Can higher reserves reduce exchange rate volatility in Nigeria? A GARCH-MIDAS approach

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Abstract

This study examines the relationship between external reserves and exchange rate volatility in Nigeria, with data from 2006 to 2022. Using the GARCH-MIDAS approach, we conduct distinct analyses covering the full sample, the period of the Global Financial Crisis (GFC), and the COVID-19 pandemic to explain the dynamics of the relationship between our variables during periods of economic stability and turbulence. Our findings provide strong evidence that higher external reserves can mitigate exchange rate volatility in Nigeria, particularly during periods of economic stress. To enhance exchange rate stability, the study recommends that policymakers should prioritize reserve accumulation, diversify the economy beyond oil, strengthen the Sovereign Wealth Fund, and strategically intervene in the foreign exchange market.

Keywords: External reserves, Exchange rate volatility, GARCH-MIDAS

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1 Introduction

Exchange rate volatility and its intricate relationship with external reserves remain an important subject of concern for policymakers, especially in emerging open economies like Nigeria as the nations navigate an increasingly interconnected global economy. At its core, the connection between higher reserves and the moderation of exchange rate volatility lies in the ability of the reserves to act as a financial buffer. A high level of reserves provides a shield against speculative attacks on a country's currency, instilling confidence among investors and stabilizing the exchange rate. The very presence of substantial reserves can serve as a deterrent, dissuading speculative forces from engaging in actions that may lead to undue volatility in the domestic currency's exchange rate. Like most open economies, Nigeria's economy has experienced significant exchange rate instability occasioned largely by the combined impact of inadequate foreign exchange earnings, speculative activities, and capital reversals (Mordi, 2006), all of which moderate the level of reserves.

The nexus between external reserves and exchange rate volatility is rooted in the buffer stock model of the demand for foreign reserves developed by Frenkel & Jovanovic (1981), and the mercantilist theories. The buffer stock model holds that countries maintain reserves as a buffer to absorb external shocks and stabilize their economies. In this sense, reserves act as financial cushions, allowing countries to intervene in the foreign exchange market to prevent excessive volatility in their exchange rates. The mercantilist approach broadly suggests that accumulating reserves through trade surpluses enhances a country's economic power and trade competitiveness and thus, its ability to influence its exchange rate.

There is extensive empirical evidence exploring the relationship between a country's external reserves and exchange rate stability, with studies spanning different regions and accounting for the unique characteristics of various environments. Ahmed *et al.* (2023) analyze reserve adequacy and its usefulness in times of external vulnerabilities. The study concludes that reserve accumulation helps stabilize economies, especially when faced with volatile capital movements and exchange rate pressures. This finding is similar to that of Jeanne & Sandri (2023), which emphasize that managing reserves is key to avoiding financial imbalances caused by sudden shifts in global capital flows. Han *et al.* (2023) reveal that reserve accumulation serves as a tool to balance private inflows and public outflows in emerging markets and posit that prudent reserve management is critical for financial stability in the face of external vulnerabilities, including currency depreciation and capital flight. Choi & Taylor (2022) differentiate between precautionary reserve accumulation and mercantilism, examining capital controls and their effect on real exchange rates and suggesting that countries build reserves to shield against financial instability and influence their exchange rates to support exports. Jeanne & Sandri (2020) argue that optimal reserves are essential for managing domestic liquidity and external shocks even in financially closed economies. Jeanne & Ranciere (2011) propose a new formula for the optimal level of international reserves in emerging markets and conclude that reserves help mitigate the negative impact of external shocks by providing liquidity during financial stress. Durdu *et al.* (2009) analyze the precautionary demand for foreign reserves in emerging economies, emphasizing the role of reserves in mitigating sudden stops and capital flight. Findings from earlier studies of Brafu-Insaidoo, (2019); Mpofu, (2016); Al-Abri & Baghestani, (2015); Grossmann & Orlov, (2014); Cady & Gonzalez-Garcia, (2007); Mordi, (2006); and Nowak, (2004) all emphasize the strategic importance of reserves in ensuring foreign exchange stability and mitigating financial volatility suggesting that higher reserves can reduce volatility by increasing the capacity of central banks to intervene in times of crisis.

It is instructive to note that existing research on Nigeria consistently supports the stabilizing effect of higher external reserves on exchange rate volatility (Adedokun, 2018; Oaikhenan & Aigheyisi, 2015; Akpan, 2013; Oladipo & Akinbola, 2011; Balogun & Salisu, 2009). However, some studies (Adekunle & Oseni, 2017; Oyejide & Ogun, 1995; Essien & Akpan, 2016) emphasize the importance of addressing structural issues, such as overdependence on oil and speculative activities, to achieve long-term exchange rate stability. Our study provides new insights, particularly in light of increasing calls for a more market-driven exchange rate regime and concerns over the challenges to reserve accumulation due to subdued trade and capital outflows triggered by monetary tightening in key global markets.

