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Abstract

This study used the vector autoregressive (VAR) method to investigate how the monetary variables responded to the Central Bank of Nigeria's implementation of the sterilization policy. The study used monthly series that spanned the period from 2010M1 to 2021M3. The variables used are broad money supply (proxied by M2), Treasury bills rate, inflation rate, exchange rate and total sterilization. The data for all the series were obtained from the CBN Statistical Bulletin, except for data on foreign interest rates, which was obtained from the Federal Bank of St Louis. Findings revealed that money supply, exchange rate and inflation rate responded negatively to shocks in sterilization policy in all the periods. The response of Treasury bills rate to shocks in total sterilization was positive up to period two. However, the response became negative after period two. Consequently, the study concludes that the monetary variables responded appropriately to the policy adopted to neutralize the impact of capital inflows in Nigeria. The study recommends that the use of sterilization policy should be complemented with other policies to avoid repeated rounds of sterilization and that domestic investment outlets have to be developed to attract more local investors in the event of a rising domestic interest rate.

Keywords: *Inflation rate, interest rate, money supply, exchange rate, sterilization policy*

JEL Classification: *E31, E43, E51, F31*

1. Background to the Study

Recently, many countries have realized the importance of capital liberalization as a measure to attract capital inflows. Mostly, developing countries whose revenue sources are not well-diversified consider capital inflows as alternative sources of funds to complement the shortfalls in revenues (Nzeh *et al.,* 2021). In Nigeria, inflows from the oil sector form a large part of capital inflows in addition to other sources such as foreign direct investment inflows, portfolio investment inflows, diaspora remittances, *etc.* (Adekunle & Sulaimon, 2018). Capital inflows fluctuate often owing to several factors which are mostly not controlled by recipient countries. Whether capital inflows rise or fall, there are attendant macroeconomic consequences that require policy interventions to address. For instance, if capital inflows rise, this leads to an increase in the monetary aggregates, exchange rate appreciation and a rise in the general price level (Adrian, 2018).

On the other hand, a fall in capital inflows results in a lower money supply, a rise in domestic interest rate, exchange rate depreciation and other macroeconomic consequences. Due to the fluctuating tendency of capital inflows, monetary authorities usually intervene in order to neutralize the monetary impact of these phenomena. Several monetary policy measures are usually employed to stabilize the economy from the adverse impact of fluctuating capital inflows.

Policy options to achieve this objective include fiscal tightening, exchange rate intervention and sterilization (Kawai & Lamberte, 2008). However, the sterilization policy has been noted as the most effective among the policy measures meant to cushion the effects of growing capital inflows (Bazot, Monnet & Morys, 2019). Sterilization has been operationally defined as the sale of domestic assets by central banks to offset an increase in the monetary base due to the purchase of foreign assets (Hashmi *et al.,* 2011). As Takagi and Esaka (1999) noted, sterilization policy entails measures fashioned out to neutralize the monetary impact of capital inflows through the open market sales of domestic securities and/or raising the reserve requirements. The theoretical underpinning guiding the implementation of sterilization policy was put forward by Kouri and Porter (1974), in which the coefficient of net foreign assets measures the degree of sterilization. The theory assumes that if the coefficient of net foreign assets equals minus one, the supply of money arising from capital inflows remains unchanged after the implementation of the sterilization policy. On the other hand, if the coefficient is close to zero, the policy affects the overall money supply by reducing it, implying that the policy effectively reduces the money supply arising from capital inflows.

Following the stated theory, the sterilization exercise is technically conducted through the change in the net domestic assets (NDA) to influence the change in the net foreign assets (NFA). Rising capital inflows entail an increase in the NFA, so in order to insulate the domestic economy from the destabilizing effects of such phenomenon, the monetary authorities will react by reducing the NDA, which could take the form of open market sale of debt instruments and or raising the reserve requirement. While net foreign assets are defined as the sum of foreign assets held by monetary authorities and deposit money banks, less their foreign liabilities, net domestic assets comprise the sum of claims on government, deposit money banks and the private sector less its liabilities to them, which includes domestic credit and other net items. Therefore, the coefficient of net foreign assets has been used extensively in the literature to capture sterilization policy. However, a major shortcoming of this approach is that since net foreign assets represent capital inflows, its coefficient is not robust enough to be used as a proxy for sterilization policy. The argument here is that since the NFA represents capital inflows, using its coefficient as a proxy for sterilization is synonymous with investigating the impact of capital inflows on any monetary policy variable and such will end up concealing the real effect of sterilization policy on such variables. In this present study, an effort was made to use total sterilization to capture sterilization policy (which incorporates the net foreign assets, net domestic assets and bank reserves) as has been put forward by Lavigne (2008) instead of the coefficient of sterilization that has been commonly used in literature.

The effectiveness of sterilization over other policy measures that prompted this present study to adopt it is that it is timely and, in most cases, requires no political intervention, which is usually associated with most policy issues (Yan & Yang, 2008). In Nigeria, the Central Bank of Nigeria (CBN) is the agency responsible for implementing monetary policy, with inflation targeting being its major policy objective. As noted earlier, sterilization policy is practically conducted by influencing net domestic assets (NDA) to neutralize the impact of the change in net foreign assets (NFA). The NFA represents

capital inflows in a country, so if it changes, the monetary authorities will influence the domestic assets at their disposal to stabilize the economy. A typical example is selling bonds through the open market operation (OMO) during rising capital inflows or buying bonds during falling capital inflows.

The effectiveness of sterilization policy is evaluated if the policy can influence some monetary variables in the desired direction. Since the main consequences of rising capital inflows are domestic currency appreciation and an increase in money supply, which transmits to domestic prices and interest rates, the extent to which sterilization policy influences these variables should form the prism under which the policy is evaluated. Consequently, the policy is expected to reduce the money supply and, hence, the inflation rate, which will reduce domestic currency appreciation. A major issue confronting monetary policy authorities in Nigeria and other countries in their quest to sterilize rising capital inflows is the tendency for rising domestic interest rates, which usually puts the monetary authorities in a dilemma. If the sterilization policy succeeds in reducing the money supply, it will raise the domestic interest rate. With a rise in domestic interest rates concerning foreign interest rates, investors will be lured to push more capital into the domestic economy, leading to a further round of sterilization (Ljubaj, Martinis, & Mrkalj, 2010). Apart from this possibility, the question is whether the actual sterilization policy in Nigeria effectively reduces the money supply because of the role of the fiscal authorities. Fiscal authorities have become habitual in the country to engage in an expansionary fiscal stance. In contrast, monetary authorities use contractionary policy measures, which usually frustrate the latter's sterilization effort.

