Shifting the paradigm for securing efficient management of exchange rate in Nigeria: A GARCH and BEKK-MGARCH analysis

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DOI: 10.22437/ppd.v11i5.25271	Received: 21.05.2023	Revised: 10.11.2023	Accepted: 18.12.2023	Published: 31.12.2023

Abstract

The influence of foreign exchange on all spheres of any economy is germane to determining its extent of development. Most developing countries have been subjected to managing the integrity of the exchange rate arising from their disadvantageous position in world trade. Nigeria is not an exemption either; this is due to its constant interventions in the foreign exchange market from time to time and by the policy of the existing government in power. However, the interventionist policy framework has been more harmful to Naira as the currency depreciates unabatedly. The pertinent question is whether monetary policy should be the only approach to effective exchange rate management or be combined with fiscal and income policies. Irrespective of the policy choice, the aim, target, and instrument must be complementary without unnecessary disruptions midway, as usually experienced in Nigeria. These inconsistencies have come to bear enormously on the country's exchange rate management. Rather than focusing on the impact of exchange rate volatility on industrial development that could warrant foreign exchange inflows, this paper considers industrialization as an approach to effectively managing exchange rates in Nigeria. This analysis employs a univariate GARCH and BEKK-MGARCH model, using high-frequency monthly time series data from 2000 to 2019, to examine the volatility transmission between the foreign exchange market and the industrial sector. The model estimation uses the Conditional Maximum Likelihood Technique (CMLT). It was discovered that industrial development positively influenced the official market exchange rate compared to the parallel market exchange rate, reducing its volatility. The study thus suggests the vigorous pursuit of foreign exchange earnings and usage policy by earning entities, floating Diaspora bonds, enhancing and encouraging remittances and repatriation of illicit financial outflows to enhance industrialization. This will discourage arbitraging, increasing foreign exchange inflows and stabilizing the economy.

Keywords: *BEKK-MGARCH, CMLT, Exchange rate, GARCH, Industrial sector*

JEL Classification: C22, F31, L60, O14.

INTRODUCTION

One of the principal macroeconomic indicators frequently manipulated to facilitate or manage an economy, particularly in developing nations, is the exchange rate. This rate, which determines the value of a domestic currency, is linked to a basket

of currencies. Through this mechanism, the market value of the domestic currency is pegged against a variety of foreign currencies and their respective weights. Consequently, the value of the domestic currency is established concerning the economies from which goods and services are imported, suggesting that the conversion rate of a country's currency largely depends on the currencies of its trading partners. It logically follows that an economy's productivity and its capacity to export more goods and services lead to increased foreign exchange inflows, thereby enhancing the domestic currency's value, assuming that the import demand elasticity exceeds one. Moreover, the appreciation or depreciation rate of a country's currency also hinges on the type of goods or services produced and exported. This raises the question: Is Nigeria effectively competing, or does it have comparative advantages in the global market?

Frequently, developing countries encounter unfavourable trade terms, trading primarily in raw products and thereby becoming vulnerable to shocks that affect their foreign exchange earnings. Consequently, their currencies are subject to market fluctuations, necessitating interventions by monetary authorities. The disparity between the demand for and supply of foreign exchange often necessitates such intervention to avert economic recession. For instance, as of the second quarter of 2021, Nigeria experienced a trade deficit of ₦1.87 trillion (NBS, 2021; Ijirshar et al. 2022), underscoring the pressure on its foreign exchange due to the need to satisfy import demands. Therefore, the monetary authority must address and alleviate further stress on the limited foreign exchange by curtailing high import bills.

Consequently, it is vital for the country to diversify its economy through the manufacturing sector, thereby aiding in fulfilling its foreign exchange requirements. However, technological underdevelopment poses a significant challenge to diversification efforts, as acquiring the necessary machinery, tools, and spare parts for industrialization demands considerable foreign exchange. Nonetheless, emphasis continues to be placed on the influence of the exchange rate on industrial development in developing countries, even though many developed nations have managed to dominate the global economy through their advanced industrial development, thereby stabilizing their exchange rates. This highlights a gap in addressing foreign exchange issues in many developing countries. This study aims to bridge this gap by employing Generalized Autoregressive Conditional Heteroscedasticity (GARCH), Baba, Engle, Kraft, and Kroner (BEKK), and Multivariate GARCH (MGARCH) models, specifically GARCH and BEKK-MGARCH, to analyze the relationship between exchange rate volatility and industrial growth rate volatility. This approach is essential for addressing the challenges of measuring the impact of industrial growth rate volatility on exchange rate volatility, underscoring the critical role of industrialization as a key source of foreign exchange earnings. Consequently, this could signify a paradigm shift from the traditional approach, potentially positively influencing Nigeria's exchange rate regime.

