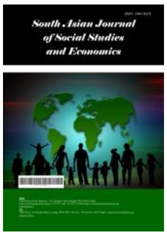

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Effectiveness of Monetary Policy Instruments on Bank Liquidity Management

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Recognising the importance of monetary and price stability for sustainable growth, many countries' Central Banks often set certain liquidity targets to be achieved using various monetary policy instruments. This study fills the gap in the literature by employing the ARDL Bounds test to examine the relative effectiveness of a combination of quantity- and price-based policy instruments used by the Central Bank of Nigeria to regulate the level of bank liquidity. Also, the likelihood ratio test is used to determine whether monetary policy instruments work better as a complement (or substitute) concerning liquidity management. Using quarterly data covering 2008/Q1-2020/Q2, we found that, price-based instruments mostly impact liquidity levels in the short- and long-run. The quantity-based instrument shows a significant impact at second lag. However, the impacts of some policy instruments were inconsistent which is partly due to their low usage as short-run measures. We found all the six monetary instruments considered in this study to be complementary for liquidity management. By implication, the combination of monetary instruments for liquidity management is in order. While MPR remains crucial in determining liquidity, a continuous review of its operationality to identify and reduce possible distortions will be beneficial. Also, there is a need for CBN to reassess the disbursement of interventions and their implications on liquidity.

Keywords: ARDL bounds test; central bank of Nigeria; liquidity management; monetary policy; price-based policy instruments; quantity-based policy instruments.

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1. INTRODUCTION

Monetary policy has over the years proven to be a vital component of macroeconomic policy and many countries of the world have, to an extent, structured their economies around a specific monetary policy framework administered by their monetary authorities. However, due to the globalization and continuous evolvement of domestic and world economies, it has become imperative for monetary authorities to re-establish specific objectives to pursue and focus on perfecting their monetary policy strategies in achieving the set objectives [1].

The Central Bank of Nigeria (otherwise known as "CBN" and (or) the "Bank"), has the objective of ensuring price and monetary stability. The strategy employed by the CBN in reaching this mandate is encompassed by effectively managing the short-term credit supply ability, which depends on the liquidity position in the money market. The liquidity position however is known to influence economic activities through aggregate demand and can be a threat to the attainment of the objective of price stability among others. Thus, the Bank needs to determine and ensure the optimal liquidity required to achieve non-inflationary growth and sustain it over time [2]. Consequently, a knowledge of the choice and effectiveness of monetary policy instruments in liquidity management remains essential.

In view of this, assessing the impact of monetary policy instruments on liquidity has been the line of thought of many studies. (e.g., see Bernanke and Blinder [3]; Saxegaard, [4]; Berger and Bouwman [5]; and Pio, Cavaliere, Muda, Chakravarthi, Rajan, Khan and Rajest, [6]. However, given that the level of financial sector development varies among countries, the referred studies have tailored their analysis to capture relevant conditions as they relate to the dynamics of the economies under review.

Before 1992, the CBN used direct policy tools like selective credit control, credit ceiling, administrative fiat, and reserve requirements to ensure effective liquidity management [7]. From 1993, an indirect framework was adopted and has been in place to date. The indirect framework is designed to operate through a transmission process. In this process, tools employed tend to affect the primary objective – price stability through the operational and intermediate targets – short-term money markets rates and the monetary base. In other words, the liquidity management of the CBN through the indirect measure is tied to the fact that managing the monetary base would translate to impacting money supply and hence lead to achieving price stability [2]. Since the introduction of the indirect policy measure regime, the CBN has deployed several tools in its quest to ensure effective liquidity management. These tools include open market operations (i.e., NTBs, bills Repos and reserve repos), reserve requirements (i.e., cash reserve ratio and liquidity ratio) and foreign exchange operations – purchases and sales. Lately, in 2006, standing and lending facilities were introduced and designed to be set around the new monetary policy rate (MPR) that was introduced at the same time to replace the minimum rediscount rate (MRR) and to anchor the short-term rates around its corridor [8].

With this exposition, Osakwe, Agbo and Okonkwo [9], Augustine, Chinwe & Ukpere, [10], Chuku [11] and Olekah [8] have amongst others, examined the CBN's monetary policy instruments in liquidity management. While this is a step forward, these studies do not show the exact link with liquidity management in the banking system. More so where they do, only a few selected price- or quantity- based policy instruments are considered. Thus, a study assessing the relative effectiveness of the monetary policy instruments used by CBN will be an important contribution to the literature. This study contributes to the literature by combining price and quantity-based monetary policy instruments in assessing the impact of the Central Bank's policy on liquidity management. We also offer further clarification of whether the instruments work as a complement or substitute. To the best of our knowledge, there has not been a study that considers both quantity and price-based policy instruments to determine their complementarity (or substitutability) in assessing the impact of monetary policy on bank liquidity. Therefore, our disquisition ultimately fills the void in the existing literature.

Through the empirical assessment undertaken, thus, the three following sub-questions are addressed. Do monetary policy instruments significantly affect the liquidity position of Deposit Money Banks (DMBs) in Nigeria? What are the relative impacts of monetary policy instruments on bank liquidity position? Are the monetary policy instruments complementary or substitutes? To achieve these, we employ the ARDL Bounds test by Pesaran, Shin, Smith & Smith, 2001) to analyse the relative long-run and short-run impacts of the monetary policy instruments on bank liquidity management in Nigeria. The study also adopts the likelihood ratio (LR) test to test for complementarity or substitutability of the instruments which is a novel and important contribution to extant studies on macroeconomic policy analysis.

Subsequent parts of this document are structured thus: the subsections herewith present key facts on monetary policy instruments and money market variables in Nigeria, the theoretical framework, and the empirical literature review. The following section (i.e., Section 2) presents the methodology. Section 3 presents and discusses our data and empirical findings, and section 4 concludes with the policy implications.

1.1 Trends in Nigeria's Key Money Market Variables

Pursuant to the CBN act of 1958, the Bank uses various monetary policy instruments to influence a set of operational and intermediate activities to achieve the ultimate target (i.e., stability prices). The various quantity-based and price-based monetary policy instruments adopted by the Central Bank of Nigeria range from Open Market Operations (OMO) to Cash Reserve Requirement (CRR). The trajectories of these instruments and their relationship with the intermediate and ultimate targets have varied over the years. To put this in context, we analyse the Bank's various monetary policy and money market indicators for the period between January 2018 - February 2021

1.1.1 Relationship between treasury bills rates, monetary policy rates, and interbank call rates

The trends of interbank call rates (IBR), treasury bills rates (TBR) and the monetary policy rate (MPR) are represented in Fig. 1. The MPR stood at 14% from January 2018 through to February 2019 after which it dropped to 13.5% and was pegged at that rate till May 2020. Between May to August 2020, the MPR was kept at 12.5%. However, at the MPC meeting of September 2020, the Committee decided to reduce the rate by 100 basis points to 11.5%. It remained at 11.5% as at February 2021.

There is a strong positive correlation coefficient of 0.841 between MPR and TBR. The MPR and IBR also show a positive but lesser degree of a correlation coefficient[1] of 0.524. Although the IBR peaked at 26.19% in February 2018, it has been on an average of 9.41% while the TBR also average at 6.98% during the period under review.

1.1.2 Relationship between interest rates and money supply

The trends and observed relationship between broad money supply and interbank call rates (IBR) in Nigeria from January 2018 to February 2021 are represented in Fig. 2. In the context of economy-wide liquidity, a decline in interest rate is expected to increase loans, trade credits and other forms of domestic credits available to individual and companies (i.e., private sector), and boost aggregate demand. On the other hand, a fall in money supply is expected to reduce lending and ultimately moderate inflation. On the flip side, a decline in interest rate is expected to cause a fafollowsll in bank liquidity as savings/investments will no longer be attractive to the private sector.

1.1.3 Relationship between open market operations, base money, and bank reserves

The trends in the monthly balances of the base money (monetary base), bank reserves and the total sales in Open market Operations (OMO) which is a quantity-based direct monetary policy activity are represented in Fig. 3. It was noted that the base money and bank reserves peaked in February 2020 at ₦7.445 trillion and ₦9.632 trillion respectively. The averages however stood at ₦9.172 billion and ₦6.759 billion respectively. Both bank reserves and based money are inversely linked to OMO bills sale with estimated correlation coefficients of -0.629 and -0.632 respectively, indicating that an increase in the sale of OMO bills will reduce bank reserves, i.e., mop up liquidity.