This study investigated how monetary variables such as money supply, domestic interest rate, and others react to the sterilization policy's implementation to evaluate the policy's effectiveness in Nigeria. This is a departure from previous studies that focused mainly on finding the degree of sterilization. Such studies include Okpanachi (2013), Nzeh *et al.* (2020) and Jume (2021) for Nigeria. For studies outside Nigeria, such studies include, among others, Djedaiet and Ayad (2017), Ponomarenko (2019), Arya, Cavoli, and Onur (2020) and Khushik, Hashmi and Shaikh (2021). This present study argues that the degree of sterilization cannot indicate the effect sterilization policy has on individual monetary variables, and thus, manipulating these variables to address the changes posed by capital inflows will be impossible without knowing how they interact with sterilization policy. Also, because of the dynamic nature of the relationship between sterilization policy and the monetary policy variables, limiting the study to only the impact of sterilization on any macroeconomic variable as done by few studies such as Elhendawy (2015) cannot address the possible reverse causality arising from monetary variables to sterilization policy. This study, therefore, used the VAR framework to capture the response of monetary variables to the implementation of the sterilization policy. The VAR method allows for the treatment of the variables as endogenous in a way that accommodates the variables' effect on one another. Thus, the possibility of a reverse causality arising from monetary variables or sterilization policy implementation can be examined. The study obtained the impulse response function and variance decomposition through the VAR to evaluate the relationship between sterilization policy and the monetary variables. The major strength of the VAR method is that it handles feedback arising from the implementation of the sterilization policy, such as the possibility of the monetary variables influencing the implementation of sterilization policy and vice-versa.

1.1 Stylized Facts on Some Variables

At this juncture, the study examines the link between capital inflows represented by the NFA and some relevant monetary variables in Nigeria. Beginning from the link between the NFA and money supply, evidence from Figure 1 shows that both the NFA and broad money supply (M2) maintained a similar trend over the sample period. In July 2015, both variables exhibited marginal decline and peaked in July 2016. In December 2016, they also attained another peak, declining from 2017 until when they marginally rose. The fact that the two variables move in similar directions indicates that the money supply rises for every rise in capital inflows, and for every decline in capital inflows, the money supply declines. By implication, it is proper to state that the rise in NFA associated with capital inflows somehow caused the rapid growth of the money supply during the capital inflows episode.

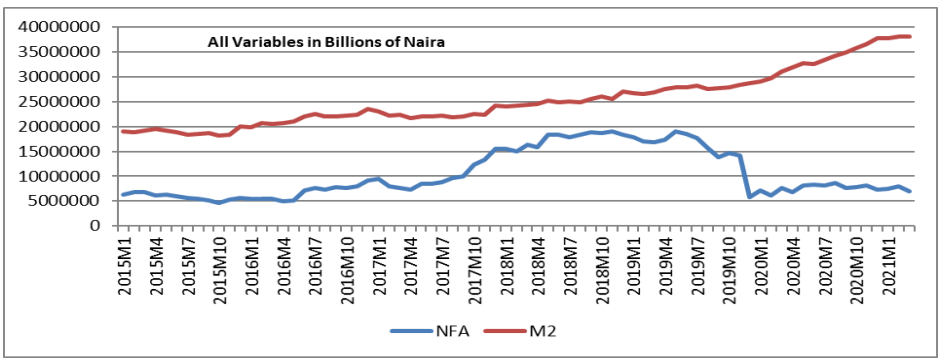

Figure 1: Monthly Trend in NFA and M2 in Nigeria
Source: CBN Statistical Bulletin (2021)

Figure 2 reveals a co-movement in the trend of the NFA and inflation rate, except for some months in 2018 and 2019 when the NFA rose higher than the inflation rate. By implication, since the NFA represents capital inflows, a rise in NFA leads to a rise in the inflation rate. The transmission mechanism through which this occurs is through the rise in money supply occasioned by a rise in capital inflows. In another respect, information in Figure 3 shows that in most periods when the NFA rose, the Treasury bills rate fell and vice *versa.* Thus, as capital inflows rose, the money supply rose and, hence, had a depressing effect on the domestic interest rate.

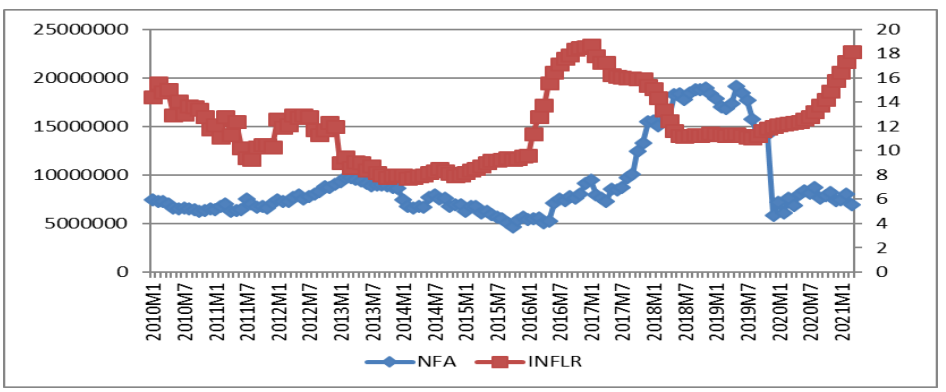

Figure 2: Trend in NFA and Inflation Rate in Nigeria
Note: NFA = net foreign assets, INFLR = inflation rate
Source: CBN Statistical Bulletin (2021)

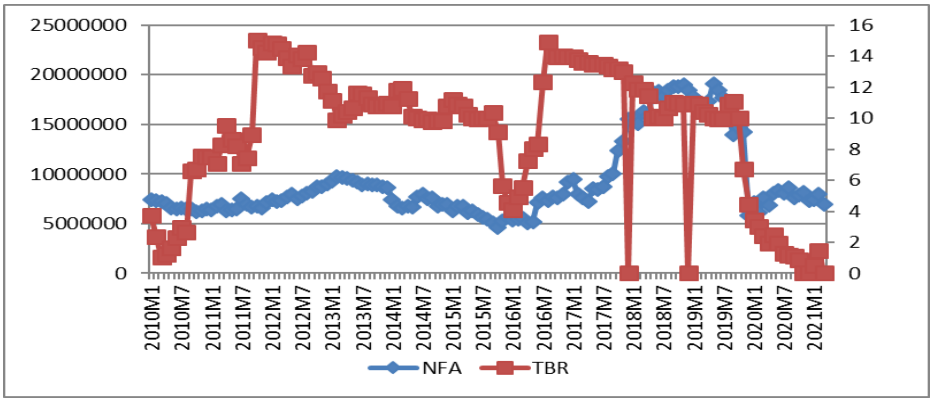

Figure 3: Trend in NFA and Treasury Bill Rate in Nigeria
Note: TBR = Treasury bill rate
Source: CBN Statistical Bulletin (2021)

2. Empirical Literature

Empirical studies have been carried out to investigate the effectiveness of sterilization policy in addressing the monetary impact of capital across different countries. Therefore, the literature review in this present study is done thematically by first considering the studies done in Nigeria and then in other countries. Some studies have been conducted in Nigeria to identify the degree of sterilization with varying results. Okpanachi (2013) found that the degree of sterilization was 69%. This result is slightly lower than the finding by Nzeh *et al.* (2020), which revealed that the degree of sterilization was 74%. In another study for Nigeria, Jume (2021) showed that the degree of sterilization was 95%, which was higher than the outcomes of previous studies. These results indicate that the monetary authorities in Nigeria sterilized much of the capital that flowed into the country within the study periods. The divergent results could be due to the different periods in which the studies were carried out. For instance, after 2013, some studies were carried out, and capital inflows were relatively very high. With such high capital inflows and the consequent improvement in the reserve position, there was the tendency for the monetary authorities to step up the sterilization measure to neutralize the monetary impact of the inflows.