Managing the exchange rate is central to the monetary policies of developing economies due to its inherent volatility. This significance stems from the pivotal role that foreign exchange plays in determining the financial sector's performance across economies. It notably impacts investment decisions, particularly those involving foreign transactions. In the case of Nigeria, which relies extensively on imported inputs for its industries, the demand for foreign exchange escalates, subsequently driving up factory gate prices. Thus, foreign exchange directly affects consumption, production, and overall economic performance. However, its volatility complicates the prediction of an economy's overall performance with precision. It follows, therefore, that any effective policy aimed at fostering development must meticulously monitor and protect the

exchange rate. Given that the price of goods and services is a critical macroeconomic indicator of an economy's performance, Subair (2018) argues that it is imperative to pursue price stability. Nonetheless, this objective is frequently undermined by the fluctuating exchange rates prevalent in developing countries, highlighting the necessity for monetary authorities to intervene in the foreign exchange market intermittently.

The exchange rate delineates a country's currency purchasing power, and as elucidated by Lothian & Taylor (2008) and Mishkin (2010), it reflects the true value of the nation's currency. A depreciation in currency leads to a decrease in its value, whereas an appreciation indicates an increase. However, Subair (2018) posits that currency appreciation seldom provokes as much debate as depreciation due to the confusion often associated with the latter and devaluation. At the same time, devaluation represents a deliberate reduction in a currency's value; depreciation results from natural market forces of demand and supply for foreign exchange. Depreciation is typically associated with a floating exchange rate regime, which can be particularly challenging for countries that are more productive in exporting finished goods, unlike devaluation (Engle, 2003; Devereaux et al., 2003; Tella, 2016; and Aro-Gordon, 2017).

In contrast to a fixed exchange rate system, Braidley and Tavlas (1991) contend that depreciation possesses a forward-looking characteristic, as the exchange rate tends to react to current prices in both goods and labour markets. Following Obstefeld and Rogoff (1995), the exchange rate stabilizes by adjusting international relative prices in response to shocks from local currency price adjustments. Nonetheless, a flexible exchange rate is prone to frequent fluctuations, often necessitating interventions to avoid resource misallocation, uncertainty, and impediments to international trade and capital flows (Jhigan, 2003). Conversely, fixing the exchange rate can lead to excess demand, a scenario prevalent in countries like Nigeria that rely on a singular major source of foreign exchange earnings, resulting in unanticipated price hikes, resource misallocation, and balance of payment challenges.

The above analysis indicates that no exchange rate regime is without flaws, leading to varied opinions on the most suitable economic policy regime. Black (1976) suggests that developing countries might benefit from adopting a floating exchange rate, contingent upon the consideration of factors such as the structural organization of the existing exchange and money markets, the geographical pattern and price elasticity of foreign trade, and disturbances like fluctuating inflation, domestic production changes, or shifts in trade terms, in the formulation of foreign exchange policies. Therefore, it is crucial to ascertain the fundamental determinants of a country's foreign exchange availability and the potential impact of any adopted policy on the economy. To accurately assess the impact of each policy regime on exchange rate movements across various periods, it is essential to consider factors such as GDP, inflation, balance of payments status, external reserves, interest rate trends, external debt stance, productivity, macroeconomic shocks, and speculative contagion. These elements play a crucial role in the analysis.

Consequently, managing the overall economy becomes imperative due to the volatility of exchange rates, which frequently engenders a host of issues with adverse effects on the general price levels, employment, income, and productivity in Nigeria. Moreover, the persistent volatility of the exchange rate renders it exceedingly difficult for business owners to make informed investment decisions. Perhaps this volatility significantly contributed to the collapse of the interwar gold standard as a significant obstacle to development.