Notably, Nigeria's exchange rate management has seen substantial evolution over the years (see Essien & Akpan, 2016). In the colonial period, the British pound served as the official currency. After gaining independence in 1960, the Nigerian pound was introduced, operating under a fixed exchange rate system initially pegged to the British pound and later to the U.S. dollar (Emenike, 2016). The introduction of the Naira in 1973 marked a transition to a managed float system. The launch of the Structural Adjustment Programme (SAP) in 1986 intensified the push for a more liberalized exchange rate market. Following this, Nigeria adopted a multiple exchange rate system to enhance foreign exchange (FX) supply to key sectors of the economy. The FX market was divided into official and Bureau de Change (BDC) segments. The official rate, determined by the Central Bank of Nigeria (CBN), was primarily used for government transactions, select corporate dealings, and formal sectors importing essential goods, with the CBN often intervening to stabilize the Naira. Conversely, the BDC segment catered to the informal market, with operators purchasing foreign currency from individuals and businesses and selling it at a premium, while the CBN also intervened to ensure stability in this segment. However, the market distortions resulting from the multiple exchange rate system led to a unification of exchange rates under the Investors and Exporters (I&E) window. This regime allowed the exchange rate to float within a specified band for both official and I&E segments. Despite these reforms, challenges such as demand pressures, speculative activities, capital flight, and external shocks—particularly falling oil prices—continued to destabilize the FX market. In 2023, the monetary authority announced a shift to a market-determined exchange rate regime, raising concerns about the country's preparedness, especially given its heavy reliance on imports and relatively low foreign reserves.

This study specifically investigates whether higher external reserves can mitigate exchange rate volatility in Nigeria. We contribute to the literature both methodologically and empirically by applying the GARCH-MIDAS framework. This approach allows us to integrate variables with mixed data frequencies, avoiding information loss typically associated with data transformation techniques such as splicing or aggregation (Tumala et al., 2023). Additionally, our study adds to the body of empirical work (Mpofu, 2016; Cady & Gonzalez-Garcia, 2007; Brafu-Insaidoo, 2019; Grossmann & Orlov, 2014) by analyzing periods before and after the global financial crisis and the COVID-19 pandemic, offering deeper insights into the dynamics of the relationship between reserves and exchange rate volatility. We also provide forecast analysis for key predictors. Overall, the study confirms that the accumulation of external reserves has a moderating effect on exchange rate volatility and outlines several implications for policymakers' consideration.

The paper is structured in four sections. Following this introduction, Section 2 provides an overview of the data used, including summary statistics and key trends. Section 3 outlines the methodology and presents the empirical findings, along with a detailed discussion. Finally, Section 4 concludes the paper, highlights policy implications and suggests avenues for future research.

2 Data Diagnostics and Stylized Facts

The study uses mixed data frequencies for daily exchange rates and monthly reserves from 2006 to 2022. The data were sourced from the online database of the Central Bank of Nigeria (CBN). The variables are captured as exchange rate (in higher frequency) and reserve series (in lower frequency) respectively, where exchange rate refers to the value of the Naira to the U.S. dollar. To explore important dynamics in the exchange series, we group the sample into the full sample, the Global Financial Crisis (GFC) period, and the COVID-19 era. Table 1 presents the summary statistics of the data set. The upper panel of the table shows the data used in the main analysis while the lower panel shows the data used for the robustness analysis.

Starting with the upper panel, the descriptive results show that the mean value of the official exchange rate was higher during the COVID period than the GFC period. The reverse is observed for the reserves series. As expected of high frequency, both the standard deviation, as well as the coefficient of variation reveal that the exchange rate is a volatile series, but the reserve appears to be the more volatile of the two series during the GFC and COVID period. The exchange rate series deviates from normal distribution as shown by the non-zero skewness statistics, as well as the leptokurtic nature of the series. This suggests that the series under investigation may need to be evaluated for features of non-normal series such as serial correlation and conditional heteroscedasticity that often plague high-frequency series. We therefore extend the preliminary analysis to include some formal econometric tests, namely the autoregressive conditional heteroscedasticity

[ARCH] test and the serial autocorrelation test. Using lags 5 and 10, the outcome of the tests shows substantial evidence for the ARCH effect and autocorrelations, and these further strengthen our preference for a GARCH-based approach.

