.473	-0.207	0.237*	-0.017	-0.022	0.009*	-0.070	-0.073	-0.035	-0.001	-0.003	0.000
7	0.450	-0.205	0.225*	0.001	-0.009	0.001	-0.101	-0.066	-0.050	0.001	-0.001	0.000
9	0.356	-0.204	0.178	0.002	-0.004	0.001	-0.079	-0.056	-0.039	0.001	-0.001	0.001
Impulse from SPR												
Period	91-Day TBR			IBR			PLR			MLR		
	$\breve{\beta}$	se	$\frac{\tilde{\beta}}{2}$	$\breve{\beta}$	se	$\frac{\tilde{\beta}}{2}$	$\breve{\beta}$	se	$\frac{\tilde{\beta}}{2}$	$\breve{\beta}$	se	$\frac{\tilde{\beta}}{2}$
1	-0.251	-0.075	0.126*	-0.204	-0.054	0.102*	0.026	-0.031	0.013	0.001	-0.002	0.001
3	-0.263	-0.159	-0.132	0.047	-0.061	0.024	0.021	-0.060	0.011	-0.001	-0.002	0.000
5	-0.242	-0.207	-0.121	-0.008	-0.023	-0.004	-0.070	-0.075	-0.035	-0.004	-0.002	-0.002
7	-0.176	-0.217	-0.088	-0.011	-0.011	-0.006	-0.085	-0.071	-0.043	0.000	-0.001	0.000
9	-0.180	-0.193	-0.090	-0.002	-0.006	-0.001	-0.077	-0.063	-0.038	0.000	-0.001	0.000

Note: * Significant shocks

Criterion for significance: $\frac{\tilde{\beta}}{2} > se(\breve{\beta})$

Appendix D
Forecast Reliability Check

Variable	In-Sample: 2010M01-2017M12				Out-Sample: 2018M07-2018M12			
	RMSE	MAE	MAPE	Theil	RMSE	MAE	MAPE	Theil
CPI	9.83	7.80	4.45	0.03	7.64	5.86	4.07	0.03
ER	37.48	33.77	15.57	0.09	51.32	45.08	20.77	0.12
GDP	10.05	7.97	6.91	0.04	7.81	6.34	5.95	0.04
Corridor_Lower_Band	1.40	1.21	33.48	0.19	3.27	2.13	112.95	0.40
MPR	7.44	6.90	159.29	0.46	4.16	3.27	23.03	0.16
Corridor_Upper_Band	1.87	1.77	45.33	0.32	0.95	0.75	415.77	0.34
91-Day_TBR	3.46	2.91	199.04	0.51	3.57	3.00	125.12	0.53
IBR	9.27	5.31	371.00	0.77	8.48	5.51	224.65	0.75

Note: RMSE: Root Mean Square Error, MAE: Mean Absolute Error; MAPE: Mean Absolute Percentage Error; Theil: Theil inequality coefficient

Appendix E FEVD: Contribution of Monetary Policy Rate Shocks to Variation in Market Rates (%)

Month	IBR	PLR	91-Day TBR	MLR
	Model 1	Model 2	Model 3	Model 4
1	0.04	0.08	11.41	0.06
2	0.74	0.53	16.08	1.23
3	0.74	3.46	17.72	1.24
4	3.54	3.36	18.47	1.39
5	3.86	5.16	19.97	1.41
6	4.24	5.45	21.03	1.39

FEVD: Contribution of the Asymmetric Corridor Shocks to Variation Market Rates (%)

Month	IBR	PLR	91-Day TBR	MLR
	Model 1	Model 2	Model 3	Model 4
1	0.35	0.79	7.25	0.26
2	0.51	1.43	7.51	0.39
3	1.03	1.42	7.15	0.49
4	1.44	2.49	6.33	1.87
5	1.33	2.48	6.23	3.73
6	1.34	2.48	6.07	3.89

Appendix F
Simulation Results

Baseline									
Period	MPR	MPR_Upper Band	MPR_Lower Band	IBR	91-Day TBR	M2	ER	CPI (%)	IIP
1	13.9	2.1	4.9	14.5	10.0	13.94	310.3	10.67	116.5
2	13.8	2.1	4.9	13.4	9.9	15.92	311.3	10.65	116.5
3	13.8	2.2	5.0	13.2	9.8	17.72	312.1	10.78	116.5
4	13.8	2.2	5.0	12.9	9.7	19.52	313.0	10.93	116.8
5	13.7	2.2	5.1	12.7	9.6	21.39	313.9	11.05	117.0
6	13.7	2.3	5.1	12.6	9.6	23.31	314.8	11.41	117.2

Scenario 1 (1% increase in MPR ceiling and floor)									
Period	MPR	MPR_Upper Band	MPR_Lower Band	IBR	91-Day TBR	M2 (%)	ER	CPI (%)	IIP
1	13.9	3.2	4.3	12.7	5.2	5.19	300.9	9.95	114.4
2	13.7	3.1	5.1	1.6	4.8	9.23	301.4	9.44	112.7
3	13.6	3.0	4.9	12.9	4.7	6.16	311.7	8.46	112.6
4	14.1	3.0	4.8	2.0	4.3	3.52	318.1	6.74	117.4
5	14.4	3.0	4.7	14.3	4.4	4.12	309.2	5.79	119.0
6	13.8	3.0	4.6	4.5	4.1	2.06	308.5	4.76	119.8

Scenario 2 (1% reduction in MPR ceiling and floor)									
Period	MPR	MPR_Upper Band	MPR_Lower Band	IBR	91-Day TBR	M2 (%)	ER	CPI (%)	IIP
1	13.5	1.2	2.3	10.4	2.9	6.32	314.9	11.97	119.0
2	13.8	1.1	3.1	13.2	3.1	5.43	322.6	11.36	119.8
3	13.7	1.0	2.9	19.2	4.2	6.92	329.0	10.54	121.5
4	12.9	1.0	2.8	7.1	4.7	7.03	332.3	10.85	122.5
5	12.3	1.0	2.7	16.1	4.3	11.21	342.1	11.83	122.9
6	12.2	1.0	2.6	10.6	3.6	15.11	348.6	12.83	123.3

Scenario 3 (1% increase in MPR ceiling and 1% decrease in MPR floor)									
Period	MPR	MPR_Upper Band	MPR_Lower Band	IBR	91-Day TBR	M2 (%)	ER	CPI (%)	IIP
1	14.0	3.2	2.3	12.2	4.6	3.35	300.9	10.12	115.8
2	13.6	3.1	3.1	2.7	4.1	5.56	301.3	9.27	115.1
3	13.4	3.0	2.9	16.8	4.1	1.54	313.5	7.76	114.9
4	13.9	3.0	2.8	3.9	4.2	-0.61	324.7	5.95	118.6
5	14.0	3.0	2.7	15.1	4.2	-1.18	319.4	5.13	119.9
6	13.4	3.0	2.6	4.2	3.6	-2.37	318.7	4.31	120.6

Scenario 4 (1% decrease in MPR ceiling and 1% increase in MPR floor)									
Period	MPR	MPR_Upper Band	MPR_Lower Band	IBR	91-Day TBR	M2 (%)	ER	CPI (%)	IIP
1	13.5	1.2	4.3	10.9	3.6	8.21	314.9	11.80	117.5
2	13.9	1.1	5.1	12.1	3.9	9.10	322.7	11.52	117.3
3	13.9	1.0	4.9	15.3	4.9	11.78	327.1	11.24	119.0
4	13.1	1.0	4.8	5.1	4.8	11.48	325.6	11.63	121.3
5	12.6	1.0	4.7	15.4	4.5	17.17	331.8	12.52	122.0
6	12.6	1.0	4.6	10.8	4.1	20.33	338.4	13.32	122.5

Scenario 5 (1% increase in Floor, Ceiling fixed)									
Period	**MPR**	**MPR_Upper Bound**	**MPR_Lower Bound**	**IBR**	**91-Day TBR**	**M2 (%)**	**ER**	**CPI (%)**	**IIP**
1	13.3	2.1	4.1	9.4	3.4	-3.2	304.4	11.6	113.0
2	13.4	2.0	5.1	6.6	3.1	2.3	308.9	11.5	112.4
3	13.3	2.0	5.3	13.5	3.7	-1.3	317.2	11.1	114.2
4	13.1	2.0	5.3	1.4	4.0	0.0	318.7	11.2	116.7
5	13.1	1.8	5.1	12.7	3.8	3.7	317.0	12.0	117.6
6	12.8	2.0	5.1	2.4	3.5	0.4	319.6	11.7	117.6

Scenario 6 (1% increase in Ceiling, Floor fixed)									
Period	**MPR**	**MPR_Upper Bound**	**MPR_Lower Bound**	**IBR**	**91-Day TBR**	**M2 (%)**	**ER**	**CPI (%)**	**IIP**
1	13.3	3.1	4.1	9.4	3.4	(0.0)	304.4	11.1	113.0
2	13.6	3.0	5.8	7.5	3.9	0.9	301.9	10.7	110.9
3	13.1	3.0	5.8	8.5	4.4	0.9	306.6	10.9	111.4
4	13.0	3.0	6.4	3.1	4.2	(2.2)	311.0	11.0	112.7
5	13.6	2.9	9.3	9.9	4.0	3.3	312.3	11.1	114.6
6	13.6	3.0	10.1	1.9	4.6	1.2	305.7	10.7	113.0

Measuring the Persistence Component of Inflation in Nigeria: A Structural VAR Approach

Eborieme, M., Nkang, N. M., Hamma, B. and Ndubuisi, M.[*]

Abstract

This paper estimated the persistent (core) component of inflation in Nigeria, within the context of a structural vector autoregression (SVAR) model, using quarterly time series data from 1981Q1 to 2016Q4. Core inflation was defined in line with the assumption of the long-run vertical supply schedule, where core shocks have no long-run impact on real output, but produce a permanent effect on measured (CPI) inflation. The results show three distinct phases in the movement of measured and core inflation during the period: in the first phase (1980Q1-1994Q2), CPI inflation under-predicted core inflation; in the second phase (1994Q3-2009Q2), the CPI inflation dynamics predicted core inflation remarkably well; and lastly between 2009Q3 and 2016Q4, measured inflation over-predicted core inflation.

Keywords: CPI inflation, core inflation, persistence, shocks, structural vector autoregression

JEL Classification Numbers: C32, E31

I. Introduction

Price stability remains one of the primary mandates of central banks. High and unstable inflation is bad for economic growth and macroeconomic stability, as it reduces the volume of investment and the efficiency of the factors of production, and in addition, weakens the efficacy of price movements, which guide economic activity. This may lead to loss of confidence by both domestic and foreign investors, and uncertainty about the future direction of monetary policy. Consequently, central banks are obsessed with keeping inflation low and stable, on the one hand, while they also grapple with financial stability on the other.

Be that as it may, inflation comprise both transitory and persistent (permanent) components. While the transitory component is due to noise in price variations and transient disturbances, arising from supply side shocks which are outside the control of the central bank, the permanent or persistent/pure inflation component is due to demand side developments from monetary policy shocks, which are within the purview of the monetary authority (see, for instance, Claus, 1997; Roger, 1998; Aleem, 2006; and Darvas and Varga, 2013). Thus, the persistent component of inflation should constitute the focus of monetary policy, especially because the primary mandate of central banks is price stability, which requires a mastery of the inflationary process that feeds into or reflects inflation expectations.

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Unfortunately, the consumer price index (CPI), a commonly used measure of inflation is prone to noise in price variations and other disturbances, which are unrelated to the pure inflationary process. Consequently, measured (CPI) inflation, as we have it, may provide a misleading guide of underlying price trends that are appropriate for monetary policy. In other words, it is not the cost of living *per se,* but permanent component of the price index related to monetary growth (or monetary inflation) that the central bank should be concerned with, in contrast to the transient noisy component created by temporary macroeconomic shocks, such as variations in economic activity or production costs (Gartner and Wehinger, 1998; Dossche and Everaert, 2005; Aleem, 2006).

