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Empirical Evidence on the Relationship between Central Bank Intervention and Macroeconomic Variables in Nigeria

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Abstract
There is evidence that foreign exchange interventions are significant sources of fluctuations on macroeconomic variables than the conventional monetary policy. The paper aims to establish, interactively, the relationship between interventions and macroeconomic variables in Nigeria. The paper employs the vector autoregressive approach, in which the effect of intervention and exogenous macroeconomic shocks is jointly examined, to characterize the interaction. The results identify the existence of interactions among the model's variables. The intervention shocks have significant negative impact on the exchange rate, and the exchange rates also response to shocks from other macroeconomic policies. In addition, the reaction of intervention to the exchange rate, as leaning against the wind, is significant. The evidence further reveals that the impact of intervention shocks to exchange rate fluctuation is more than one of the conventional monetary policy shocks. Amongst others, the paper recommends the implementation of a more transparent and accountable intervention regimes as well as that embarking on reforms that encourage exports in order to earns more foreign exchange to have funds to support interventions in stabilising the exchange rates.

Keywords: Foreign exchange intervention, Exchange rate, Macroeconomic Variables, Vector autoregressive

Introduction

The international financial system has evolved with different exchange rate arrangements. Countries' currencies are fixed in relation to the US dollar, whose value was in turn expressed in gold under the Bretton Woods system of 1946 to 1973. Afterward, around the 1980s, many countries maintain the fixed exchange rate system. Due to the currency crises of the 1990s and 2000s, some countries institute inflation targeting in their monetary policy, and shifted to the floating systems. Global exchange rates remain fluctuating and excessively volatile the flexible system, pressuring the monetary authorities to increase interest rates as output stalls (Singh, 2023). Panda et al. (2019) note that the volatility of exchange rates is worse for the emerging markets economies with globally integrated financial systems.

The pursue of greater flexibility in Africa offers independency and greater scope for the monetary policy (Ndikumana, 2016). The adoption of flexible exchange rate system makes the countries more vulnerable to continuous exchange rate fluctuations. Excessive swings in the exchange rate makes the government, via the central banks, to interfere in order to stabilise it by means of foreign exchange intervention (thereafter, intervention). The central banks buy or sell foreign exchange to weaken (or strengthen) the national currencies. The central banks use intervention for macroeconomic stabilization in the context of the demeanor of monetary policies. In Nigeria, successive government have embarked on

convergence of monetary policy regimes as they 'lean against the wind' to reduce exchange rate depreciation. The Central Bank of Nigeria (CBN) continues to manage the naira by regular intervention to prevent sharp depreciation (Omojolaibi & Gbadebo, 2014). Viziniuc (2021) notes that the practice of intervention has witnessed a sizable increase in frequency and magnitude.

The role of intervention in influencing the exchange rate and mitigating it from swings has taken continuous debates (Davis et al., 2023; Viziniuc, 2021). Because the conduct of interventions and other exogenous macroeconomic policies, including the monetary, may be considered together to affect exchange rate stabilization, the effects of intervention need to be analysed, interactively alongside the effects of monetary policy implementations (Viziniuc, 2021; Ponomarenko, 2019; Alder et al., 2019; Hoshikawa, 2017). Intervention may affect monetary stock if the implementation is not well sterilised, whereas intervention policy signals future changes in central bank's monetary stance. This is because monetary policy can affect interventions since any change in the policy rate can impact the exchange rate and central banks may simultaneously apply intervention to stabilise it due to the impact of the earlier implemented monetary policy. Ponomarenko (2019) finds that money stock on the banking balance sheet expands in response to an increase intervention through the reserves. Hoshikawa (2017) shows that intervention adds to the money growth despite the sterilization.

There is empirical evidence on the implications and economic relevance of intervention on other macroeconomic variables. This strand of evidences, for instance Adler and Mano (2021), Alder et al. (2019) and Blanchard et al. (2015), reflect endogeneity issues that hinder the recognition of its economic effects, on monetary policy and exchange rate. Alder et al. (2019) find that intervention by buying foreign exchange in the order of 1% point of the gross domestic product (GDP) causes a between 1.7–2.0% depreciation of the nominal exchange rate. Blanchard et al. (2015) reveals that central bank intervention of 1% of GDP would have about 1.5% (short-run) effect on exchange rate, which tend to fade away in 6–8 quarters.

An examination of the potential interdependence between intervention and macroeconomics variables is important. This paper uses annual data to analyse the integrated interactions of considered macroeconomic variables. The unified framework is important because, curbing exchange rate fluctuation cannot be attributed solely to intervention. Macroeconomic policies including monetary policy, output shocks and regulations on the aspects of foreign transactions may affect the impact of intervention. Intervention appears more effective when it is consistent with the monetary policy, since it can create expansionary credit on central banks' balance sheets (Choi & Limnios, 2022; Adler & Mano, 2021). The interactions for other stabilization policies must be controlled to examine the relevance of interventions (Mpofu & Peters, 2017). This study investigates the extent to which macroeconomic fluctuations in the Nigerian settings are influenced by intervention shocks.

The paper pursues three main aims: The first is whether intervention curbs exchange rate movement, and should be continuously applied to control erratic swings. The second is whether intervention drives monetary aggregates and should be considered as a monetary policy option. The third is whether the intervention influence and is driven by macroeconomic shocks. For the aim, the paper conjectures and tests three hypotheses based on evidence for Nigeria. The paper hypothesizes that (1) interventions significantly curb exchange rate movement, (2) interventions significantly drive monetary based, and hence, have implications for monetary policy, and (3) interventions have not led to other macroeconomic shocks.

The evidence clearly identifies interactions amongst the variables. The intervention shocks have significant negative impact on exchange rates, and the exchange rates response to shocks from other policies. The evidence further reveals that the reaction of intervention to the exchange rate is significant, and the impact of intervention shocks to exchange rate fluctuation is more than one of the conventional monetary policy shocks. This has implications for pursue of future intervention policies, which would be better implemented with more exports-oriented policies that promote earning of foreign exchange to support interventions in stabilising the exchange rate. The remainder of the research is organized as: Section 2 reviews literature, section 3 presents methodology, section 4 presents results, discussing the dynamic interactions and responses of the variables, and section 5 concludes the paper.

