Domestic Interest Rate and Capital Inflows Policy in Nigeria

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ABSTRACT: The implementation of sterilization policy has been noted to raise domestic interest rates as it is designed to lower money supply. This occurs due to the inverse relationship between money supply and interest rates, with a rise in interest rates attracting additional inflows into the economy, putting pressure on monetary authorities. The verification of this hypothesis in the Nigerian context formed the motivation for this study. The main purpose of this study is to investigate whether sterilization policy actually raises domestic interest rates in Nigeria. Using a monthly dataset from 2010M1 to 2021M3 and the ARDL estimation technique, total sterilization serves as a proxy for sterilization policy, while the treasury bills rate proxies the domestic interest rate. Findings reveal that sterilization policy has a positive and significant impact on domestic interest rates in both the short-run and long-run. Additionally, money supply negatively affects domestic interest rates in the short-run, while world interest rates have a negative and significant impact on domestic rates in both the short and long runs.

JEL classification: E4, E5, P2.

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1 Introduction

The term "capital inflows" refers to the influx of resources into an economy, which can take various forms, such as foreign direct investment (FDI), foreign portfolio investment (FPI), remittances, external loans, and more. In countries like Nigeria, where revenue constraints are recurrent, capital inflows provide an important source of income. In recent years, Nigeria has attracted substantial inflows due to various factors, including reforms put in place (Audu et al., 2020; Jume, 2021). The sources of capital inflows in Nigeria include FDI, foreign loans, FPI, remittances, and official development assistance (**?**). While capital inflows are crucial for many economies, they can lead to instability in the macroeconomic environment if not properly managed. This is because such inflows tend to increase the domestic money supply through the accumulation of foreign currency (Ansari et al., 2023). Blanchard et al. (2015) noted that global shocks to capital flows represent a significant policy challenge for economies with open capital and financial accounts. Similarly, Adrian (2018) identified three major risks associated with capital inflows: financial stability risks, macroeconomic risks, and the potential for sudden reversals of capital flows, especially equity capital flows.

A short-run macroeconomic risk of a surge in capital inflows is the excessive expansion of aggregate demand. When a country maintains an officially determined exchange rate, its commitment to defend the parity requires the monetary authorities to intervene in the foreign exchange market by purchasing the foreign exchange generated by capital inflows. This intervention creates high-powered domestic money, which can lead to a corresponding expansion in broad money supply, thus lowering domestic interest rates and increasing aggregate demand. Additionally, the risk of a sudden reversal in capital inflows can have negative consequences for both financial stability and economic activity.

To mitigate the adverse monetary impacts of capital inflows, policymakers in various countries have adopted measures to reduce their economies' vulnerability. Kawai and Takagi (2008) identified three broad categories of macroeconomic measures available to countries facing surges in capital inflows: sterilization, exchange rate flexibility, and fiscal tightening. However, conventional sterilization policies, which involve the issuance of bonds, are typically prioritized due to their timeliness and relatively low political interference (Yan and Yang, 2008). Takagi and Esaka (2001) noted that sterilization policies are designed to offset the effects of reserve inflows on the monetary base through measures such as open market sales of domestic securities and increases in reserve requirements.

The Central Bank of Nigeria (CBN) focuses on price stability as its primary monetary policy objective, which explains the increasing reliance on sterilization policies, especially during periods of intense capital inflows. However, by reducing the money supply, sterilization policies can also lead to a rise in domestic interest rates, creating a policy dilemma. Cavallino and Hofmann (2022) noted that higher interest rates can attract further capital inflows into an economy. Ooi (2008) also observed that the issuance of short-term sterilization bonds might actually encourage capital inflows, potentially undermining the success of sterilization efforts. This can create a cycle where foreign investors, motivated by higher domestic interest rates, increase their investments, placing additional pressure on monetary authorities (Ljubaj et al., 2010). Moreover, a rise in domestic interest rates raises the cost of capital, which negatively affects productivity. High interest rates have been a long-standing issue in Nigeria, with producers often struggling to secure funding from commercial banks. Thus, if sterilization policies lead to an increase in domestic interest rates, the difficulties faced by domestic investors may worsen. This study aims to assess whether sterilization policies exert upward pressure on domestic interest rates in Nigeria, as has been observed in other contexts. Given that interest rates are a particularly sensitive issue in Nigeria, mainly due to the persistently high inflation rate, this study holds particular relevance.

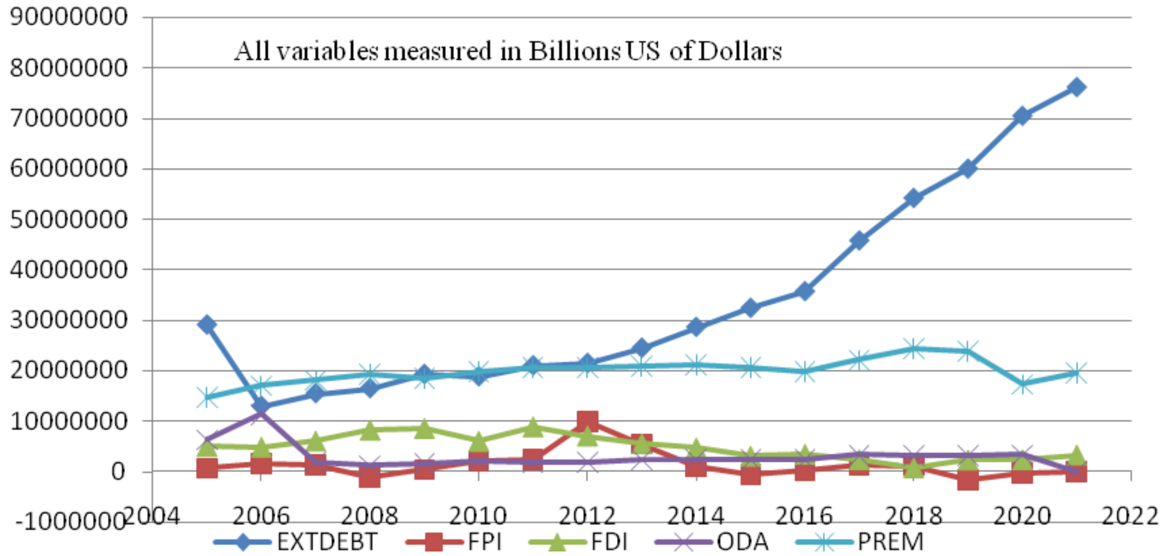
Nigeria is one of the largest economies in Africa, with the highest GDP in 2013 after its economy was rebased. It is also a major destination for capital inflows, which brings both benefits and challenges due to their volatility. Nigeria, like many African nations, requires capital inflows to bridge revenue gaps. However, the potential negative effects of volatile capital inflows mean that such countries must implement policies to manage their economies effectively. This study suggests that if sterilization policies are found to attract more capital inflows by raising domestic interest rates, the insights gained could be valuable for other African countries with similar economic structures. Scholars like Ljubaj et al. (2010) have argued that sterilization policies can increase capital inflows by raising domestic interest rates, but there is a significant gap in the literature to support this claim. This study aims to fill this gap by investigating the impact of sterilization policies on the treasury bills rate, which is directly influenced by the sale of sterilization bonds. The findings could provide valuable policy guidance for Nigeria and other African nations facing significant capital inflows.

The remainder of the paper is structured as follows. Section 2 discusses stylized facts related to the variables used in the study. Section 3 reviews relevant literature. Section 4 outlines the estimation method adopted. Section 5 presents the framework of analysis. Section 6 provides the research findings and discussions. Section 7 offers conclusions.