As previously mentioned, the imperative to intervene in the foreign exchange market arises from the volatility of exchange rates. This need becomes more pronounced in technologically underdeveloped economies. Such economies depend on imported inputs and intermediate goods for their domestic production, rendering them susceptible to fluctuations in exchange rates. For instance, Nigeria's endeavour to industrialize encounters competition from other sectors for limited foreign exchange, destabilizing its exchange rate management. Ogiogio (1996) identifies the causes of unstable exchange rate management in Nigeria as a lack of fiscal discipline, absence of monetary targets, day-of-the-week and month-of-the-year effects, an unstable auction system, and the impact of bidding. These various exchange rate policy regimes have consistently led to confusion, with the exchange rate volatility adversely affecting Nigeria's industrial sector.

Entering the manufacturing sector for any country reliant on imported raw materials invariably entails taking on exchange rate risk, often leading to volatility and unpredictable movements in the real exchange rate. Adebiyi & Omotayo (2009) argue that greater volatility correlates with higher risks associated with exchange rate fluctuations. Moreover, several consequential effects stem from exchange rate risk, including liquidity overhang, smuggling, reduced capacity utilization of domestic industries, and the vulnerability of economies dependent on a single major source of foreign exchange to external shocks. The phenomenon of round-tripping, exacerbated by exchange rate volatility, is further intensified by the high arbitrage premium between the official and parallel market exchange rates. This situation often encourages capital flight, hampering private investment, especially in the industrial sector. However, numerous other factors facilitating the exchange rate pass-through (ERPT) to the industrial sector can be categorized into primary, secondary, and subsidiary, as depicted in Figure 1.

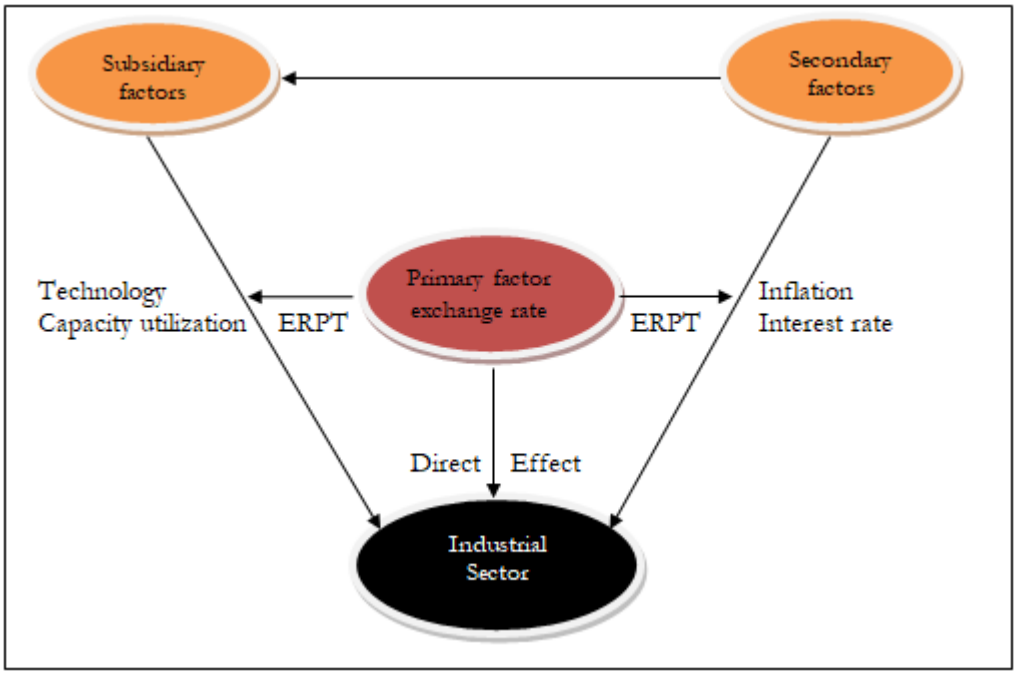

Figure 1. Exchange rate pass-through (ERPT) factors to the industrial sector

Figure 1 underscores the exchange rate's significant impact on developing nations' economies, highlighting the necessity of periodically monitoring and regulating exchange rate movements (Subair et al. 2015). According to Malami (2021), Figure 1

illustrates a process born from circumventing market forces to achieve "selfish interests." This occurs when a domestic country loses confidence in its currency and seeks to adopt another nation's currency that consents to this arrangement, leading to a purely aspirational agreement on exchange rate regimes. Therefore, implementing effective exchange rate policies to achieve industrial growth and sustainable development is crucial in determining the most appropriate exchange rate regime.