In Nigeria, inflation had been on the rise since the beginning of 2015, leaving the single-digit territory in February 2016 at 11.4 per cent to 18.6 per cent in December, 2016. This trend has been occasioned by a recession in output growth and foreign exchange market crisis, arising from the slump in crude oil prices in the international market. On the other hand, the trend of broad money growth has been fluctuating, compared with the measured (CPI) inflationary trend during the period. Thus, the measured (CPI) inflation over the period may be due to both transitory disturbances, including some of the macroeconomic shocks mentioned above, as well as, monetary growth. However, the influence of monetary inflation (that is persistent or core) inflation, which is under the control of the Central Bank of Nigeria (CBN) that feeds into measured (CPI) inflation, is unknown, though vital to monetary policy.

This study is, therefore, an attempt to measure the persistent component of inflation (core inflation) in Nigeria using a multivariate model, in order to guide monetary policy actions to changes in measured (CPI) inflation. Although much work has been done on inflation in Nigeria, specific studies on inflation persistence are scarce. To the best of our knowledge, the closest study to date is that of Adenuga, Adebayo and Elisha (2012), which used SVAR method to study the macroeconomic variables that drive core inflation movements in Nigeria. They employed official data on core consumer price index (measured in Nigeria as headline inflation less farm produce), but did not estimate the persistent (or core) component of inflation. Another study by Omotosho and Doguwa (2013) focused on the dynamics of inflation volatility in Nigeria using a GARCH model. Others (see, for example, Asogu, 1991; Moser, 1995; Fakiyesi, 1996; Masha, 2000; Adenekan and Nwanna, 2004; Olubusoye and Oyaromade, 2008; amongst many) were either concerned with drivers or sources of inflation. Consequently, this paper is an attempt to fill this gap by estimating the persistent component of inflation in Nigeria using the multivariate SVAR approach of Quah and Vahey (1995).

The rest of the paper is structured as follows. Section 2 is the review of literature covering theoretical and empirical as well as a brief review of inflation trends in Nigeria. Section 3 details the methodology and in Section 4, the empirical results are presented. Finally, Section 5 concludes the paper.

II. Literature Review

II.1 A Brief Theoretical Basis

The Phillips curve relation is one of the principal macroeconomic theories that explain inflation based on the relationship between inflation and unemployment. Thus, the persistent component or core inflation measure in this paper derives from the notion of a vertical long-run Phillips curve, a property which has been predicted by models ranging from Lucas (1972, 1973) to Taylor (1980) (see Quah and Vahey, 1995). Under this thesis, core inflation is defined as the component of measured (CPI) inflation that has no medium- to long-run impact on real output because of the belief that the impact of movements in core inflation on the real economy is at best weak, taking account of financial and wage contracts.

In theory, there a number of identifying properties for long-run inflation, one of which is used in identifying core inflation in this paper, following Quah and Vahey (1995). The assumption is that observed changes in measured (CPI) inflation are affected by two types of shocks which are uncorrelated with each other. The first of these shocks (or identifying properties) has no impact on real output in the medium to long-run, while the second has unrestricted effects on measured inflation and real output, but does not affect core inflation. The shocks are assumed to be uncorrelated at all leads and lags. Accordingly, an estimate of core inflation which corresponds to this shock can be constructed based on dynamic restrictions in the spirit of Blanchard and Quah (1989).

II.2 Empirical Review on Inflation Persistence

Although the literature recognises both univariate and multivariate approaches to the measurement of inflation persistence, most empirical works are based on multivariate techniques. This is because univariate techniques are said to assume certain features of inflation that are not well supported by economic theory (Roger 1998; Dossche and Evaraert, 2005). Thus, the ensuing review of related empirical studies would be mostly multivariate in scope. One of the most influential empirical studies based on the multivariate approach is Quah and Vahey (1995). With the imposition of dynamic restrictions, they used a VAR system based on a long-run economic hypothesis to construct a measure of core inflation for England. The SVAR system was estimated using real industrial output growth and the one month change in the log of the retail price index over the period 1969:3 to 1994:3 along with 12 lags, a constant, time trend and seasonal dummies. The results showed that core inflationary disturbances have little impact on the real economy in the short-run. Also, there was an overstating of inflationary pressures in the late 1980s and finally, core inflation responded more quickly to recent inflationary tendencies in the economy than other measures.

In a related study for India and Pakistan, Aleem (2006) analysed the effect of aggregate demand and supply shocks on output and inflation using monthly data from 1994:6 to 2004:12. The index of industrial production (IIP) and wholesale price index (WPI) were used as activity and inflation variable for India, while the index of manufacturing production (IMP) and consumer price index (CPI) were used in the case of Pakistan. Results showed that actual inflation in India remained around the core inflation during the most of the estimation period, while core inflation was found to remain above the actual inflation in Pakistan during the period. They concluded that the estimations of core inflation in this manner can be vital for monetary policy.

In the EU, Gartner and Wehinger (1998) estimated core inflation indicators for 9 countries using the multivariate approach that was based on the SVAR model. Apart from inflation and output growth used as variables in the bivariate model, a trivariate model including short-term nominal interest rates to capture monetary disturbance was also estimated. Their analysis spanned 1971:1 to 1996:4 while values for 1997 and 1998 were forecasts from the estimated VAR models. Furthermore the analysis was based on an IS-LM/AS-AD framework for small open economies with fixed exchange rate regimes. Results point to the conclusion that inflation is essentially demand-driven, and do not support the view that inflation is purely a monetary phenomenon.

Darvas and Varga (2013) measured inflation persistence in central and eastern European countries using both the Kalman-Filter and Flexible Least Squares approaches and quarterly data on seasonally adjusted inflation from 1993Q1 to 2012Q4. The results of the study showed that inflation persistence tends to be higher in times of high inflation. Furthermore, in most central and eastern European countries covered in the study, inflation persistence had declined, with the exception of the Czech Republic, Slovenia and Slovakia, where persistence was rather stable.

Dossche and Everaert (2005) measured inflation persistence for the euro area and the United States from 1970Q1 to 2003Q4 using both univariate and multivariate approaches. While the univariate method relied on time series data on inflation only, information on real output and the central bank's key interest rate was added to the multivariate model. Their results confirm that the shifts in the central bank's inflation target induce a non-stationary component in inflation rate. Furthermore, slow adjustment of inflation expectations due to changes in central bank's inflation target and persistence of shocks were important factors determining the observed inflation persistence. The study concluded that in a stable inflation regime, inflation persistence is relatively lower, and that it would be difficult to dis-inflate in the case where monetary policy gave rise to unstable inflation because of the slow adjustment of inflation expectations in response to changes in the inflation target.
Goyal and Pujari (2005) use SVAR and Granger causality test to analyse core inflation for India based on monthly data on indices of wholesale price and industrial production. The findings show that core inflation was consistently below headline inflation throughout the sample period. Moreover, core inflation granger-causes headline inflation but the reverse was not true. Also, a unidirectional causality runs from core inflation to output.

Bjørnland (2000) provided evidence on the core inflation for Norway using the multivariate approach, which distinguished domestic core inflation from imported core inflation. The results clearly show that measured (CPI) inflation deviated significantly from core inflation several times within the sample period. Also, the comparison of CPI inflation to domestic/imported core inflation portrays a similar trend. Adverse oil price shocks, positive non-core (productivity) shocks and negative non-core shocks accounted for these deviations.

Using monthly data and the multivariate SVAR approach, Claus (1997) studied the underlying inflation in the United States from 1969Q1 to 1997Q4. The results showed that temporary factors helped to contain inflationary tendencies. The findings also suggest that the monetary authority focuses on underlying inflation as a guideline for policy. Machado and Portugal (2013) studied inflation persistence in Brazil using a multivariate model based on quarterly data which covered 1995Q1 to 2011Q1. The authors conclude that inflation expectations, shifts in inflation targets, output deviations and the natural rate of interests in inflation persistence should not be neglected in the dynamics of inflation. In addition, the expectations-based persistence was both high and almost unchanged over recent years.
The studies reviewed above are based on variants of both the univariate and multivariate approaches to the measurement of inflation persistence. In all of these studies none was carried out on Nigeria. The closest study on inflation in Nigeria to the ones above as well as the current study is the one by Omotosho and Doguwa (2013) which focused on the dynamics of inflation volatility in Nigeria using a GARCH model. Our study is markedly different in the sense that it uses multivariate (SVAR) to measure inflation persistence given that knowledge of the magnitude and duration of temporary and persistent shocks to the inflation rate is critical to achieving the price stability objective of monetary policy.

II.3 A Review of Inflation Trends in Nigeria

Nigeria did not record cases of high inflation until the early 1970's when it rose dramatically. Prior to the 1970s, headline inflation was relatively stable, averaging 3.5 per cent between 1960 and 1970. However, some factors including; post-independence industrial policy; increase in government spending to finance the civil war; low levels of production during the war; post-war reconstruction expenditures; and the 'Udoji' wage increase induced high inflation over the period (Aminu, 2006; CBN, 2007). Since 1981, incidents of high inflation have become more frequent. During the oil market collapse of the early 1980's, headline inflation increased from 16.1 per cent in 1980 to 38.8 per cent in 1983. Core and food inflation exhibited similar trend as the headline inflation, with food inflation rising substantially to 42.2 per cent in 1984. The sharp increase in headline and core inflation was as a result of severe shortages in the supply of goods and services, austerity measures of import restriction and foreign exchange constraints introduced in 1983 to stem the imminent collapse of the economy. The increase in food inflation was majorly attributed, to rigid control on the marketing of agricultural commodities CBN, 2007).

Although headline inflation decelerated significantly in the mid-1980s, it became obvious that contractionary monetary policy and the fiscal measures adopted were inadequate. Consequently, in 1986, Nigeria adopted the Structural Adjustment Programme (SAP) to liberate the economy. However, the balance of payments crisis that necessitated the SAP persisted, leading to fuel price adjustment in 1988, and a significant depreciation of the exchange rate. Subsequently, headline and core inflation increased to 61.2 and 50.0 per cent in 1988, while food inflation rose to 69.9 per cent in 1989.

Excess money supply, severe shortage in commodity supply and protracted labour and political unrest following the annulment of the June 1993 election accounted for the rise in headline inflation in the early 1990s, from 23.0 per cent in 1991 to 48.8, 61.3 and 76.8 per cent in 1992, 1993 and 1994, respectively. Thus, the government reverted to a guided de-regulation framework, changing the exchange rate regime in 1994 and introducing the autonomous foreign exchange market (AFEM) in 1995. The adverse conditions of that period led to a significant increase in food inflation to 63.6 per cent in 1994, while core inflation rose to 69 per cent in 1995. However, owing to favourable fiscal balance, effective monetary policy measures of the CBN, increase in credit to the private sector and low interest rates between 1995 and 1997, headline inflation declined rapidly to 14.3 per cent in 1996, 10.2 per cent in 1997, 11.9 per cent in 1998 and 0.2 per cent in 1999. Similarly, food inflation declined from 12.9 per cent in 1996 to 6.3, 4.3 and 5.0 per cent in 1997, 1998 and 1999, respectively. Core inflation also decreased from 15.3 per cent in 1996 to 1.4 per cent in 1999. Nevertheless, policy reversals and inconsistencies, the general elections of 1999, increase in wages, and banking sector distress contributed to a significant rise in headline inflation, to 14.5, 16.5 and 23.8 per cent in 2000, 2001 and 2003, respectively. Food inflation exhibited similar trend as the headline inflation, rising to 28.9 per cent in 2001 (CBN, 2007).

The macroeconomic reform programmes of the government after the 2003 elections, coupled with efforts by the CBN, to achieve financial stability in the banking sector impacted positively on the economy, contributing to a decline in headline inflation, from 10.0 per cent in 2004 to 6.6 per cent in 2007. Similarly, food and core inflation declined from 12.1 and 5.9 per cent in 2004 to 8.2 and 3.6 per cent in 2007, respectively according to data from the National Bureau of Statistics. However, persistent structural rigidities, the general elections of 2007 and the continued effect of fuel price hike caused headline inflation to increase to 15.1 per cent in 2008, before declining to 12.1, 11.8 and 10.3 per cent in 2009, 2010 and 2011, respectively. Due to the prevailing conditions, food inflation increased to 18.0 per cent in 2008, before declining to 11.0 per cent in 2011, while core inflation fluctuated between 10.4 and 10.8 per cent over the same period. Although headline inflation increased to 12.2 per cent in 2012, the efficacy of monetary and fiscal policies, coupled with relative stability in exchange rate led to its decline to 8.0, 8.0 and 9.6 per cent in 2013, 2014 and 2015, respectively. Food inflation moderated to 9.3, 9.2 and 10.6 per cent in 2013, 2014 and 2015, respectively due largely to increased agricultural production, while core inflation declined to 7.9 and 6.2 per cent in 2013 and 2014, before increasing to 8.7 per cent in 2015 (NBS, 2015).