2 Some stylized facts

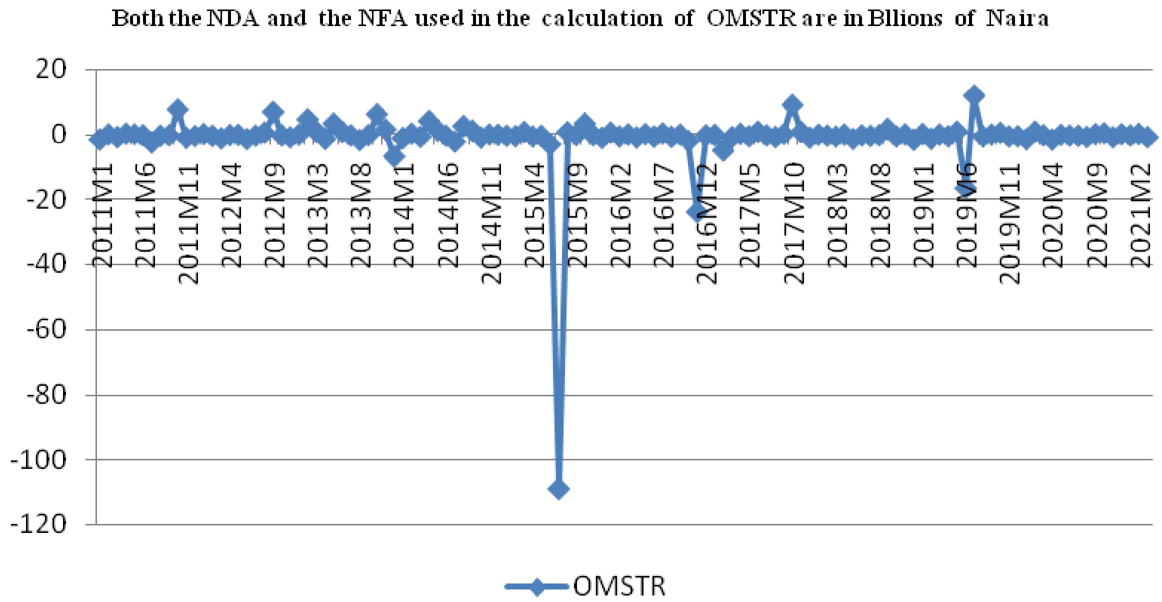
Figure 1 shows the sources of capital inflows in Nigeria. It can be observed that, during the sample period, external debt increased more than other sources of inflows starting from 2013. The decline in external debt before 2013 could be attributed to the debt relief granted to the country in 2005. Following external debt, remittances showed slight growth between 2017 and 2019. In contrast, FDI was higher than FPI up to 2012, when both reached a peak. The increase in FDI and FPI in 2012 could be due to investor confidence following the peaceful election that ushered in a new civilian regime. Official development assistance (ODA) has remained sluggish throughout the sample period.

Figure 1: Sources of capital inflows in Nigeria



Note: EXTDEBT – external debt, FPI – foreign portfolio investment, FDI – foreign direct investment, ODA – official development assistance, PREM – personal remittances. Source: World Development Indicators (2021).

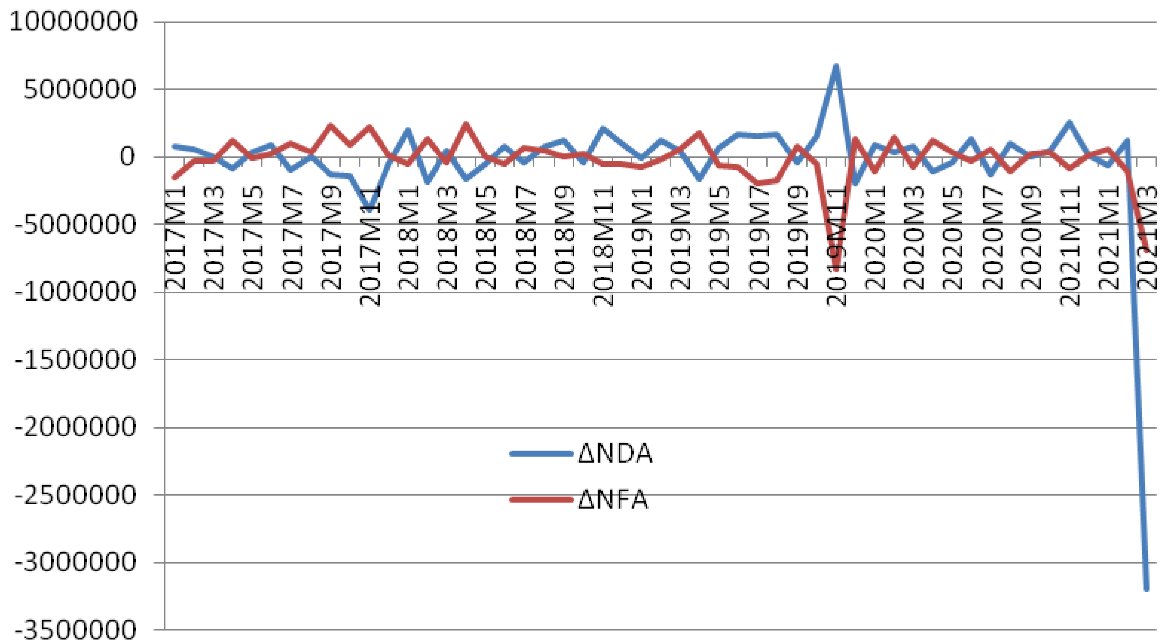
Figure 2: Movement in monthly open market operation (OMO) sterilization ratio



Note: OMSTR – OMO sterilization ratio. Source: CBN Statistical Bulletin (2021).

To provide insight into how sterilization exercises are carried out, the study uses a diagram to show the movement of the monthly OMO sterilization ratio by the Central Bank of Nigeria (CBN) from January 2011 to February 2021. The OMO sterilization ratio is calculated as $\frac{\Delta \text{NDA}}{\Delta \text{NFA}}$, following Lavigne (2008). Figure 2 shows the monthly fluctuations in the OMO sterilization ratio manipulated by the monetary authorities in Nigeria between 2011 and 2021. In October 2010, there was an increase in the use of OMO sterilization, as seen from the spike in the trend. Further evidence of increased OMO sterilization can be observed in September 2012, February, May, and October 2013, and April 2014. However, in July 2015, there was a sharp decline in OMO sterilization due to falling inflows during that period. A similar decline in OMO sterilization occurred in August 2016 and May 2019. Between October 2017 and July 2019, OMO sterilization measures were increasingly utilized, after which the trend stabilized. It should be noted that a lack of commitment to sterilized interventions results from low capital inflows. The depletion of foreign reserves caused by low capital inflows, a current phenomenon in Nigeria, explains the reduction in sterilized interventions, particularly after 2019. Moreover, open market sterilization is just one component of sterilization measures in Nigeria, as other measures - such as changes in the cash reserve ratio - are also employed. This could account for the relatively low spikes in the OMO sterilization trend.