In another study in Nigeria, Isa, Ibrahim and Ezekiel (2020) showed that both positive and negative aspects of capital inflows significantly impacted monetary policy behaviour. The outcome of this study implies that the conduct of monetary policy in Nigeria is influenced mainly by shocks arising from capital inflows. This finding supports the earlier studies that revealed that the CBN extensively engaged in sterilization exercises during rising capital inflows. To evaluate the effect of the sterilization exercise on the domestic interest rate, another study in Nigeria by Nzeh, Nwogwugwu, Nkamnebe, Eze, Yusuf and Okafor (2021) revealed that sterilization policy actually raised the domestic interest rate, but only in the short-run. The result indicates that investors react sharply to changes in domestic interest rates occasioned by the sterilization measures. With such a rise in domestic interest rates, there is a tendency for foreign investors to push more investments into the economy, requiring additional sterilization exercises to mop up the ensuing liquidity. The rise in domestic interest rate occasioned by the sterilization exercise is one of the reasons for exercising caution in implementing sterilization policy in Nigeria. Due to the usually high inflation rate in Nigeria, there is a tendency for interest rates to be high. Therefore, if sterilization measures continue to raise

domestic interest rates, such could worsen the already high interest rate and adversely affect domestic investment.

Several outcomes have been recorded for studies conducted in other countries. In a cross-country study that involved 28 countries, Bleaney and Devadas (2013) revealed that the countries sampled sterilized broad money supply to a larger degree than reserve money. This high degree of sterilization has also been found in a country-specific study of China by Chung *et al.* (2014), which showed that the monetary authorities sterilized most of the capital that penetrated the country within the period. However, partial sterilization of capital inflows was identified as being achieved by the Central Bank of Pakistan by Khushk, Gilal, and Taherani (2015). The result for Pakistan found support in a study by Khushik, Hashmi and Shaikh (2021) that used the vector error correction model (VECM), two staged least squares (2SLS) and the generalized method of moments (GMM) to reveal that the degrees of sterilization from the three models are low. Also, a study by Ponomarenko (2019) indicated further proof of partial sterilization for some emerging market economies, which found incomplete sterilization within the study period. Full sterilization was, however, achieved by the Algerian Central Bank, as observed in a study by Djedaiet and Ayad (2017), supporting the earlier studies by Bleaney and Devadas (2013) and Chung *et al.* (2014). Equally, a country-specific study for Vietnam by Hoang, Nguyen and Nguyen (2020) showed that the State Bank of Vietnam fully mitigated the impact of capital inflows through sterilized intervention.

For studies that went beyond finding the degrees of sterilization, Elhendawy (2015) revealed that a long-run relationship existed between sterilization policy and the inflation rate in Egypt—in another study involving 28 emerging market economies, Arya, Cavoli, and Onur (2020) revealed that fixed exchange rate regime and sterilization policy led to capital inflows. The role of sterilization policy in attracting capital inflows in emerging market economies, as observed by this study, found support in the study by Nzeh *et al.* (2021) for Nigeria. To support the earlier stand that sterilization policy could introduce some instability, Agénor, Jackson and da Silva (2020) revealed that sterilized intervention could be expansionary through a bank portfolio effect and may increase volatility and financial stability risks. This was further supported by a study in India by Rishada, Gupta, and Sharma (2022), which found that the central bank intervention in capital inflows increased reserve accumulation, which puts pressure on the money supply. The study found that the Central Bank of India was able to sterilize about 93 per cent of the capital inflows. In Russia, Drygalla (2023) revealed that shocks to the oil price and private capital flows had a huge inflationary effect. The study concludes that the external shocks can be lowered by adopting an inflation-targeting strategy. By implication, high capital inflows, a tendency in most oil-producing countries like Nigeria, require measures to reduce their inflationary impact.

The reviews of past studies so far have indicated diverse outcomes both within Nigeria and outside Nigeria. The study contends that the discrepancies in these results could be because these studies were conducted in different countries and periods. For studies that produce different degrees of sterilization, even though they were conducted in the same country, the study periods during which they were conducted account for the difference. Since capital inflows differ in each period and in different countries that face peculiar macroeconomic environments, it is expected that the implementation of sterilization policy should produce different degrees of sterilization. However, evidence indicates that the degree of sterilization in countries that attract high capital inflows is usually high.

An example is China and some oil-producing countries such as Russia, Algeria and Nigeria. The partial sterilization found in Pakistan proves that capital inflows are lower

in this country than in neighbouring China. The implementation of sterilization policy was also revealed to influence some monetary variables such as domestic interest rate and money supply in Nigeria and India. What the literature did not reveal is the behaviour of some monetary variables with regard to the implementation of sterilization policy, and this is the area in which the present study intends to contribute to the knowledge.

3. Methodology

This paper used a monthly series that covered the period from 2010M1-2021M3, and all the data were sourced from the CBN Statistical Bulletin, except data on foreign interest rates, which was obtained from the Federal Bank of St Louis. The monetary variables included in the study are broad money supply (proxied by M2), Treasury bills rate (a proxy for domestic interest rate), inflation rate and exchange rate. The effect of the exogenous monetary factor on the domestic monetary variables was captured by the foreign interest rate, which was proxied by the U.S. Federal Fund rate. The policy adopted to cushion the monetary impact of capital inflows, which the study considered, is the sterilization policy. Briefly, the study explains the justification for including the monetary variables in the study. Capital inflows encourage an increase in the supply of resources in the domestic economy, increasing money supply and rising price levels. Capital inflows encourage the appreciation of domestic currency by leading to the penetration of foreign exchange into the economy. The implementation of sterilization policy is therefore targeted at reducing the money supply and the inflationary trend as well as stabilizing the domestic currency. Among the measures adopted to achieve this is the open market operation wherein debt instruments are sold to reduce the money supply, which affects the domestic interest rate. The paper proxied sterilization policy by the total sterilization, following Lavigne (2008). Total sterilization is expressed as:

$$TSTR = (\Delta RD - \Delta NDA) / \Delta NFA \qquad (3)$$

Where TSTR denotes total sterilization, ΔRD represents a change in reserve deposit, ΔNFA represents a change in the net foreign assets, and ΔNDA represents a change in the net domestic assets. As preliminary investigations, the study carried out unit root tests to identify the order of integration of the series. The augmented Dickey-Fuller and the Phillip-Perron tests were employed to examine this at the level and first difference, respectively. Having ascertained that the series are integrated of order one, the study investigated the co-integrating relationship among the variables using the Johansen co-integration test. The co-integration results indicated that the series did not have a long-run relationship, so the study estimated an unrestricted VAR to obtain the impulse response function and the variance decomposition. However, before this, the lag length selection was done under various information criteria, and the VAR stability was conducted using the inverse root of autoregressive characteristics polynomial.