Table 1. Summary Statistics, Heteroscedasticity and Autocorrelation Tests

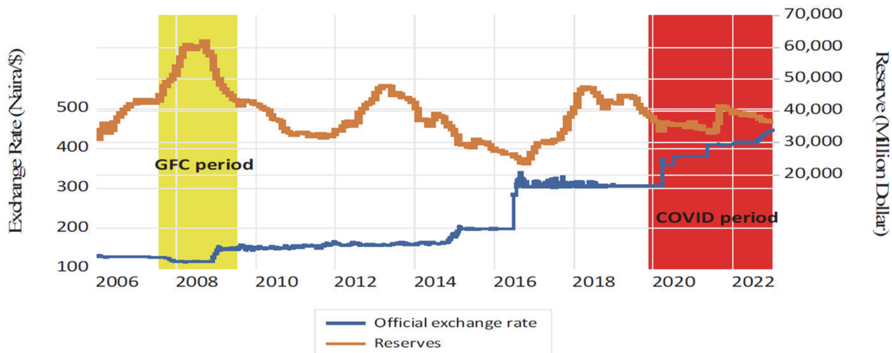
Summary Statistics	Official Exchange Rate			Reserves		
	Full Sample	**COVID**	**GFC**	**Full Sample**	**COVID**	**GFC**
Mean	227.5052	390.9919	127.7689	38965.0900	36926.5100	47033.2500
Coeff. Var.	0.4418	0.0918	0.0756	33.8331	5.6677	67.9098
Std. Dev.	100.5149	35.8781	9.6713	7697.2270	2216.0340	8676.7650
Skewness	0.6649	-1.0449	1.0818	0.6783	0.3175	0.1891
Kurtosis	1.9616	3.6075	3.4390	3.6669	2.3135	2.0152
Probability	0.0000	0.0000	0.0000	0.0001	0.5097	0.3776
Observations	4434	804	912	204	37	42
Frequency		**Daily**			**Monthly**	
Start	02-01-2006	2-12-2019	2-01-2006	2006M1	2019M12	2006M1
End	30 12 2022	30-12-2022	30-06-2009	2022M12	2022M12	2009M6
	BDC Exchange Rate			**Reserves**		
Mean	343.1813	470.0892		36647.7400	36340.2900	
Coeff. Var	0.5507	0.0321		16.9429	0.0639	
Std. Dev.	189.0196	60.4028		5814.5130	2323.6500	
Skewness	0.9550	-0.2435		-0.0311	0.9562	
Kurtosis	3.3476	2.6738		2.3194	3.0334	
Probability	0.0000	0.0235		0.0000	0.0000	
Observations	3,395	524		3,212	429	
Frequency	**Daily**			**Monthly**		
Start	01-04-2010	02-12-2019		2010 M1	2019 M1	
End	29-12-2020	02-12-2022		2022 M12	2022 M12	
Autoregressive Conditional Heteroscedasticity (ARCH) and Serial Autocorrelation tests						
Sample with Official Exchange Rate				*Sample with BDC Exchange Rate*		
ARCH (5)	6.8868***	7.1449	0.1529	10.47604**	9.7304***	
ARCH (10)	6.5878***	7.2644	0.1367	10.34914**	8.5729**	
Q (5)	366.66***	356.06***	40.564***	170.79***	3.4743	
Q (10)	379.52***	373.34***	74.147***	191.76***	6.9201	

Note: Std. Dev. is the standard deviation statistic while Coeff.. denoting coefficient of variation is calculated as (Std. Dev./Mean). Regarding the conditional heteroscedasticity and autocorrelation tests, the reported figures are F-statistics for the ARCH test and Ljung–Box Q-statistics for the autocorrelation test, considered at two different lag lengths (k = 10 and k=20). The null of no conditional heteroscedasticity and serial correlation are tested for ARCH and autocorrelation tests, respectively. Statistical significance of tests at 1%, 5%, and 10% levels, denoted by ***, **, and *, respectively, indicates the rejection of the null hypotheses.

For robustness analysis, we also include the Bureau de Change (BDC) exchange rate. Since BDC data was unavailable before 2010, we similarly limit the sample size for foreign exchange reserves to this period. The summary statistics of these series are shown in the lower part of Table 1. The results indicate that the BDC exchange rate had a higher mean value during the COVID-19 period, while reserves had a lower mean value during the same period. Over the full sample, the moderate mean of the BDC rate (343.1813) combined with a relatively high coefficient of variation (0.5507) suggests occasional fluctuations. The positive skewness (0.9550) and high kurtosis (3.3476) indicate a right-skewed distribution, implying occasional spikes in the BDC exchange rate. In contrast, the negative skewness (-0.24353) and lower kurtosis (2.673789) during the COVID-19 period suggest a more symmetric distribution with shorter tails. The probability values of 0.000 and 0.02348 for skewness in the full sample and COVID-19 period, respectively, indicate statistical significance, underscoring the importance of these findings in understanding the relationship between BDC exchange rates and reserves during these economic periods. Furthermore, the statistical significance of the ARCH effects across the lags examined confirms the presence of volatility, providing additional justification for employing the GARCH-MIDAS approach.