1.1.4 Deposits money banks liquidity indicators

The trends in the DMBs closing balances and monthly SLF and SDF from January 2018 - February 2021 are represented in Fig. 4. During this period, the SDF and SLF values fluctuated within averages of ₦1.05 trillion and ₦966.04 billion, respectively. Although SLF and DMBs show similar spikes in certain periods, a negative

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[1] The correlation coefficients are computed using Microsoft Excel. Similar data for plotting the graphs are employed

correlation coefficient of -0.017 was noted between both in the period under review. This underpins banks' unwavering preference for collateralised interbank OBB rates in the Nigerian financial system. However, consistent with economic resonance, the correlation coefficient between the DMBs closing balances and SLF is negative (-0.102) which indicates banks' recourse to the discount window in periods of liquidity strain. The DMBs balances averaged ₦375.76 billion with closing balances of ₦255.54 billion in February 2021.

1.2 Concise Theoretical Framework

There have been no definite theories that capture the effectiveness of monetary policy vis-à-vis liquidity. Available theoretical models focus on monetary policy and interest rates, and (or) prices and growth in output, but with an undertone of liquidity. For instance, Friedman's [12] Quantity Theory of Money, in its basic form represented by Irving Fisher's Eqn., shows that money supply directly affects prices as follows equation (1).

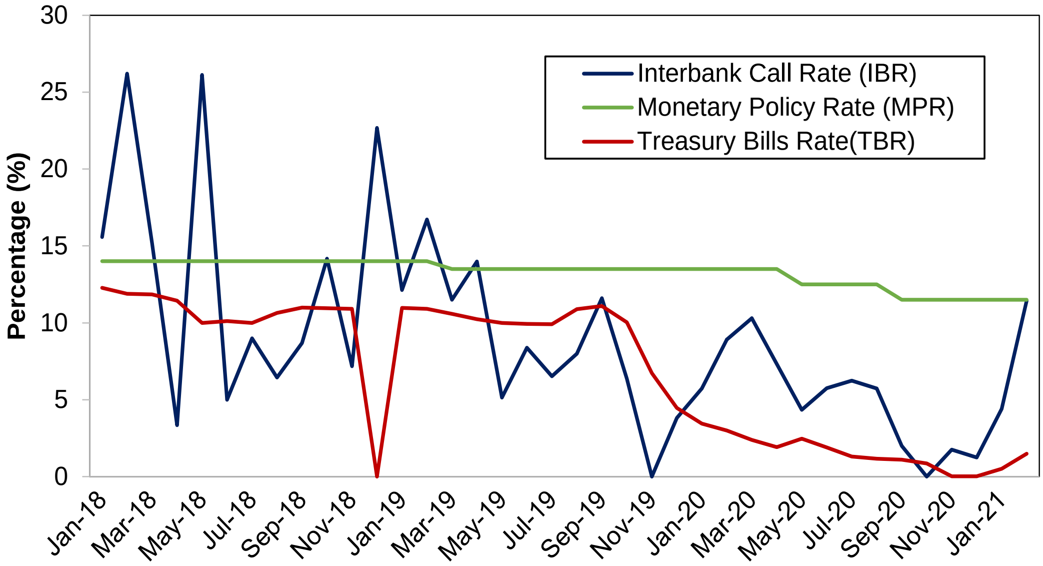

Fig. 1. Trends in Monetary Policy Instruments Rates in Nigeria
Source: computed by authors based on data from CBN

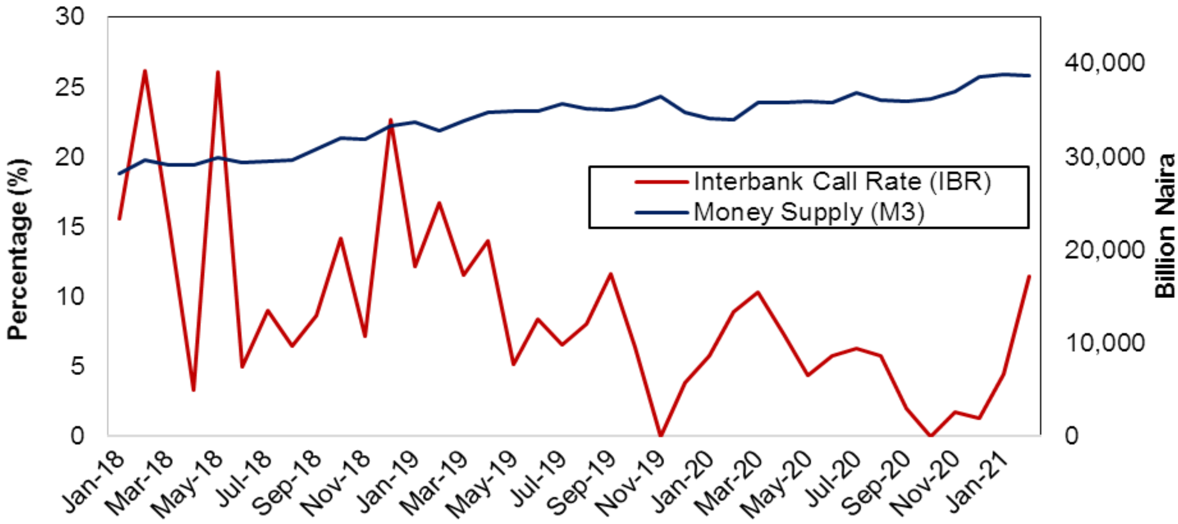

Fig. 2. Trends in Broad Money Supply and Inter-bank Call Rates in Nigeria
Source: computed by authors based on data from CBN

$$MV = PT \quad (1)$$

Alternatively,

$$MV + M'V' = PT \quad (2)$$

where M represents money supply, while V, P and T represent the velocity of circulation, price level and volume of transactions respectively. Although this theory has come under a lot of criticism, it has an established relevance on the basis for explaining monetary policy transmission in many developing economies including Nigeria.

In recent times, researchers have proposed interesting modifications to the extant theories to incorporate the dynamics of the liquidity effect vis-à-vis interest rates and prices, and to analyse and/or explain how such liquidity effect is captured. A relevant and more precise of these studies is the liquidity effect of the traditional sticky prices model by Ohanian and Stockman [13] where liquidity effect is seen as the statistical relationship between bank reserves and short-term interest rates such that a specific policy action of the Central Bank has the same impact on the bank reserves and the short-term interest rates.

1.3 Empirical Literature Review

Knowing the importance of money and price stability in achieving sustainable growth, several empirical studies on the effectiveness of monetary policy vis-à-vis liquidity management and money market performance. Crucially, these studies, which vary in terms of key variables and methodologies adopted, and the region and (or) countries of focus, have tailored their analysis to capture many conditions as they relate to the dynamics of their respective economies. Having these in mind, our review of empirical studies on monetary policy instruments and liquidity covers studies with a scope that cut across the continents. Spanning through Europe, Asia and (North & South) America and Africa, particularly, Nigeria as the present study relates to the Nigerian monetary policy framework.

In general, it is observed that monetary policies impact the liquidity of an economy through various channels. For instance, in the study carried out by Bernanke and Blinder [3], it was observed that liquidity is impacted by the monetary policy through bank loans and bank deposits. i.e., the credit and money channels. While investigating whether monetary policy effects vary between financial crises and normal times, Berger and Bouwman [5] showed that monetary policy impacts are significant. However, its effects in terms of liquidity creation by small banks are inconsequential. In the case of larger banks, the effects are seen to be varied, albeit weak. The study used a VAR approach with a single equation model to test the hypothesis that monetary policy impacts on and off bank balance sheet liquidity creation.