3.1 Framework of Analysis

This study is guided by the estimation of the monetary policy reaction function by Cumby and Obstfeld (1983), which is stated as follows:

$$\Delta NDA = \lambda_1 (CA + K) + \eta^1 x_t \qquad (1)$$

Where: ΔNDA denotes *a* change in net domestic assets, η_1 represents the degree of sterilization, CA represents current account balances, while K represents capital

account balances. x is *a* vector of other explanatory variables. Under the balance of payments, if the current account (C) and the capital account (K) balances are summed up, the outcome is equivalent to the change in net foreign assets (ΔNFA). Consequently, equation 1 can be reformulated as follows:

$$\Delta NDA = \lambda_1 \Delta NFA + \eta^1 x_t$$

where: ΔNFA is the change in net foreign assets (a proxy for capital inflows)

Equation 2 is a simple representation of the monetary policy reaction function. The coefficient λ_1 indicates the degree to which capital is sterilized and is called the sterilization coefficient. λ_1 has a range of values from zero to one (i.e. $0 \leq \lambda \leq 1$). A full or complete sterilization is achieved if λ_1 = –1. When sterilization is complete, it implies that the monetary authorities are able to completely insulate the domestic economy from the monetary impact of capital inflows. However, if λ_1 approaches zero, the implication is that the sterilization exercise is not potent to completely insulate the domestic economy from the monetary impact of capital inflows. If λ_1 = 0, it indicates that the sterilization exercise has no impact on the money supply.

3.2 The VAR Model

The paper employed the VAR framework because of the possible feedback that may occur among the variables used in the study. The suitability of the VAR model as used in this paper is based on its relevance in treating all the model's variables as endogenous so that it can handle any effect each variable has on the others. The choice of this model is mainly because monetary variables usually exhibit feedback, using models that handle only one-way causal relationships cannot produce optimal results since such a model overlooks the possible feedback among the variables. Thus, to capture the responses of monetary variables to shocks in sterilization policy, this paper employed a six-variable VAR model comprising total sterilization, which represents the policy variable: exchange rate, inflation rate, Treasury bills rate and money supply, which represent monetary variables and foreign interest rate which captures the impact of shocks in an exogenous variable. The following unrestricted VAR model thus guided in the estimation:

$$\begin{bmatrix} LTSTR_t \\ EXCHR_t \\ FORNINT_t \\ INLFR_t \\ TBR_t \\ LM2_t \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \\ b_6 \end{bmatrix} + \begin{bmatrix} B_{1,1} & B_{1,2} & B_{1,3} & B_{1,4} & B_{1,5} & B_{1,6} \\ B_{2,1} & B_{2,2} & B_{2,3} & B_{2,4} & B_{2,5} & B_{2,6} \\ B_{3,1} & B_{3,2} & B_{3,3} & B_{3,4} & B_{3,5} & B_{3,6} \\ B_{4,1} & B_{4,2} & B_{4,3} & B_{4,4} & B_{4,5} & B_{4,6} \\ B_{5,1} & B_{5,2} & B_{5,3} & B_{5,4} & B_{5,5} & B_{5,6} \\ B_{6,1} & B_{6,2} & B_{6,3} & B_{6,4} & B_{6,5} & B_{6,6} \end{bmatrix} \begin{bmatrix} LTSTR_{t-1} \\ EXCHR_{t-1} \\ FORNINT_{t-1} \\ INFLR_{t-1} \\ TBR_{t-1} \\ LM2_{t-1} \end{bmatrix} + \begin{bmatrix} \mu^{LTSTR_t} \\ \mu^{EXCHR_t} \\ \mu^{FORNINT_t} \\ \mu^{INFLR_t} \\ \mu^{TBR_t} \\ \mu^{LM2_t} \end{bmatrix} \quad (4)$$

where b_i and B_i are the vector of intercept terms and the regression coefficients, respectively and μ_t represent the random variables that are expected to have zero mean and constant variance, $LTSTR$= log of total sterilization, $EXCHR$= exchange rate, $FORNINT$ = foreign interest rate, $INLFR$ = inflation rate, TBR = Treasury bills rate and $LM2$ = log of money supply.

3.3 Justification for Variable Inclusion in the Model

The VAR model above includes the exchange rate because of its role in sterilization policy. In the first place, capital inflows lead to domestic exchange rate appreciation. To mitigate the monetary impact of capital inflows on the economy, the monetary authorities intervene through the exchange rate market to purchase the foreign exchange generated by the capital inflow (Adrian, 2018). Such intervention results in an increase in base money, thus leading to increased money supply. Money supply and inflation rate were included in the study because capital inflows raise the domestic money supply, which leads to inflation. Sterilization policy is thus targeted at lowering the high inflation rate arising from the monetary impact of capital inflows. A way to evaluate the effectiveness of sterilization policy is to examine if it actually reduces the money supply. The Treasury bills rate is included to account for the open market operations of the monetary authorities. The Central Bank of Nigeria usually floats the Treasury bills during rising capital inflows to insulate the macroeconomic environment from overheating. The foreign interest rate was included to account for the exogenous shocks that could affect the sterilization exercise. It should be noted that if the domestic interest rate is higher than the foreign interest rate, this could attract more inflows into the domestic economy, thereby thwarting the sterilization exercise.

4. Results and Interpretation

The results of descriptive statistics in Table 1 indicate that the variable with the highest mean is the exchange rate, with a mean value of 273.1 and a standard deviation of 115.4. However, the variable that exhibited the lowest mean is total sterilization, with a mean of 0.69 and a standard deviation of 5.02. In another respect, the exchange rate exhibits the highest range among the variables, suggesting it is more volatile than the others. It can also be observed that the mean and median of the variables are very close, which signifies that these variables are symmetric.