In 2016, headline inflation increased beyond the targeted single-digit, rising from 9.6 per cent in January, to 18.3 per cent in October, owing majorly to increase in the prices of goods and services resulting from exchange rate challenges and a subsequent decline in the value of the naira. Similarly, food inflation increased from 10.6 to 17.1 per cent, and core inflation from 8.8 to 18.1 per cent over the same period (NBS, 2016a; NBS 2016b; CBN, 2016). Overall, the level of money supply plays a major role in inflationary trends in Nigeria. Additionally, increase in real output, principally food production has a dampening effect on inflation, while high inflation could also be associated with the long-run depreciation of the exchange rate.

III. Methodology

The focus of this section is on the description of the data, as well as, the specification and identification of the structural VAR model.

III.1 Data Sources and Description

To implement our model we use quarterly time series of the CPI inflation and real GDP as the measured inflation and activity variables, respectively. Nigeria's inflation is measured by the total consumer price index, as it provides a good reflection of the cost of living. Similarly, the real GDP is the most reliable and readily available measure of economic activity in Nigeria. Other measures such as manufacturing capacity utilisation or index of industrial production are a lot less reliable and cannot serve as a broad measure of economic activity since these sectors contribute less than 10 per cent to overall output. The consumer price index (CPI) and real GDP data were sourced from the Central Bank of Nigeria (CBN) Statistical Database. The data set runs from 1981Q1 to 2016Q4.

III.2 The Structural VAR Framework and Identification Scheme

The structural vector autoregression (SVAR) approach was adopted to measure the persistent component of inflation (core inflation) in line with the work of Quah and Vahey (1995). In this method, core (or persistent component) of measured inflation is assumed to have no medium to long-run impact on real output in line with the long-run vertical supply schedule, which supposes that in the long-run output is affected only by supply shocks while inflation is affected only by demand shocks.

In the extant literature, several techniques have been employed to carry out such estimations, including univariate time series and structural time series modeling methods. However, these methods involve assumptions about core inflation that has little economic interpretation (Quah and Vahey 1995). Consequently, we assume that there are only two structural shocks on the economy: supply (non-core) shocks, which have permanent effects on output and (CPI) inflation and demand (core) shocks which have no long-run effects on output but permanent effects on (CPI) inflation. Specifically, the two variables were used in their stationary form, namely, Δy (first differences of the log of real GDP) and π (year-on-year CPI inflation):

Given that the matrix $x_t = [\Delta y_t, \pi_t]'$ is a stationary process, the bivariate moving average representation may be written as:

$$\Delta y_t = B_{11}(L)\varepsilon_{1t} + B_{12}(L)\varepsilon_{2t} \quad (1)$$
$$\pi_t = B_{21}(L)\varepsilon_{1t} + B_{22}(L)\varepsilon_{2t} \quad (2)$$

or, in a more compact form,

$$x_t = B(L)\varepsilon_t \quad (3)$$

where$B(L)$ are polynomials in the lag operator and ε_t stands for pure structural shocks (core and noncore shocks), which are serially uncorrelated with constant variance. The variance/covariance matrix is given as:

$$\sum_{\varepsilon} = \begin{bmatrix} var(\varepsilon_{1t}) & cov(\varepsilon_{1t}, \varepsilon_{2t}) \\ cov(\varepsilon_{1t}, \varepsilon_{2t}) & var(\varepsilon_{2t}) \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad (4)$$

Since the core and noncore shocks are unobservable, the need arises to recover these shocks from a reduced form VAR that is predicated on real GDP and inflation data. The VAR in standard form is represented as:

$$A(L)x_t = e_t \quad (5)$$

Where: $e_t = [e_{1t}, e_{2t}]'$ are the VAR residuals and (L) is the invertible matrix lag operator. The residuals are not pair-wise orthogonal since they are correlated, with their expected value not equal to zero. The variance/covariance matrix of residuals is given by;

$$\Omega_e = \begin{bmatrix} var(e_{1t}) & cov(e_{1t}, e_{2t}) \\ cov(e_{1t}, e_{2t}) & var(e_{2t}) \end{bmatrix} \quad (6)$$

The Wold Representation Theorem connote that, given the assumption of weak regularity conditions, a stationary process can be represented as an invertible distributed lag of serially uncorrelated disturbances (Quah and Vahey 1995). Therefore, the bivariate Wold moving average representation can be written as:

$$x_t = C(L)e_t \quad (7)$$

Where $C(L)$= $(L)^{-1}$; the Wold innovations, e_t are contemporaneously correlated. However, these innovations can be orthogonalised by imposing restrictions in such a way that the covariance term is zero $(Ee_{1t}, e_{2t} = 0)$. The application of the restrictions eventually produces the bivariate moving average representation containing the pure structural shocks depicted in (3).

Thus, from (3) and (7), the Wold innovations are composites of the structural shocks:

$$e_t = B^{-1}\varepsilon_t \quad (8)$$

Therefore,

$$Ee_t e_t' = EB^{-1}\varepsilon_t \varepsilon_t' (B^{-1})^{-1} \quad (9)$$

Alternatively, (9) can be written as (Enders 2003);

$$\Omega = B^{-1} \textstyle\sum_{\varepsilon} B^{-1} \quad (10)$$

Consequently, to recover the structural shocks from the Wold innovations, four restrictions are imposed. However, given the symmetry of the system represented by (10), there are three independent equations [involving var(e_{1t}), var(e_{2t}) and e_{1t}, e_{2t}] to determine four unknown values $(b_{11}, b_{12}, b_{21}, b_{22})$. These equations constitute three restrictions. The fourth restriction required is that the core shock has no long-run effect on real GDP (Quah and

Vahey 1995). Given the four restrictions, the sequences $\{\varepsilon_{1t}\}$ and $\{\varepsilon_{2t}\}$ can be recovered in order to estimate the persistent component of inflation. The structural shocks are ordered in the following way (Ouliaris 2016 and Martel 2008):

$$\begin{bmatrix}\Delta y_t \\ \pi_t\end{bmatrix} = \begin{bmatrix}v_1 \\ v_2\end{bmatrix} + \sum_{j=0}^{\infty} \begin{bmatrix}b_{11,j} & b_{12,j} \\ b_{21,j} & b_{22,j}\end{bmatrix} \begin{bmatrix}\varepsilon_{1,t-j} \\ \varepsilon_{2,t-j}\end{bmatrix} \quad (11)$$

The long-run response matrix is $B = \sum_{j=0}^{\infty} B$. Given the formula: $(n_2 - n)/2$, only one additional restriction is required to be imposed on the long-run matrix. The restriction implies that, $\sum_{j=0}^{\infty} b_{11,j} = 0$. The decomposition of inflation is given as (omitting the intercept term for now):

$$\pi_t = \sum_{j=0}^{\infty} b_{21,j} + \sum_{j=0}^{\infty} b_{22,j} \quad (12)$$

The persistent component of inflation (or the component of measured inflation that is output-neutral in the medium to long-run or underlying inflation or core inflation) is calculated from the effects of the core shocks on inflation:

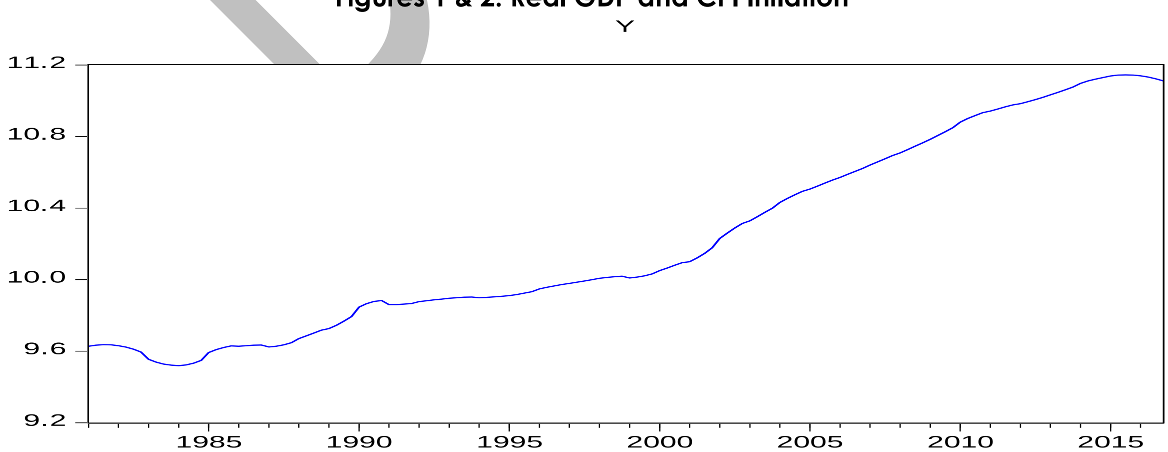
$$\pi_t^{pc} = \sum_{j=0}^{\infty} b_{21,j}\varepsilon_{1t-j}$$

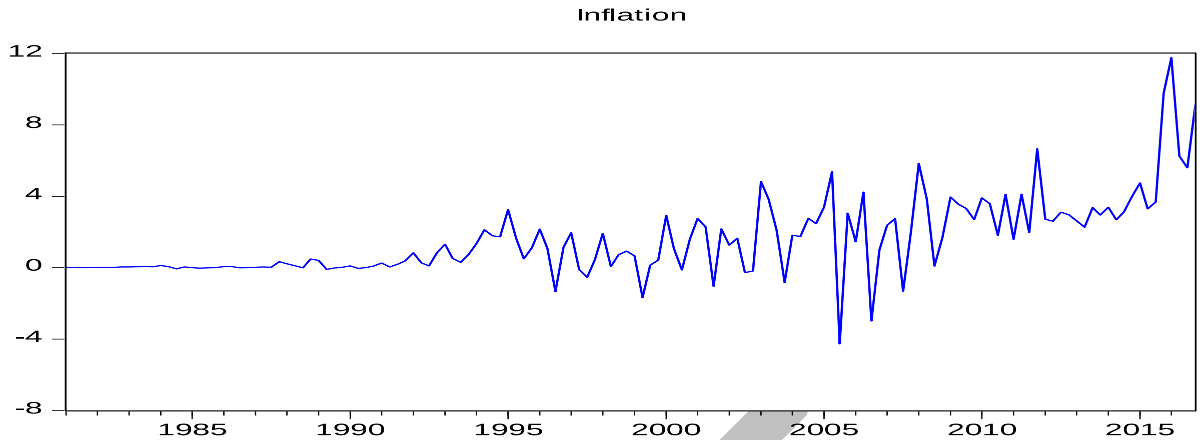
IV. Empirical Analysis

IV.1 Time Series Properties of Data

The evidence indicates that the model specification in the previous section is in harmony with the time series properties. Preliminary graphical analysis indicates that real GDP is trending and thus, likely to be non-stationary. Real GDP is expressed in logarithmic form. Similarly, the trend of measured (or CPI) inflation, π, portrays the likelihood of mean reversion and thus, may be stationary (Figure 2).

Figures 1 & 2: Real GDP and CPI Inflation





The Phillips-Perron based unit root test in Table 1 shows that the hypothesis of a unit root cannot be rejected in the case of output, Y. Thus, Y is integrated to the first order, I(1). However, the hypothesis of a unit root is rejected for the inflation variable at the 1 per cent level.

Table 1: Phillips-Perron Unit Root Test

Variables	PP Statistic	Remark
Y	-2.51	I(1)
π	-2.91***	I(O)
Δy	-4.24***	I(O)

***Rejection of unit root hypothesis at 1 percent level

The lag length criteria are found in Appendix 1. Accordingly, a stable VAR resulted from three lags (see Appendix 2).