Empirical Review

The has been a matter of research inquiries. There are debates about the objectiveness, impacts, effectiveness and efficiency of intervention. While the efficiency of the foreign exchange market, credibility of government and a smooth transmission channel matter for intervention to be effective, it has been argued that intervention works through monetary medium to impact the exchange rates. (Ning et al., 2017; Khuntia et al., 2018; Ponomarenko, 2019; Adler et al., 2019; Viola et al., 2019; Akdogan, 2020; Viziniuc, 2021; Diniz-Maganini et al., 2023; Montoro & Ortiz, 2023). Montoro & Ortiz (2023) note that the portfolio balance models contend that with incomplete markets, if the domestic and foreign assets are imperfect substitutes, then intervention can affect the exchange rate.

Kumar (2015) compares the efficiencies of Indian rupee in the periods before and after the subprime crisis, and reveals that the although the market was inefficient, but that efficiency was attained and improved after the crisis. The efficiency is improved because of foreign exchange interventions. Ning et al. (2017) investigate the foreign exchange market in China before and after the 2015 major foreign exchange reform. They find that the pre-reform market was more efficient relative to the post-reform. The decline in the market efficiency level is because of the various interventions by the People's Bank of China since the reform. Khuntia et al. (2018) examine the efficiency of the Indian currency's market against other currencies and identifies that the efficiency in the currency's market had fluctuated because of various events including financial crises, legal reforms, institutional structures, central bank actions, macroeconomic fluctuations, and political instability.

Anjaly (2022) observe that reserve banks deter appreciation than depreciation and find asymmetric in intervention. The South Africa's intervention was found to significantly increase exchange rate volatility, whereas Brazil's intervention in was found to be insignificant, to control market volatility. Diniz-Maganini et al. (2023) use the multifractal detrended fluctuation to analyse the exchange rate market efficiency of the BRICS countries during 2009–2021 period, and find substantial differences in the efficiency of the countries, with China the least efficient and South Africa the most efficient. Based on daily exchange rates, our analysis shows that after a country shift to a flexible exchange rate regime, the price efficiency of its currency improves, but not immediately. However, all the countries experience improvements in market efficiency in the study periods.

Kubo (2017) examine the efficacy of intervention in the Thailand, and reveal that foreign reserve is the main determinants of exchange rate fluctuation, and that intervention influences the inflation via the exchange rate. Hoshikawa (2017) investigate rebounds in the exchange rate after intervention. The result show that when intervention is strongly effective, exchange rate rebounds is immediate the next day. However, the intervention effect is slightly reduced by the rebound after major intervention. Ponomarenko (2019) apply the VAR to examine the effect of intervention on different components of the banking balance sheet for 19 emerging economies for quarterly data during 2001:Q4 to 2016:Q1. The paper finds that money stock expands in response to an increase in the central bank reserves. In addition, external transactions contribute to the money growth despite the sterilization. Adler et al. (2019) find robust evidence that intervention has significant effect on the exchange rate, as well as symmetric and persistent effect for foreign exchange purchases and sales. The paper indicates that a purchase of foreign currency of 1 percentage of GDP leads to around 1.7 to 2.0 depreciation of the nominal exchange rates. Viola et al. (2019) use quantile regression to examine the effects of interventions on exchange rate volatility in Brazilia from 2003 to 2014. The demonstrate different impacts of the intervention along the distribution of exchange rate volatility. Polania et al. (2022) evaluate whether interventions have impacts on exchange rate levels or its volatility in the Colombia. The paper finds no significant impact for different subsamples, as well as tests that control for monetary authority that implement the interventions.

Akdogan (2020) uses the Propensity Score Matching approach to evaluate the response of central banks to volatility of exchange rates in advanced and emerging economies, and finds that central banks respond more to exchange rate appreciation. Ito and Yabu (2020) provide the best proxy for interventions, during 1971 to 1990 when formal intervention amounts and timings were not disclosed in Japan. The accuracy of the proxy drives about 99.8% of real settlement-based interventions. Viziniuc (2021) use the dynamic

stochastic general equilibrium (DSGE) model to investigate where the bank intervenes to dampen exchange rate volatility through changing its foreign reserve. Although the result indicates potential benefits of interventions, especially when currency mismatch is high, but intervention generate winners and losers, particularly, when exchange rate disequilibrium is created from domestic developments. Gbadebo (2023) show that interventions' announcements generate appreciation shocks, and are effective to influence the exchange rate.

Methodology

In order to depict a dynamic system that accommodate multi-policy shock, multi-variables and multi-equations (i.e., policy reaction functions) for the system's variables, the paper applies VAR model to analyses the relations amongst monetary policy, exchange rate volatility and intervention. First, the study conducts the pre-test analysis. The unit root test is completed based on the Phillip-Perron (PP) approach to verified stationarity. The test checks the null $\varphi = 1$ (of nonstationarity) against the alternative, $\varphi > 1$ (of stationarity). The stationarity test starts with assumption that each variable (x_t) follows the AR(p) process:

$$\Delta x_t = \theta_0 + \sum_{i=1}^{p} \varphi_j x_{t-i} + a_t \quad (1)$$

The test defines φ in (1) as, $\varphi = \sum_{i=1}^{p} \varphi_j$ and, $\delta_j = -\sum_{j=i+1}^{p-1} \varphi_j$ i = 1,2, … , $p-1$, and $k = p-1$. The test allows autocorrelation in a_t by estimating an "unaugmented" model of (1). The PP statistic (τ_{PP}) is:

$$\tau_{PP} = \tau_\mu(\hat{\sigma}_\mu/\hat{\sigma}_\mu) - \frac{1}{2}(\hat{\sigma}_t^2 - \hat{\sigma}_0^2)/\Sigma_\ell \quad (2)$$

The consistent estimator of the long-run variance ($\hat{\sigma}$) uses a kernel function as weight.