Regardless of the specific exchange rate policy implemented, the underlying aim of such a policy is to preserve the domestic currency's value by maintaining a stable and competitive exchange rate, which Rajan (2012) identifies as fundamental to any economy's industrial development process. Moreover, it is vital to ensure efficiency in the foreign exchange market by achieving external balance without compromising the need for internal balance and the overarching goal of macroeconomic stability. Achieving an efficient foreign exchange market requires that prevailing exchange rates fully reflect information regarding actual profits from any arbitrage or speculation activity, aligning closely with equilibrium expected profits, thereby ensuring that the actual exchange rate matches the equilibrium exchange rate at the transaction time (Odusola, 2006). The International Monetary Fund's (IMF)'s broad classification of exchange rates into De jure and De facto regimes is based on individual countries' foreign exchange arrangements and restrictions, largely relying on self-reported national policies (Rajan, 2010). In response to the complexities encountered, the IMF has expanded its methodology for classifying exchange rates to include the assessment of unofficial policies as determined by its staff, acknowledging the nuanced realities different nations face.

From the analysis presented, it becomes evident that official intervention in the exchange rate market introduces a certain degree of flexibility. The De jure classification of exchange rate regimes is more comprehensible and manageable (Ho & McCauley, 2002). This is attributed to the fact that the De jure classification aids in addressing the issue of exchange rate volatility by pinpointing the primary source of the problem. Accordingly, verbal interactions assess the exchange rate situation, signalling the need for policymaker interventions. Conversely, De facto exchange rate regimes emphasize the behaviour of the exchange rate to ascertain the appropriate regime to adopt. To this end, the IMF has implemented a new coding system, drawing on various information sources, including staff reports, press releases, and other pertinent documents, as well as the behaviour of bilateral nominal exchange rates and reserves. The objective of this classification system, as Rajan (2012) asserts, is to determine the extent to which the exchange rate regimes in place align with or deviate from the official declarations made by various countries. Rajan (2012) expands on this by incorporating the concept of exchange rate regime flexibility (or rigidity) into the Frankel-Wei (2007) methodology for deducing implicit basket weights, culminating in the creation of an intervention index. This index assesses the consistency of a country's exchange rate regime with its official statements, whether these regimes fall under the De jure or De facto categories. Over time, the IMF has categorized fixed, flexible, and multiple exchange rates into distinct groups: hard exchange rate peg, soft (hybrid) exchange rate peg, and floating exchange rate peg (IMF, 2008).

Despite reclassifying exchange rate regimes into the hard peg, soft (hybrid) peg, and floating peg (IMF, 2008), various options within these categories remain available for countries to adopt as circumstances dictate. However, in many developing countries, where financial markets are not fully developed and capital mobility is limited, the feasibility of implementing a freely floating exchange rate system is constrained, as

Black (1976) suggested. These countries exert minimal control over their trade terms, indicating that a floating exchange rate might be preferable if such terms are volatile, assuming import demand is elastic. Conversely, a pegged rate may be more advantageous in cases of inelastic import demand. Mansur (1983) advocates integrating the real production economy with financial transactions within an inter-temporal multi-sector general equilibrium framework. This approach would yield an optimal trajectory for the exchange rate and intermediate variables (such as the balance of payments and budgetary positions) based on various parameters and objectives. Mansur (1983) also proposes several tests for assessing the appropriateness of an exchange rate regime, illustrated by a schematic diagram in Figure 2.