Figure 3: Sterilization exercise of the CBN from 2017M1-2021M2

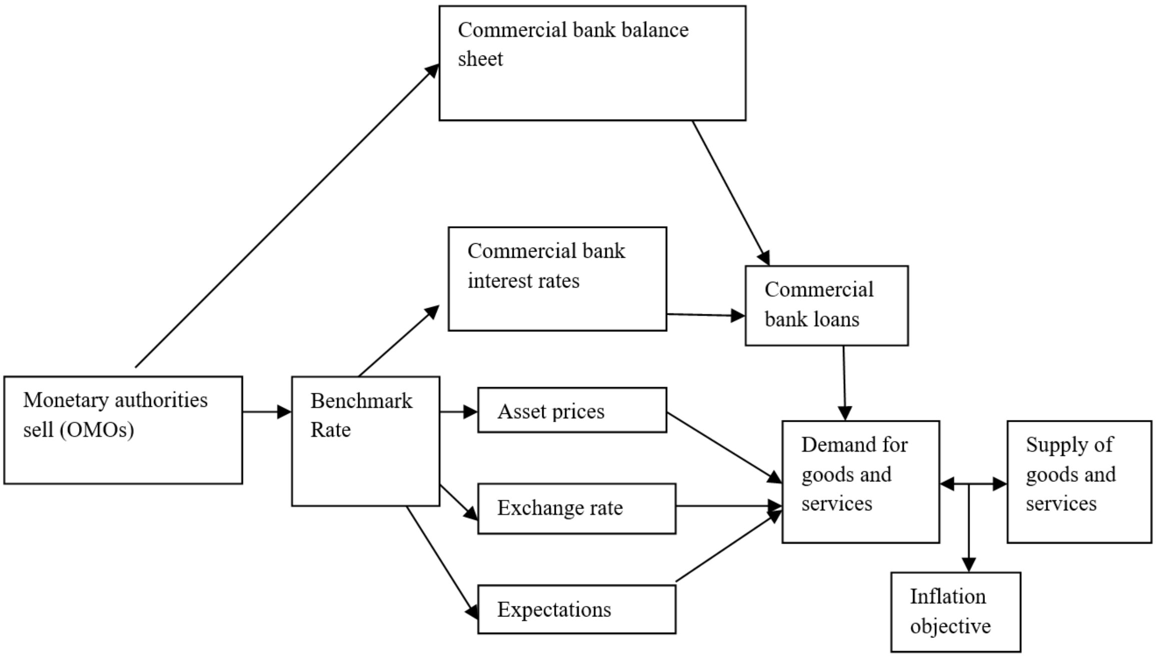


Note: ΔNDA – change in the net domestic assets (NDA), ΔNFA – change in the net foreign assets (NFA).
Source: CBN Statistical Bulletin (2021).

In a similar vein, the study provides a diagram illustrating the actual sterilization exercises carried out by the monetary authorities, where the NDA is manipulated to influence the NFA. Figure 3 presents a scenario that explains the recent sterilization measures implemented by the CBN. Operationally, monetary authorities conduct sterilization activities by reducing the NDA when the NFA is rising, in order to neutralize the destabilizing impact of the increasing NFA on the domestic economy. The reverse occurs when capital inflows fall. As NFA increased in September and November 2017, the monetary authorities responded by reducing the NDA. Similarly, between February and April 2018, as NFA rose, the NDA was also lowered. However, when NFA declined in January and November

2018 and between July and November 2019, the NDA increased. The figure shows that, starting from 2019, the decline in NFA led to a reduced commitment by the monetary authorities to undertake sterilization exercises, as evidenced by the sharp rise in NDA during that period. The study suggests that part of the reason for the drop in inflows during this time was the impact of the COVID-19 pandemic, which disrupted economic activities globally.

Figure 4: Transmission channels of monetary policy sterilization

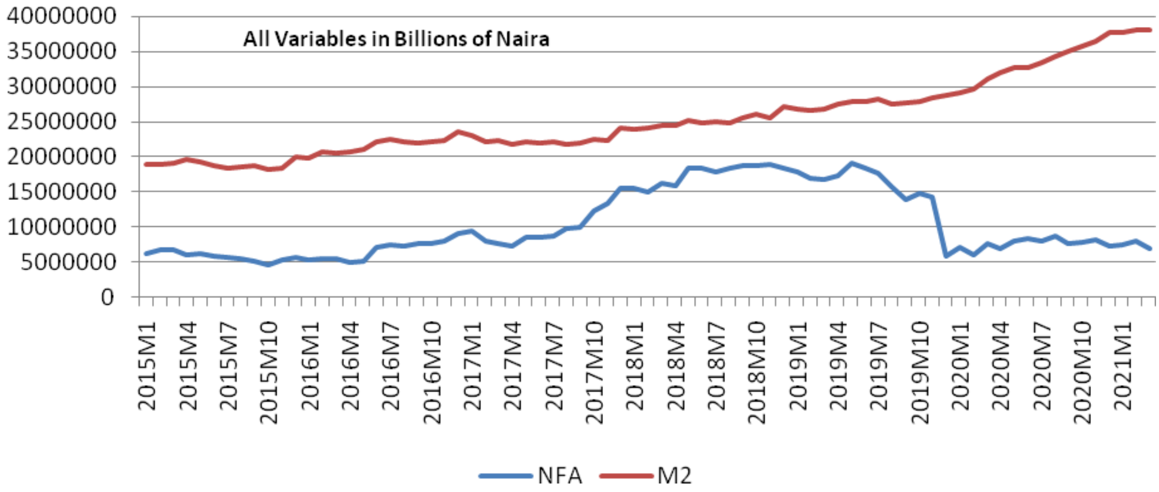


Source: Authors' compilation with some adaptation from Mannathoko (2020).

Figure 4 depicts the transmission channels for monetary policy sterilization, showing how sterilization interacts with other economic variables. As the monetary authorities sterilize inflows, changes in the benchmark rate (monetary policy rate in Nigeria) are expected to influence commercial bank interest rates, asset prices, and, ultimately, the demand for the local currency, which in turn affects the nominal exchange rate. Consequently, people's expectations regarding future interest rates and economic growth also influence asset prices and the demand for the local currency to purchase assets and securities. Large sales of foreign exchange by the authorities to sterilize anticipated inflows are likely to affect commercial bank balance sheets and their willingness to lend. As credit increases, demand for goods and services rises, which in turn affects the supply of goods and services and contributes to inflationary pressures.

The effect of capital inflows is primarily to increase the money supply, which then affects other macroeconomic variables. To illustrate this, Figure 5 shows the relationship between NFA and broad money supply (M2). The data reveal that both NFA and M2 follow similar trends over the sample period. For example, both variables declined marginally in July

Figure 5: Monthly trend in NFA and M2 in Nigeria



Source: CBN Statistical Bulletin (2021).

2015 and peaked in July 2016. Another peak occurred in December 2016, after which both variables declined through 2017 before gradually increasing again in December. The near-co-movement of these two variables suggests that when capital inflows rise, money supply increases, and when inflows fall, money supply declines. However, in 2019, when NFA sharply dropped, the money supply did not follow the same trend. This indicates that the rise in NFA, associated with capital inflows, was a key driver of the rapid growth in money supply during the capital inflow episode. The expansion in monetary aggregates caused by capital inflows underscores the need for sterilization policies to mitigate their impact on the macroeconomic environment. The CBN remains aware of this and is prepared to intervene to prevent excessive capital inflows from overheating the economy.