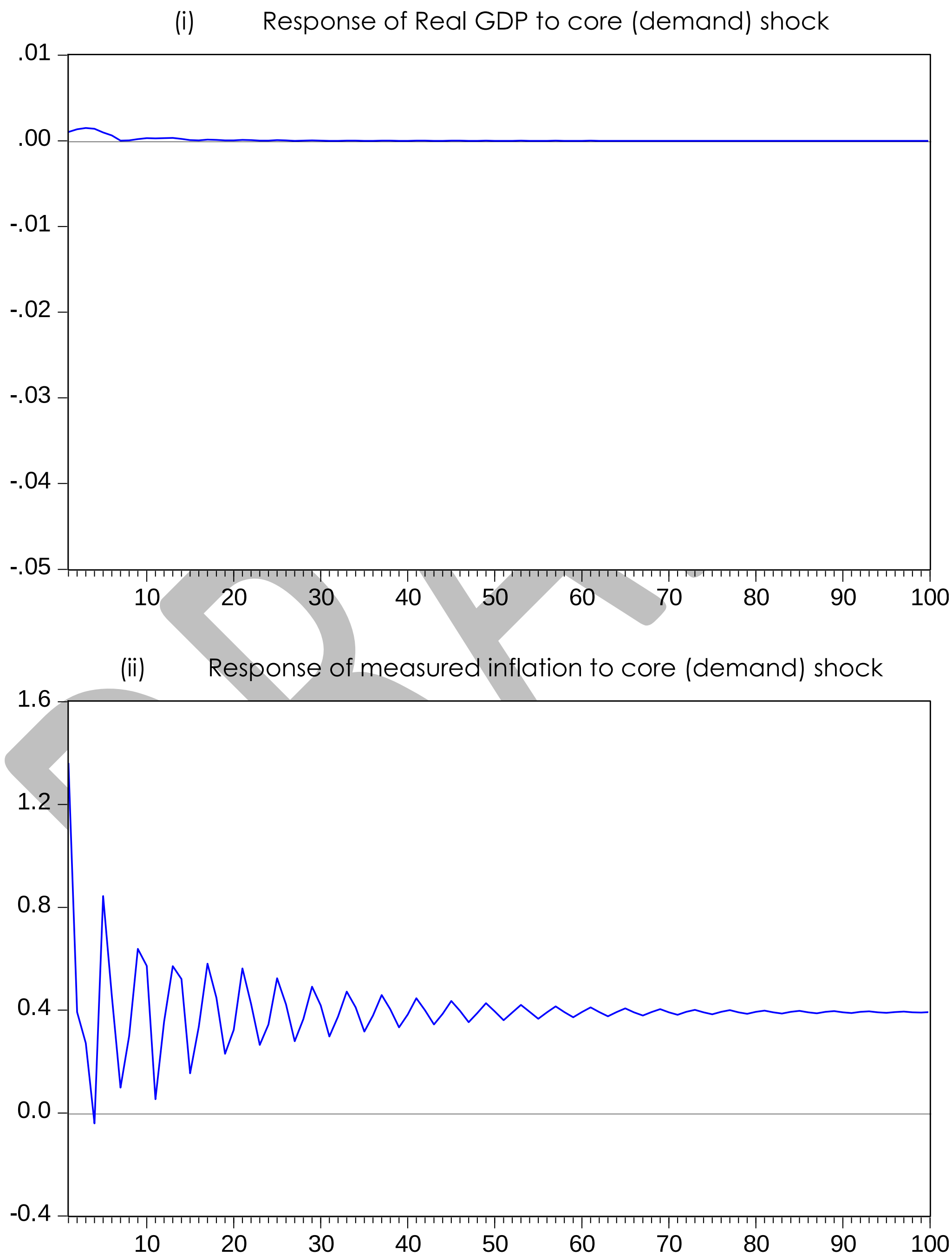
IV.2 Results and Discussion

IV.2.1 Dynamic Impulse Responses

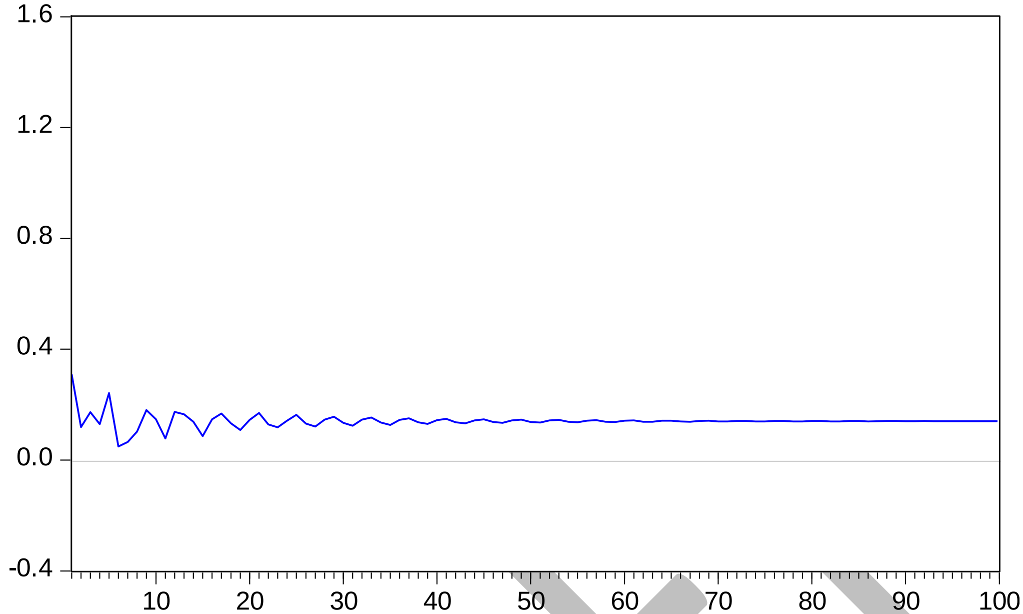
The four categories of impulse responses are presented in Figure 3. The *a priori* economic hypothesis is that the core shock has no long-run effect on real output. The response of real GDP to a positive core shock in panel (i), results in an immediate increase in output within the first few quarters, which quickly fades to zero in line with the neutrality of real output to the effect of a core shock in the long-run. Panel (ii) shows that the effect of a one standard deviation shock (core) caused inflation to rise as theoretically expected, but the shock did not die out over time. A one standard deviation supply shock (non-core) caused a gentle increase in measured inflation in panel (iii). When this increase is compared to the effect of core (demand) shock on inflation, it becomes obvious that the former is benign in comparison to the latter. This may not be unexpected as Bjørnland (2000) observed that if the measure of core inflation was to be a useful indicator of inflation pressure in an economy, then core shocks should not contribute significantly to inflation movements.

A one standard deviation non-core shock produced a permanent effect on real GDP as theoretically anticipated (panel iv). However, the observed decline in real output, rather than an increase, may be attributed to the conspicuous absence of widespread beneficial productivity shocks in both technical and socio-economic spheres.

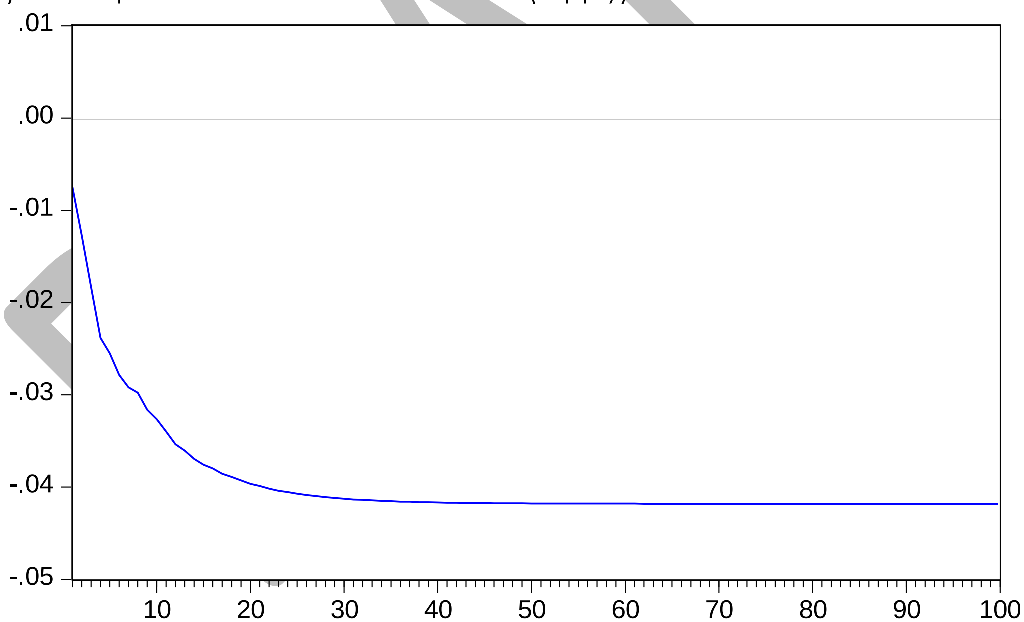
Figure 3: Bivariate SVAR: Accumulated Impulse Responses



(iii) Response of measured inflation to non-core (supply) shock



(iv) Response of Real GDP to non-core (supply) shock



IV.2.2 Variance Decomposition

The two permanent shocks produced the expected effects on measured inflation and output as shown in the variance decomposition in Tables 2 and 3. Core shocks explained between 93 and 94 per cent of the variance of inflation throughout the forecast horizon in Table 2. The proportion of variation in measured inflation accounted by non-core shock is small, reaching a maximum of 6.75 per cent and thereafter, declined to 5.62 per cent in the long-run. Consequently, demand shocks constitute the main cause of variations in measured inflation in Nigeria.

Table 2: Variance Decomposition of Inflation

Quarter	Core Shocks	Non-core
1	94.37	5.63
2	93.43	6.57
3	93.25	6.75
4	93.50	6.50
5	93.58	6.42
25	94.38	5.62
50	94.38	5.62
75	94.38	5.62
100	94.38	5.62

Source: Estimation results

The variance decomposition of real GDP is presented in Table 3. Core shocks explained a minor portion of the variance in real GDP, which validates our identification scheme. Thus, the proportion of the variance in real output explained by core shocks declined from 3.90 per cent through the medium term to 2.66 in the long-run.

Table 3: Variance Decomposition of Real GDP

Quarter	Core Shock	Non-core Shock
1	3.90	96.10
2	3.43	96.57
3	3.14	96.86
4	2.89	97.11
5	2.70	97.30
25	2.61	97.36
50	2.66	97.34
75	2.66	97.34
100	2.66	97.34

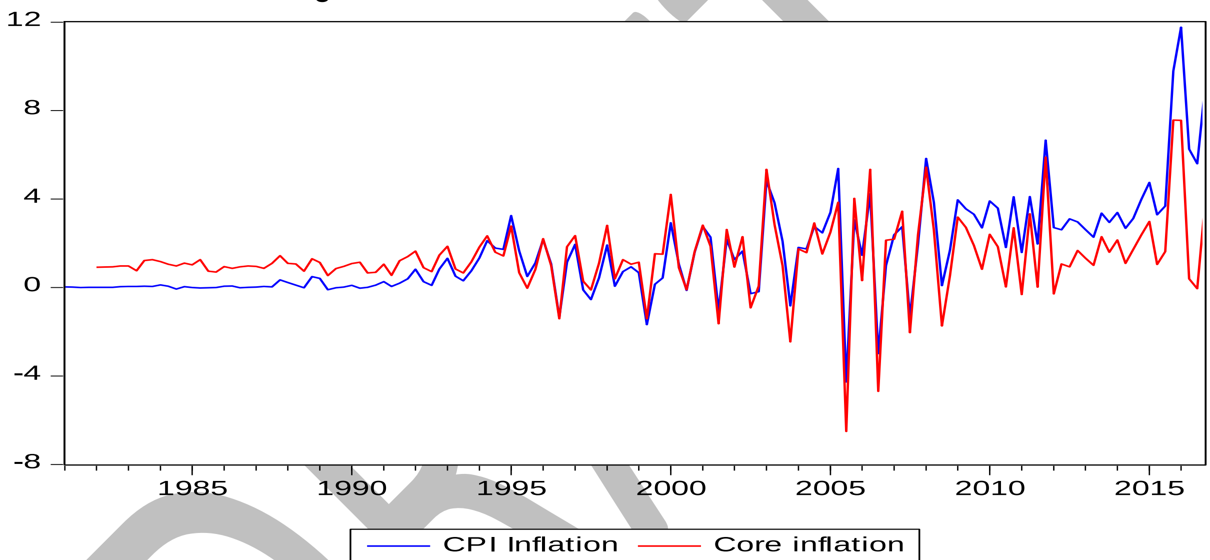
Source: Estimation results

IV.2.3 Measuring Core Inflation

The computation of the persistent component of measured inflation follows from the exposition on the SVAR framework and identification scheme. CPI inflation and core inflation are plotted in Figure 4. Following from the variance decomposition, core shocks are the main drivers of measured inflation. As evident on Figure 4, core inflation versus CPI inflation can be divided into three distinct episodes. The first episode starts from the early 1980s up to 1994Q2 during which period, measured inflation under-predicted core inflation. In other words, the underlying inflationary process was stronger than what CPI inflation portrayed. This may be attributed to the impact of positive non-core shocks that brought down measured inflation below the core inflation.