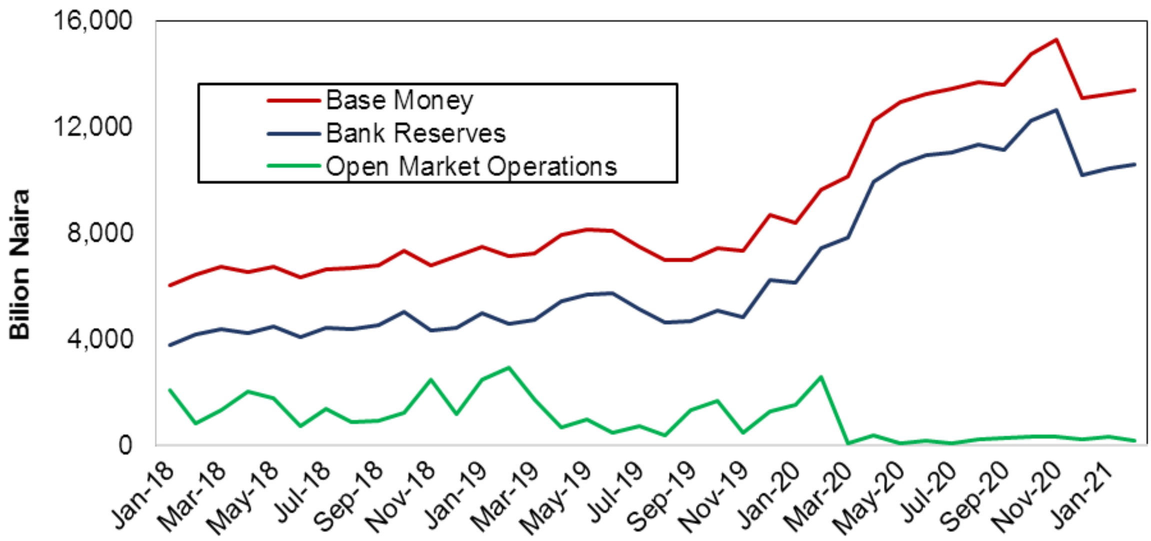

Fig. 3. Base Money, Bank Reserves and OMO Sales in Nigeria

Source: computed by authors based on data from CBN

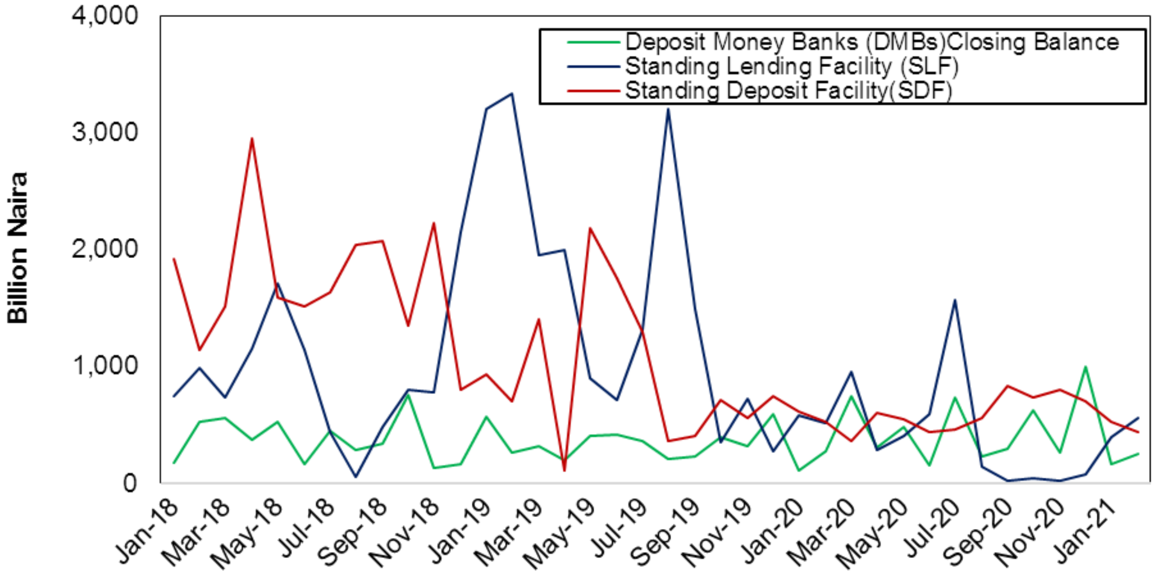

Fig. 4. Deposits Money Banks Liquidity Indicators in Nigeria

Source: computed by authors based on data from CBN

The causality, interrelatedness, impacts and even the determinants of monetary policy instruments and liquidity creation for various countries, have been analysed in several other extant studies. For Southern America, Khemraj [14] conducts a similar study for Guyana. Not only did this study go a step further in examining excess liquidity effects on prices and exchange rate but also it comprehensively reviewed the determinants of liquidity and bank reserves. The study established that the Bank of Guyana use Open Market Operations (OMO) to create liquidity and manage the same in times of excess liquidity. Accordingly, the Bank of Guyana sells their short-term treasury bills weekly vis-à-vis the broad money and reserve money targets.

Turning to the European countries, Fernandez-Amador et *al.,* [15] employed the VAR model to analyse the monetary policy and liquidity nexus focusing on stock liquidity both at the micro and macro level in German, French and Italian. Having used base money growth and Euro overnight index average (EONIA) interest rate as monetary policy proxies, they found that the impact of the monetary policy on liquidity measures is much more significant than macroeconomic variables' impact. They concluded that though the shocks for EONIA are generally statistically insignificant, an increase in the monetary base will result in a significant rise in stock liquidity and vice versa for contractionary monetary policy.

Similarly, Lovin [16] employed a two - multiple linear regression model to analyse the interrelatedness between monetary policy and liquidity in Romania. They considered the volatility of money market rates, the volume of REPO transactions carried out between the NBR and banks (Open Market Operations), total banking system assets and total external funding for the banks. It was concluded that the open market operations of the National Bank of Romania are quite effective in managing liquidity in the money market. However, it was noted that the NBR open market impact on the money market is only for banking sector stability.

Also, Nather [17] provides an insight into the effect of standing facilities, on interbank lending and bank liquidity. Key variables considered are policy rate, marginal lending rate, bank liquidity holding and standing facilities. The study put the simple two-bank theoretical model into an empirical test – applying a Nash bargaining solution. The study, among other things, found that, if it is suspected that the interbank market yields lower than the central bank's standing facilities or the anticipated returns from investments, no liquidity will be held for the interbank market funds.

Knowledge of the peculiarity of the CBN's monetary policy instruments in liquidity management has welcomed several rich studies on Nigeria. For instance, the descriptive analysis by Olekah, [8] is worth mentioning. Olekah, [8] provides a review of the performance of standing facilities and liquidity management in Nigeria. As discount windows constitute a major indirect monetary policy used by the Central Bank of Nigeria as indirect monetary policy instruments, the study discusses the various ways by which the lending and deposit facilities are used to meet intermediate and ultimate targets including the desired level of liquidity. The major conclusion emanating from the study is that standing facilities are basic measures and subsequently, a complementing measure needs to be put in place in other to curtail liquidity within the economy.

Augustine et al. [10] analyse various drivers of excess liquidity in the Nigerian banking system. Their choice variables range from the DMBs aggregate closing balances and treasury bill rate to lending facility rate and interbank rate, The paper essentially emphasises idle liquidity over banks' operational needs and monetary policy efficacy. Their results show a significantly positive relationship between standing lending facility rate and excess liquidity and interbank rate used as a proxy for monetary policy. But, a significantly negative link was established between the cash reserve ratio, treasury bill rate and excess liquidity.

Chuku [11] offered a more interesting view of the discourse. The study looks at the effectiveness of the various monetary policy instruments of the Central Bank of Nigeria (CBN) concerning prices and output using Structural Vector Autoregression (SVAR) and Broad Money (M2), Minimum Rediscounted rate (MRR) and Real Effective Exchange Rate as quantity-based and price-based nominal anchors of the CBN. Although the study does not show the exact link with liquidity in the economy, it submits that the use of the quantity of money (M2) in the economy as an instrument for monetary policy implementation offers the best benefits because it affects economic activities modestly.

However, Agbo and Okonkwo [9] had a contrary view. They adopted the DSGE Model and Vector Error Correction Mechanism with several monetary policy proxies including monetary policy rate, cash reserve ratio, treasury bill rate together with an average liquidity ratio of deposit money banks. They recommend a price-based monetary policy as a reliable short-term tool. The difference in the submission by Chuku [11] and Agbo and Okonkwo [9] perhaps is because of their final targets in that the former study is about output and prices while the latter is about banking sector credits.

In as much as these studies extensively deal with the effectiveness of the monetary policy, to the best of our knowledge, there have been very few or no studies that use a combination of the conventional quantity-based and price-based policy instruments to determine the complementarity (or substitutability) in assessing the impact of monetary policy on liquidity. This kind of study is vital to help build a complete body of evidence on the effect of monetary policy on liquidity management. Our study, therefore, seeks to bridge this gap in the literature.