Table 1. Result of Descriptive Statistics

	LNTSTR	EXCHR	FORNINT	INFLR	LM2	TBR
Mean	0.69	273.1	1.57	12.06	7.28	9.05
Median	4.30	222.9	1.57	11.70	7.27	10.13
Maximum	6.32	494.7	2.49	18.72	7.58	15.00
Minimum	-7.02	151.8	0.50	7.70	7.01	0.00
Std. Dev.	5.02	115.4	0.53	2.98	0.15	4.27
Skewness	-0.25	0.34	-0.00	0.44	0.05	-0.75
Kurtosis	1.16	1.56	1.81	2.33	2.04	2.45
Jarque-Bera	20.36	14.25	7.88	6.92	5.24	14.60
Probability	0.00	0.00	0.01	0.03	0.07	0.00
Sum	93.34	36868.6	212.93	1628.2	982.9	1222.8
Sum Sq. Dev.	3389.2	178589.	38.16	1192.8	3.08	2447.7
Observations	135	135	135	135	135	135

Source: Compiled by the authors

The results of the unit root tests in Tables 2 and 3 indicate that at the 5% significance level, none of the series achieved stationarity (had unit root) at the level. However, after the first difference, all the series exhibited stationary (absence of unit root). That is to say that after the first differencing of the series, they became *I(1).* The fact that the series is *I(1)* implies that the Johansen co-integration test is more suitable for testing the long-run relationship among the series.

Table 2. ADF Unit Root Results at Level and at First Difference

	Level		First Difference		Order of Integration
	ADF t-stat.	ADF Critical value at 5%	ADF t-stat.	ADF Critical value at 5%	
Variables					
TSTR	-2.64	-2.88	-20.41*	-2.88	*I(I)*
EXCHR	-0.29	-2.88	-8.48*	-2.88	*I(I)*
FORNINT	-1.51	-2.88	-10.85*	-2.88	*I(I)*
INFLR	-1.58	-2.88	-5.06*	-2.88	*I(I)*
M2	0.10	-2.88	-12.13*	-2.88	*I(I)*
TBR	-2.11	-2.88	-16.22*	-2.88	*I(I)*

Source: Compiled by the authors

Note: * denotes the rejection of the null hypothesis at the 5% level of significance

Table 3. P.P. Unit Root Results at Level and at First Difference

	Level		First Difference		Order of Integration
	P.P. t-stat.	P.P. Critical value at 5%	P.P. t-stat.	P.P. Critical value at 5%	
Variables					
TSTR	-1.97	-2.88	-33.51*	-2.88	*I(I)*
EXCHR	-0.21	-2.88	-8.48*	-2.88	*I(I)*
FORNINT	-1.66	-2.88	-41.11*	-2.88	*I(I)*
INFLR	-1.46	-2.88	-12.16*	-2.88	*I(I)*
M2	0.10	-2.88	-12.18*	-2.88	*I(I)*
TBR	-2.53	-2.88	-17.14*	-2.88	*I(I)*

Source: Compiled by the authors

Note: * denotes the rejection of the null hypothesis at the 5% level of significance

The study used 8 lags for lag order selection, and the optimal lag was selected based on the respective information criteria. In Table 4, evidence shows that all the three commonly used information criteria, namely the Akaike information criterion (AIC), the Schwarz information criterion (SIC) and the Hannan-Quinn information criterion (H.Q.), indicated that lag 1 is the optimal lag. Thus, the study chose lag 1 to estimate the VAR model.

Table 4. Result of Lag Length Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1389.21	NA	140.42	21.97	22.10	22.02
1	-339.51	1983.6	1.64*	6.00*	6.94*	6.39*
2	-313.38	46.91	1.92	6.16	7.91	6.87
3	-288.21	42.79	2.30	6.33	8.88	7.37
4	-269.98	29.28	3.10	6.61	9.97	7.97
5	-241.60	42.90	3.60	6.73	10.89	8.42
6	-209.17	45.96	3.98	6.79	11.76	8.81
7	-185.83	30.87	5.17	6.98	12.76	9.33
8	-129.70	68.94*	4.10	6.67	13.25	9.34

Source: Compiled by the authors

To test for the stability of the VAR model, this study is guided by the condition that the VAR is stable if the roots of the autoregressive equation clusters inside the unit circle. The finding in Figure 3 indicates that the roots of the equation are located inside the unit circle. By implication, the VAR model used in the study is stable.

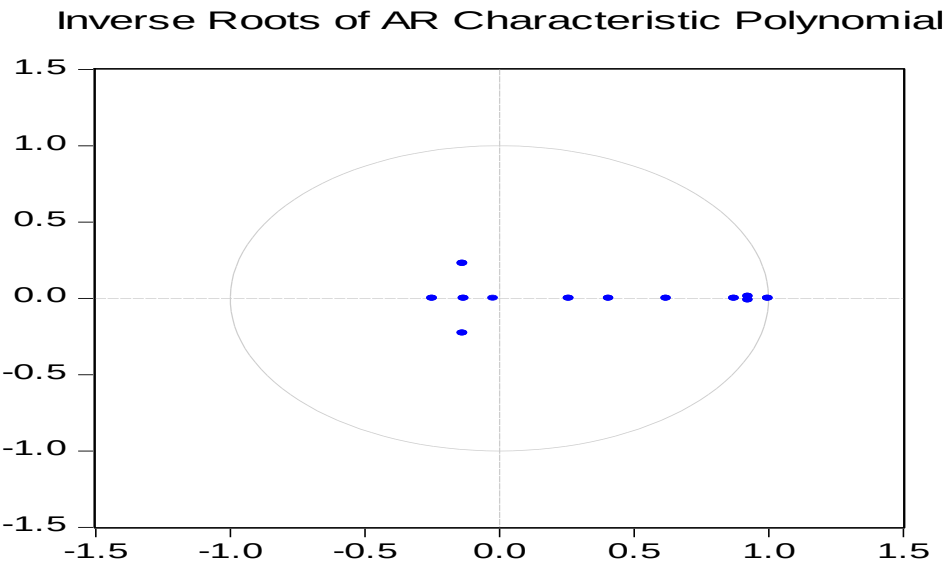

Figure 3 Result of the VAR Stability Test
Source: Created by the authors

Having ascertained that the VAR model is stable, the study tested co-integration among the series. Tables 5 and 6 show the co-integration results under the Trace and the Maximum Eigenvalue, respectively. Results indicate the absence of co-integration under each test as the p-values are greater than the 5% significance level. This implies that the study can only consider short-run impact, indicating that an unrestricted VAR must be estimated to obtain the impulse response function and the variance decomposition.