The optimal lag (p) selected, for parsimonious parameterization of the cointegration and specification for the VAR. Afterward, the paper uses the Johansen test to establish the existence of cointegration. The test requires even if all series in $\boldsymbol{y}_t = (y_{1t}, y_{2t}, \cdots, x_{nt})'$ is $I(d)$, the linear combination of $\mathbf{y}_t$'s element in (3) will be $I(0)$.

$$\Delta \mathbf{y}_t = \sum_{i=1}^{k-1} \boldsymbol{D_i} \Lambda \mathbf{y}_{t-i} + \boldsymbol{\pi} \mathbf{y}_{t-k} + \boldsymbol{e}_t \quad (3)$$

The test verifies rank (r) of the cointegrating space of matrix $\boldsymbol{\pi}$, using the Trace statistic (η_r) (4):

$$\eta_r = T \sum_{i=r+1}^{n} \ln(1 - \lambda_i) \quad (4)$$

The estimated eigenvalues need to be larger than the critical values, for the null to be rejected. The asymptotic distributions properties of the estimation of η_r requires the multivariate central-limit theorem. The long-run covariance matrix of the bivariate Brownian motion is:

$$\lim_{T\to\infty} T^{-1} E\left(\left(\sum_{t=1}^{T} \boldsymbol{e}_t\right)\left(\sum_{r=1}^{T} \boldsymbol{e}_t\right)'\right) \equiv \Omega = \begin{pmatrix} \sigma_1^2/(1-\rho)^2 & \theta\sigma_1\sigma_2/(1-\rho) \\ \theta\sigma_1\sigma_2/(1-\rho) & \sigma_2^2 \end{pmatrix} \quad (5)$$

Where $\begin{cases} T^{-1} \sum_{t=1}^{T} \boldsymbol{p}_t \boldsymbol{e}_t \Rightarrow \int_0^1 \boldsymbol{B}(r) d\boldsymbol{B}(r)' + \boldsymbol{G} + \boldsymbol{\Gamma}; \\ \boldsymbol{G} = \begin{pmatrix} \sigma_1^2/(1-\rho)^2 & \theta\sigma_1\sigma_2 \\ \theta\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}: \\ \boldsymbol{\Gamma}' = (1-\rho)^{-\rho} \begin{pmatrix} \sigma_1^2/(1-\rho)^2 & \theta\sigma_1\sigma_2 \\ \theta\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}. \end{cases}$

$$T^{-1} \sum_{t=1}^{T} z_t v_t = (0:1)\left[\int_0^1 B(r) dB(r)' + G + \Gamma\right] \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$T^{-1} \sum_{t=1}^{T} z_t v_t = \int_0^1 B_2(r) dB_1(r) + \frac{\theta\sigma_1\sigma_2}{1-\rho}$$

$\boldsymbol{e}_t = (v_t, \varepsilon_{2t})'$; $\boldsymbol{B}(r) = (B_1(r), B_2(r), T^{-1/2}\boldsymbol{P}_{[Tr]} = T^{-1/2} \sum_{t=1}^{[Tr]} \boldsymbol{e_t} \Rightarrow \boldsymbol{B}(r),\ r \in [0,1],\ T \to \infty$.

Second, the paper presents the VAR (6), which holds set of K endogenous variables $y_t = (y_{1t}, \dots, y_{kt}, \dots, y_{Kt})$, to examine the interconnectedness.

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t \quad (6)$$

Where, A_i $(i = 1, \dots, p)$ represent $(K \times K)$ coefficient matrices, u_t is a K-dimensional process. VAR(p) has empirical features of 'stability' analysed by the eigenvalues of A of the VAR(p):

$$\xi_t = A\xi_{t-1} + v_t \quad (7)$$

If the variables are cointegrated, the empirical process procedure becomes appropriate to depict the VECM. That is assume $\mathbf{x_t} \sim l(1), \Delta\mathbf{x_t} \sim l(0)$ and $\mathbf{x}_t$ is cointegrated with rank r and $\boldsymbol{\Pi} = \beta\alpha'$, the VECM that imposes further restriction on (6) due to the integrated but co-integrated data is:

$$\Delta\mathbf{x} = c + \sum_{i=1}^{p} \Phi_\tau \Delta\mathbf{x} + \beta\alpha'\mathbf{x} + u_t \quad (8)$$

Where, c is the matrix of exogenous constant, β is the matrix of cointegration vectors and α is a matrix that indicates how each difference series responds to perturbations in the long run equilibrium

Third, the paper estimates the impulse response function (IRF) and the Forecast Error Variance Decomposition (FEVD) to diagnose the system dynamics:

$$y_t = \Phi_0 u_t + \Phi_1 u_{t-1} + \Phi_2 u_{t-2} + \cdots \quad (9)$$

with $\Phi_0 = I_K$ and Φ_s computed recursively ($\Phi_s = \sum_{j=1}^{s} \Phi_{s-j} A_j$ (for $s = 1,2, \ldots, A_j = 0$ for $j > p$). The forecasts for horizons $h \geq 1$ of the $VAR(p)$-process is recursively generated from:

$$y_{T+h|T} = A_1 y_{T+h-1|T} + \cdots + A_p y_{T+h-p|T} \quad (10)$$

Where, $y_{T+j|T} = y_{T+j}$ for $j \leq 0$.