3 Theoretical issues

Over the years, capital inflows and their effects on the economy have garnered significant theoretical interest among scholars. The theoretical framework proposed by Edwards and Khan (1985) modifies the conditions for money market equilibrium to incorporate the effects of sterilization of capital inflows. This model evaluates the effectiveness of sterilization policies in exerting upward pressure on domestic interest rates, thereby maintaining interest rates at the level that prevailed before the capital inflows. It assumes that as capital mobility increases, domestic interest rates will be influenced more by external factors; however, as capital mobility decreases, domestic variables will exert greater influence over domestic interest rates. Similarly, Cumby and Obstfeld (1983) developed a theoretical model to estimate the monetary policy reaction function, which in turn quantifies the degree of sterilization. This model derives the monetary policy reaction function by assuming that the central bank neutralizes (or sterilizes) the monetary effects of capital inflows by adjusting its net domestic assets (NDA). The model posits that the reserve money created by the central bank through exchange rate intervention will lead to zero reserve money if the central bank uses its monetary policy instruments to withdraw the reserve money created. Consequently, any increase in NFA will be offset by a reduction in NDA. A key limitation of this theory is its reliance on the existence of developed financial institutions and an independent central bank.

Montiel (1999) introduced the overheating theory, which focuses on the real appreciation of the domestic currency that could ultimately weaken the current account. According to the theory, capital inflows - regardless of their composition - imply a surplus in the financial account. In the absence of an equivalent deficit in other parts of the balance of payments, and under a fixed exchange rate regime, the central bank would intervene to prevent the nominal appreciation of the currency. This intervention would lead to the accumulation of reserves, which would increase the monetary base. As a result, money supply would rise, which in turn would drive higher domestic demand and ultimately lead to overheating and a deterioration of the current account.

The signaling channel theory, as described by Sarno and Taylor (2001), suggests that intervention impacts exchange rates by providing the market with new, relevant information. The theory operates under the implicit assumption that authorities have superior information compared to market participants and are willing to reveal this information through their actions in the foreign exchange market. Sterilized intervention affects exchange rates through the signaling channel because private agents adjust their exchange rate expectations. This shift occurs either because agents revise their views about future actions of the monetary authorities or because they reassess the effects of certain actions by the authorities. The core idea is that exchange rate intervention is seen as a signal of the future stance of monetary policy. As exchange rates are forward-looking variables, a shift in expectations regarding future movements in factors like relative money supply will influence the current exchange rate.

Several studies have empirically examined the measures implemented by central banks to shield their domestic economies from the adverse effects of capital inflows. Khushik et al. (2015) explored the extent to which the Central Bank of Pakistan sterilizes the impact of changes in net foreign assets (NFA) on the domestic monetary base. The study found that the central bank partially sterilized its foreign exchange operations. Similarly, a study on Algeria by Djedaiet and Ayad (2017) provided evidence of full sterilization by the Algerian central bank. For BRICS nations - Brazil, Russia, India, China, and South Africa - Sunny and Unnikrishnan (2017) revealed that all member countries undertook partial sterilization, although the degree varied across countries. In a broader analysis of emerging market economies, Ponomarenko (2019) observed that increases in central banks' NFA resulted in lower interbank interest rates, indicating incomplete sterilization with expansionary effects on the real sector. Agénor et al. (2020) suggested that sterilized interventions could have expansionary effects through a bank portfolio mechanism, potentially increasing financial instability and volatility risks in an open-economy context. Meanwhile, Hoang et al. (2020) showed that the State Bank of Vietnam (SBV) was unable to fully neutralize the influence of capital inflows on domestic money supply during foreign exchange market interventions. The study also highlighted that capital inflows were highly responsive to changes in domestic monetary conditions.

Focusing on 28 emerging market economies, Arya et al. (2020) demonstrated that greater exchange rate fixity, when combined with sterilized interventions, could encourage capital inflows, amplifying their effects. In Nigeria, Nzeh et al. (2020) found that the Central Bank of Nigeria's (CBN) sterilization policy effectively regulated money supply and curtailed capital inflows during both normal and high-inflow periods. This was corroborated by Jume (2021), who reported that the CBN successfully offset 95% of capital inflows during the analysis period, exceeding the findings of Nzeh et al. (2020). In Pakistan, Khushik et al. (2021) revealed sterilization degrees of -0.18, -0.20, and -0.19 across three econometric frameworks, aligning with earlier findings by Khushik et al. (2015). For India, Rishad et al. (2022) showed that the central bank successfully sterilized 93% of its interventions, with capital mobility recorded at 72% during the study period. Karahan and Bayır (2022), examining Brazil, China, Turkey, and Poland, found that pre-COVID-19 expansionary monetary policies, which reduced interest rates, spurred increased foreign direct investment (FDI) inflows. In contrast, Nzeh et al. (2021) reported that in Nigeria, sterilization policies initially led to an increase in the prime lending rate in the short run, but eventually caused a decline after a lag period.

4 Methodology

The COVID-19 pandemic significantly impacted the macroeconomic environment, potentially influencing the implementation of sterilization policy in Nigeria. The study hypothesized the presence of structural breaks, prompting the inclusion of a dummy variable in the model. To detect structural breaks, the study first examined the graph of net foreign assets (NFA) to identify potential disruptions in the series and determine the timing. This step aimed to ascertain whether capital inflows, as represented by NFA, experienced shocks during the study period that could affect sterilization efforts. The NFA graph, depicted in Figure 4, revealed a sharp break in October 2019, suggesting potential structural breaks in the model. To formally confirm this, the study employed the cumulative sum (CUSUM) of squares test to identify outliers. If the CUSUM of squares statistic deviates beyond the critical bands of the 5% confidence interval for parameter stability, it indicates the presence of outliers. This test was further corroborated using the Chow breakpoint test to pinpoint structural breaks within the identified period. Under the null hypothesis of no structural breaks, rejection implies their existence in the model. The series' order of integration was assessed using the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The autoregressive distributed lag (ARDL) model was then applied to estimate short- and long-run coefficients. Optimal lags for the ARDL estimation were selected using the Akaike information criterion (AIC), Schwarz criterion (SC), and Hannan-Quinn criterion (HQ). Post-diagnostic tests were conducted to ensure the validity of the results.

The study utilized monthly data spanning January 2010 to March 2021. Most variables were sourced from the Central Bank of Nigeria's Statistical Bulletin, except for the US Federal Funds rate, obtained from the Federal Reserve Bank of St. Louis. The treasury bill rate, expressed as a percentage, served as a proxy for the domestic interest rate due to its sensitivity to capital inflows (refer to Figure 6). Total sterilization, measured in billions of naira, was used as a proxy for sterilization policy due to its direct influence on deposit money banks' reserve positions (Lavigne, 2008). Broad money supply (M2), also in billions of naira, represented the domestic money supply, while the inflation rate, measured in percentage terms, captured price levels. The exchange rate was expressed as the nominal naira-to-dollar value. World oil prices, represented by the price of Bonny Light crude in billions of naira, served as a proxy for expected inflation (Vinayagathasan, 2013). The US Federal Funds rate, measured as a percentage, was used as a proxy for global interest rates (Kim and Roubini, 2000). For normalization and easier interpretation, variables such as money supply, exchange rate, total sterilization, and world oil prices were logarithmically transformed.

5 Framework of analysis

To provide a quantitative framework for managing capital inflows through policy intervention, Cumby and Obstfeld (1983) introduced the estimation of a monetary policy reaction function to determine the degree of sterilization. The monetary policy reaction function is expressed as:

$$\Delta \text{NDA} = \alpha_1(\text{CA} + \text{K}) + Y^1 x_t \tag{1}$$

where: ΔNDA - change in the net domestic assets, α_1 - degree of sterilization, CA - current account balance, K - capital account balance, and x_t - vector of other variables that could also affect monetary policy actions.