Figure 1 shows the trend of official exchange rate and foreign reserves in Nigeria for the period 2006M01 to 2022M12. The distinct periods in the entire sample frame are the GFC and the COVID-19 Pandemic. A cursory look at the figure shows that both exchange rates and reserves trended in opposite directions, across the different episodes of tranquillity and turbulence in most of the period. A clear episode of the movement in the opposite direction of the variables can first be observed during the GFC. During the GFC, reserves trended upward while the exchange rate trended downward. During the GFC, specifically in 2008, Nigeria recorded the highest external reserves accumulation (US$60 billion) due to the reforms embarked on by the government that enforced fiscal rectitude (excess crude savings) despite constitutional limitations. During the period, oil prices witnessed an upward spiral, and the country earned a debt write-off from the Paris Club. However, the exchange rate trended downwards primarily due to huge portfolio outflows as international investors exited the Nigerian financial markets to address challenges in their home countries (Arunma, 2010). However, the reserve fell to US$42.4 billion in 2009 because of the decline in the price of crude oil which negatively affected accretion to external reserves. During the period, the drop in foreign exchange reserves, and heightened demand pressure in the foreign exchange market led to a significant depreciation in the naira exchange rate.

Figure 1. Monthly trends in Exchange rate and Reserve in Nigeria (2006-2022)

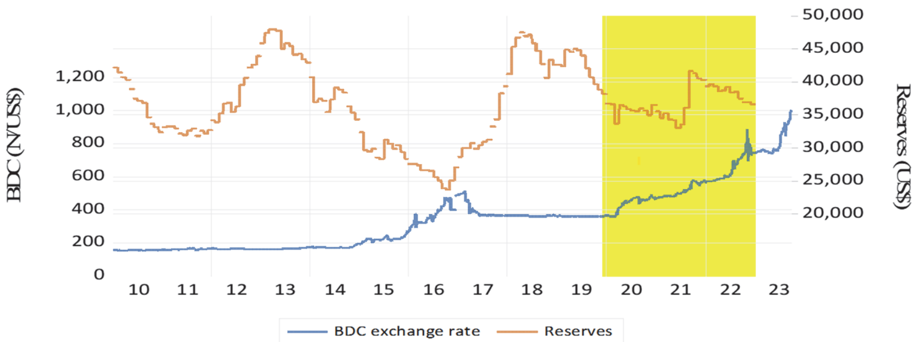


Note: The first and the second shaded areas represent the periods of the global financial crisis (GFC) and COVID-19 pandemic, respectively.
Source: Central Bank of Nigeria

Another notable instance of opposite movement between our variables occurred during the COVID-19 pandemic (December 2019 to December 2022). During this period, Nigeria's external reserves declined, while the exchange rate depreciated. This aligns with the a priori expectation that a decrease in reserves weakens the central bank's ability to stabilize the exchange rate and weakens investor confidence in the capital market, contributing to the depreciation of the naira. The depletion of reserves during the pandemic was driven by lower oil prices and supply chain disruptions, which resulted in higher import costs. Combined with heightened demand pressure in the foreign exchange market to meet these import obligations, this situation led to significant volatility in the naira exchange rate.

Figure 2 illustrates the trend using the Bureau de Change (BDC) exchange rate and external reserves from 2010 to 2022. The graph suggests a converging relationship between the BDC exchange rate and reserves, indicating a potential negative correlation over the period, including during the COVID-19 pandemic. Notably, between December 2019 and December 2022, both the BDC exchange rate and reserves exhibited significant volatility. The BDC exchange rate trended upward due to the global economic slowdown, which disrupted supply chains and reduced demand for crude oil, Nigeria's primary export. This, in turn, led to a drop in foreign investment inflows, increasing pressure on the naira. Additionally, the pandemic's impact on export earnings resulted in a reduced supply of foreign exchange, contributing to a depletion of the country's reserves during this period.

Figure 2. Monthly trends in BDC and Reserves in Nigeria (2010-2022)



Note: The shaded areas represent the period of the COVID-19 pandemic.
Source: Central Bank of Nigeria

3 Methodology and Results

We utilize the GARCH-MIDAS model of Engle *et al.* (2013) to simultaneously accommodate the daily exchange rate volatility and the monthly changes in the stock of external reserves in a single modelling framework. We found the model a suitable approach to examine the response of exchange rate volatility to changes in the level of external reserves. Using this approach, we maintain natural frequencies of occurrence of the variables under investigation, thereby overcoming the challenges of information loss associated with the data-splicing technique of transforming data into uniform frequency. More importantly, our preference for the GARCH-MIDAS model is further motivated by its ability to contain richer information related to financial market volatility, which, according to Li *et al.* (2023), can enhance the model's predictive power.