The second episode spans from 1994Q3 to 2009Q2. Within this period, the CPI inflation dynamics tracks or predicts core inflation remarkably well as there is a good match between the peaks and troughs of both curves. The third episode ranged from 2009Q3 to 2016Q4, during which period, the underlying inflationary process was subdued relative to measured inflation. This was due to the effect of negative non-core shocks on output leading to the over-prediction of the persistent component of inflation. In general, data on GDP growth rate for Nigeria (from The Economist Intelligence Unit) shows a precipitous deceleration, beginning from 2010 to 2016, and the reflection of this trend finds expression in measured (CPI) inflation over-predicting core inflation. The adverse effect of supply shocks on the Nigerian economy is best observed in the long spikes with respect to CPI inflation between 2015Q4 and 2016Q4, during which period, the economic recession began.

Figure 4: Measured Inflation and Core Inflation



The descriptive statistics in Table 4 provides further insight to the behaviour of core inflation and measured inflation. Broadly, the various measures of central tendency further corroborate the outcome of Figure 4. The correlation coefficient of core inflation and measured inflation is 0.79 and is significant at the 1 per cent level. Thus, on the average, there is significant co-movement between both measures of inflation.

Table 4: Descriptive Statistics of Measured Inflation/Core Inflation

Statistics	Measured Inflation	Core Inflation
Mean	1.59	1.37
Median	1.07	1.10
Standard Deviation	2.20	1.73
Skewness	1.43	-0.08
Kurtosis	7.17	8.30

Source: Estimation results

V. Summary and Conclusion

This study applied the methodology of Quah and Vahey (1995) to measure the persistence component of inflation in Nigeria. Central banks across the world are entrusted with the key mandate of ensuring price stability, with some of them explicitly targeting inflation. Given this scenario, it becomes important, for apex monetary authorities to clearly distinguish between measured (CPI) inflation and the underlying inflation. Measured inflation does not provide a good guide for monetary policy, because, it often includes 'noise' that could be attributed to short term non-core shocks that temporarily cause inflation to fluctuate around the persistent core component.

Given that the mandate of a central bank is primarily not the control of non-core disturbances the need therefore arises to construct an objective measure of the underlying inflationary process in Nigeria - predicated on economic theory – that could serve as a guide in the implementation of monetary policy.

Thus, this study relied on the multivariate SVAR econometric approach to measuring core inflation to achieve the objective. The results show that core (demand) shocks constitute the main source of variations in core inflation, while non-core (supply) shocks are the principal cause of variations in real output. More importantly, the findings indicate that core inflation is the primary cause of movements in measured (CPI) inflation. Furthermore, three distinct episodes of movements in the two measures of inflation were identified in the results: in the first episode, CPI inflation under-predicted core inflation from the 1980s to early 1990s; the second episode witnessed near perfect match between core inflation and measured (CPI) inflation; and the last episode, from 2009Q2 to 2016Q4, saw CPI inflation over-predicting core inflation.

A key policy implication of this paper is the need for the central bank to exercise caution in basing monetary policy decisions on CPI inflation instead of the underlying inflationary process. For example, it may not be an appropriate policy for the Bank to tighten its stance in a situation where CPI inflation over-predicts core inflation. Thus, it is our expectation that this study will serve as useful guide to the apex monetary authority in the conduct of monetary policy.

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Appendix 1
Lag Length Criteria

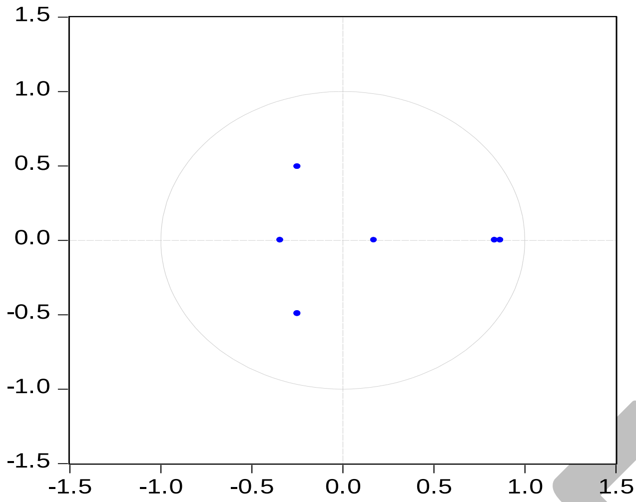
Lag	LogL	LR	FPE	AIC	SC	HQ
0	116.2184	NA	0.000615	-1.717570	-1.6741	-1.699908
1	187.5613	139.4673	0.000224	-2.730245	-2.599853	-2.677259
2	192.6554	9.805120	0.000220	-2.746697	-2.529378	-2.658387
3	197.3776	8.947434	0.000218	-2.757558	-2.453311	-2.633924
4	233.0368	66.49234	0.000135	-3.233636	-2.842461*	-3.074678
5	242.7657	17.84854	0.000124	-3.319785	-2.841683	-3.125503*
6	244.1059	2.418373	0.000129	-3.279788	-2.714757	-3.050181
7	251.8860	13.80522*	0.000122*	-3.336631*	-2.684673	-3.071700
8	254.2400	4.106191	0.000125	-3.311879	-2.572993	-3.011624
9	256.9862	4.707931	0.000128	-3.293026	-2.467212	-2.957447

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Appendix 2
VAR Stability

Inverse Roots of AR Characteristic Polynomial



Roots of Characteristic Polynomial
Endogenous variables: Δy π
Exogenous variables: C
Lag specification: 1 3

Root		**Modulus**
0.867222		0.867222
0.836702		0.836702
-0.247635	- 0.493809i	0.552422
-0.247635	+ 0.493809i	0.552422
-0.341544		0.341544
0.173330		0.173330

No root lies outside the unit circle.
VAR satisfies the stability condition

An Empirical Analysis of the Determinants of Foreign Exchange Market Pressure in Nigeria

Mamman, S. O., Aliyu, S. R. and Odu, A. T. *

Abstract

This paper sets out to evaluate the various domestic and foreign factors that determine the foreign exchange market pressure in Nigeria. To achieve this, we used monthly data for the period 1995 – 2016 to compute an index for the foreign exchange market pressure within the Aizenman & Binici's (2016) framework. We then used the Generalised Method of Moments (GMM) to estimate a single-recursive equation model of the determinants of foreign exchange market pressure, with the commonly expected theoretical factors. These factors include: crude oil prices; domestic credit; imports; portfolio inflow; and all-share index. The data was obtained from the Central Bank of Nigeria and Chicago Board of Exchange. The use of GMM allows for the endogeneity inherent on the specified model. The results indicated that domestic factor, including domestic credit, inflation, and imports, and foreign factors, including crude oil prices and global capital market volatility, were significant determinants of Nigeria's foreign exchange market pressure during the review period. In addition, we could not find evidence of significant influence of portfolio capital flows on the foreign exchange market pressure during the review period. This, we argue, may reflect the effectiveness of central bank's reserve accretion policies in shielding the foreign exchange market from the vagaries of the portfolio flows.

Keywords: Foreign Exchange Market Pressure, Endogeneity, GMM
JEL Classification: C26, F31

I. Introduction

Excessive Foreign Exchange Market Pressure (EMP) is an important source of difficulties in domestic macroeconomic management in many developing countries, including Nigeria. This is, especially true in the context of commodity-exporting small open economy setting, where imports constitute a large proportion of GDP. In such settings, the difficulty of macroeconomic management arises chiefly from two perspectives. On the one hand, the dependence of such economies on commodity exports places a constant need to maintain significant level of foreign reserves to stabilise their currencies over the commodity market cycles. Maintenance of currency stability in such economies is not only important, but also necessary for domestic price stability because of the large proportion of imports in their GDP with significant exchange rate pass-through. On the other hand, because of their dependence on commodity exports for foreign exchange, maintaining significant level of foreign reserves during declining global commodity market becomes more challenging given the need to finance the large imports bill, which continues to exert pressure on the foreign exchange market, necessitating foreign interventions.

The foreign exchange pressure often manifests in the simultaneous movement in the exchange rate[1] and foreign reserves, as authorities intervene in the foreign exchange market

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to reduce volatility and maintain exchange rate stability. The interventions to ensure exchange rate stability are crucial because fluctuations in the foreign exchange market could offset all other markets' performance (such as the money market and capital market) where it serves as a key determinant.

In the context of fixed regimes and managed floats, some variants of which most developing operate, the foreign reserves are used not only as a buffer to support the exchange rate, but are also increasingly regarded as indicator of the health of the economy. Therefore, by causing reserves declines, excessive foreign exchange market pressure can, in itself and independent of its initial cause, trigger further foreign exchange outflow leading to currency crisis. For instance, if the private sector interprets an episode of rising foreign exchange market pressure (manifesting in form of exchange rates and reserves movements) as a sign of future currency crisis, capital outflow may be initiated. This could further have adverse effect on foreign reserves (continuous depletion) possibly leading to currency crisis through speculative attacks, as was experienced during the chain of currency crisis of Mexico in 1994, Asian in 1997 and Argentina in 2001. Nigeria has also witnessed a number of currency crisis, most of which were heralded by enduring and significant rise of the foreign exchange market pressure. For instance, the recent currency crisis experienced during 2015 to 2017 were partly attributable to the rising foreign exchange market pressure associated with speculative demand for forex, as well as, the fixity of the exchange rate admist lower reserves acretion.

For maintaining price and currency stability, therefore, policymakers must find an effective means of dealing with foreing exchnage market pressure. In the context of small open commodity exporting economy, this entails good undersanding of the causes of foreing exchnage market pressure. While there are a number of theoretically important factors determining the foreign exchange market pressure, identification of those that are empirically important to each economy and over time is crucial for policymakers as they strive to maintain monetary and exchange rate stability.

Despite the potential importance of identifying the factors determinig foreign exchange market pressure in monetary policy making, the literature is surprisingly scanty. In deed, for Nigeria, in particular there are two notable previous atttempts, CBN (2016) and Jimoh, Juzhar, and Mohd-Dan (2014). These works both focussed on estimating the foreign exchange market pressure indices and, hence, identifying the historical episodes of the foreign exchange market pressure for Nigeria. While CBN (2016) discussed the various theoretical factors that can cause the foreign exchange market pressure to rise, it does not examine their empirical importance in Nigeria. This work, therefore, contributes to the literature in a number of ways. First, it computes the foreign exchange market pressure for Nigeria, using a number of alternative approaches and, hence, identifies the historical episodes from 1995 to 2016 thereby updating the existing studies by covering the recent period of foreign exchange crisis in the country, 2015-2017. Secondly, it deepens the empirical literature by identifying the empirical roles of several theoretically important factors

[1] Theoretically, whether the exchange rate changes along with reserves or not during EMP depend on the type of exchange rate regime in operation. Where a rigidly fixed regime operates, the official exchange rate remains unchanged while the black market rate changes. In the case of flexible or dirty float, both official and parallel rates may change, albeit disproportionately depending on the level of flexibility of the official rate.

in the evolution of foreign exchange market pressure in Nigeria. Thirdly, it examines the relative role of external and domestic factors in determining the foreign exchange market pressure in Nigeria.