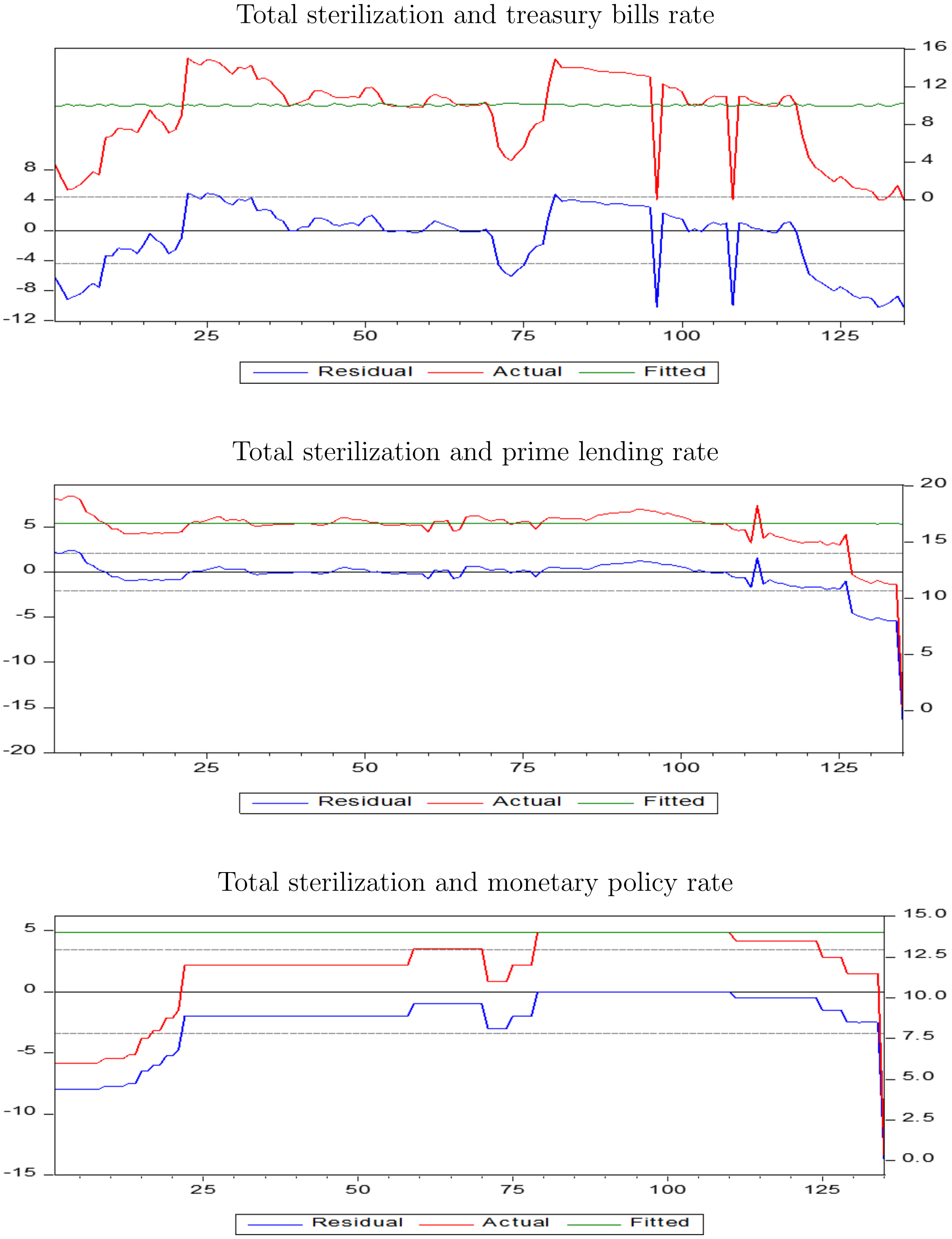
Since the balance of payments requires that the sum of the current and capital account balances $(\text{CA} + \text{K})$ equals the change in net foreign assets (ΔNFA), approximated by the change in international reserves, the equation can be simplified to:

$$\Delta \text{NDA} = \alpha_1 \Delta \text{NFA} + Y^1 x_t \tag{2}$$

This simplified function defines α_1, known as the *sterilization coefficient*, which ranges from -1 to 0:

- If $\alpha_1 = -1$, the sterilization policy fully offsets the monetary effects of capital inflows, ensuring no impact on the domestic money supply.

Figure 6: Relationship between total sterilization and key economic rates



- If $\alpha_1 = 0$, the policy has no sterilization effect, leaving reserve money entirely in the market.
- Intermediate values suggest partial sterilization, where the monetary impact is only partially neutralized.

Building on this work, Edwards and Khan (1985) developed a theoretical framework analyzing the link between sterilization and domestic interest rates. The model modified the money market equilibrium condition by incorporating the effects of sterilized intervention. A refinement by Cavoli (2005) formalized this relationship as follows:

$$i_t = \lambda i_t^* + (1 - \lambda)\tau_t \tag{3}$$

where: $0 < \lambda < 1$.

Equation (3) demonstrates that the domestic interest rate (i_t) is a weighted average of international monetary conditions (i_t^*) and domestic monetary conditions (τ_t). The parameter λ captures the degree of capital mobility, while i_t^* is determined by uncovered interest parity (UIP). Cavoli (2005) further defined the shadow interest rate (τ_t) as:

$$\tau_t = \eta + \Pi_{t+1}^e + \delta(m_t^d - m_t) \tag{4}$$

where: η - constant term, Π_{t+1}^e - expected future inflation rate, and $(m_t^d - m_t)$ - monetary disequilibrium, weighted by δ (a full equilibrium real interest rate).

The sterilization of capital inflows and its effect on the money stock is captured by the following equation:

$$\Delta M_t = (1 + \phi)\Delta F_t \tag{5}$$

where: ΔM_t - change in the money supply, ϕ - sterilization coefficient ($\phi \leq 0$), and ΔF_t - change in the net foreign assets (proxy for capital inflows). Expressing equation (5) in log differences leads to:

$$\Delta m_t = (1 + \phi)\Delta f_t \tag{6}$$

By substituting equation (6) into equation (4) and incorporating other explanatory variables, the domestic interest rate (i_t) can be expressed as:

$$i_t = \phi_0 + \phi_1 i_t^* - \phi_2 \Delta f_t - \phi_3 m_{t-1} + \phi_4 \Pi_{t+1}^e + \phi_5 p_t + \phi_6 y_t \tag{7}$$

where: i_t - domestic interest rate, i_t^* - foreign interest rate, Δf_t - change in the net foreign assets, m_t - money supply, Π_{t+1}^e - expected inflation rate, p_t - price level, y_t - national income, and $\phi_0, \phi_1, \phi_2, \ldots$ - coefficients capturing the relationship between variables.

The baseline model used to investigate the impact of sterilization policy on the domestic interest rate, modified from Cavoli (2005), is specified as:

$$TBR_t = f(M2_t, TSTR_t, INFLR_t, EXCHR_t, WOP_t, WINT_t) \tag{8}$$

where: TBR_t - treasury bills rate, $M2_t$ - broad money supply, $TSTR_t$ - total sterilization, $INFLR_t$ - inflation rate, $EXCHR_t$ - exchange rate, WOP_t - world oil price, and $WINT_t$ - world interest rate.