2. MATERIALS AND METHODS

2.1 Data Description, Sources and Summary Statistics

The study considers six key variables namely deposit money banks balances (DMBs), monetary policy rate (MPR), cash reserve ratio (CRR), OMO sales (OMOs), standing lending facility rate (SLF) and standing deposit facility rate (SDF). These variables are quarterly time series data for 2008Q1-2020Q2. The start period captures the conduct of monetary policy during the global financial crises, which caused liquidity strains in the Nigerian banking system. Though principally influenced by data availability, the end period suitably mirrors the early impact of COVID-19 and the resultant accommodative monetary policy stance. MPR, CRR, SLF and SDF are proxies for price-based monetary policy instruments, OMOs represent the quantity-based monetary policy instrument, while DMBs is used as a proxy for liquidity.

We source all variables excluding OMOs from the CBN statistical department. We compute three-month averages of OMOs (extracted from the CBN database) to have quarterly series data as it is a daily volume. We use all variables in their form. Summary statistics and graphical illustrations of the variables are represented in Table 1 and Fig. 5 respectively.

2.2 Methodology

2.2.1 Model specification

Drawing from Eqs. (1) and (2), the link between liquidity and Central Bank's monetary policy instruments is represented as follows:

$$y_t = \alpha + \phi' x_t + \varepsilon_t \quad (3)$$

Where y_t is liquidity level at time t; x_t is the vector of both quantity- and price-based monetary policy instruments at time t; ε_t is the error term.

2.2.2 Estimation procedure

To determine the appropriate method to estimate Eq. (3), it is necessary to properly consider the underlying time-series properties of the variables to avert spuriousness. Our estimation procedure is inclined to the study by Shrestha and Bhatta [18] which indicates that, firstly, the stationarity of the variables must be tested. If all the variables are stationary at level, an Ordinary Least Square (OLS) or a Vector Autoregressive (VAR) method will suffice to assess the link among the variables of interest in Eq. (3). Conversely, if they are non-stationary at levels, the relationship in Eq. (3) may be estimated with alternative methods that require co-integration among the variables. In this case, the Johansen test and Autoregressive Distributed Lag (ARDL) Cointegration test (ARDL bounds test) by Pesaran et al [19] are suitable methods to adapt.

- *Unit Root Tests*

Following the above exposition, to check if the variables are stationary, we adopt the Augmented Dickey-Fuller (ADF) test complemented by the Phillips-Perron (PP). The standard ADF model is presented below:

$$\Delta Y_t = \alpha + \lambda t + \rho Y_{t-1} + \sum_{p=1}^{n} \delta_p \Delta Y_{t-p} + \varepsilon_t \qquad (4)$$

Where Y_t is a time series variable, Δ is the first difference operator, α and λ are constant and time trend coefficient respectively. Finally, p represents the lag order.

The PP test on the other hand corrects for the problem of lag selection which may have occurred using the ADF. It achieves this by combining the standard Dickey-Fuller test with non-parametrically modified test statistics [20]. A significant advantage of the PP test over the ADF is the fact that it corrects for heteroscedasticity and autocorrelation issues. Following, Shrestha and Bhatta [18], we specify the PP unit root test equation as follows:

$$\Delta Y_t = \delta Y_{t-1} + \beta_i D_{t-1} + e_t \qquad (5)$$

Where D_{t-1} is a deterministic trend component and e_t is an $I(0)$ with a mean of 0. The null hypothesis is tested for $\delta = 0$. Despite the similarities in the hypothesis testing technique, the procedure to calculate the t-ratio to delta is the δ is different from the ADF.

- *The ARDL Bounds Test (Cointegration Test)*

Where the time series data has mixed stationarity results, we will adopt the ARDL bounds test by Pesaran et al [19] to test for cointegration. This has been widely employed in extant studies that assessed the effectiveness of monetary policy (see e.g., [21,22]);[23]. As applicable, the ARDL bounds test, will subsequently be employed in evaluating the relative impacts (long-run and short-run) of the monetary policy instruments on liquidity management.

The ARDL (p, q, . . ., q) modelling approach is illustrated as follow,

$$y_t = \sum_{j=1}^{k} \alpha_0 + \alpha_0 t + \sum_{i=1}^{\rho} \beta_i y_{t-i} + \sum_{i=0}^{q} \phi_{j,i} x_{j,t-i} + e_t \qquad (6)$$

Where y_t and $x_{j,t}$ represent dependent and explanatory variables respectively;[2] and e_t is the error term. Through a simple linear transformation of Eq. (6), a dynamic error correction model (ECM) that allows to test for long run cointegration can be derived as follows:

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{\rho-1} \beta_i \Delta y_{t-i} + \sum_{j=1}^{k} \sum_{i=1}^{q-1} \phi_{j,i} \Delta x_{j,t-i} + \pi_1 y_{t-1} + \sum_{j=1}^{k} \lambda_j x_{j,t-1} + e_t \qquad (7)$$

[2] *The definitions of the variables and identities are presented in sub-section 5.1 on data.*

where α_0, β_i and $\phi_{j,i}$ represent measurements of short-run dynamics; π_1 measures the adjustment and λ_j represents measurements of long-run relationship. The optimal lag order for the dependent variable (q) and regressors (q), which may be different across regressors, can be obtained based on information criterion. The variables in $(y_t, x_{j,t})$ are allowed to be purely I(0), purely I(1) or co-integrated [24].

Table 1. Variables definition and summary statistics

Variable	Label	Obs.	Mean	SD	Min.	Max.
Monetary Policy Rate (%)	*MPR*	51	11.387	2.577	6.000	14.000
Cash Reserve Ratio (%)	*CRR*	51	14.304	9.519	1.000	31.000
Standing Lending Facility (%)	*SLF*	51	13.132	2.824	8.000	16.000
Standing Discount Facility (%)	*SDF*	51	7.721	2.671	1.000	11.000
Open Market Operations Sales (₦'Trillion)	*OMOs*	51	1.428	1.592	0.000	7180.61
Deposit Money Banks Closing Balances (₦' Billion)	*DMBs*	51	358.002	239.472	25.210	1133.670

Source: Authors' compilation based on data from the Central Bank of Nigeria (CBN) Statistics

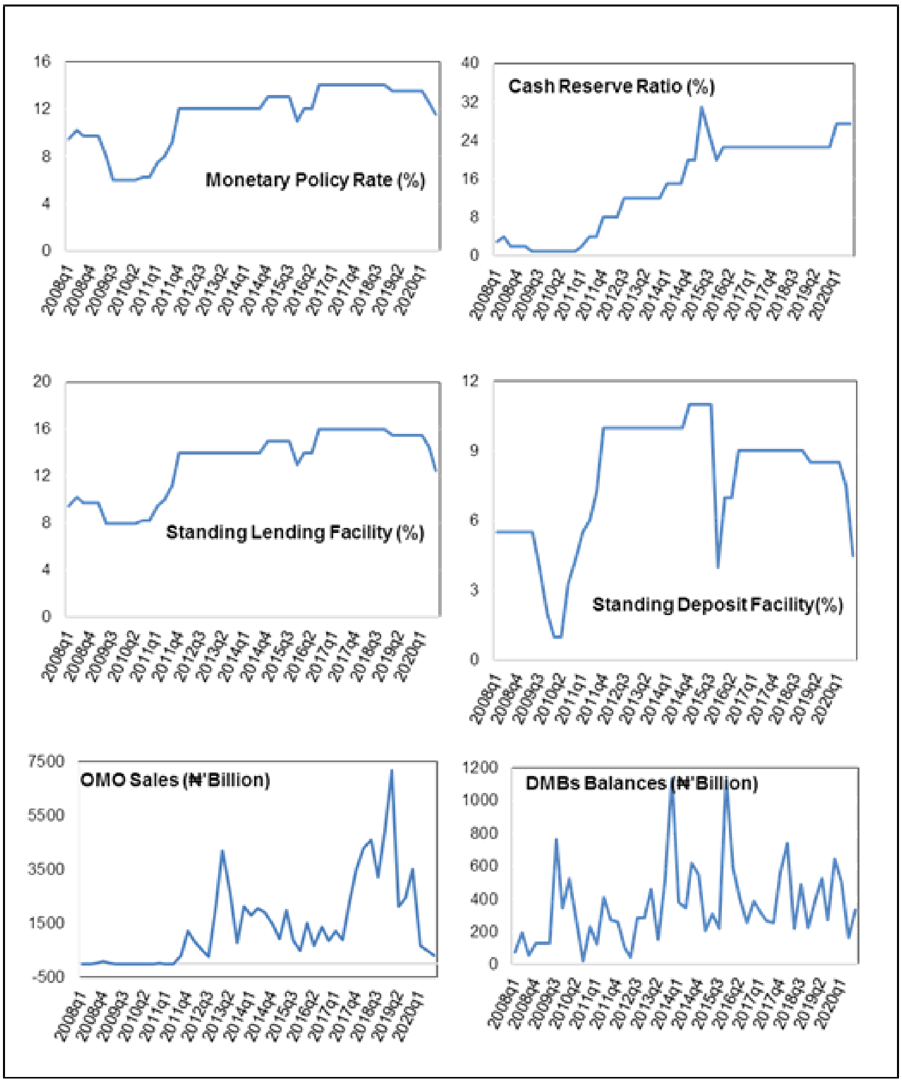

Fig. 5. Trends of the variables used for empirical analysis
Source: Computed by authors based on data sourced from CBN Statistical Database & Statistics Department