The rest of the paper is organised as follows: the next Section reviews the related literature. Section 3 describes the methodological approach, while Section 4 discusses the results. Section 5 concludes the paper.

II. Literature Review

Foreign Exchange Market Pressure, conventionally known as Exchange Market Pressure (EMP), is a phenomenon that describes an abnormal condition where there is an excess demand for a currency relative to its supply, which consequently leads to depreciation in exchange rate as well as movement in international reserves (Weymark, 1995). It could also go the other way - that is having an excess supply to its demand that could lead to currency appreciation, as well as movement (Inflow) in the foreign reserves. Put differently, it could be seen as excess money driven by abnormally large excess domestic currency demand or supply, which forces the monetary authorities to take measures to stem disruptive appreciation or depreciation of the currency (Kumah, 2011).

Girton and Roper (1977) first propounded this concept in their seminal work "*Monetary Model of Exchange Market Pressure Applied to the Postwar Canadian Experience*". When there was a high degree of misalignment between the actual real exchange rate and the level of exchange rate with the absence of central bank intervention. They defined exchange market pressure as a measure of the volume of intervention necessary to achieve any desired exchange rate target. They imply the degree of money market disequilibrium that must be removed through either exchange rate or foreign reserve, but not the two simultaneously. This concept was later formalised by Weymark (1995) and defined as "*The measures of the total excess demand for a currency in international markets as the exchange rate change that would have been required to remove this excess demand in the absence of exchange market intervention, given the expectations generated by the exchange rate policy actually implemented*".

Eichengreen, Rose, and Wyplosz (1996) added to the definitional concept of interest rate differentials[2] as a monetary policy intervention tool together with changes in exchange rate and movement in foreign reserves and in addition could be used to ward-off speculative attacks. Although this last component was suggested as useful by some researchers, some argued against it that it could not be incorporated as some speculators could actually predict the changes and adjust their balances to neutralise the effect.

II.1 Measurement of Exchange Market Pressure

The measurement of exchange market pressure is very crucial as the index could reflect the reaction function of the monetary authority to particular misbalances. While Girton and

[2] The difference between domestic interest rate and foreign interest rate

Roper (1977) proposes the use of two components (Exchange rate and Reserve movement), Weymark (1995) proposed the use of elasticity index of the two components of Girton and Roper (1977) rather than equal weights. But Eichengreen et al. (1996) identified the relevance of interest rate as a policy tool that could be used to wade off speculative attacks and also indicated that using equal weights could lead to bias result as a more volatile variable could dominate other variables. Hence, variables with higher variance should be given lower weights. This method is known as precision weights (Li, Ramkishen, & Willett, 2006). Li, *et al.* (2006), however, modified Weymark's (1995) methods of elasticity, indicating that this method should be the second best approach as sometimes the precision weight method could produce biased result because it could only capture speculative attacks that are successful, but not the unsuccessful ones. There have been several modifications on works on exchange market pressure. However, Li, *et al.* (2006) method may have come up with some suggestions, but this method had some key algebraic assumptions that needed to be satisfied before it could actually fit well. Where these conditions fail, the method could be flaw and hence, it would be safer to use the Eichengreen, *et al.* (1996) methods with fewer assumptions as was modified by Klaassen and Jager (2008).

A dominant view in previous empirical studies on foreign exchange market pressure appears to be the use of exchange rate determination models for evaluating exchange market pressure. The methods, in terms of measurement of the EMP index, as well as, the outcomes, in terms of direction and signs, remain inconclusive issue. Studies like (Tanner, 1999; 2002), Kumah (2011) and Braga de Macedo, Pereira, & Reis (2008) suggested that monetary intervention in the form of either increase in interest rate or shrinking money supply could be used to abating exchange market pressure. The study further indicated that interest rate differential is a significant component of the exchange market pressure index as initially indicated by Eichengreen *et al.* (1996). However, studies like Stavarek & Marek (2009), Stavárek, (2010) found no significant effect of interest rate differentials on exchange market pressure index. However, in the Nigerian case, only works such as CBN (2016) and Jimoh, Juzhar, and Mohd-Dan (2014) were identified; with only Jimoh, Juzhar, and Mohd-Dan (2014) identified to have empirically verified the theoretical proposition. But the work was limited to domestic factors as determinants of exchange market pressure and, like others in the literature, did not also consider some external factors like prices of major export commodities like crude oil prices, which are important in commodity exporting, open developing country like Nigeria. This among other factors is what this study attempts to address.

III. Methodology

III.1 Theoretical Framework

The monetary approach to exchange rate and balance of payment determination provides the suitable theoretical framework for the analysis of foreign exchange market pressure. Indeed, the model of exchange market pressure was derived from this theory. It demonstrates the effect of monetary adjustments to foreign exchange market model as was used by previous studies on exchange market pressure. This was able to capture the simultaneous movement in both exchange rate and international reserves.

The basic tenet is that exchange rate between two currencies (say naira and dollar) is determined by relative money demand and money supply between these currencies resulting from changes in the balance of payment (surplus and deficits in the current and capital account) (Krugman, Obstfeld, & Melitz, 2005). The relative strength of the demand for the two currencies, within an open economy context, reflects the underlying relative demand for merchandise, physical and financial assets denominated in the currencies. According to this theory, therefore, a number of domestic and external factors could have significant influence in the foreign exchange market by adversely affecting the relative demand for currencies, thereby raising the exchange market pressure. These include: declining productivity in the home country; rising imports; rising demand for foreign currency-denominated assets or declining demand for home currency-denominated assets due to future expectations; rising inflation; and declining export commodity prices. Based on this theory, external supply shock in the global market for export commodity, say, decline in the international oil price, could alter the exchange market pressure in a number of ways. First, it could directly lead to current account deficit as the import outweighs the export. This raises EMP as the financing gap increase, leading to declining reserves or depreciating currency or a combination of both, depending on the exchange rate regime. Secondly, by significantly reducing foreign reserves, declining oil price may introduce negative sentiments in the foreign exchange market, thereby raising speculative behaviour in the market. This could significantly raise the EMP. In addition, where capital account deficit occurs, a weakening commodity export sector can reduce the inflow of capital and leave the foreign exchange market vulnerable to foreign exchange pressure (Akram & Byrne, 2015).

A key implication of this theoretical model is that, instruments that are useful in monetary management can also be effective in the management of exchange market pressure. For instance, interest rate deferential, domestic credit growth, foreign exchange interventions, relative inflation, etc. are potential determinants of exchange market pressure. In addition, all sources of external shocks that have effects on the monetary sector are also potential sources of foreign exchange pressure.

III.2 Empirical Framework

Various indices for measuring foreign exchange market pressure as suggested by Aizenman and Binici (2016) were used. This is because they combined both the traditional and improved methods. These indices include:

$$emp_t = \frac{e_t - e_{t-1}}{e_{t-1}} - \frac{ir_t - ir_{t-1}}{ir_{t-1}} \quad (1)$$

Where emp_t is exchange market pressure; e_t is the exchange rate (local currency per U.S. dollar) and ir_t is the foreign exchange reserve (minus gold). The measure here gives a relative change in exchange rate and foreign exchange reserves. This measure was further modified with the addition of interest-rate differentials aimed at shoring up the exchange rate pressure as a complement to foreign exchange intervention as indicated by Aizenman and Binici (2016) thus, the modification is given as;

$$emp_t = \frac{e_t - e_{t-1}}{e_{t-1}} - (i_t - i_t^*) - \frac{ir_t - ir_{t-1}}{ir_{t-1}} \quad (2)$$

Where $i_t$and $i_t^*$are the money market rate for home and base country (the U.S.). Another measure given again is the difference between exchange rate depreciation/appreciation and foreign exchange reserves deflated by base money and considered as the monetary model-based EMP, constructed as follows:

$$emp_{base1,t} = \frac{e_t - e_{t-1}}{e_{t-1}} - (i_t - i_t^*) - \frac{ir_t - ir_{t-1}}{mb_{t-1}} \quad (3)$$

Where $mb_{t-1}$is the monetary base expressed in U.S dollar. The last one was constructed by taking standardised difference between the exchange rate and foreign reserve changes and shown as:

$$emp_{std,t} = \frac{\Delta e_t - \mu e}{\sigma e} - \frac{\Delta i_t - \mu i}{\sigma i} - \frac{\Delta ir_t - \mu ir}{\sigma ir} \quad (4)$$

Where $\Delta e_t$and $\Delta ir_t$are the percentage change in the exchange rate and international reserves, $\Delta i_t$is interest rate differential, and μ and σ are the mean and standard deviation of respective variables. This study computes all the aforementioned alternative indices for comparative purposes and to determine the most efficient measure of exchange market pressure. Having derived the Exchange Market Pressure index, the study then proceeds to the estimation of the determinants of the EMP market pressure. Following the model of Aizenman and Binici (2016) for a cross-country analysis, as given below, is adapted for time series analysis:

$$emp_{it} = \beta_0 + \beta_1 emp_{t-1} + \beta_2 X_t + \beta_3 Y_t + \beta_4 Z_t + \varepsilon_{it} \quad (5)$$

emp_{it} = Is the exchange market pressure for country *i* at time *t*
emp_{it-1} = The lagged value of exchange market pressure
X_t = a vector of domestic factors such as change in real GDP per capita, inflation, change in domestic credit/GDP, trade balance/GDP, short-term external debt/GDP, and stock market returns;
Y_t = Includes capital flows (net or gross) as share of GDP, capital controls, and commodity terms of trade.
Z_t = Includes external factors such as global liquidity indicators, including the Treasury EuroDollar rate (TED) spread, the Volatility Index (VIX), the change in effective federal funds rate, the slope of the U.S. yield curve (the difference between 10-year long term and 3-month short-term yields).

The determinants of exchange market pressure in Nigeria was evaluated, using this methodological framework of Aizenman and Binici (2016).The choice of these determinants were based on their performance in previous studies and their availability in Nigeria. Hence, our empirical model is then stated as:

$$emp_t = \alpha_0 + \alpha_1 emp_{t-1} + \alpha_2 DCR_t + \alpha_3 INF_t + \alpha_4 Crude_t + \alpha_5 imp_t + \alpha_6 ASI_t + \alpha_7 pfi_t + \alpha_8 vix_t \quad (6)$$

Two variants of model/equation 3.6 were estimated. These are general unrestricted and parsimonious variants. In addition, each of the general unrestricted and parsimonious variants in turn has two models, denoted as model 1 and model 2, respectively. Model 1 is a longer sampled starting from 1995, while model 2 is a shorter sampled model, which started from 2007. The reason for this variation in the sample size was the unavailability of a key variable (portfolio flows) from the starting period. Monthly data set from 1995 to 2016 were used in the estimation. This was to enable the study cover as many periods of exchange rate reforms in Nigeria. In addition, the *Emp*$_{base1}$ index was chosen for estimation as it performed better than other indices in terms of mimicking the behaviour of the trend of foreign exchange market pressure in Nigeria. Table 1 contains the definition and measurement of the variables, as well as, the sources of data.

Table 1: Data and Sources

Variable definition	*Variables Definition*	*Data source*
DCR_t	Domestic credit	CBN statistical database
inf_t	Inflation rate	CBN statistical database
$crude_t$	Crude oil prices	CBN statistical database
ASI_t	All-share Index	CBN statistical database
pfi_t	Portfolio inflows	CBN statistical database
IMP_t	Level of Imports	CBN statistical database
VIX_t	Volatility Index	Chicago Board Option Exchange

III.3 Technique of Estimation

This study uses the Generalised Methods of Moment (GMM) to estimate the model because the potential problems of heteroskedasticity and endogeneity, as could be theoretically expected. Hence, this resulted in the use of both endogenous and exogenous instrumental variables in estimating the equation. Notwithstanding, this also implies that the estimation was done with the direct method rather than the structural method.