The following is the generic representation of the GARCH-MIDAS framework comprising of two components involving the mean and conditional variance equations, with the latter further divided into short- and long-run components to accommodate the predictor series.

$$sr_{i,t} = \mu + \sqrt{\tau_t \times h_{i,t}} \times \varepsilon_{i,t}, \tag{1}$$

$$\varepsilon_{i,t} \big| \Phi_{i-1,t} : N(0,1), \forall\, i = 1, \ldots, N_t$$

$$h_{i,t} = (1 - \alpha - \beta)\frac{(sr_{i-1,t} - \mu)^2}{\tau_i} + \beta h_{i-1,t} \tag{2}$$

$$\log(\tau_i) = m + \theta \textstyle\sum_{k=1}^{k} (\omega_{1,}\omega_{2,}) X_{t-k} \tag{3}$$

Equations 2 and 3 capture the conditional variance of the GARCH-MIDAS model representing the short- and long-run components, respectively, while equation (1) is the conditional mean equation. The parameters (μ) in equation (1) is the unconditional mean of the exchange rate volatility, $h_{i,t}$ following a GARCH (1, 1) process is the short-run component of the high-frequency series while α and β are the ARCH and GARCH terms conditioned to be positive and/or at least zero ($\alpha > 0$ and $\beta \geq 0$) and summing to less than a unit ($\alpha + \beta < 1$).

The term τ_t captures the long-run component that incorporates the exogenous series (or realized volatility where there is no exogenous series) and involves repeating the monthly value of changes in external reserves through the days in that month. The $log(\tau)$ rather than τ is considered to ensure the positivity of the long-run volatility, and is the beta weighting scheme, such that;

$$\phi_k(\omega_1, \omega_2) = \frac{\left(k/(K+1)\right)^{w_1-1} . \left(1 - k/(K+1)\right)^{w_2-1}}{\sum_{l=1}^{K} \left(l/(K+1)\right)^{w_1-1} . \left(1 - l/(K+1)\right)^{w_2-1}} \tag{4}$$

where the weights, ϕ_k, are primarily determined by two parameters, for instance, ω_1 and ω_2, respectively. It is logical to discover $\phi_k > 0$ for $k = 1, \ldots, K$ and $\sum_k^K \phi_k = 1$.

A positive coefficient of the exogenous factor, (ϕ), will imply that changes in external reserves increase long-run exchange rate volatility, as well as the converse. More specifically, the hypothesis that higher changes in external reserves will lead to higher volatility of the exchange rate being examined will hold if θ is positive and statistically significant.

We employ the modified Diebold and Mariano pairwise test (Diebold & Mariano, 1995; Harvey et al., 1997) to evaluate the out-of-sample forecast performance of GARCH-MIDAS-Y (the model that contains changes in external reserves as the predictor) model against the competing GARCH-MIDAS-RV model (the model that contains realized volatility as the predictor). The traditional and modified Diebold and Mariano (DM) test equations are specified as follows:

$$DM = \frac{diff^{*}}{\sqrt{V(diff)/_{T}}} \sim N(0,1) \tag{5}$$

$$MDM = \left[\sqrt{T + 1 - 2h + T^{-1}h(h-1)/_{T}}\right] DM \tag{6}$$

where $diff = l(\varepsilon_{CTR}) - l(\varepsilon_{AR})$, $l(\varepsilon_{CTR})$ is the loss function of the alternative carbon risk models, $l(\varepsilon_{AR})$ is the loss function of the autoregressive (baseline) model, $diff^{*}$ and $V(diff)$ are the mean and variance of the loss differentials respectively, h is the forecast horizon.

We test the null that $E(diff) = 0$ against the alternative $E(diff) < 0$ (negative Diebold and Mariano statistics) which suggests that the GARCH-MIDAS-Y is preferred to the GARCH-MIDAS-RV model if the former is lower error and more accurate than the latter. There are other possibilities such as $E(diff) > 0$ where the reverse holds, and $E(diff) = 0$ where there is no difference in the forecast accuracies.

Recall that we estimated the nexus between exchange rate volatility and changes in external reserves using the GARCH-MIDAS approach. We compare results for the impact of realized volatility, as well as the effect of the level of changes in external reserves on exchange rate volatility in line with the modern mercantilism perspective which holds that stabilization of the domestic exchange rate volatility during shocks is one of the motives for reserves accumulation. It is also essential to examine whether factors outside changes in external reserves can provide additional information about the dynamics of exchange rate volatility in Nigeria.

We explain the nexus with the following model parameters; μ is the unconditional mean for changes in reserves; α, the ARCH coefficient; β, GARCH coefficient; θ, the slope coefficient which measures the impact of either realized volatility or the exogenous factor (changes in reserves) on exchange rate volatility; ω, the adjusted beta polynomial weight; and m, the long run constant term.