The bounds test entails the test for non-existence of long-run relationship among the variables under review. In other words, the bounds test is used to test the null hypothesis which states that no cointegration (i.e., $H_0: \pi_1 = 0; \lambda_j = 0 \; \forall j$) using the Fisher test. Pesaran et al. (2001) provides the critical values for the F-statistics and defines lower and upper bounds, derived from the hypothesis that all variables are I(0) and I(1) respectively. This addresses the non-standard and asymptotic nature of the test statistics. The decision rule is as follows:

- Calculated value of *F*-statistics (or *t*-statistics as applicable) **>** Upper bound: Variables are cointegrated.
- Calculated value of *F*-statistics (or *t*-statistics as applicable) **<** Lower bound: No long-run relationships exist between variables. (Therefore, a short-run ARDL model will be appropriate).

To test for complementarity and/or substitutability of the monetary policy instruments, different versions of Eq. (7) with regards to the number of policy instruments included will be estimated and subjected to Likelihood Ratio (LR) test to arrive at the preferred parsimonious model that passes a range of diagnostics tests.

- *Test for Endogeneity: Toda and Yamamoto Augmented VAR Model.*

In addition to the ARDL model, which may be restricted to a unidirectional analysis, we consider an augmented VAR non-Granger causality procedure related to Toda and Yamamoto [25] to allow for bi-directional interaction of the variables. The bi-directional interactions are very crucial in informing Central Banks' policy directions [26]. The Toda-Yamamoto procedure can analyse time-series that have different stationarity order. It augments the standard VAR by applying asymptotic theory to correct for mixed integrated order so far, the highest integration order does not exceed the VAR lag length order. The key parameters of use in the model to capture any integration order misalignment amid the time-series interactions are the VAR optimal lag length and the maximum integrated order i.e VAR ($k + d_{max}$). The VAR variant of Toda-Yamamoto model is presented as follows:

$$\begin{aligned}
&[y_t \; x_{1t} \cdots x_{nt}] = [\alpha_0 \; \alpha_1 \cdots \alpha_n] + \\
&\textstyle\sum_{i=1}^{k} [\beta_{01} \; \beta_{11} \cdots \beta_{n1} \quad \beta_{02} \; \beta_{12} \cdots \beta_{n2} \quad \cdots\cdots \quad \cdots\cdots \quad \cdots\cdots \quad \beta_{0n} \; \beta_{16} \cdots \beta_{66}][y_{t-i} \; x_{1t-i} \cdots x_{nt-i}] + \\
&\textstyle\sum_{j=1}^{k+d_{max}} [\vartheta_{01} \; \vartheta_{11} \cdots \vartheta_{n1} \quad \vartheta_{02} \; \vartheta_{12} \cdots \vartheta_{n2} \quad \cdots\cdots \quad \cdots\cdots \quad \cdots\cdots \quad \vartheta_{0n} \; \vartheta_{16} \cdots \vartheta_{66}][y_{t-j} \; x_{1t-j} \cdots x_{nt-j}] + \\
&[\varepsilon_{0t} \; \varepsilon_{1t} \cdots \varepsilon_{nt}]
\end{aligned} \tag{8}$$

Where y_t and $x_{n,t}$ are the dependent and explanatory variables respectively. k denotes the optimal lag length determined by Information Criteria. d_{max} is the maximum order of integration. From Eq. (8), Toda-Yamamoto uses modified Wald to test for restrictions on the parameters of lag k VAR and estimate the VAR ($k + d_{max}$) with an asymptotic chi-square distribution and k degree of freedoms in the limit [27]. Thus, the ($k + d_{max}$) becomes the optimal lag used for estimating the model.

3. RESULTS AND DISCUSSION

3.1 Time Series Properties

Following the exposition in subsection 3.2.2, we conduct the unit root tests using ADF and PP tests with and without trend. The results presented in Table 2 indicate that *OMOs* and *DMBs* are stationary at levels. However, all the variables (*DMBs, MPR, CRR, OMOs*, *SLF* and *SDF) are* stationary at first difference under all methods at 1% significance level. With these results, we conclude that *OMOs* and *DMBs are I (0)* variables while *MPR, CRR, SLF* and *SDF* are *I (1)* variables.

Since our variables have mixed stationarity, we test for co-integration using ARDL Bounds test by Pesaran et al [19]. At this stage, five (5) models of eq. 7 (Models A, B, C, D and E) are tested for cointegration and subsequently estimated. These models are estimated to determine which best explains Nigerian Banks' liquidity management. This is with the view to addressing the research question on whether the selected CBN's monetary policy instruments are substitutes or complements for effective management of bank liquidity. We arrived at the five (5) Models by including the regressors cumulatively into each model. Thus, Models A, B, C, D and E contain respectively, 1, 2, 3, 4 and 5 regressors.[3]

The cointegration test outcomes reported in Table 3 show evidence of cointegration among the variables in the Models at all significance levels (i.e., at 1, 2.5, 5 and 10 percent levels). The calculated F-statistics and t-statistics in all cases are respectively higher and lower than the applicable upper-bounds critical values. Therefore, we reject the null hypothesis and conclude that there is a long run relationship between the variables in the respective models. Such long-run relationship can be estimated.

3.2 Diagnostic Tests

Given the existence of cointegration, the ARDL model (Eq. 7) consequent on which the Bounds test is applied, is suitable to estimate both the short- and long-run coefficients and to generate the coefficient of adjustment of integrating the short and long-run dynamics and (or) relationships. Table 4 presents the results of the coefficients and the necessary diagnostics conducted.

First, optimal lag orders for each model as reported in Table 4 are selected based on Akaike Information Criteria (AIC). Secondly, the Durbin Watson and Breusch Godfrey LM tests are carried out to check for first-order autocorrelation and higher-order correlation, respectively. Thirdly, to ensure the validity of the model, Breusch Pagan and Ramsey's RESET tests were carried out to test for homoscedasticity and model specification error of the models. Lastly, the stability of coefficients is verified using graphs to illustrate the cumulative sum of recursive residuals (CUSUM) and cumulative sum of square recursive residuals (CUSUM-Squared).

The results, as presented in table 5 show that, generally, all models fit the data well, passing all diagnostic tests, that is, free from first and higher-order correlation problems, well-specified and free from heteroscedasticity problems. The models are stable as the CUSUM, and CUSUM-squared graphs reported in Appendix a show that all the sum of recursive residuals and recursive squared residuals fall within the 95% level confidence interval.

Finally, to arrive at the preferred model, we conduct restriction tests whereby the five (5) models are tested against each other using the LR test[4]. For each LR test, the model with more regressors is treated as the unrestricted model while the model with fewer regressors is treated as the restricted model. Thus, the null hypothesis for each LR test is that the restriction of a fewer regressor is valid. As such, the policy instruments will be considered complementary if we reject the null hypothesis otherwise, it is taken as a substitute. The LR test results indicate that Model E, which contains all the policy instruments, is preferred to any form of restrictions represented by Models A-D.

Moreover, the adjusted-R2 is satisfactorily high for Model E implying strong evidence that the regressors in model E explain a larger part of banks' liquidity in Nigeria. Thus, we conclude that Model E is the most preferred to assess the effectiveness of monetary policy instruments on bank liquidity in Nigeria. In what follows, we focus our discussion on the estimated coefficients of Model E with some relevant policy and research implications.

3.3 Short-run Effects

For the preferred parsimonious Model E, many of the monetary policy instruments considered with their lagged values are statistically significant in the short run. Table 4 reveals that SLF has an estimated effect of ₦2.62 billion increase in DMBs stemming from a percentage increase in SLF. However, its positive impact on DMBs balances contrasts with economic resonance as an increase in SLF rate should discourage DMBs' recourse to the facility, hence a drop in bank liquidity. The result is closely related to the finding by Augustine et al. [10] where the positive

[3] Specifically, besides DMBs (i.e., dependent variable), Model A, the restrictive model, contains only MPR, Model B contains MPR and CRR regressors, Model C contains MPR, CRR and OMOs regressors, Model D contains MPR, CRR, OMOs and SDF regressors, and finally, Model E is the most unrestricted model that contains all the regressors in the study – MPR, CRR, OMOs, SLF and SDF.