The paper applies (8) for specific relationship amongst intervention, money supply exchange rate, and other variables to achieve the aims. The paper adopts information from sizeable evidence in literature involving intervention and exchange rate. These control variables can substantially affect intervention impact in curbing exchange rate fluctuation. The six variables for the empirical VAR/VECM model include the exchange rate, cumulative net foreign assets, reserve growth, money supply growth, consumer price index, and nominal gross domestic product, and are respectively, EXCH, CNFA, GRES, MSGR, CCPI, NGDP. The estimated VAR is:

$$\begin{bmatrix} \triangle \mathrm{EXCH_t} \\ \triangle \mathrm{CNFA_t} \\ \triangle \mathrm{GRES_t} \\ \triangle \mathrm{MSGR_t} \\ \triangle \mathrm{CCPI_t} \\ \triangle \mathrm{NGDP_t} \end{bmatrix} = \alpha\beta \begin{bmatrix} \mathrm{EXCH_{t-1}} \\ \mathrm{CNFA_{t-1}} \\ \mathrm{GRES_{t-1}} \\ \mathrm{MSGR_{t-1}} \\ \mathrm{CCPI_{t-1}} \\ \mathrm{NGDP_{t-1}} \end{bmatrix} + \sum_{i=1}^{p-1} \Gamma_i \begin{bmatrix} \triangle \mathrm{EXCH_{t-1}} \\ \triangle \mathrm{CNFA_{t-1}} \\ \triangle \mathrm{GRES_{t-1}} \\ \triangle \mathrm{MSGR_{t-1}} \\ \triangle \mathrm{CCPI_{t-1}} \\ \triangle \mathrm{NGDP_{t-1}} \end{bmatrix} + c + u_t \quad (11)$$

c is the intercept vector, and u_t contains the structural disturbances representing shocks in exchange rate, foreign assets, foreign reserves, money supply, price level, and output level. The first equation is exchange rate model which includes money, and output recognised in monetary business cycle. The commodity price controls for inflation reacted to by the monetary authority. The second and third equations are similar to those adopted in previous. The fourth and fifth equations represent the monetary policy equations. These equations confirm whether intervention affects growth in money supply, and inflation (via price level) target, in order to establish whether the intervention is sterilised. The last equation represents how the real sector responds to the exchange rate, intervention, money growth, reserve and price level. Because intervention causes severe volatility of reserves and net foreign assets some authors recommend using change in reserve (Ponomarenko, 2019) and/or cumulative net foreign assets (Adler, & Mano, 2021). The data is from the CBN bulletins and the estimation is based on annual information from 1973, when the naira was introduced, to 2022.

Results

The Phillip-Perron tests fail to reject the non-stationarity evidence, at the level of 5% significance, for exchange rate, foreign assets, money supply, and gross domestic product, depicting the variables as integrated ($I(1)$). The evidence rejects the non-stationarity null for the reserve growth and price index, and identify both series as $I(0)$. However, the test for the series' first difference ($\Delta \mathrm{x}_t$) indicates the deviations are not trended (i.e., $\Delta \mathrm{x}_t \sim l(0)$). Table 1 (2) reports the result for the optimal lag selection (cointegration test). For the different information criteria, the iteration with the highest absolute AIC (-18.528) suggests optimal parameterization of the cointegration with choice lag of 2 would make the autoregressive model likely more parsimonious. The cointegration (Trace) test reported considers both drift and linear trend with

2 lags. The outcome identifies five co-integrating equations, at the point where the statistic ($\eta_r = 0.4031$) is lower than the corresponding critical value 3.8416. At r = 4, the convergence property is satisfied. The VECM is suitable, and estimated for (11) to depict the interdependence to make statistical inference on the reflected dynamics.

Table 1:
Lag selection criteria

Lag	FPE	AIC	SC	HQ
0	0.0000	0.9001	0.5320	0.6784
1	0.0081*	-18.528*	-7.1812*	-15.936*

* Indicates lag order selected. Each test is at 5% level.
AIC (Akaike information criterion), FPE (Final prediction error), HQ (Hannan-Quinn criterion) SC (Schwarz criterion).

Table 2:
Unrestricted cointegration test

Hypothesized No. of C.E.(s)	Trace Stat. (η_r)	0.05 C.V.
None *	567.16	125.61
At most 1 *	250.50	95.755
At most 2 *	135.88	69.819
At most 3 *	78.654	47.853
At most 4	0.4031	3.8416

Note: Critical Value (C.V.); Cointegrating equations (C.E.)

The estimation outcome for the parsimonious dynamic system is reported in Table 3. Not all coefficients are signed consistent to related theories, but the models are significant and some with higher exploratory powers. For the exchange rate system ($\triangle \mathrm{EXCH_t}$), the evidence shows that the intervention proxies, $\triangle \mathrm{CNFA_{t-1}}$ (-5.6145) and $\triangle \mathrm{GRES_{t-1}}$have negative coefficients. This implies intervention leads to exchange rate appreciation because when intervention increases, the exchange rate decreases and appreciates. This evidence identifies that CBN's intervention, by selling the dollars in reaction to the exchange rate swings, significantly curbs exchange rate movement. The first null that intervention does not affect the exchange rate is refuted. The coefficients of foreign asset (-5.6145) and reserve (-0.0311) in the exchange rate are negative and significant, indicating intervention has significant contemporaneous effect on the exchange rate. This result is consistent with previous evidence. The monetary variable ($\triangle \mathrm{MSGR_{t-1}}$) shows positive impact on exchange rate, causes depreciation. This is not surprising because monetary shock can cause exchange rate to overshoot.