The results rendered in Table 2 revealed the persistence in exchange rate volatility in Nigeria, for the full and GFC samples. For the full sample, it is partly revealed by the statistical significance of the ARCH (0.25582) and GARCH (0.5278) terms and partly because the addition of the two terms is less than 1 (0.78362). For the GFC sample, the statistical significance is revealed by the ARCH (0.29147) and GARCH (0.6647) terms and partly because the addition of the two terms is less than 1(0.95617). However, there was no volatility persistence in the COVID-19 pandemic sample. This is indicated by the non-significance of the ARCH (0.0000) and GARCH (0.3131) terms, though the addition of the two terms is less than 1 (0.3131). An analysis of the volatility persistence of the full sample and the GFC samples indicated higher persistence during the GFC than the full sample.

For the full sample, the findings indicated that the realized volatility coefficient (0.0296) heightens the long-run changes in exchange rate in most of the period. Also, the changes in external reserves as indicated by the slope coefficient of the exogenous factor (0.1000) indicated that changes in reserves induce the level of volatility in exchange rate. In terms of magnitude, the Y-factor term is higher than the realised volatility term. The results are evident from the positive and statistically significant coefficients of theta for the model variants. Given the statistical significance of the estimates, the analyses of the nexus of the variables in our full sample seem not to agree with the study of the mercantilist view that changes in reserves are expected to dampen the volatility in exchange rate. The result implies that higher reserves may not dampen the volatility in exchange rate. This may not be unconnected to the reason that the CBN did not sufficiently intervene in the official window of the foreign exchange market in most of the periods of the full sample.

For the GFC sample, the findings indicated that the realized volatility coefficient (0.1497) heightens the long-run volatility in the exchange rate.

However, the changes in external reserves (-0.0002) dampen the level of volatility in the exchange rate. The development may be due to the high accretion to reserves occasioned by the high crude oil prices, debt relief, and domestic reforms during the GFC. Nigeria's response to the GFC, including increased foreign exchange interventions, effectively stabilized the naira and reduced volatility. In contrast, for the COVID-19 sample, the realized volatility coefficient (0.0002) had a negligible impact on long-run exchange rate volatility. Meanwhile, changes in external reserves (0.10001) significantly increased volatility. This can be linked to the depletion of reserves due to lower oil prices, higher import costs, and capital outflows during the pandemic. The decline in global oil prices and widespread economic disruptions exacerbated the challenges faced by Nigeria, leading to increased exchange rate volatility.

Some relevant exchange rate and reserves management policy implications can be drawn from the findings. One, an increase in the stock of external reserves dampens exchange rate volatility as can be observed during the GFC when a high level of reserves dampens exchange rate volatility. Hence, Nigeria should consider maintaining a certain level of reserves on a stable and sustainable basis to stabilise the Naira exchange rate, meet its external obligations and strengthen its trade competitiveness.

Table 2. GARCH-MIDAS estimates on Reserves-Exchange Rate nexus

		μ	α	β	θ	w	m
Full Sample	RV	0.00059* (0.0003)	0.25582*** (0.026)	0.5278*** (0.0)	0.0296*** (0.02)	16.732 (12.19)	0.01358*** (0.000)
	Y	0.00033 (0.000)	0.0500 (0.032)	0.9000*** (0.050)	0.1000*** (0.034)	5*** (0.032)	0.0034*** (0.001)
GFC Sample	RV	0.0000 (0.0001)	0.29147*** (0.02979)	0.6647*** (0.0289)	0.1497*** (0.0335)	2.9223 (1.9344)	0.0032*** (0.0007)
	Y	0.0000 (0.0001)	0.0502*** (0.0029)	0.9003*** (0.0086)	-0.0002*** (0.0000)	4.9989*** (0.5476)	0.0000*** (0.0000)
COVID Sample	RV	0.0002 (0.0006)	0.0000 (0.0054)	0.3131 (1120)	0.0002 (1.8978)	25.465 (0.0000)	0.0032 (0.0000)
	Y	0.0004 (0.0004)	0.0500 (0.0999)	0.90001*** (0.1501)	0.10001 (0.0804)	5*** (0.7206)	0.0015*** (0.0012)

Note: The values in parentheses are the standard error while ***, ** and * imply 1%, 5% and 10% levels of significance. μ as the unconditional mean for changes in reserves; α, the ARCH coefficient; β, GARCH coefficient; θ, the slope coefficient which measures the impact of either realized volatility or the exogenous factor (changes in reserves) on exchange rate volatility; ω, the adjusted beta polynomial weight; and m, the long run constant term. A positive coefficient of Y implies that changes in external reserves increase long-run exchange rate volatility. RV is the realized volatility for the GARCH-MIDAS Model.