[4] Given that the restriction is on the parameters and the ARDL bounds test reports both the R-squared and log-likelihood values for each of the models, an LR test is suitable to test the restrictions on substitutability or complementarity of the variables. The LR test is expressed as LR(r)=-2LLR-LLU~r2. Where LLUis the log-likelihood value for the unrestricted model; LLR is the log-likelihood value for the restricted model, and r is the number of restrictions on the parameters.

relationship is ascribed to banks' reserves being more than their operational needs.

Consistent with expectations, the SDF showed a negative relationship such that a percentage increase in the current, first lag and second lag rates will cause the DMBs balances to reduce by ₦1.47 billion, ₦1.29 billion, and ₦0.41 billion respectively. The MPR was found to be statistically insignificant at both 10%, 5% and 1% levels. However, its first lag is found to be statistically significant with a ₦1.62 billion increase in bank liquidity balance. Nevertheless, the directions do not conform with expectations.

Although the magnitude of its impact on DMBs is not large, the CRR has a significant negative impact on DMBs in the short run which conforms to a-priori expectation. The estimations show that a percentage increase in CRR would cause about ₦0.39 billion decrease in DMBs balances. While its first lag is largely insignificant, the second lag of CRR accounts for a ₦0.44 billion change in DMBs balances at 5% level. Lastly, the current value, first and second lags of OMO sales have negative impacts on bank liquidity balances. This conforms to a-priori expectations albeit only its second lag is found to be statistically significant with a negligible impact of ₦0.6 million. Similarly, the first lag of DMBs has a positive impact on the current level of DMBs balances though not statistically significant at the conventional levels.

3.4 Long-run Effects

The long-run results also in Table 4 revealed that MPR has a negative impact on DMBs balances – a 1% increase in MPR leads to a ₦1.39 billion decrease in DMBs balances. While this trend may be contrary to expectations, our result corresponds with Chen, Wu, Jeon, & Wang, [28] and [29]. Specifically, Pham et al. [29] in their study on Vietnamese commercial banks, found that the effect of the base rate on creation of liquidity by Vietnamese commercial banks is significant, albeit negative. Their stance that expansionary monetary policy through low interest rates would stimulate a buoyant banking system liquidity corresponds with existing literature, and applicable within the Nigerian context which has a somewhat similar level of financial market development.

Both CRR and SDF indicated a positive impact on DMB balances with a 1% increase leading to a ₦0.19 billion and ₦0.89 billion increase in DMBs balances, respectively. This directional relationship with DMBs balances does not conform to a-priori economic expectation seemingly, due to the long-term impact of persistent injection of interventions. In fact, the choice of policy tool may cause market distortions in some cases. For example, as indicated by IMF [30], In a bid to control exchange rate pressures and inflation in 2011, the CBN increased MPR by 275 bps and CRR to 8%. The Bank further intervened by purchasing bonds totalling ₦2 trillion to correct for impact of their initial policy actions. Thus, injecting liquidity in the banks.

Similar to the short run, the current value of our quantity-based instrument OMO sales as well as SLF rate are largely insignificant in the long-run. The reported value of the Error Correction Coefficient (-1.41) suggests speedy adjustment towards equilibrium. The magnitude of the coefficient of the error correction is similar to the values reported in acceptable extant studies like Persaran and Smith [31], Narayan and Smyth [32], Loayza and Ranciere [33] suggesting oscillatory convergence which adjusts speedily beyond equilibrium at first, then subsequently falls back to equilibrium.

Notably, the long-run impact of MPR, CRR and SDF on bank liquidity level is significant, however, CRR and SDF contrast with a-priori expectations. While we note that some studies have shown interesting results contrary to a-priori expectations (see Abid & Lodhi, [34], further research into this relationship will be welcomed.

3.5 Testing for Endogeneity

The result for the estimated Toda and Yamamoto augmented VAR model (Eq. 8), which deals with issues of possible endogeneity in the model is presented in Table 5 above. It shows that DMBs has independent causality with all the instruments (i.e., MPR, OMO, CRR, SDF and SLF) implying that changes in liquidity do not induce a response from the bank's monetary policy stance. In other words, DMBs balance is statistically insignificant in affecting the monetary policy tools of CBN. This is plausible since the CBN monetary policy ultimate target is inflation suggesting why the Monetary Policy Committee's decisions are based on price level and recently, output.

Table 2. Results of unit root tests of the variables

	ADF				PP				
	Without Trend		With Trend		Without Trend		With Trend		***Decision***
Variables	**Level**	**1st Diff**	**Level**	**1st Diff**	**Level**	**1st Diff**	**Level**	**1st Diff**	
mpr	-1.200	-5.397***	-1.248	-5.352***	-1.435	-5.487***	-1.801	-5.444***	$I(1)$
crr	-0.731	-8.545***	-2.595	-8.468***	-0.550	-8.666***	-2.547	-8.582***	$I(1)$
slf	-1.391	-5.434***	-0.402	-5.529***	-1.496	-5.585***	-0.935	-5.664***	$I(1)$
sdf	-1.791	-6.891***	-1.480	-6.943***	-1.888	-6.903***	-1.623	-6.949***	$I(1)$
omo	2.856*	-8.475***	-3.307*	-8.447***	-2.730*	-9.009***	-3.319*	-9.029***	$I(0)$
$dmbs$	-5.848***	10.540***	-6.161***	-10.444***	-5.822***	-13.141***	-6.123***	-13.068***	$I(0)$

*Notes of the table: 1. The null (H_0) hypothesis for the tests is non-stationary (i.e., unit root) and the alternative hypothesis is level stationary; 2 *, ** and *** indicate 10%, 5% and 1% significance levels respectively; 3. ADF is Augmented Dickey and Fuller; PP is Phillips and Perron; 4. We allowed maximum lengths for both ADF and PP and conducted the test with and without trend*

Table 3. Results of ARDL bounds test for Cointegration

			Model A (with K=1)				
		Critical Values				**Critical Values**	
F-Statistic	Significance	I(0)	I(1)	*t-Statistic*	Significance	I(0)	I(1)
15.017	10%	4.04	4.78	-5.627	10%	-2.57	-2.91
	5%	4.94	5.73		5%	-2.86	-3.22
	2.5%	5.77	6.68		2.5%	-3.13	-3.50
	1%	6.84	7.84		1%	-3.43	-3.82
			Model B (with k=2)				
		Critical Values				**Critical Values**	
F-Statistic	Significance	I(0)	I(1)	*t-Statistic*	Significance	I(0)	I(1)
15.986	10%	3.17	4.14	-6.925	10%	-2.57	-3.21
	5%	3.79	4.85		5%	-2.86	-3.53
	2.5%	4.41	5.52		2.5%	-3.13	-3.80
	1%	5.15	6.36		1%	-3.43	-4.10
			Model C (with k=3)				
		Critical Values				**Critical Values**	
F-Statistic	Significance	I(0)	I(1)	*t-Statistic*	Significance	I(0)	I(1)
11.792	10%	2.72	3.77	-6.864	10%	-2.57	-3.46
	5%	3.23	4.35		5%	-2.86	-3.78
	2.5%	3.69	4.89		2.5%	-3.13	-4.05
	1%	4.29	5.61		1%	-3.43	-4.37

			Model D (with k=4)				
		Critical Values				**Critical Values**	
F-Statistic	Significance	I(0)	I(1)	*t-Statistic*	Significance	I(0)	I(1)
9.972	10%	2.45	3.52	-6.784	10%	-2.57	-3.66
	5%	2.86	4.01		5%	-2.86	-3.99
	2.5%	3.25	4.49		2.5%	-3.13	-4.26
	1%	3.74	5.06		1%	-3.43	-4.60
			Model E (with k=5)				
		Critical Values				**Critical Values**	
F-Statistic	Significance	I(0)	I(1)	*t-Statistic*	Significance	I(0)	I(1)
6.750	10%	2.26	3.35	-6.060	10%	-2.57	-3.86
	5%	2.62	3.79		5%	-2.86	-4.19
	2.5%	2.96	4.18		2.5%	-3.13	-4.46
	1%	3.41	4.68		1%	-3.43	-4.79