The formula for total sterilization, adapted from Lavigne (2008), is given by:

$$TSTR = \frac{\Delta RD - \Delta NDA}{\Delta NFA} \tag{9}$$

where: $TSTR$ - total sterilization, ΔRD - change in reserve deposits, ΔNDA: change in the net domestic assets, and ΔNFA: change in the net foreign assets.
The ARDL model used for estimating results is specified as:

$$\begin{aligned}
\Delta TBR_t = \alpha_0 &+ \sum_{j=1}^{k} \beta_i \Delta TBR_{t-1} + \sum_{j=1}^{k} \xi_i \Delta TSTR_{t-1} + \sum_{j=1}^{k} \rho_i \Delta M2_{t-1} \\
&+ \sum_{j=1}^{k} \upsilon_i \Delta INFLR_{t-1} + \sum_{j=1}^{k} \tau_i \Delta EXCHR_{t-1} + \sum_{j=1}^{k} \theta_i \Delta WOP_{t-1} \\
&+ \sum_{j=1}^{k} \kappa_i \Delta WINT_{t-1} + \delta_1 TBR_{t-1} + \delta_2 TSTR_{t-1} \\
&+ \delta_3 M2_{t-1} + \delta_4 INFLR_{t-1} + \delta_5 EXCHR_{t-1} + \delta_6 WOP_{t-1} \\
&+ \delta_7 WINT_{t-1} + \delta_8 \mathrm{Dum}_t + \mu_t
\end{aligned} \tag{10}$$

where: Dum_t - takes the value 0 for 2010M1–2019M12 and 1 for 2020M1– 2021M3, and μ_t - error term.
The short-run parameter coefficients are denoted as: $\beta, \xi, \rho, \upsilon, \tau, \theta,$ and κ, while the long-run parameter coefficients are represented by: $\delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6, \delta_7,$ and δ_8.
The null hypothesis for determining whether the series are co-integrated is specified as:

$$H_0 : \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = 0 \quad \text{(No co-integration).}$$

This is tested against the alternative hypothesis:

$$H_1 : \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq \delta_7 \neq \delta_8 \neq 0 \quad \text{(Presence of co-integration).}$$

If the series are found to be co-integrated, the following error correction model is specified:

$$\begin{aligned}
TBR_t = \alpha_0 &+ \sum_{j=1}^{k} \beta_i \Delta TBR_{t-1} + \sum_{j=1}^{k} \xi_i \Delta TSTR_{t-1} + \sum_{j=1}^{k} \rho_i \Delta M2_{t-1} \\
&+ \sum_{j=1}^{k} \upsilon_i \Delta INFLR_{t-1} + \sum_{j=1}^{k} \tau_i \Delta EXCHR_{t-1} + \sum_{j=1}^{k} \theta_i \Delta WOP_{t-1} \\
&+ \sum_{j=1}^{k} \kappa_i \Delta WINT_{t-1} + \varphi ECM_{t-1} + \mu_{2t}
\end{aligned} \tag{11}$$

where: ECM_{t-1} - error correction model, and φ - coefficient of the error correction model.

The results from the descriptive test presented in Table 1 show that there is evidence of closeness between the mean and the median of all the variables. This suggests that the distributions of the variables are symmetric. A distribution is considered symmetric when the values of the variables occur at regular frequencies, with the median, mean, and mode typically coinciding at the same point. Among the variables, the inflation rate has the highest mean, with a mean value of 12.06 and a standard deviation of 2.98. On the other hand, the variable with the lowest mean is total sterilization, which has a mean value of 0.69 and a standard deviation of 5.02. Treasury bills rate was found to have the highest range among the variables during the sample period, indicating the highest volatility in comparison to other variables. Conversely, total sterilization has the smallest range, suggesting that it exhibited the least volatility during the period. In terms of skewness, it was found that the treasury bills rate, total sterilization, and foreign interest rate are negatively skewed (i.e., they are skewed to the left), while the remaining variables are positively skewed (i.e., they are skewed to the right). Regarding kurtosis, evidence suggests that all the variables are heavy-tailed, as indicated by their positive kurtosis values.

Table 1: Descriptive statistics

	TBR	TSTR	M2	EXCHR	INFLR	WOP	WINT
Mean	9.05	0.69	7.28	2.39	12.06	6.99	1.57
Median	10.13	4.30	7.27	2.34	11.70	4.98	1.57
Maximum	15.00	6.32	7.58	2.69	18.72	17.45	2.49
Minimum	0.00	−7.02	7.01	2.18	7.70	4.31	0.50
Std. dev.	4.27	5.02	0.15	0.18	2.98	4.68	0.53
Skewness	−0.75	−0.25	0.05	0.13	0.44	1.74	−0.00
Kurtosis	2.45	1.16	2.04	1.28	2.33	4.06	1.81
Jarque-Bera	14.60	20.36	5.24	16.87	6.92	74.87	7.88
Probability	0.00	0.00	0.07	0.00	0.03	0.00	0.01
Observations	135	135	135	135	135	135	135

In this study, a stationarity test was conducted to determine the order of integration of the series using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The results are analyzed under the null hypothesis of non-stationarity, which is tested at the 5% critical value. The null hypothesis is rejected if the t-statistic is less than the critical value; otherwise, it is not rejected. Table 2 summarizes the results of the stationarity tests conducted at both levels and at first differences. The findings reveal that all the series, except total sterilization, exhibited non-stationarity at level under both the ADF and PP tests. This can be observed from the respective t-statistics, which are higher than the critical values. However, after taking the first difference, all the series became stationary, indicating that they were integrated of order one, i.e., I(1).

Before examining the impact of sterilization on the domestic interest rate, the study first checked for the presence of structural breaks in the model. To do this, the study initially plotted the graph of the cumulative sum of squares (CUSUM) to investigate

Table 2: Results of unit root tests at level and first difference

Variables	ADF (level)	PP (level)	ADF (first diff.)	PP (first diff.)	Order of integration
TSTR	−3.97*	−10.01*	−6.43*	−9.10*	$I(0)$
TBR	−2.11	−2.53	−16.22*	−17.14*	$I(1)$
EXCHR	−0.29	−0.21	−8.48*	−8.48*	$I(1)$
INFLR	−1.58	−1.46	−5.06*	−12.16*	$I(1)$
M2	2.29	2.29	−11.57*	−11.61*	$I(1)$
WINT	−1.51	−1.66	−55.61*	−41.11*	$I(1)$
WOP	0.40	0.45	−11.47*	−11.47*	$I(1)$

Note: Asterisks (*) indicate rejection of the null hypothesis at the 5% level.

possible outliers in the model. Following this, a formal test was conducted using the Chow breakpoint test for structural breaks, specifically within 2019, which was identified as the breakpoint period. The graph in Figure 7 shows that the CUSUM of squares statistic falls outside the critical bands of the 5% confidence interval, indicating that the model is unstable. To formally confirm this result, the Chow breakpoint test results in Table 3 reveal that at the 5% level of significance, the null hypothesis of no structural break is rejected. This further proves the presence of a structural break in the model. Consequently, the inclusion of a dummy variable in the ARDL model is warranted to adjust for the identified instability.