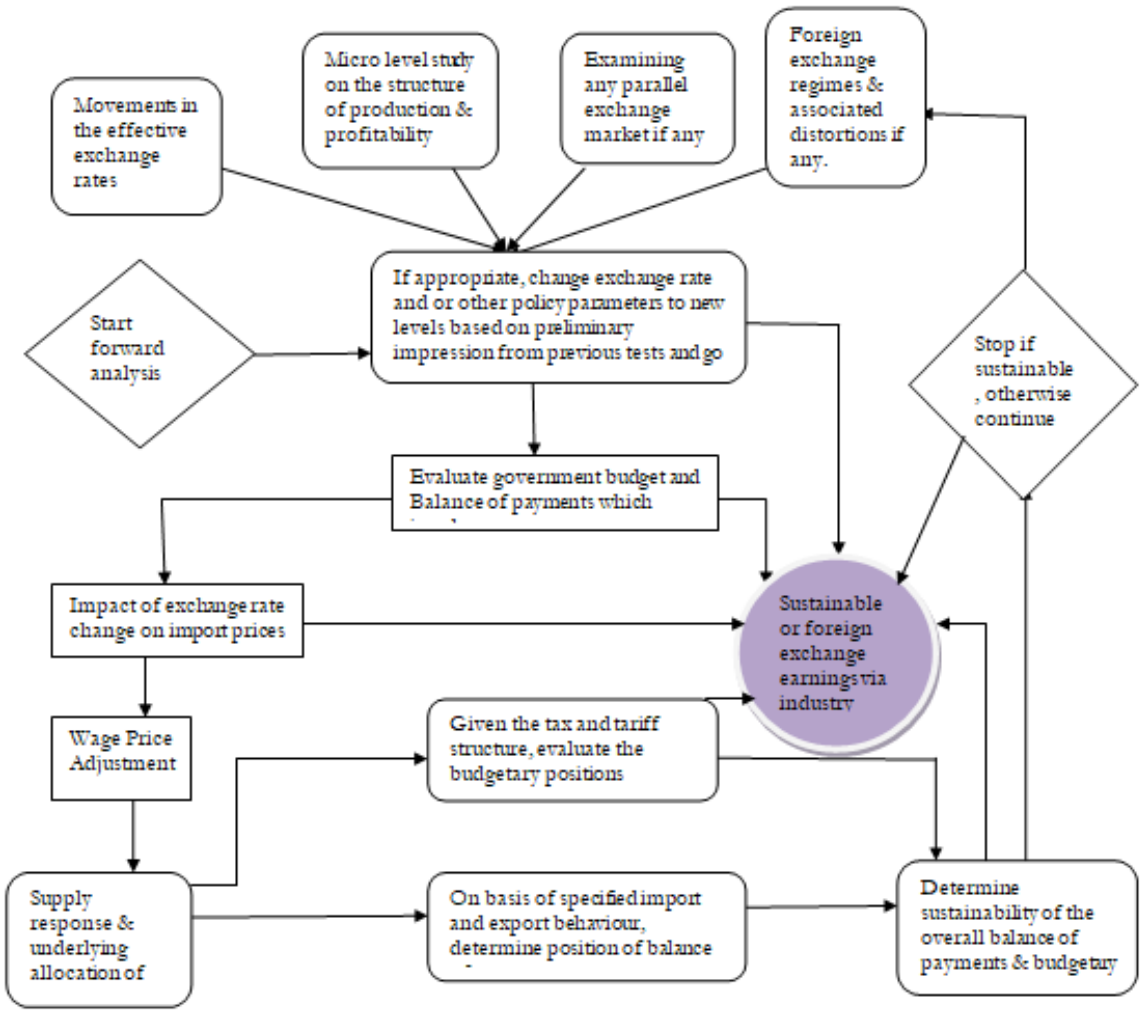

Figure 2. Tests for determining suitable exchange rate regime
Source: Adapted from Mansur (1983)

From Figure 2, the backward-looking and forward-looking tests, as Mansur (1983) outlined, significantly impact the foreign exchange reserves. This, in turn, reflects the adequacy of the current exchange rate and the potential effects of earning foreign exchange through pragmatic industrialization. The forward-looking test suggests that variations in the exchange rate typically have detrimental effects on trade and investment due to the misallocation of resources. Thus, Bradley and Tavlas (1991) justify adopting fixed exchange rates. However, Feldstein's (1990) earlier study on the U.S. economy indicates that the exchange rate's misalignment, rather than its variability, critically undermines direct investment performance. Feldstein (1990) posits that to

rectify the U.S. external imbalance, "the dollar should fall by a further 10 to 15 per cent in trade-weighted terms, with even larger declines against the Mark and Yen to reduce the U.S. trade deficit."