Notes of the table: 1. The null hypothesis (H_0) is no cointegration between the variables; 2. K is the number of parameters; 3. The decision rule using F-statistics is to reject the H_0 if the calculated F-statistics is greater than the critical values for I(1) regressors while the decision rule using t-statistics is to reject H_0 if calculated t-statistics is less than the critical value for I(1) regressors [19]

Table 4. Results of ARDL Model of Liquidity Balances in Nigeria

			Dependent Variable: D(DMBs)		
Explanatory Variables:	**Model A**	**Model B**	**Model C**	**Model D**	**Model E**
	Part A: Short Run Effects:				
Constant	210.18	410.52**	446.05**	901.77***	998.57**
	(156.80)	(196.48)	(215.92)	(286.71)	(439.74)
D(DMBs (-1))	-		-	-	0.265
					(0.157)
DMPR	-91.17*		-	108.25	-96.266
	(43.23)			(65.86)	(105.911)
DMPR (-1)			-		161.57**
					(74.83)
DCRR		-23.243*	-22.62*	-33.837*	-38.60**
		(13.387)	(13.74)	(16.84)	(16.85)
DCRR (-1)		-47.7***	-47.75**	-72.367***	-67.74***
		(13.35)	(13.35)	(17.54)	(19.194)
DCRR (-2)	-	-	-	-36.862*	-28.290
				(20.00)	(24.13)
DCRR (-3)	-	-	-	-	-44.31**
					(20.55)
DOMOs	-	-			-0.044
					(0.032)

	Dependent Variable: D(DMBs)				
Explanatory Variables:	**Model A**	**Model B**	**Model C**	**Model D**	**Model E**
	Part A: Short Run Effects:				
DOMOs (-1)	-	-			-0.022 (0.027)
DOMOs (-2)	-	-			-0.058** (0.026)
DSDF	-	-		-130.521*** (45.70)	-147.66*** (47.97)
DSDF (-1)	-	-	-		-129.36** (50.26)
DSDF (-2)	-	-	-		-41.81 (29.08)
DSLF	-	-	-		262.61** (111.05)
Error Correction Adjustment *(DMBS (-1))*	-0. 8.26*** (0.146)	-0.945*** (0.136)	-0.950*** (0.138)	-1.03*** (0.197)	-1.407*** (0.212)
	Part B: Long-Run Effects:				
MPR	14.293 (17.824)	-14.726 (26.458)	-19.675 (27.257)	-136.92*** (40.069)	-139.553** (59.39)
CRR	-	10.155 (6.978)	10.393 (7.032)	22.380** (7.692)	19.09** (8.294)
OMOs	-	-	0.0111 (0.0265)	0.018 (0.022)	0.025 (0.021)
SDF	-	-	-	98.79*** (73.209)	89.55*** (24.44)
SLF	-	-	-	-	21.577 (61.20)
	Models Characteristics:				
Information Criteria	AIC	AIC	AIC	AIC	AIC
Lag Order	(1.1)	(1,0,2)	(1,0,2,0)	(1,1,3,0,1)	(2,2,4,3,3,1)
No of Obs.	47	49	47	47	47
R^2	0.496	0.597	0.600	0.7142	0.827
Adjusted R^2	0.461	0.5482	0.5389	0.6348	0.700
Log-Likelihood	-320.43	-315.20	-315.100	-307.14	-295.29

	Dependent Variable: D(DMBs)				
Explanatory Variables:	**Model A**	**Model B**	**Model C**	**Model D**	**Model E**
	Part A: Short Run Effects:				
	Models Diagnostics Tests:				
Breusch Godfrey LM test	0.877	0.632	0.697	0.6225	0.4363
DW-Test	1.673	1.803	1.841	1.812	1.749
Ramsey Reset Test	0.625	0.14	1.54	0.250	0.9167
Breusch-Pagan Test	0.538	0.274	0.1834	0.239	0.1043
Cusum & Cusum^2 Tests	Within Limits	Within Limits	Within Limits	Within Limits	Within Limits
	***LR* test of Complementarity/Substitutability of Variables:**				
Model A vs. B	-	10.47***	-	-	-
Model B vs. C	-	-	0.200	-	-
Model A vs. C	-	-	10.68	-	-
Model C vs. D	-	-	-	15.91***	-
Model A vs. D	-	-	-	26.58***	-
Model B vs. D	-	-	-	16.11***	-
Model A vs. E	-	-	-	-	50.30***
Model C vs. E	-	-	-	-	39.62***
Model B vs. E	-	-	-	-	39.82***
Model D vs. E	-	-	-	-	23.71***

Notes of the table:

1. Standard errors, i.e., *, ** and *** are 10, 5 & 1% levels of significance respectively
2. DW-Test is Durbin-Watson d-statistics for 1st order autocorrelation (i.e., correlated residual)
3. Breusch Godfrey LM test for higher-order autocorrelation (i.e., serial autocorrelation)
4. Ramsey Reset Test for omitted variables (i.e., model specification error)
5. Breusch-Pagan $|^2$ Test for homoscedasticity (i.e., constant variance)
6. Cusum and Cusum^2 Test for the stability of the estimated parameters and the Model

Table 5. Results of T-Y Modified Multi-Variate Non-Granger Causality Test

		Dependent Variable: DMBs			
Independent Variable	***Lag*** K	***Lag*** $K + d_{max}$	***Chi-Sq.***	***Prob***	***Causality Outcome***
MPR	*1*	*1+1*	*2.240093*	*0.3263*	≠
OMOs	*1*	*1+1*	*0.245799*	*0.8844*	≠
CRR	*1*	*1+1*	*2.548159*	*0.2797*	≠
SDF	*1*	*1+1*	*4.103381*	*0.1285*	≠
SLF	*1*	*1+1*	*3.462662*	*0.1770*	≠

Notes of the table: The Lag ($K + d_{max}$) represents augmented VAR lag order. The Lag (K) selection criterion is based on SIC which reveals optimal lag length to be 1. ≠ denotes no that the dependent does not cause the independent variables and vice versa.

4. CONCLUSION AND POLICY IMPLICATIONS

This research work examines the effectiveness of various quantity- and price-based monetary policy instruments of the Central Bank of Nigeria which are essential in achieving its statutory mandate. In addition, it assesses the combination of the instruments on bank liquidity, providing an intuition on whether they are complements or substitutes.

The study adopts time-series data approach with quarterly data sourced for the period 2008Q1-2020Q2. It employs ARDL Bounds test in carrying out analysis of the existence of a connection between the quantity- and price-based policy instruments, and liquidity level and examines the impact of the former on the latter. Deposit money banks' balance is used to proxy liquidity level. Monetary policy rate, cash reserve ratio, standing lending facility rate and standing deposit facility rate are disaggregated components used as price-based instruments while OMO sales are used as the quantity-based instrument.

The empirical results reveal that all the monetary policy instruments and bank liquidity level share similar movements that may be linked to form equilibrium long-run relationship. Also, both long-run and short-run impacts of the instruments on bank liquidity balances are found to be mostly significant. The LR test reveals that the unrestricted model that contains all the policy instruments are preferred to any form of restricted model. Thus, all the five monetary policy tools considered in this study are complementary. The results offer interesting responses to the first and second research questions as highlighted in the introduction – monetary policy instruments have significant effect on banks' liquidity position in the Nigerian economy and complement each other.

In terms of the relative impacts of monetary policy instruments on banks' liquidity position, the price-based instruments are relatively more effective in managing liquidity in Nigeria. Other than MPR and SLF which are found to be insignificant in short-run and long-run respectively, all other price-based tools impact liquidity in both time profiles. However, MPR, Cash Reserve Ratio and Standing Deposit Facility rate demonstrated contradictory impacts in the long-run, defying a-priori expectations. Our quantity-based instrument, i.e., OMO sales show that its current value has insignificant impact in both periods but its lagged values have a negligible but statistically significant impact on bank liquidity. The inconsistent results between the short- and long-run impacts perhaps are because the policy instruments are often used as a short-run measure.

Several policy implications emerge from this study. First, for the short-run dynamics, though the current value of OMO sales is non-impacting, its previous values remain vital for liquidity management. Thus, CBN should continue to use these instruments as complements to other tools. Secondly, CBN should reassess the disbursement of interventions and their implications on liquidity. Lastly, while studies (including this study) have shown that MPR pass-through to other rates and macroeconomic variables is slow and incomplete, it remains crucial in determining liquidity. Thus, the CBN should continue its use as a monetary policy instrument. Nonetheless, a continuous review of its operationality to identify and reduce possible distortions may be beneficial.