Figure 7: CUMSUM of squares

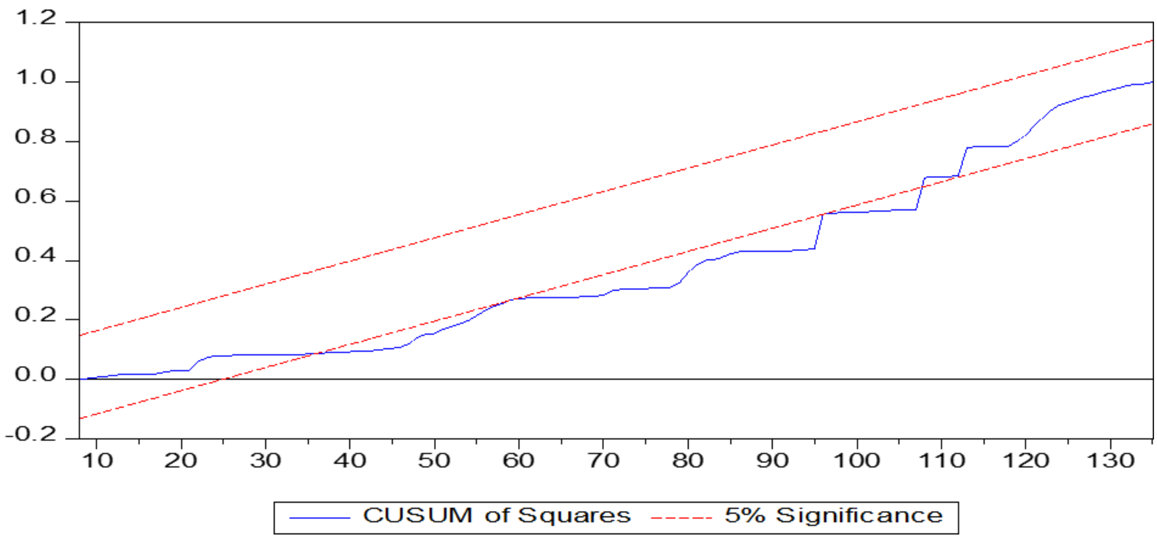


Table 3: Chow breakpoint test of structural breaks

Test statistic	Value	Test	Prob.
F-statistic	15.88	F(7,121)	0.00
Log likelihood ratio	88.00	Chi-square(7)	0.00
Wald statistic	111.22	Chi-square(7)	0.00

6 Research findings and discussions

The optimal lag length selected for the estimation of the ARDL model, based on the three commonly used information criteria, is lag 1, as shown in Table 4.

Table 4: Lag order selection results

Lag	LogL	LR	FPE	AIC	SC	HQ
1	471.3	NA	2.26*	−6.41*	−4.98*	−5.83*
2	501.89	53.34	3.87	−5.88	−3.02	−4.72
3	535.83	55.04	6.38	−5.41	−1.11	−3.66
4	559.88	35.98	1.26	−4.78	0.94	−2.45
5	618.79	80.70	1.49	−4.70	2.46	−1.79
6	666.71	59.62	2.21	−4.45	4.14	−0.95
7	717.28	56.54	3.34	−4.24	5.79	−0.16
8	815.74	97.68*	2.60	−4.78	6.68	−0.12

Note: * - 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, and HQ - Hannan-Quinn information criterion.

The findings in Table 5 reveal that, in the short run, total sterilization has a positive and statistically significant impact on treasury bills, with a significance level of 10%. Specifically, a one-unit increase in total sterilization results in a 0.06% rise in the treasury bills rate. Conversely, the study shows that money supply negatively and significantly impacts the treasury bills rate. A one-unit increase in money supply leads to a 54.76% decrease in the treasury bills rate. Furthermore, the world interest rate is found to have a negative and significant impact on the treasury bills rate. A one-percent increase in the world interest rate results in a 49.68% fall in the treasury bills rate. While most other variables do not significantly affect the treasury bills rate, the coefficient of the dummy variable is statistically significant. The coefficient of the error correction model (ECM) is negative and significant at the 5% level, satisfying the condition for co-integration. The ECM results suggest that approximately 30% of the errors generated in each period are corrected by the system in the subsequent period. In the long run, total sterilization continues to exert a positive and significant impact on the treasury bills rate. A one-unit increase in total sterilization leads to a 0.20% rise in the treasury bills rate. However, the world interest rate negatively impacts the treasury bills rate, with a one-percent increase in the world interest rate reducing the treasury bills rate by 161.99% in the long run. While the dummy variable's coefficient remains significant, the other variables are not found to have a significant long-run impact on the treasury bills rate. The significant coefficient of the dummy variable indicates that it effectively accounts for the instability in the model over the long term.

Overall, the results demonstrate that total sterilization has a positive and significant impact on the treasury bills rate in both the short and long run. This suggests that

Table 5: Results of estimated coefficients

Variable	Coefficient	Std. error	t-statistic	Prob.
Short-run Results				
D(TSTR)	0.06	0.03	1.70	0.09
D(M2)	−54.76	16.90	−3.23	0.00
D(EXCHR)	−1.37	5.27	−0.26	0.79
D(INFLR)	0.09	0.13	0.68	0.49
D(WOP)	−0.09	0.07	−1.33	0.18
D(WINT)	−49.68	18.83	−2.63	0.00
D(DUM)	−2.42	1.12	−2.15	0.03
D(@TREND())	0.63	0.26	2.42	0.01
CointEq(-1)	−0.30	0.058	−5.22	0.00
Long-run Results				
TSTR	0.20	0.12	1.66	0.09
M2	44.93	35.76	1.25	0.21
EXCHR	−4.47	17.04	−0.26	0.79
INFLR	0.29	0.42	0.69	0.48
WOP	−0.31	0.23	−1.36	0.17
WINT	−161.99	60.08	−2.69	0.00
DUM	−7.90	3.27	−2.40	0.01
C	−189.96	257.91	−0.73	0.46
@TREND	2.06	0.82	2.51	0.01

Dependent variable: TBR.

the efforts of monetary authorities to neutralize the monetary impact of capital inflows through sterilization have led to an increase in domestic interest rates during the study period, which aligns with prior expectations. These findings support the view held by some scholars that sterilization policies can lead to higher domestic interest rates, thus attracting more capital inflows. For instance, Arya et al. (2020) found that sterilized interventions led to high capital inflows in 28 emerging market economies. Similarly, Nzeh et al. (2021) showed that sterilization policies raised domestic interest rates during their study period, which is consistent with the present study's findings. However, these results contrast with those from Brazil, China, Turkey, and Poland, where Karahan and Bayır (2022) found that monetary policies implemented before COVID-19, which reduced interest rates, attracted more foreign direct investment (FDI). The study suggests that the type of capital inflows into a country should determine the effect of changes in interest rates induced by sterilization measures. Specifically, the impact on foreign portfolio investment differs from that on FDI.

In the short run, money supply is found to negatively and significantly impact the treasury bills rate. This suggests that rising money supply creates liquidity in the banking system, which forces domestic interest rates to fall, aligning with prior expectations and consistent with Nzeh et al. (2021) findings. World interest rate was also found to negatively impact the treasury bills rate in both the short and long run, contrary to expectations. A rise in world interest rates is typically expected to push domestic interest rates higher, as higher global rates may reduce foreign capital inflows and cause domestic investors to channel investments abroad. This dynamic reduces money supply, depreciates the currency, and leads to higher domestic interest rates.

Inflation rate was found to positively impact the treasury bills rate, although the impact is not statistically significant. Rising inflation generally triggers measures to reduce money supply, such as bond sales or increases in the cash reserve ratio, which can lead to higher interest rates. This result is consistent with Nzeh et al. (2021). Lastly, world oil prices were found to negatively impact the treasury bills rate, although this result is not significant. Rising oil prices often lead to increased money supply, which can reduce domestic interest rates. The lack of significance may be attributed to recent fluctuations in oil prices.