Table 3:
The parsimonious VECM

Error Correction:	$\triangle \mathbf{EXCH_t}$	$\triangle \mathbf{CNFA_t}$	$\triangle \mathbf{GRES_t}$	$\triangle \mathbf{MSGR_t}$	$\triangle \mathbf{CCPI_t}$	$\triangle \mathbf{NGDP_t}$
$\triangle \mathrm{EXCH_{t-1}}$	2.1316	1.4E+11	0.7893	8.1211	0.0464	1.0207
	(0.1913)	(0.0081)	(0.092)	(0.8835)	(0.0595)	(0.0467)
$\triangle \mathrm{CNFA_{t-1}}$	-5.6145	1.7E+13	1.1E+8	15.2345	-2.4514	28.0514
	(0.0114)	(0.0855)	(0.3483)	(0.1312)	(0.5614)	(0.0014)
$\triangle \mathrm{GRES_{t-1}}$	-0.0311	-1.1211	-0.2520	1.0689	-0.0619	19.6305
	(0.0321)	(0.000)	(0.1952)	(0.2030)	(0.1002)	(0.0087)
$\triangle \mathrm{MSGR_{t-1}}$	0.0019	1.6E+16	0.03027	-0.1018	1.4256	-0.1131
	(0.0031)	(0.6809)	(0.0192)	(0.0068)	(0.0009)	(0.0007)
$\triangle \mathrm{CCPI_{t-1}}$	-0.3743	2.2212	0.0765	-22.9633	0.5974	0.0980
	(0.4233)	(0.0011)	(0.5742)	(0.0694)	(0.1321)	(0.1037)
$\triangle \mathrm{NGDP_{t-1}}$	-0.0413	-3.6E+08	0.8837	-4.5325	-0.1741	1.2E+16
	(0.2194)	(0.5112)	(0.1820)	(0.2639)	(0.0052)	(0.0087)

ECM_{t-1}	-0.2328	-0.331	-0.2190	0.1843	-0.5614	0.1214
	(0.0190)	(0.0000)	(0.0086)	(0.162)	(0.006)	(0.000)
$\bar{R}^2$	0.8288	0.8121	0.6882	0.6470	0.5438	0.3256
F-stat.	12.591	17.288	12.619	8.3122	2.3326	0.6653

The two intervention variables positively affect the monetary policy variables (i.e., the $\triangle \mathrm{MSGR_t}$ equation), although the effect was not significant. A non-significant coefficient is signal for sterilization of intervention (Omojoliabi & Gbadebo, 2014). This shows that intervention does not drive the monetary aggregates and may not be considered as a monetary policy option. The effect of intervention on output shocks is large and significant, for the two intervention proxies. Not all the other macroeconomic variables are intervention driven. In particular, the evidence support that drives outputs but not the price level, and as such may not be effective for inflation targeting purpose. The joint significant test shows that intervention, on average, had a significant cumulative effect on money supply. For the examined domestics' spillover effects of intervention macroeconomic fluctuations influenced by intervention shocks, the evidence shows intervention shocks had positive spillover effects on both output.

This finding suggests the central banks intervention influence exchange rate although intervention does not influence volume of money. This is not surprising because sterilized intervention does have significant effects on the exchange rate. Past studies suggest channels via which sterilized intervention affects the exchange rate. The 'expectation' or 'signaling' channel is a path for such intervention to smoothen undulations because intervention contains information about the future of monetary policy. The channel requires that the central bank backs interventions with the expected change in policy. The portfolio channel explains that intervention influence exchange rate through asset prices. Due to the intervention, the change in relative supply of foreign exchange affects the domestic assets prices, if they are imperfect substitutes. For the aim, the paper examines the dynamic analysis based on the IRFs to depict interventions and other exogenous policies response shocks interactions. Figure 1–4 provide the visual representations of the system effects to shocks.

Figure 1 depicts the responses of each exogenous variables to the exchange rate shocks. The first plot shows how exchange rate responses to own shocks. The second and third show interventions responses to exchange rate shocks. The fourth and fifth show how money growth and price (monetary policy) response, and the last graph show response of outputs. Importantly, for the intervention proxies, the foreign asset and reserves were initially sustained in responses to exchange rate shocks, but foreign asset gradual increase after the sixth innovations, while the reserve dropped after the eight-year. The money supply initially rises above the mean up to the second period, but maintain gradual fall till the sixth year.

Figure 2 depicts responses of each exogenous variables to the monetary policy. The evidence infer that the exchange rate increases (appreciate) in response to money shocks. Marginal depreciation is revealed in fourth year contrary to 'delayed' overshooting pitched. The reserves decrease initial but eventually remain stable. The 100% shocks on money supply creates an initial increase response at foreign assets, but later fall after the first up till the tenth year. The intervention increases a bit on impact, which may be interpreted as the 'leaning-against-the-wind' intervention. The increase in money supply leads to the appreciation of the exchange rate, and the monetary authority may intervene to purchase dollars to weaken it. The effect of monetary shock on price (output) appears explosive via a graduating increasing time from initial impact. This shows that monetary policy has an overall positive effect on output and prices.

Figure 3 show responses of system variables to intervention shocks. With the foreign assets shocks, the exchange rate was stable but begins to settle (i.e., depreciate) after the sixth year. The intervention shocks have larger impact on exchange rate compare to the conventional monetary policy. The growth in reserve was stable all through the shocks. Money supply increases marginally, in response to the intervention shocks indicating that intervention shocks may not be sterilized according to earlier findings. The exchange rate immediately depreciates, but later rebound to initial start over time. The responses bands are within a 90% confidence, implying the effects noted are not significant.

The reaction of output to intervention shock based on the foreign assets appears positive, implying a counter-cyclical policy. The estimate of monetary policy is consistent with studies on forward-looking

counter-inflation fragments of monetary rule on outputs. But with the growing reserve, output experience falls due to up to the eighth year but appear to be rise steadily afterward. Overall, intervention impinges positive shocks on outputs. Lastly, Figure 4 show responses of system variables to output shocks. With regard to the exchange rate response, the result in the third chart shows a prolonged decline in appreciation of the naira arising from the shock to output. This response is however not too strong.

Table 4 reports the FEVD to show the variance decomposition (V.D.) of each variable shocks for 1 to 10 years horizons. The percentage of variances accommodated in the variable, which decided other variables is represented. The error decomposition of exchange rates shows that through the analysed period, exchange rate is driven by own self. Intervention shocks, based on foreign assets accumulation, contribute between 1% and 9% of exchange rate shocks in in the entire periods. This contribution is lower than that of the conventional monetary policy (1-18%). The evidence seems to identify lesser contribution of the reserve to the decomposed exchange rate variance. The contribution of output and commodity price are not very strong over the period. decomposition of the foreign assets shows that the asset is key factor that determines own error variances over time. Money supply and commodity price's contributions are not significant in explaining the decomposition of the foreign assets. The evidence shows the contribution of other variables are marginal.