The GMM is a generic estimator, which belongs to a class of estimators known as M-estimators that are defined by minimising some criteria function as implied in it follows the moment conditions, which are functions of the model and variable such that their expected value is zero[3] (Wooldridge, 2001). The GMM is considered as robust estimator in that it does not require information of exact distribution of the disturbances, but has to be identified, that is, there must be at least as many instrumental variables as there are parameters to estimate. This then forms the value of our optimised objective function[4]. The GMM has the advantage of being consistent irrespective of the weighting matrix used as it has three basic methods.

[3] $E(m(y_t\beta)) = 0$ where m, is the identity function, $y_t$is the variable as β is the parameter

[4] The Objective of the GMM is now to solve $\min_{\hat{\beta}_{GMM}}\{1/n\left(Z'(y - X\hat{\beta}_{GMM})\right)'.W_n.1/n\,(Z'(y - X\hat{\beta}_{GMM}))\}$ where $Z\,(vector of instruments) = (n \times l)$, $X\,(vector of explanatory variables) = (n \times l) W_n (weighting matrix) = (l \times l)$

IV. Presentation and Discussion of Results

Tables 2 and 3 show the general unrestricted and parsimonious model 1 and model 2. Table 2 shows the general unrestricted model and the sub-model 1 and model 2, respectively, as indicated earlier. However, the models were then reduced using the General-to-Specific methods to obtain the parsimonious short-run models. Table 3 shows the parsimonious short-run model in which the fundamentals all conformed to the economic theoretical signs with plausible magnitudes. The J-statistics, however, serves as an omnibus test statistics was used to test for over-identification restriction under the null hypothesis of well-specified model.

The model, however, passed the over-identification restriction test from the *p-value,* indicating no problem of over-identification in the model. This could be seen from the estimated output in the appendix. Furthermore, a unit root test was carried out to determine the level of stationarity of the variable, using the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) and the Augmented Dickey-fuller (ADF) test. The result indicated that the dependent variable (Exchange market pressure) and the independent variables such as oil prices, inflation rate and volatility index were all stationary, but variables such as imports, domestic credit ratio and All share index were not stationary (but stationary at first difference). This is presented in Appendix 6.

The parsimonious models were lastly subjected for endogeneity and simultaneity tests as shown in Table 4 below. This was to indicate whether some of the explanatory variables were endogenous, as well as, to justify the use of the GMM technique ahead of OLS. This was because OLS tend to be biased in the presence of endogeneity. Interestingly, it did pass the endogeneity test and also identified the endogenous variables in the model.

Table 2: General Unrestricted Model

Dependent Variable: EMPbase1	***Model 1. (longer sample)***		***Model 2. (shorter sample)***	
Variables	*Coefficient*	*P. values*	*Coefficient*	*P. values*
C	*33.07*	*0.0001*	*5.361*	*0.816*
EMPbase(-1)	*0.21*	*0.0649*	*0.4185*	*0.0007*
Log(crude)	*5.138*	*0.0194*	***-4.6727****	*0.0971*
Log(Imp)	*-3.180*	*0.0027*	***-1.995***	***0.1707***
DCR	*-2.961*	*0.0258*	*-6.2072*	*0.0267*
VIX	*-0.234*	*0.0001*	*-0.166*	*0.0545*
Inf	*-0.114*	*0.0625*	***0.132***	***0.5576***
@pch(ASI)	***-1.164***	***0.7683***	***-5.5393***	***0.1612***
Log(Pf)	***Unavailable***	***-***	*2.921*	*0.0442*
J. Statistics	*12.139*	*0.145*	*14.048*	*0.081*
	Instrumental variables: *c log(imp(-1)) empbase1(-2) empbase1(-3) log(ms(-2)) log(ms(-3)) @pch(asi) @pch(asi(-3)) log(imp) inf(-1) log(crude(-1)) vix dcr(-2) @pch(asi) empbase1(+1)*		***Instrumental variables: c*** *log(imp(-1)) empbase1(-2) empbase1(-3) log(ms(-2)) log(ms(-3)) @pch(asi) @pch(asi(-3)) log(imp) inf(-1) log(crude(-1)) vix dcr(-2) @pch(asi) empbase1(+1) log(pf(-1))*	

Table 3: Parsimonious models

	Dependent Variable: *EMPbase*	***Model 1. (longer sample)***		***Model 2. (shorter sample)***	
s/n	*Variables*	*Coefficient*	*P. values*	*Coefficient*	*P. values*
1.	*C*	*32.967*	*0.00*	*-26.08*	*0.0932*
2.	*EMPbase(-1)*	*0.213*	*0.048*	**Removed**	-
3.	*Log(crude)*	*5.127*	*0.016*	**Removed**	-
4.	*Log(Imp)*	*-3.184*	*0.002*	**Removed**	-
5.	*DCR*	*-2.90*	*0.037*	*-6.256*	*0.0009*
6.	*VIX*	*-0.24*	*0.00*	*-0.139*	*0.1190*
7.	*Inf*	*0.115*	*0.059*	**Removed**	**-**
8.	***@pch(ASI)***	**Removed**	**-**	**Removed**	**-**
9.	*Log(Pf)*	**Unavailable**	**-**	*2.195*	*0.0045*
10.	*J. Statistics*	*12.189*	*0.203*	*0.5883*	*0.745*
		Instrumental variables: *c log(imp(-1)) empbase1(-2) empbase1(-3) log(ms(-2)) log(ms(-3)) @pch(asi) @pch(asi(-3)) log(imp) inf(-1)inf(-3) log(crude(-1)) vix dcr(-2) @pch(asi) empbase1(+1)*		***Instrumental variables****: c log(ms(-2)) log(ms(-3)) DCR(-2) log(pf(-1)) vix*	

This indicates that we have used the appropriate technique. At this point, it is worth noting that a variable (crude oil prices) had a wrong sign and was statistically significant in the second model. This is surprising as it was counter-intuitive. In trying to address this issue we took its first difference value as well as its log difference after which its instruments were changed and yet it was not remedied. Furthermore we checked for structural break[5], but still there was no improvement. However, it did not enter the parsimonious model after failing the relevant coefficient restriction tests at the third stage. Also, several variables such as inflation rate, level of imports, share returns of all share indices did not enter the second parsimonious model.

Table 4: Summary of Endogeneity test

Model 1				***Model 2***		
Endogenous variables	***Difference in J-statistics***	***p.value***	***Remarks***	***Difference in J-statistics***	***p. value***	***Remarks***
Empbase1	*14.69428*	*0.0021*	*endogenous*	*Not used*	-	-
Dcr				*3.054288*	*0.0805*	*Endogenous*
Inf				*Not used*	-	-
Log(pf)	*Not used*	-	-	*3.395120*	*0.0654*	*Endogenous*

Note: Null hypothesis was stated as exogenous variables

IV.1 Model Selection

Having estimated two models, one with longer sample and the other with shorter sample, the latter was done as a result of the non-availability of the data for capital flows (portfolio inflows) from the starting period. We tried to ascertain the argument that capital flow is a key determinant for foreign exchange market pressure and hence, the second model was

[5] The structural break test carried out to see whether the breaks must have accounted for the change in the sign of the coefficient. The result is given appendix below.

estimated. However, having presented with two parsimonious models, it becomes necessary to choose the most robust among the two. Based on the objective of the study, which lies on the predictive power of the estimators and being less bias, this will serve as a good criterion for the choice of the model. Secondly, the technique was used because of the potential problem of which could result to serial correlation, the Durbin Watson statistics could serve as another good selection criterion and lastly, the conformity of the two models to theory were checked, that is, which best mimic the theoretical framework for the study in terms of fundamentals, their sign and magnitude.

Based on the outlined criteria above, starting with the J-statistics and their respective probability level indicates that they are both good models as their respective values are 12.19 (0.20) for model 1 and 0.59 (0.745) for model 2 with *p.values* in parenthesis. The second criterion which is based on the Durbin Watson (DW) statistics showed that model 1 with DW value of 2.35 performed better than model 2 with value 1.55. This criterion is important as the technique seeks to reduce the serial correlation to avoid obtaining a bias result. Finally, on the theoretical ground, with the exception of share prices of all-share index, all other theoretically informed variables were statistically significant with their right signs and plausible magnitude. However, the second model could not meet the full theoretical expectations as only domestic credit and portfolio flows were statistically significant and thus, implying that the model has failed to explain the determinants of the foreign exchange market pressure**.** Based on the aforementioned evaluation, it is indicative that model 1 is the most appropriate model for the analysis.

IV.2 Discussion of Results

The coefficient of the lagged value of exchange market pressure appears with the expected sign that suggests that a unit increase in the lagged value of the market pressure would increase the current value by 0.21 units, indicating some persistence in the exchange market pressure. This implies that if the previous market situation was an appreciating pressure, it could be endured to the current market condition and vice versa at a plausible magnitude. This is in-line with the findings of Aizenman & Binici, (2015) for both emerging and developed economies.

The coefficient of crude oil prices, which served as supply factor in the model, was correctly signed and is statistically significant. This suggests that an increase in crude oil price leads to an appreciating exchange market pressure (alternatively suppresses the depreciating exchange market pressure) by about 0.05 units[6]. This implies that an increasing price of the crude oil as a major export commodity (through demand shock) would increase the foreign reserves, which then would subdue the prevailing depreciating market pressure through the supply of foreign exchange to the foreign exchange market. This is in-line with study of (Basher, Haug & Sadorsky, 2016) who suggested that oil exporting countries tends to enjoy some appreciation of their exchange rate during a demand shock in the global oil prices.

[6] Variables such as crude oil prices, imports and portfolio flows were logged. Because the dependent variable in not logged, the coefficients cannot be interpreted as elasticity. DCR was the ratio of domestic credit to money supply. However for interpretational convenience, we divide the coefficients of these variables by 100. Inflation rate was not logged but expressed in decimal before estimation.

However, crude oil prices are not determined domestically. Hence, it is considered as an external factor since Nigeria belong to the cartel of OPEC (Organisation of Petroleum Exporting Countries), which decides the prices or quantity of production.

The level of imports also showed its expected sign with a plausible magnitude and was statistically significant. The value of its coefficients indicated that a unit increase in the level of import would reduce the appreciating market pressure (alternatively reduces the appreciating market pressure) by about 0.032 units. This means that an increasing level of importation leads to increase in the demand for foreign exchange that further result to a depreciating market pressure.

The domestic credit is statistically significant with plausible magnitude. However, the absolute value of the ratio of domestic credit was used because the logarithmic value gave a non-significant coefficient. This suggests that a unit increase in the domestic credit accounts for reduction in the appreciating exchange market pressure (or alternatively increase the depreciating exchange market pressure) by about 0.029. This implies that loose monetary policy could inform a prevailing depreciating exchange market pressure.

This result also justifies the monetary theory that monetary expansion through increase in money supply could deplete the foreign reserves and also has a chain effect on the exchange rate (depreciation). This lends support to the findings of Aizenman & Binici, (2016) for emerging markets economies, Stavárek (2010) and Kumah (2011) also share a similar opinion, but put precisely that raises the volatility in the exchange market pressure. However, Stavarek & Marek (2009) are of the contrary view.

The coefficient of inflation rate was correctly signed and significant. This implies that an increase in the level of inflation leads to a decrease in the appreciating exchange market pressure (or alternatively increase the depreciating exchange market pressure) by about 0.0012 units. This indicates that a rise in inflation rate could lead to economic agents to hoard foreign currency (that is the dollar) taking advantage of the arbitrage gap. This also lends support to the findings of Aizenman & Binici, (2015) for emerging markets. The coefficient of global indicator for volatility, which was a measure of risk, is also correctly signed and is statistically significant. Thus, a unit increase in the global indicator for volatility tends to increase the depreciating exchange market pressure by about 0.24 units. This indicates that a higher expectation (risk value) in the global stock market could spillover to domestic economy thereby leading to outflow of capital. This variable served as an external factor in determining the market pressure.