Table 5. Result of Unrestricted Co-Integration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.21	86.17	95.75	0.19
At most 1	0.14	54.95	69.81	0.42
At most 2	0.10	34.30	47.85	0.48
At most 3	0.09	19.80	29.79	0.43
At most 4	0.04	6.13	15.49	0.67
At most 5	0.00	0.12	3.84	0.72

Source: Compiled by the authors
Trace test indicates no co-integration at the 0.05 level
**denotes rejection of the hypothesis at the 0.05 level

Table 6. Result of Unrestricted Co-integration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.21	31.21	40.07	0.34
At most 1	0.14	20.65	33.87	0.70
At most 2	0.10	14.49	27.58	0.78
At most 3	0.09	13.66	21.13	0.39
At most 4	0.04	6.01	14.26	0.61
At most 5	0.00	0.12	3.84	0.72

Source: Compiled by the authors

Max-eigenvalue test indicates no co-integration at the 0.05 level

**denotes rejection of the hypothesis at the 0.05 level

The impulse response results in Appendixes A and B indicate that the exchange rate responded negatively to shocks in total sterilization in all the periods. This result is in accordance with expectation as sterilized intervention leads to domestic currency depreciation through its effect on the money supply. Similarly, the study finds that the inflation rate responded negatively to shocks in total sterilization. Again, this is expected as sterilization policy reduces the money supply, leading to a decline in the inflationary trend. This result supports the study by Elhendawy (2015) in Egypt, even though the two studies used different methods. The finding, however, shows that the Treasury bill rate responded positively to shocks in sterilization policy up to period two, after which the response became negative. The positive response of the Treasury bill rate is in line with the theoretical postulation. In theory, the domestic interest rate is expected to rise with the implementation of the sterilization policy as the policy leads to a fall in the money supply. Empirically, this finding supports Nzeh et al. (2021) even though this present study used the VAR method against the work of Nzeh et al. (2021), who used the ARDL method. As noted earlier, since the sterilization policy is designed to work in the short-run, the Treasury bill rate's negative response after period two indicates that after the policy implementation, the interest rate reverts to its normal trend. With respect to money supply, evidence shows that it responded negatively to shocks in total sterilization in all the periods. This aligns with apriori expectation as the main rationale for implementing sterilization policy is to drain off liquidity in the system occasioned by rising capital inflows. However, the result contrasts with the findings of Agénor, Jackson, and da Silva (2020), who found that the implementation of sterilization policy resulted in an expansionary money supply.

In a different vein, the response of total sterilization to shocks in the inflation rate is positive in period one, negative in period two through period four and positive after period four and all through the period. This implies that as inflation rises, monetary authorities respond by employing a sterilization policy, lowering the money supply and, thus, reducing the inflationary trend. However, as the sterilization policy is mainly designed to work in the short term, inflationary pressure mounts again after the policy discontinuation. Also, the study finds that total sterilization responded negatively to shocks in the money supply during the period. Capital inflows encourage the growth in money supply, and consequently, monetary authorities react through sterilized intervention, which is geared towards draining off the liquidity in the system.

The results of the variance decomposition indicate that the contributions of shocks in money supply, inflation rate and Treasury bill rate to shocks in total sterilization rose consistently from one to the last period. It is also found that apart from the shocks to itself, which was 95.06% in the first period, shocks in total sterilization contributed to about 4.93% of shocks in the exchange rate in the first period, which rose continuously throughout the period.

5. Conclusion

This paper examined the response of monetary variables to implementing sterilization policy in Nigeria. The study's findings showed that the exchange rate, money supply, and inflation rate responded negatively to shocks in total sterilization during all periods. The Treasury bill rate responded positively to shocks in total sterilization up to period two, after which the response became negative. In a different vein, the response of total sterilization to shocks in the inflation rate was positive in period one, negative in period two through period four and positive after period four and all through the period. The finding equally revealed that total sterilization responded negatively to shocks in money supply in the period. The outcome of the results has established that sterilization policy in Nigeria effectively influences the monetary variables appropriately, which is supported by past studies that have established high degrees of sterilization policy. In another vein, the study has established that changes in domestic monetary variables can also influence capital inflows, thus affecting how sterilization policy is implemented. These outcomes have implications for Nigeria's monetary policy management. One of such implications is that the continuous implementation of sterilization policy could end up reducing liquidity in the banking system, which affects domestic credit expansion and hence retards domestic investment.

Again, a rise in domestic interest rates arising from the implementation of the sterilization policy may result in further capital inflows as foreign investors may want to invest more in the domestic economy, which can thwart the sterilization exercise. If such high inflows become persistent, it may lead to another round of sterilization policy to neutralize the additional inflows, thus putting the monetary authorities under intense pressure. By examining how monetary variables responded to the implementation of capital inflows and finding the response of sterilization policy to changes in the monetary variables, this study has added to the empirical literature. With respect to the findings, the study recommends that even though sterilization policy is more effective, especially in the short run, other measures of neutralizing the monetary impact of capital inflows should be pursued. This is because the implementation of a sterilization policy comes with some costs. One such is that it leads to future fiscal costs owing to the debt burden arising from debt instruments floated during the exercise. Paying the accumulated debt could mount pressure on the fiscal authorities. In addition, continuous implementation of sterilization policy could affect domestic credit provision as it reduces liquidity in the banking system, which may adversely affect the growth of investment.

Consequently, the study recommends adopting other measures meant to reduce the monetary effect of capital inflows, such as a reduction in government expenditure. Also, attractive domestic investment outlets should be developed, and the citizens should be informed of these investment opportunities. Even if the sterilization policy raises domestic interest rates, much of the investments will come from domestic investors to reduce the adverse effect of abrupt capital reversal by foreign investors. For future studies, the study recommends that the macroeconomic impact of fiscal policy implementation during periods of rising capital inflows should be investigated to

ascertain if such policy is effective in insulating the economy from the monetary impact of such inflows.

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Appendix A
Tabular Results of Impulse Response

Accumulated Response of LNTSTR

Period	LNTSTR	EXCHR	FORNINT	INFLR	TBR	LM2
1	5.17	0.00	0.00	0.00	0.00	0.00
2	4.84	-0.02	-0.04	-0.44	0.07	-0.34
3	4.74	-0.19	-0.02	-0.15	0.06	-0.57
4	4.81	-0.36	-0.01	-0.00	0.08	-0.69
5	4.77	-0.49	-0.00	0.11	0.07	-0.81
6	4.74	-0.57	0.00	0.21	0.08	-0.91
7	4.712	-0.60	0.00	0.28	0.08	-0.98
8	4.68	-0.61	0.00	0.35	0.08	-1.04
9	4.65	-0.60	0.00	0.41	0.08	-1.09
10	4.62	-0.57	0.00	0.46	0.08	-1.12