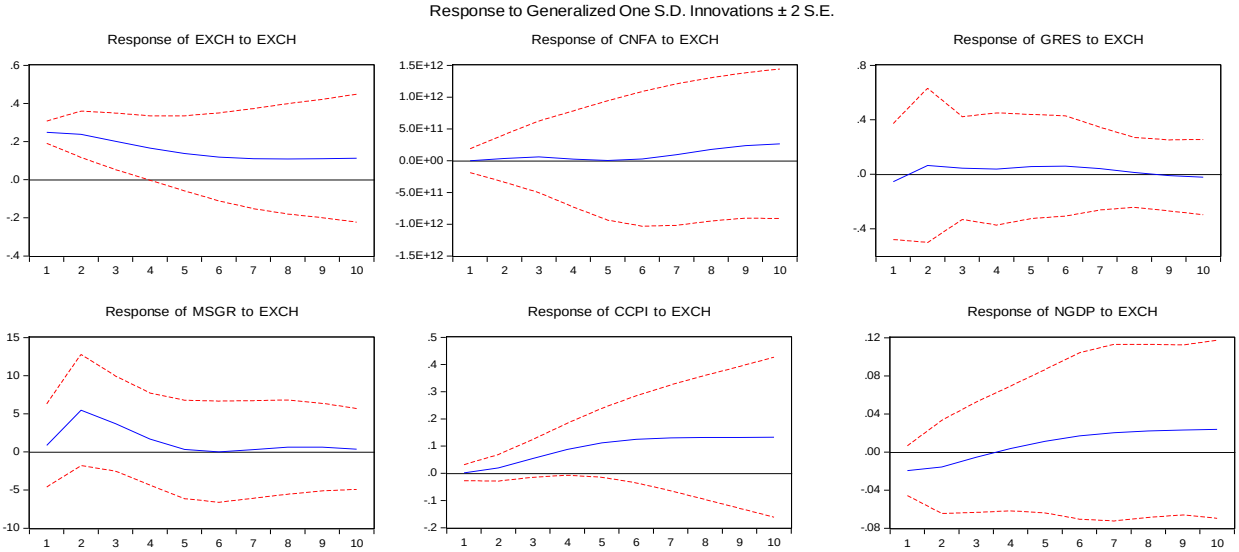

Figure 1: *Exchange rate shocks*

Note: The solid (broken) lines give point estimate (one standard deviation, S.D.) bands. The dashed lines are 90% likelihood bands (i.e., 1.65 standard error bands). The Figure depicts responses of each exogenous variables to the corresponding shock for a tenth year.