V. Conclusion

A key finding of this study is the relative dominance of depreciating exchange market pressure (compared with appreciating exchange market pressure) across the various exchange rate reforms in Nigeria. This implies that the imbalance of the demand and supply forces in the foreign exchange market pressure in Nigeria has predominantly created shortages, which the various exchange rate reforms had not sustainably addressed. The study also identified that no domestic factor was positively associated with an appreciating exchange market pressure, while factors such as domestic credit, level of imports, inflation rate were positively associated with a depreciating market pressure irrespective of their magnitudes. This further suggests that the effectiveness and potency of domestic policy instruments is limited to dealing with appreciating pressure. This must have been the reason for the depreciating nature of the foreign exchange market pressure in Nigeria. On the external factors, only crude oil prices were associated with an appreciating foreign exchange market pressure, while global indicator for volatility (which was a measure of risk) was negatively associated with an appreciating exchange market pressure. However, the past values of the foreign exchange market pressure tend to move in the same direction.

This study, therefore, recommends that government should tread with caution when trying to stimulate the economy through loose monetary policy. This is because the dominant factors are monetary fundamentals and could have negative effects on the foreign exchange market as some of these fundamentals tend to move in opposing direction. Also, less restriction for capital mobility could be adopted as the findings have indicated that foreign exchange market pressure is more responsive to oil prices than capital flows in the form of portfolio flows. Our paper further suggests that there may be no modest solutions for Nigeria controlling the foreign exchange market pressure, but could avoid some complications through removal of some form of capital control considering the existence of impossible trinity.

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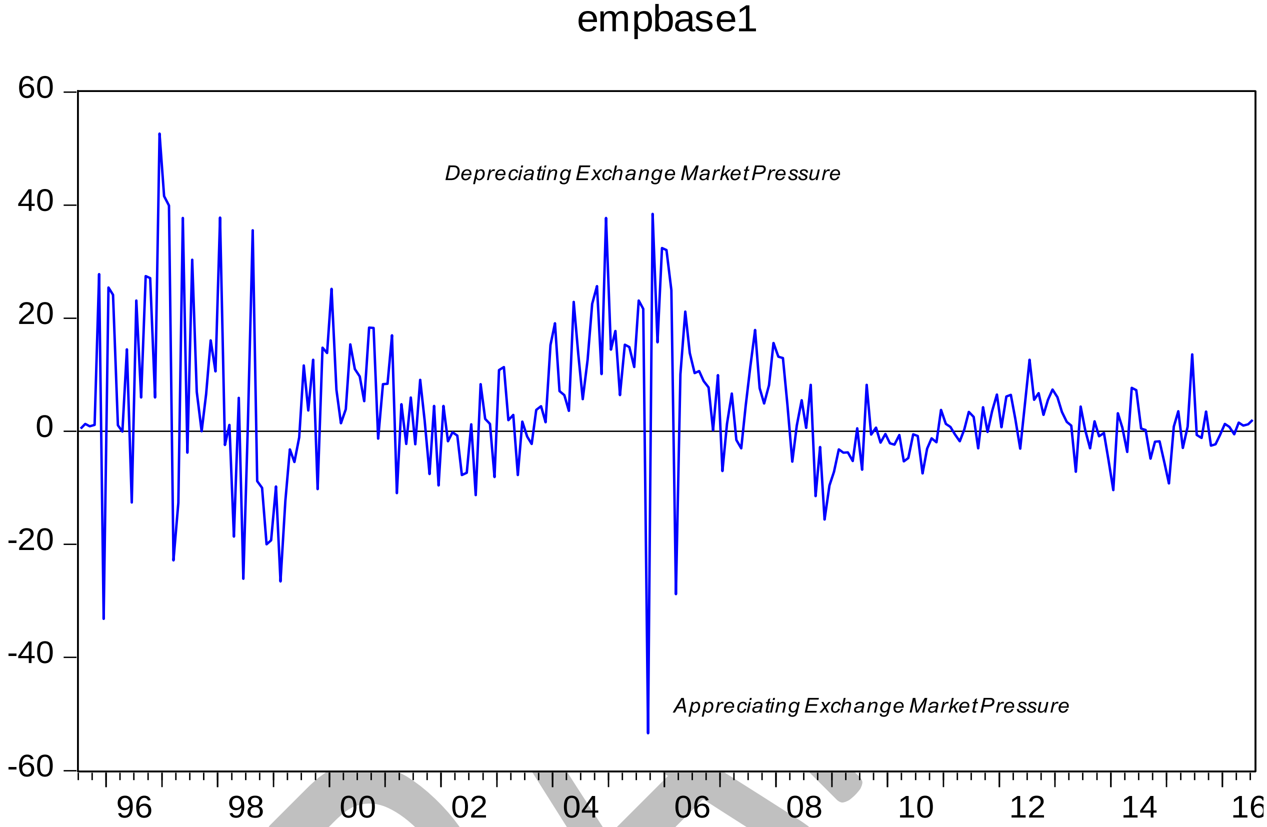
Appendix

Appendix 1: Foreign Exchange Market Pressure for Nigeria (1995 – 2016)



Formula: / $emp_t = \frac{e_t - e_{t-1}}{e_{t-1}} - (i_t - i_t^*) - \frac{ir_t - ir_{t-1}}{mb_{t-1}}$ *(base month = May, 2005)*

Source: *Author's computation using data obtained from Central bank of Nigeria and Federal Reserve Economic Data*

Appendix 2: General unrestricted Estimated model 1 (longer sample)

Dependent Variable: EMPBASE1
Method: Generalised Method of Moments
Sample (adjusted): 1996M04 2016M07
Included observations: 240 after adjustments
Linear estimation with 1 weight update
Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)
Standard errors & covariance computed using HAC weighting matrix(Prewhitening with lags from AIC maxlags, Daniell kernel, Newey-West fixed bandwidth = 5.0000)
Instrument specification: LOG(IMP(-1)) EMPBASE1(-3) LOG(CRUDE)
EMPBASE1(-2) (INF(-3)) LOG(MS(-2)) LOG(MS(-3)) @PCH(ASI(-3))
LOG(IMP) (INF(-1)) LOG(CRUDE(-1)) VIX DCR(-2) @PCH(ASI)
EMPBASE1(+1)
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	33.07354	8.376309	3.948462	0.0001
EMPBASE1(-1)	0.210209	0.113343	1.854639	0.0649
LOG(CRUDE)	5.137907	2.182832	2.353780	0.0194
VIX	-0.239471	0.058897	-4.065946	0.0001
LOG(IMP)	-3.180330	1.047210	-3.036956	0.0027
DCR	-2.960621	1.319876	-2.243105	0.0258
INF	-0.113916	0.060854	-1.871968	0.0625
@PCH(ASI)	-1.164003	3.945777	-0.295000	0.7683

R-squared	0.144041	Mean dependent var	4.111430
Adjusted R-squared	0.118214	S.D. dependent var	12.51319
S.E. of regression	11.75032	Sum squared resid	32032.25
Durbin-Watson stat	2.344725	J-statistic	12.13948
Instrument rank	16	Prob(J-statistic)	0.145088

Appendix 3: General Unrestricted Estimated model 2 (shorter sample)

Dependent Variable: EMPBASE1
Method: Generalised Method of Moments
Sample (adjusted): 2007M02 2016M07
Included observations: 110 after adjustments
Linear estimation with 1 weight update
Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)
Standard errors & covariance computed using HAC weighting matrix(Prewhitening with lags from AIC maxlags, Bartlett kernel, Newey-West fixed bandwidth = 5.0000)
Instrument specification: LOG(IMP(-1)) EMPBASE1(-3) LOG(CRUDE)
EMPBASE1(-2) (INF(-3)) LOG(MS(-2)) LOG(MS(-3)) @PCH(ASI(-3))
LOG(IMP) (INF(-1)) LOG(CRUDE(-1)) VIX DCR(-2) @PCH(ASI)
EMPBASE1(+1) LOG(PF(-1))
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.361856	23.02835	0.232837	0.8164
EMPBASE1(-1)	0.418549	0.119334	3.507383	0.0007
LOG(CRUDE)	-4.672709	2.790256	-1.674653	0.0971
DCR	-6.207211	2.760826	-2.248317	0.0267
LOG(PF)	2.920585	1.433428	2.037483	0.0442
INF	0.132479	0.225141	0.588426	0.5576
VIX	-0.165936	0.085309	-1.945130	0.0545
LOG(IMP)	-1.995309	1.445939	-1.379940	0.1707
@PCH(ASI)	-5.539347	3.925134	-1.411250	0.1612

R-squared	0.006008	Mean dependent var	0.946943
Adjusted R-squared	-0.072725	S.D. dependent var	5.668722
S.E. of regression	5.871232	Sum squared resid	3481.608
Durbin-Watson stat	2.338654	J-statistic	14.04843
Instrument rank	17	Prob(J-statistic)	0.080512

Appendix 4: Parsimonious Estimated Model 1(longer sample)

Dependent Variable: EMPBASE1
Method: Generalised Method of Moments
Sample (adjusted): 1996M04 2016M07
Included observations: 240 after adjustments
Linear estimation with 1 weight update
Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)
Standard errors & covariance computed using HAC weighting matrix (Prewhitening with lags from AIC maxlags, Daniell kernel, Newey-West fixed bandwidth = 5.0000)
Instrument specification: LOG(IMP(-1)) LOG(CRUDE) EMPBASE1(-3) EMPBASE1(-2) (INF(-3)) LOG(MS(-2)) LOG(MS(-3)) LOG(IMP) (INF(-1)) LOG(CRUDE(-1)) @PCH(ASI(-3)) @PCH(ASI) VIX DCR(-2) EMPBASE1(+1)
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	32.96763	8.090181	4.075018	0.0001
EMPBASE1(-1)	0.212528	0.106985	1.986508	0.0481
LOG(CRUDE)	5.126924	2.105443	2.435081	0.0156
VIX	-0.235319	0.063986	-3.677655	0.0003
LOG(IMP)	-3.183730	1.003779	-3.171743	0.0017
DCR	-2.903894	1.385389	-2.096085	0.0372
INF	-0.115151	0.060664	-1.898157	0.0589

R-squared	0.143291	Mean dependent var	4.111430
Adjusted R-squared	0.121230	S.D. dependent var	12.51319
S.E. of regression	11.73021	Sum squared resid	32060.30
Durbin-Watson stat	2.348874	J-statistic	12.18907
Instrument rank	16	Prob(J-statistic)	0.202859

Appendix 5: Parsimonious Estimated model 2 (shorter sample)

Dependent Variable: EMPBASE1
Method: Generalised Method of Moments
Sample (adjusted): 2007M02 2016M08
Included observations: 115 after adjustments
Linear estimation with 1 weight update
Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)
Standard errors & covariance computed using HAC weighting matrix
(Prewhitening with lags from AIC maxlags, Bartlett kernel, Newey-West fixed bandwidth = 5.0000)
Instrument specification: LOG(MS(-2)) LOG(MS(-3)) DCR(-2) LOG(PF(-1)) VIX
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-26.08115	15.40344	-1.693203	0.0932
DCR	-6.255603	1.831420	-3.415711	0.0009
LOG(PF)	2.194838	0.757722	2.896628	0.0045
VIX	-0.138743	0.088313	-1.571033	0.1190

R-squared	0.029675	Mean dependent var	0.916294
Adjusted R-squared	0.003450	S.D. dependent var	5.562314
S.E. of regression	5.552709	Sum squared resid	3422.417
Durbin-Watson stat	1.546386	J-statistic	0.588312
Instrument rank	6	Prob(J-statistic)	0.745160

Appendix 6: Summary of Unit root test

Variables	***Level***		***First Difference***	
	ADF	***KPSS***	***AD F***	***KPSS***
EMPbase	-8.57*	0.08*	-	-
Crude oil prices	-1.88	0.19*	-10.92*	-
Imports	-0.71	1.88	-14.11*	0.07*
DCR	-0.80	1.65	-19.42*	0.09*
inf	-5.20*	0.23*	-	-
VIX	-3.83*	0.17*	-	-
ASI	-2.09	1.25	-5.91*	0.08*
Portfolio flows (pf)	-1.85	0.46*	-10.13*	-

Note: * and ** indicate significance at 1 and 5 per cent levels

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