Table 6 presents the post-diagnostic test results, which indicate the robustness of the model. The study cannot reject the null hypothesis of no heteroskedasticity, as evidenced by a p-value of 0.14, which exceeds the 5% significance level. Similarly, the null hypothesis of no serial correlation cannot be rejected at the 5% significance level, given a p-value of 0.08. Regarding model specification, the results indicate that the model is well specified. The null hypothesis of a correctly specified model cannot be rejected, as the p-value of 0.21 is greater than the 5% threshold. The stability tests confirm the model's robustness. Both the CUSUM and CUSUM of squares tests, shown in Figure 8, indicate that the model is stable, with their plots falling within the critical bands of the 5% confidence interval for parameter stability. This stability implies that including the dummy variable successfully addressed the model's instability. However, the normality test results, shown in Figure 9, suggest that the null hypothesis of normally distributed error terms can be rejected.

Table 6: Post-diagnostic results

Test	p-value
Heteroskedasticity test: ARCH	0.14
Serial correlation: Breusch-Godfrey LM test	0.08
Model specification: Ramsey RESET test	0.21

7 Conclusions

This study investigated the impact of sterilization policy on domestic interest rates, with a focus on its role in preventing overheating of the domestic economy caused by capital inflows. The study was motivated by the hypothesis that sterilization, by reducing money supply, tends to raise domestic interest rates. The findings confirm this hypothesis, showing a significant positive impact of sterilization policy on treasury bills rates. This indicates that investors respond swiftly to changes in domestic interest rates induced by sterilization measures, carrying important policy implications. If sterilization

Figure 8: CUMSUM plots

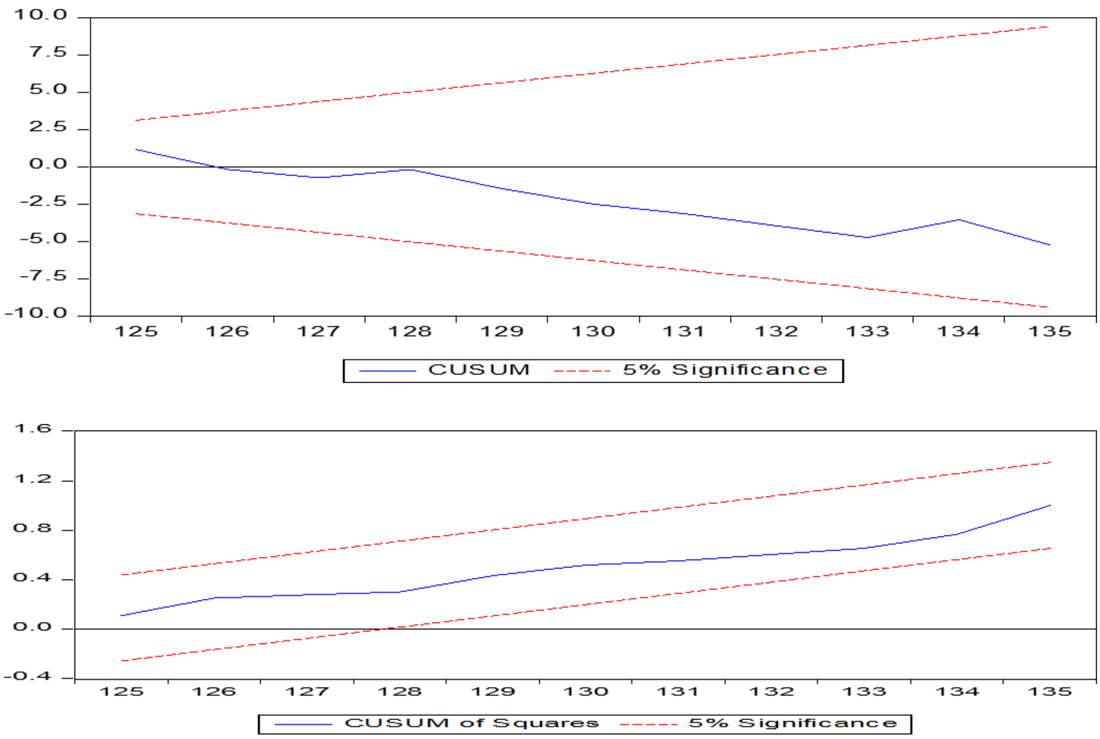
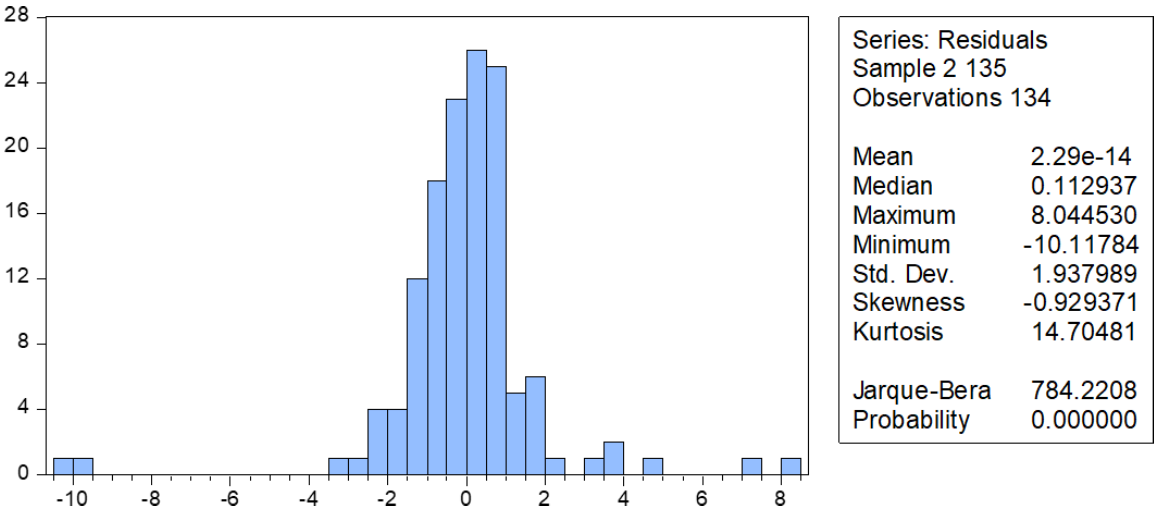


Figure 9: Normality test results



policy increases domestic interest rates, it imposes future debt repayment burdens for the bonds issued to absorb excess inflows. For monetary authorities, the risk of capital reversal induced by such policies can disrupt monetary policy management, undermining any short-term economic gains and posing challenges to macroeconomic stability. To prevent unintended adverse effects in Nigeria and other African countries, the study offers several recommendations.

First, policymakers should critically evaluate the choice of measures used to mitigate the destabilizing impact of capital inflows. Since bond issuance under sterilization raises domestic interest rates, leading to further rounds of sterilization and pressure on monetary authorities, less costly and less distortionary alternatives, such as fiscal tightening, should be considered during periods of rising capital inflows.

Second, in Nigeria and other African nations, high levels of debt and associated servicing costs already constrain public investment in essential infrastructure. Continued reliance on bond issuance for sterilization could exacerbate the debt burden, potentially leading to a cycle of perpetual indebtedness. Policymakers should therefore prioritize strategies that avoid escalating fiscal pressures.

Third, to minimize the risks of abrupt capital reversals associated with short-term sterilization instruments, monetary authorities should diversify the maturity structure of debt instruments. Extending maturity periods encourages longer-term investment in the economy. Increasing the domestic ownership of bonds can further reduce risks of sudden capital outflows and associated macroeconomic distortions.

Finally, the results of this study offer valuable lessons for other African countries experiencing volatile capital inflows. Adopting sustainable and strategic approaches to managing capital inflows can safeguard macroeconomic stability while avoiding adverse long-term consequences for fiscal and monetary systems.

8 Disclosure statement

The authors declare that they have no relevant or material financial interests that could have influenced the research described in this paper.

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