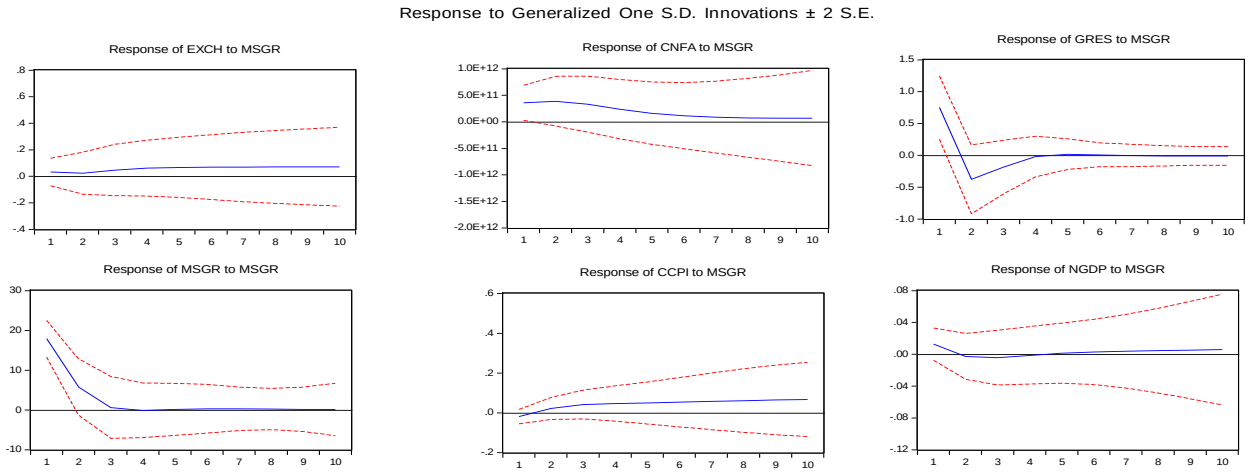

Figure 2: *Monetary policy shocks*

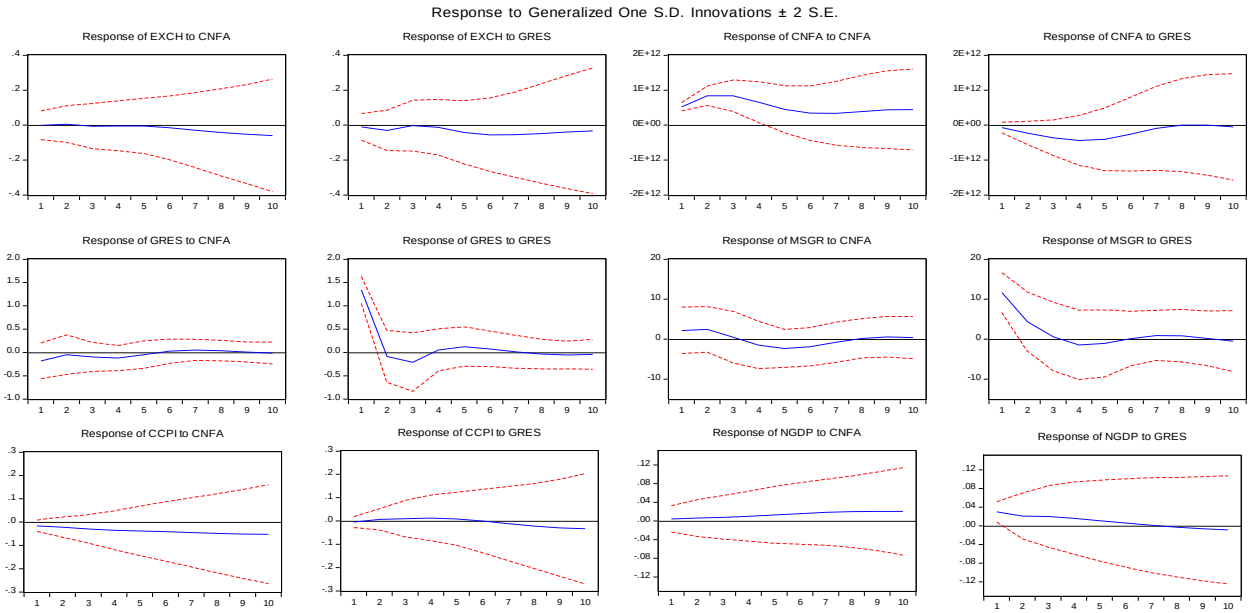

Figure 3: *Intervention shocks*

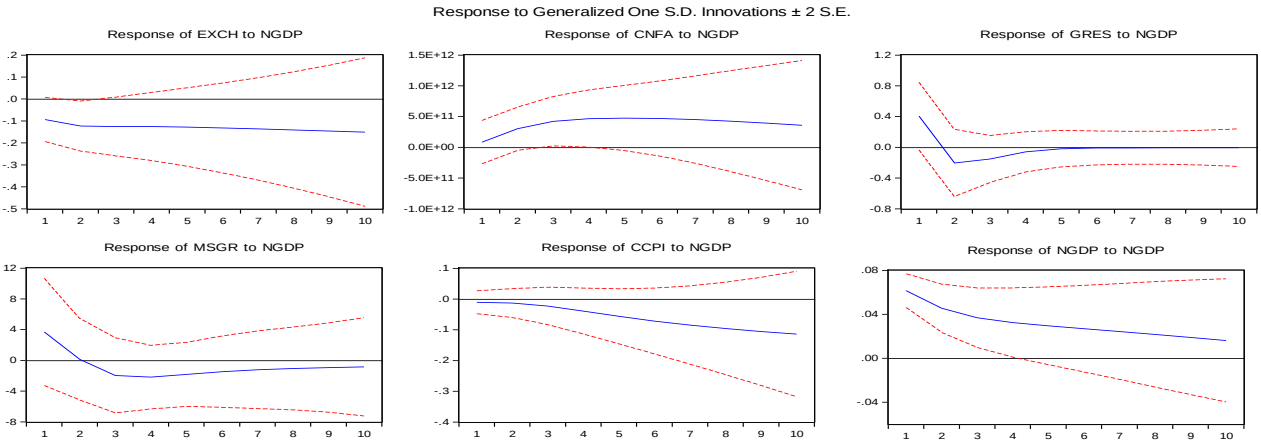

Figure 4*: Output shocks*
Note: The solid (broken) lines give point estimate (one standard deviation, S.D.) bands. The dashed lines are 90% likelihood bands (i.e., 1.65 standard error bands). The Figure depicts responses of each exogenous variables to the corresponding shock for a tenth year.