Two, exchange rate volatility also drives changes in external reserves as the level of the reserves will be depleted during interventions in the foreign exchange market to stabilise the rate, hence, policymakers in Nigeria need to pay attention to the measures that lead to accretion to external reserves and other relevant policy instruments for the stabilization of the naira exchange rate. Implementing policies to reduce the economy's dependence on oil revenue can help stabilize the exchange rate by reducing its sensitivity to fluctuations in oil prices. This should include promoting diversification of revenue sources, such as through increased tax collection and non-oil exports.

In addition to the impact analyses, we conduct the forecast evaluation by comparing the realized volatility (RV)-based model against the predictive model that contains the predictor of interest; changes in Reserves (Y). We employ the modified Diebold and Mariano (MDM) statistics for the forecast evaluation. The MDM statistic should be negative and statistically significant to indicate that the preferred model (the GARCH-MIDAS-Y model that contains Y) performs better than the benchmark model (see Adediran & Swaray, 2023). We evaluate the out-of-sample forecasts of the three samples (full sample, GFC and COVID) over four forecast horizon periods – 10-day, 20-day, 60-day, and 120-day ahead forecasts.

The out-of-sample forecast evaluation conducted with the modified MDM test in Table 3 suggests that changes in reserves contain relevant information for predicting exchange rate volatility than the realized volatility consistently. The Analysis shows that the reserves-based model consistently outperforms RV-based predictive models, especially during the

Table 3. Out-of-sample forecast evaluation of the exchange rate and reserves nexus

Predictor	Full Sample			
	h=10	**h=20**	**h=60**	**h=80**
RV vs Y	25.06***	17.79**	10.38***	6.52***
	GFC Sample			
RV vs Y	-5.67***	-3.99***	-2.77***	2.53**
	COVID Sample			
RV vs Y	7.85***	5.57***	3.79***	5.96***

Note: The reported values in the table are the test statistic as per Harvey et al. (1997). If the value of the statistic is negative and statistically significant, then the GARCH-MIDAS-Y (with the exogenous factor, for instance, change in reserves) is considered the most accurate for the out-of-sample forecasts of exchange rate volatility. The syntax ***, ** and * indicates statistical significance at 1%, 5% and 10%, respectively. RV is the realized volatility for the GARCH-MIDAS Model

GFC. The associated MDM statistics are negative and statistically significant in h=10, h=20 and h=60 but positive and significant in h=80. This implies that there is evidence of equal predictability in the sample analysis.

3.1 Robustness Check

To check the robustness of our results, we examine whether changes in monthly reserves can influence the volatility of the daily Bureau de Change (BDC) exchange rate in Nigeria. Our decision to consider the BDC exchange rate is because the BDC exchange rate plays a significant role in Nigeria's foreign exchange market. Available data on the daily BDC exchange rate necessitated us to consider the period 2010-2022 for our analysis. In the sample, the major episode of shock experience was during the COVID-19 pandemic (2020-2022).

The results in Table 4 revealed the volatility persistence in the BDC exchange rate for the full sample (2010-2009), and the COVID-19 period (2020-2022). For the full sample, it is partly revealed by the statistical significance of the ARCH (0.0606) and GARCH (0.9383) terms and partly because the addition of the two terms is less than 1 (0.9989). For the COVID-19 sample, the volatility persistence is revealed by the significance of the ARCH (0.4523) and GARCH (0.4561) terms and partly because the addition of the two terms is less than 1(0.9084). An analysis of the volatility persistence of the two samples indicated higher persistence in the full sample than in the COVID-19 sample.

The coefficient of the exogenous variable (-0.0051) indicated that changes in reserves dampen the level of volatility in the BDC exchange rate. This is evident from the negative and statistically significant coefficients of the theta. Given the statistical significance of the estimates, the analyses of the nexus of the variables in our sample seem to agree with the mercantilist view that the accumulation of reserves could dampen the volatility in exchange rate. This may be because the CBN periodically make interventions in the BDC segment of the foreign exchange market using the reserves. For the COVID-19 pandemic period, we found that the theta value is higher than the realised volatility and is statistically significant (0.1677), implying that changes in reserves heighten volatility in the BDC exchange rate. This may not be unconnected with the depletion of the reserves during the pandemic that made it ineffective to stabilise the Naira exchange rate and the stoppage of the sales of foreign exchange to the BDCs by the CBN.

Some relevant exchange rate and reserves management policy implications can be drawn from the findings. One of them is that an increase in the stock of external reserves could dampen volatility in the BDC exchange rate if the CBN strategically intervened in the BDC segment of the foreign exchange market.