Accumulated Response of EXCHR

Period	LNTSTR	EXCHR	FORNINT	INFLR	TBR	LM2
1	-2.76	12.13	0.00	0.00	0.00	0.00
2	-7.17	26.58	0.01	1.750	-0.13	1.46
3	-11.83	39.77	0.10	5.12	-1.42	3.75
4	-16.46	50.91	0.27	9.49	-3.57	6.22
5	-20.93	60.15	0.52	14.50	-6.50	8.69
6	-25.15	67.85	0.85	19.89	-10.03	11.10
7	-29.13	74.37	1.23	25.44	-14.04	13.43
8	-32.87	79.97	1.66	31.03	-18.41	15.68
9	-36.40	84.86	2.14	36.57	-23.06	17.84
10	-39.72	89.18	2.66	42.01	-27.90	19.90

Accumulated Response of FORNINT

Period	LNTSTR	EXCHR	FORNINT	INFLR	TBR	LM2
1	0.0003	0.0002	0.004	0.00	0.00	0.000
2	0.0003	0.000	0.008	-9.66	0.0002	0.0002
3	0.0007	0.001	0.01	-0.0001	0.001	0.0007
4	0.001	0.002	0.01	-0.0005	0.002	0.001
5	0.001	0.002	0.02	-0.001	0.003	0.002
6	0.001	0.003	0.02	-0.001	0.005	0.004
7	0.002	0.005	0.02	-0.002	0.007	0.005
8	0.002	0.006	0.03	-0.003	0.01	0.007
9	0.002	0.007	0.03	-0.003	0.01	0.009

10	0.003	0.009	0.04	-0.004	0.01	0.01

Accumulated Response of INFLR

Period	LNTSTR	EXCHR	FORNINT	INFLR	TBR	LM2
1	-0.09	0.08	-0.01	0.64	0.00	0.00
2	-0.31	0.23	-0.03	1.19	-0.03	0.11
3	-0.60	0.44	-0.05	1.70	-0.12	0.24
4	-0.88	0.69	-0.07	2.17	-0.25	0.38
5	-1.14	0.97	-0.09	2.62	-0.42	0.52
6	-1.40	1.27	-0.11	3.03	-0.62	0.67
7	-1.65	1.56	-0.13	3.43	-0.85	0.81
8	-1.89	1.85	-0.15	3.82	-1.10	0.95
9	-2.12	2.12	-0.16	4.19	-1.38	1.08
10	-2.34	2.37	-0.17	4.55	-1.67	1.21

Accumulated Response of TBR

Period	LNTSTR	EXCHR	FORNINT	INFLR	TBR	LM2
1	0.22	0.03	0.02	0.03	2.08	0.00
2	0.05	0.02	-0.02	0.23	3.25	0.44
3	-0.00	0.15	-0.04	0.29	4.49	0.77
4	-0.13	0.39	-0.08	0.30	5.57	1.11
5	-0.25	0.73	-0.13	0.28	6.55	1.43
6	-0.38	1.13	-0.17	0.25	7.42	1.75
7	-0.50	1.54	-0.22	0.22	8.20	2.06
8	-0.63	1.96	-0.26	0.20	8.88	2.36
9	-0.76	2.38	-0.31	0.20	9.47	2.63
10	-0.89	2.77	-0.36	0.20	9.99	2.90

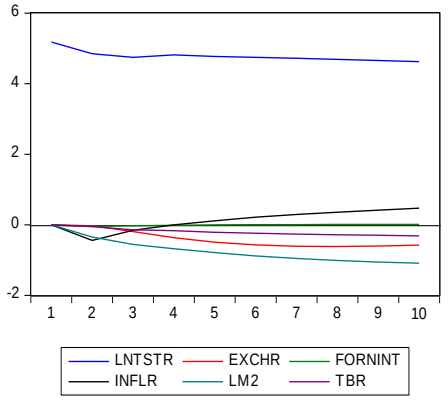
Accumulated Response of LM2

Period	LNTSTR	EXCHR	FORNINT	INFLR	TBR	LM2
1	-0.0004	0.001	0.0003	0.001	-0.003	0.01
2	-0.0005	0.003	0.0003	0.002	-0.007	0.01
3	-0.001	0.004	0.001	0.004	-0.01	0.02
4	-0.001	0.004	0.002	0.005	-0.01	0.03
5	-0.001	0.0047	0.003	0.005	-0.01	0.03
6	-0.001	0.004	0.004	0.006	-0.02	0.04
7	-0.0011	0.004	0.005	0.006	-0.02	0.04
8	-0.0008	0.003	0.006	0.007	-0.02	0.04
9	-0.0005	0.003	0.007	0.007	-0.02	0.05
10	-0.0001	0.002	0.008	0.007	-0.02	0.05

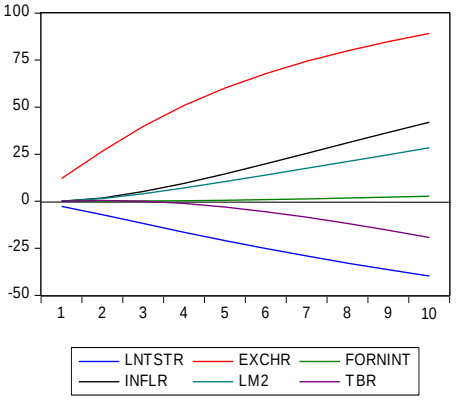
Appendix B

Result of Impulse Response Function in Graphical Form

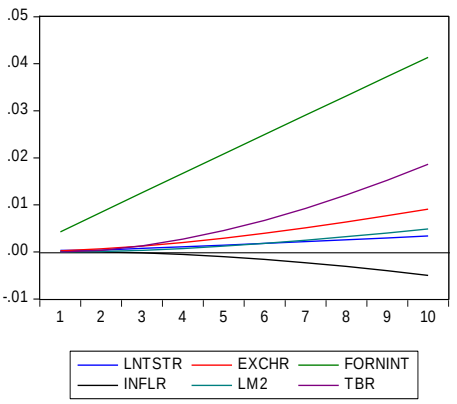
Accumulated Response of LNTSTR to Cholesky
One S.D. Innovations



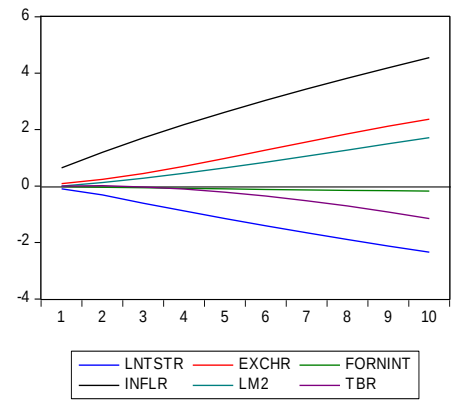
Accumulated Response of EXCHR to Cholesky
One S.D. Innovations