Table 4:
Forecast error variance decomposition

V.D.(X_t)	Year	S.E.	u_{EXCH}	u_{CNFA}	u_{GRES}	u_{MSGR}	u_{CCPI}	u_{NGDP}
$EXCH_t$	1	0.283999	100.0000	20.00000	0.000000	0.000000	0.000000	0.000000
	2	0.385484	97.88362	13.16096	0.690571	0.051242	0.343913	0.744027
	3	0.451024	94.31545	10.50382	0.770110	0.562191	1.160512	1.856743
	4	0.502456	89.59472	13.28220	0.714878	1.343363	2.215870	3.048796
	5	0.548032	84.26059	11.29395	0.664719	2.151208	3.314711	4.215303
	6	0.591351	78.65381	11.91214	0.640225	2.900352	4.346090	5.320216
	7	0.634135	73.00785	18.33252	0.640862	3.571042	5.253368	6.350232
	8	0.677169	67.50615	22.34814	0.661836	4.159706	6.013176	7.301650
	9	0.720717	62.28412	35.25977	0.697799	4.667920	6.623785	8.176149
	10	0.764753	57.42726	32.53392	0.743887	5.100684	7.096597	8.978383
$CNFA_t$	1	9.31E+11	0.000813	99.99919	0.000000	0.000000	0.000000	0.000000
	2	1.22E+12	0.002049	94.32077	0.514976	0.463367	0.038034	2.684779
	3	1.42E+12	0.082949	84.19362	1.484484	0.473623	0.179738	7.534067
	4	1.59E+12	0.567775	72.55182	2.082386	0.380040	0.396435	12.66301
	5	1.77E+12	1.515284	61.49426	2.326834	0.428750	0.592543	16.87121
	6	1.94E+12	2.761043	52.15019	2.400288	0.566948	0.714123	19.86562
	7	2.11E+12	4.154766	44.72559	2.408480	0.714846	0.759786	21.83004
	8	2.27E+12	5.620053	38.97936	2.394409	0.833865	0.749911	23.04727
	9	2.42E+12	7.130922	34.56469	2.373048	0.913124	0.707275	23.75364
	10	2.55E+12	8.685503	31.16616	2.348946	0.954060	0.650999	24.11504
$GRES_t$	1	1.321893	1.680641	1.346135	96.97322	0.000000	0.000000	0.000000
	2	1.430196	4.887651	2.154544	83.43657	7.719791	0.466838	0.273962
	3	1.460526	5.696740	2.194387	80.83723	8.453274	0.502064	0.576304
	4	1.464913	5.746857	2.183152	80.36622	8.417309	0.499065	0.728307
	5	1.466707	5.733528	2.180191	80.19705	8.399236	0.499579	0.786608
	6	1.467700	5.727609	2.190137	80.11295	8.388182	0.499925	0.810237
	7	1.468284	5.727383	2.210350	80.05831	8.381799	0.499950	0.822257
	8	1.468672	5.730951	2.232391	80.01857	8.378098	0.499891	0.830107
	9	1.468961	5.737462	2.251462	79.98771	8.375429	0.499807	0.836315
	10	1.469200	5.746162	2.266299	79.96172	8.373099	0.499696	0.841826
$MSGR_t$	1	17.91171	1.256321	14.73749	29.93737	54.06883	0.000000	0.000000
	2	19.38905	6.883541	13.47785	30.62166	48.32464	0.553018	0.002080
	3	20.15636	12.76712	12.48284	28.37290	44.75066	1.043870	0.128079
	4	20.64199	15.96266	11.90419	27.09462	42.72802	1.214341	0.387746
	5	20.88768	17.39897	11.63054	26.47316	41.73288	1.246566	0.674379
	6	21.00938	18.01259	11.49886	26.16752	41.25200	1.243370	0.931574
	7	21.07268	18.26292	11.43005	26.01093	41.00934	1.236409	1.148477
	8	21.10899	18.35009	11.39124	25.92175	40.87472	1.232940	1.330491
	9	21.13393	18.36273	11.36631	25.86061	40.78551	1.233412	1.485573
	10	21.15525	18.34191	11.34633	25.80881	40.71118	1.236589	1.620423
$CCPI_t$	1	0.103418	8.190696	2.984554	9.862812	5.567348	0.000000	0.000000
	2	0.145074	4.410988	4.984199	12.60389	28.34578	0.443403	0.021063
	3	0.172288	19.75666	6.838500	8.962531	28.10206	0.894036	0.038598
	4	0.196819	33.64446	8.861666	7.480030	21.74813	0.944479	0.183932
	5	0.213857	39.13809	11.49929	6.503146	18.62710	0.869970	0.369425
	6	0.225763	40.54451	14.63112	5.836571	16.87636	0.797622	0.516997
	7	0.236323	40.61065	17.94205	5.383782	15.41154	0.735124	0.611528
	8	0.247382	40.39666	21.24285	4.978209	14.07098	0.676601	0.665433
	9	0.259496	40.17920	24.47118	4.573843	12.79862	0.619835	0.691180
	10	0.272732	39.90580	27.61746	4.187584	11.59099	0.564849	0.694946
$NGDP_t$	1	0.061642	10.87792	0.845316	6.626407	0.843373	0.484695	78.22064

2	0.080744	6.342279	0.635899	4.182163	1.667833	1.254365	79.40357
3	0.095529	5.570018	0.670125	3.010712	2.469855	1.605070	75.05587
4	0.108362	6.270378	0.825668	2.405202	2.675052	1.658849	69.77559
5	0.119985	7.541495	0.970851	2.106879	2.631748	1.575093	64.75651
6	0.130616	9.073975	1.057895	1.970319	2.514252	1.438796	60.33807
7	0.140285	10.74462	1.095509	1.909200	2.378130	1.291570	56.57964
8	0.148995	12.50274	1.104789	1.880431	2.239352	1.155485	53.42242
9	0.156767	14.33160	1.102568	1.863458	2.103330	1.043777	50.76636
10	0.163652	16.22855	1.099523	1.848182	1.973215	0.965428	48.50669

Implications and Conclusions

Studies claimed that intervention shocks are important sources of exchange rate fluctuations than the implementation of conventional monetary policy. Despite depletion of the reserve due to continuous defending of the exchange rate, the Nigerian apex bank occasionally intervenes and this necessitate the need to examine how interventions affects the exchange rates, and other macroeconomic variables, including outputs and money supply. By classifying the effects from intervention on exchange rate dynamics, the central bank can better operate monetary policy. Based on an autoregressive framework, the effects of interventions and other macroeconomic policy on the exchange rate are jointly analysed.

The results show existence of interactions among the policies and the exchange rate. The CBN interventions have significant negative impacts, and impinge depreciatory shocks on the exchange rates in the short run. The impact of intervention shock on exchange rate fluctuations is more than relative to that of the conventional monetary policy shocks. This suggests that when implementing exchange rate policies, it is important to consider the likely influence of conventional monetary policy. The reaction of intervention to the exchange rate (as leaning-against-the-wind) is found to be substantial and significant.

The effect of intervention shock on output appears to be insignificant, supposing that intervention have only a temporary influence on the outputs. It practically difficult to demonstrate evidence that intervention has a long lasting, quantitatively significant effect for output stabilization. This has implications for pursue of future intervention policies. In reality as CBN continues to intervene, the exchange rate remains volatile.

Because excessive exchange rate volatility is detrimental, sending incorrect signals for economic stability, investment and growth, the paper offers recommendations to ensure consistent pursue of the intervention policies to mitigate future shocks. The CBN should engage in more transparent and accountable intervention regimes. The apex bank should embark on reforms to encourage exports and earns foreign exchange to support interventions in stabilising the exchange rates. Future interventions would be efficient, if well sterilized in order to maintain a stable price level, and exchange rates.

Limitations and Future Research

This paper establishes the relationship between interventions and macroeconomic variables in Nigeria. However, the outcome of the research has limitations. The empirical evidence applies coarse proxies, change in reserve and the cumulative net foreign assets, for intervention. Usually, these proxy for intervention are polluted by factors such as valuation changes and other foreign asset transactions, which affect nation's foreign reserves but do not constitute intervention directed at exchange rates (Ponomarenko, 2019).

In addition, this paper focuses only on periods with direct interventions. In past, the Nigerian authorities have engaged indirect interventions, which are not captured by evidence presented in the study. The paper supposes that future research can complete evidence on the effectiveness of intervention by considering periods involving indirect interventions as well as establish likely structural breaks in the system due to the indirect intervention clusters.

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