DISCLAIMER

This paper represents the views of the authors and does not necessarily reflect those of the Central Bank of Nigeria (CBN).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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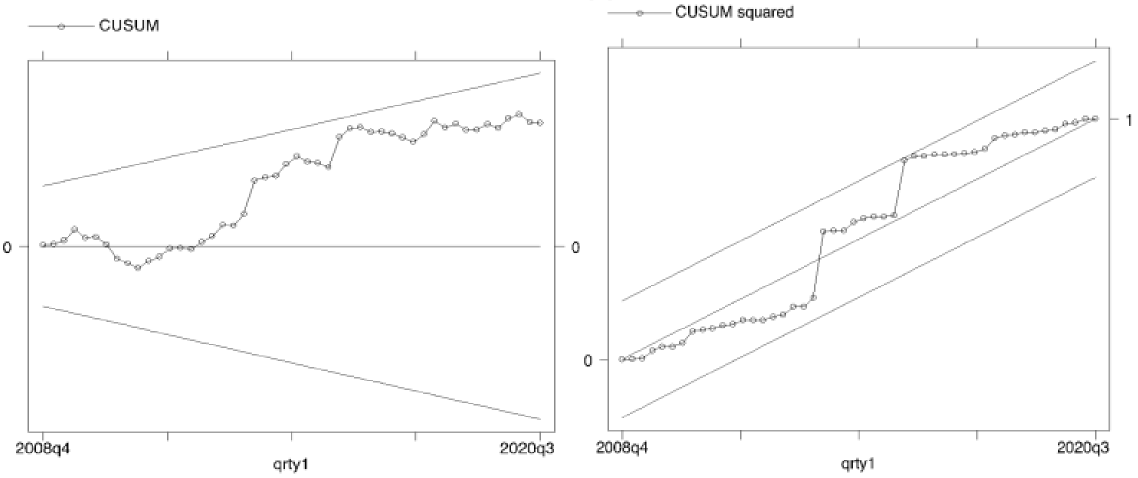
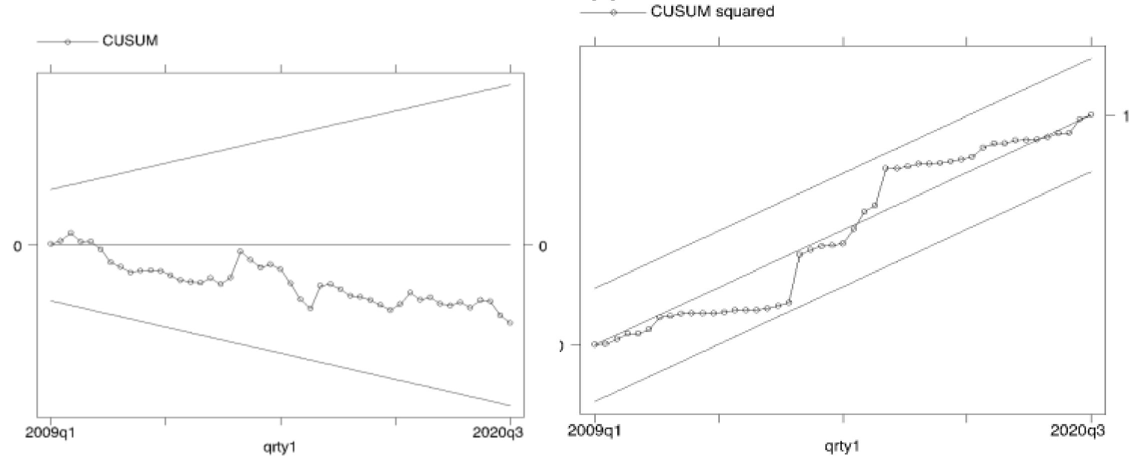
APPENDIX

A. Stability Test Results

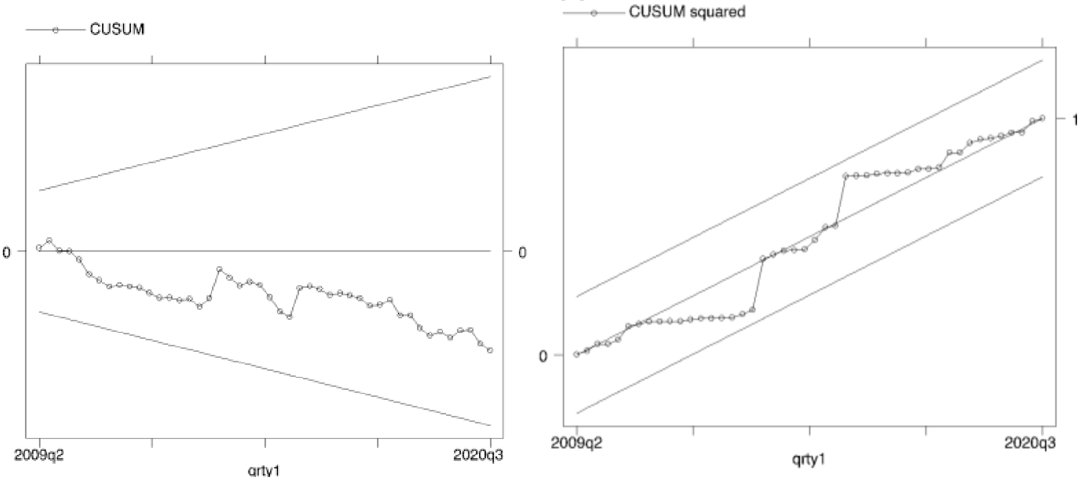
Model A – Two (2) Variables



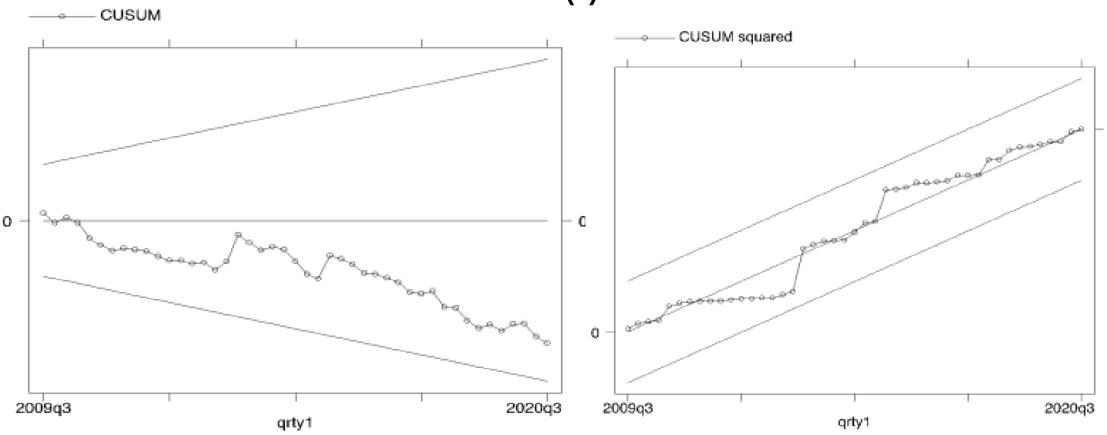
Model B – Three (3) Variables



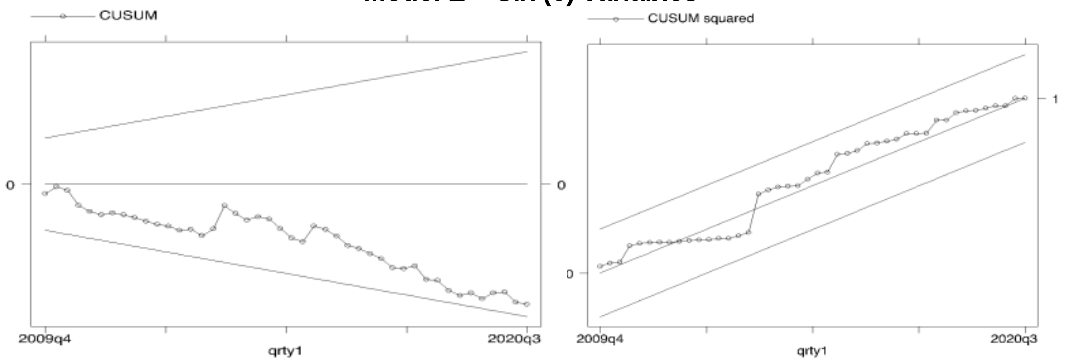
Model C – Four (4) Variables



Model D – Five (5) Variables



Model E – Six (6) variables



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