Table 4. GARCH-MIDAS estimates on Reserves- BDC Rate nexus

		μ	α	β	θ	w	m
Full Sample	RV	0.0000*** (0.0000)	0.0606*** (0.0004)	0.9383*** (0.0003)	0.0000 (0.0000)	7.0836 (0.000)	0.0081*** (0.001)
	Y	0.0000 (0.0000)	0.079*** (0.0009)	0.9185*** (0.0006)	-0.0051*** (0.001)	1.0866*** (0.013)	0.0001*** (0.000)
COVID	RV	0.0004** (0.0002)	0.4523*** (0.0516)	0.4561*** (0.0265)	0.1677*** (0.0381)	49.996** (22.446)	0.0082*** (0.0016)
	Y	0.0003 (0.00004)	0.0500*** (0.0087)	0.9000*** (0.036)	0.0993*** (0.0282)	5*** (0.7916)	0.0014*** (0.0003)

Note: The values in parentheses are the standard error while ***, ** and * imply 1%, 5% and 10% levels of significance. μ as the unconditional mean for changes in reserves; α, the ARCH coefficient; β, GARCH coefficient; θ, the slope coefficient which measures the impact of either realized volatility or the exogenous factor (changes in reserves) on exchange rate volatility; ω, the adjusted beta polynomial weight; and m, the long run constant term. A positive coefficient of Y implies that changes in external reserves increase long-run exchange rate volatility. RV is the realized volatility for the GARCH-MIDAS Model

The out-of-sample forecast evaluation conducted with the modified MDM test in Table 5 suggests that changes in reserves contain relevant information for predicting BDC exchange rate volatility than the realized volatility consistently. The Analysis shows that the reserves-based model consistently outperforms RV-based predictive models, especially during the GFC. The associated MDM statistics are negative and significant in h=10,

Table 5. Out-of-sample forecast evaluation for the BDC exchange rate and reserves nexus

Predictor	**Full sample**			
	h=10	**h=20**	**h=60**	**h=80**
RV vs Y	-2.8998***	-2.2556**	-1.9442**	-1.7023*
		COVID		
RV vs Y	7.2735***	5.1749***	3.5489***	6.1904***

Note: The reported values in the table are the test statistic as per Harvey *et al.* (1997). If the value of the statistic is negative and statistically significant, then the GARCH-MIDAS-Y (with the exogenous factor, for instance, change in reserves) is considered the most accurate for the out-of-sample forecasts of BDC exchange rate volatility. The syntax ***, ** and * indicates statistical significance at 1%, 5% and 10%, respectively. RV is the realized volatility for the GARCH-MIDAS Model h=20, h=60 and h=80 for the full sample but positive and significant in all for the COVID-19 period. This implies that there is evidence of equal predictability in the sample analysis.

4 Conclusion, Policy Issues and Agenda for Future Research

This study examines the role of changes in external reserves in reducing the volatility dynamics of the exchange rate in Nigeria, both from in-sample estimation of the impact and out-of-sample forecasting perspectives. Employing the GARCH-MIDAS model, we estimate the GARCH-MIDAS-RV, as well as the GARCH-MIDAS-Y models and show that both the realised volatility and changes in reserves drive higher volatility in the exchange rate, especially in the full sample and during the COVID-19 sample. Changes in reserves, however, dampen exchange rate volatility during the GFC, because of the huge buildup of reserves that stabilizes the naira exchange rate. We checked the robustness of our analysis by replacing the nominal exchange with the BDC exchange rate because of the peculiarity of Nigeria's foreign exchange market and repeated the analysis.

Our analysis suggests that changes in external reserves have a significant predictive power for exchange rate volatility in Nigeria. To ensure exchange rate stability, the CBN and fiscal authority should prioritize policies that encourage reserve accumulation. Strategic interventions in both the official and BDC segments of the foreign exchange market are also essential. Given Nigeria's unique challenges, diversifying its export base beyond oil is crucial. Policies should focus on developing the real sector and providing incentives for industries with export potential. This will reduce reliance on commodity cycles and ensure a more consistent flow of foreign exchange. A robust Sovereign Wealth Fund (SWF) can be strengthened as a countercyclical tool, accumulating savings during periods of high oil prices and providing a financial safety net during downturns.

In conclusion, it is important to highlight some limitations of this study. First, Nigeria has adopted various exchange rate regimes over the years, each with unique implications for exchange rate volatility. Our analysis focused on major macroeconomic shocks, such as the global financial crisis and the

COVID-19 pandemic, without considering regime changes. Future research could enhance our findings by dividing the data into sub-samples based on these different exchange rate regimes to better capture their impact on volatility. Additionally, while our study employed a two-variable GARCH-MIDAS framework, this approach is limited in incorporating other macroeconomic factors that may simultaneously influence both reserves and exchange rate volatility, such as oil price shocks. Future studies could adopt a more comprehensive methodology that includes these key determinants to further explore their joint effects on exchange rate dynamics in Nigeria.

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