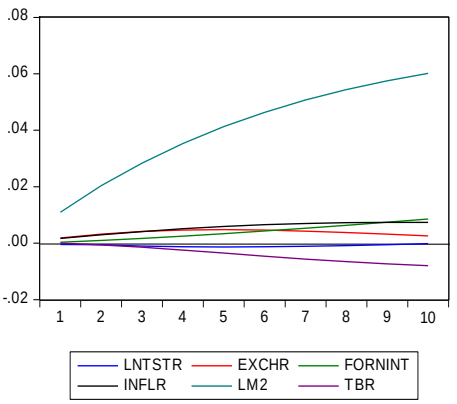
Accumulated Response of FORNINT to Cholesky
One S.D. Innovations



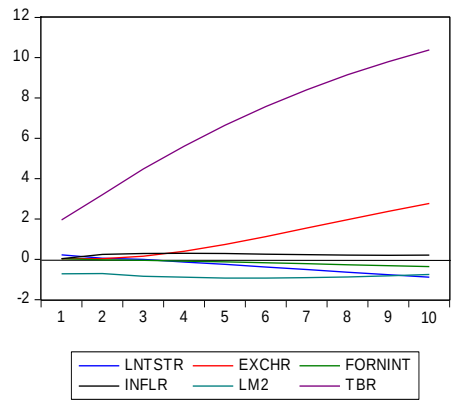
Accumulated Response of INFLR to Cholesky
One S.D. Innovations



Accumulated Response of LM2 to Cholesky
One S.D. Innovations



Accumulated Response of TBR to Cholesky
One S.D. Innovations



Appendix C Results of Variance Decomposition

Variance Decomposition of LNTSTR

Period	S.E.	LNTSTR	EXCHR	FORNINT	INFLR	LM2	TBR
1	5.17	100.0	0.00	0.00	0.00	0.00	0.00
2	5.21	98.80	0.003	0.008	0.72	0.44	0.01
3	5.23	98.21	0.10	0.009	1.02	0.60	0.03
4	5.24	97.96	0.20	0.01	1.11	0.65	0.04
5	5.24	97.81	0.26	0.01	1.15	0.70	0.04
6	5.24	97.72	0.29	0.01	1.19	0.73	0.05
7	5.25	97.67	0.29	0.01	1.21	0.75	0.05
8	5.25	97.64	0.29	0.01	1.22	0.76	0.05
9	5.25	97.62	0.29	0.01	1.24	0.76	0.05
10	5.25	97.60	0.29	0.01	1.25	0.77	0.05

Variance Decomposition of EXCHR

Period	S.E.	LNTSTR	EXCHR	FORNINT	INFLR	LM2	TBR
1	12.4	4.93	95.06	0.00	0.00	0.00	0.00
2	19.70	6.96	91.68	6.93	0.78	0.52	0.03
3	24.54	8.10	87.98	0.001	2.39	1.45	0.05
4	27.88	9.03	84.10	0.004	4.30	2.32	0.21
5	30.38	9.77	80.11	0.01	6.35	3.16	0.56
6	32.36	10.31	76.25	0.01	8.36	3.95	1.08
7	34.03	10.69	72.63	0.03	10.22	4.68	1.73
8	35.48	10.94	69.30	0.04	11.88	5.34	2.46
9	36.77	11.11	66.27	0.05	13.33	5.95	3.26
10	37.94	11.20	63.55	0.07	14.58	6.50	4.07

Variance Decomposition of FORNINT

Period	S.E.	LNTSTR	EXCHR	FORNINT	INFLR	LM2	TBR
1	0.004	0.56	0.31	99.11	0.00	0.00	0.00
2	0.006	0.29	0.61	98.71	0.0002	0.03	0.33
3	0.007	0.45	1.06	96.41	0.06	0.12	1.88
4	0.008	0.48	1.57	93.45	0.20	0.28	3.98
5	0.009	0.50	2.09	90.01	0.38	0.47	6.52
6	0.01	0.51	2.58	86.36	0.52	0.67	9.25
7	0.01	0.51	3.03	82.69	0.82	0.86	12.05
8	0.01	0.52	3.44	79.11	1.06	1.04	14.80
9	0.01	0.52	3.81	75.70	1.29	1.20	17.45
10	0.01	0.52	4.13	72.50	1.53	1.33	19.96

Variance Decomposition of INFLR

Period	S.E.	LNTSTR	EXCHR	FORNINT	INFLR	LM2	TBR
1	0.66	2.24	1.75	0.06	95.92	0.00	0.00
2	0.90	6.74	3.73	0.09	87.55	1.85	0.01
3	1.11	11.51	5.88	0.09	79.12	3.18	0.19
4	1.27	13.29	8.33	0.09	73.55	4.23	0.48
5	1.42	14.24	10.62	0.09	68.84	5.23	0.95
6	1.55	14.73	12.49	0.09	64.98	6.10	1.58
7	1.67	14.94	13.88	0.09	61.84	6.88	2.33
8	1.78	15.00	14.81	0.09	59.30	7.57	3.20
9	1.87	14.95	15.38	0.08	57.22	8.19	4.15
10	1.96	14.85	15.66	0.08	55.51	8.72	5.16

Variance Decomposition of LM2

Period	S.E.	LNTSTR	EXCHR	FORNINT	INFLR	LM2	TBR
1	0.01	0.15	2.60	0.10	2.23	94.90	0.00
2	0.01	0.09	2.41	0.22	2.05	95.03	0.17
3	0.01	0.15	2.15	0.34	2.00	94.97	0.37
4	0.01	0.14	1.89	0.48	2.00	94.85	0.61
5	0.01	0.13	1.70	0.64	1.97	94.68	0.85
6	0.02	0.12	1.59	0.81	1.93	94.44	1.08
7	0.02	0.12	1.54	1.01	1.88	94.15	1.27
8	0.02	0.13	1.54	1.22	1.82	93.84	1.42
9	0.02	0.15	1.57	1.45	1.78	93.50	1.52
10	0.02	0.18	1.63	1.69	1.74	93.15	1.59

Variance Decomposition of TBR

Period	S.E.	LNTSTR	EXCHR	FORNINT	INFLR	LM2	TBR
1	2.09	1.11	0.02	0.01	0.02	11.91	86.90
2	2.45	1.29	0.01	0.04	0.71	8.66	89.26
3	2.77	1.05	0.21	0.04	0.59	6.98	91.10
4	3.00	1.09	0.84	0.05	0.50	5.97	91.51
5	3.20	1.09	1.86	0.06	0.45	5.28	91.22
6	3.36	1.13	3.06	0.07	0.41	4.80	90.49
7	3.49	1.18	4.27	0.09	0.39	4.45	89.59
8	3.59	1.24	5.40	0.10	0.37	4.20	88.66
9	3.68	1.31	6.39	0.11	0.35	4.03	87.78
10	3.74	1.37	7.26	0.12	0.34	3.92	86.96

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