Conversely, the Asian financial crisis has been attributed to exchange rate rigidity, allowing their currencies, according to Ohno (1998), to deviate from a strict dollar peg in the medium to long term. This strategy aims to neutralize inflation gaps and movements of major currencies. Employing a Frankel-Wei (2007)-type regression, Ohno (1998) analyzed changes in each Asian currency against major currencies from 1980 to 1997. The findings suggest that adopting a common currency basket in the region did not significantly enhance stability. Thus, Ohno (1998) recommends pragmatic exchange rate policies that differentiate between normal and crisis periods. The study concludes that there should not be any drastic reform of the current exchange rate regime in developing Asia to maintain competitiveness during normal times. Supporting Ohno's (1998) stance, Hoffman (2007) advocates for a flexible exchange rate regime over a fixed one, arguing that flexible exchange rates more effectively buffer against external shocks. Analyzing data from 42 developing countries, Hoffman (2007) explores the relationship between exchange rate regimes and macroeconomic volatility, mainly how external shocks affect small, open developing economies with varying exchange rate regimes. Utilizing a panel vector autoregression (PVAR) approach to assess how economies react to external disturbances, the findings indicate that external shocks have less of a contractionary effect under floating than under pegged exchange rates. Therefore, Hoffman (2007) concludes that floating exchange rate regimes are preferable for developing countries.

The inconsistency in the adoption of exchange rate regimes significantly contributes to volatility, as the management of the exchange rate undergoes periodic changes. The Central Bank of Nigeria (CBN) categorizes the historical progression of exchange rate regimes in Nigeria into three distinct phases: initially, a period without a defined exchange rate regime before the establishment of CBN in 1958, followed by a fixed exchange rate regime from 1959 to June 1986, and subsequently, a flexible exchange rate regime from June 1986 to the present. Mordi (2006) elaborates further, indicating that Nigerian exchange rate management has undergone several phases, with ongoing adjustments as the Central Bank manipulates the foreign exchange market to fulfil its objectives. These goals encompass price stability, preserving external reserves, economic diversification, and reducing the discrepancy between the official and parallel/bureau-de-change rates (CBN, 2016; Tella, 2017). According to the comprehensive summary in Table 1, Nigeria has primarily operated under a fixed exchange rate regime, albeit with intermittent adjustments, such as from 1959 to 1980, and with minor variations. Komolafe (1996) points out that the oil shocks of the 1970s prompted the country to adopt an independent exchange rate policy, leading to the eventual pegging of the Naira to a basket of seven currencies from its principal trading partners over time.

In 1986, with the initiation of the Structural Adjustment Programme (SAP), the exchange rate of the Naira was allowed to float, prompted by speculations that the Naira was overvalued (Olagunju, 2008). Recognizing the potential risks associated with a floating exchange rate, particularly the possibility of a rapid devaluation of the Naira, the policy was designed with several mechanisms intended to stabilize the Naira's external value. These mechanisms, as detailed by the Central Bank of Nigeria (CBN) in 1996, encompass a variety of approaches, including the trade-weighted exchange rate

(Goldberg, 2004), the average pricing method, the marginal pricing method, the modal average method, and the Dutch Auction System (DAS).

Table 1. Summary of exchange rate management in Nigeria

No	Year	Management Technique	Remarks
1.	1959-1967	Fixed parity solely with British pounds sterling (£)	Suspended in 1972
2.	1968-1972	Inclusion of the U.S. dollar ($) in the parity exchange	The aftermath of the 1967 devaluation of the pound sterling (£) and the emergence of a strong U.S. dollar ($)
3.	1973	Revert to fixed parity with the British pound sterling (£)	Devaluation of the U.S. dollar ($)
4.	1974	Parity to both British pounds and U.S. dollar	To minimize the effect of the devaluation of the individual currency
5.	1978	Trade (Import) – weighted basket of currency approach	Tied to seven currencies such as British pounds, U.S. dollar, German mark, French franc, Japanese yen, Dutch guilder, Swiss franc
6.	1985	Referenced on the U.S. dollar	To prevent the prevalence of arbitrage in the basket of currencies.
7.	1986	Adoption of second-tier foreign exchange (SFEM)	Deregulation of the economy
8.	1987	Merger of the first and second-tier markets	Merger of rates
9.	1988	Introduction of the inter-bank foreign exchange market (IFEM)	Merger between the autonomous and the foreign exchange market (FEM) rates
10.	1994	Fixed exchange rate	Regulate the economy
11.	1995	Introduction of the autonomous foreign exchange market (AFEM)	Guided deregulation
12.	1999	Re-introduction of the inter-bank foreign exchange market (IFEM)	Merger of the dual exchange rate following the abolition of the official exchange rate from January 1, 1999
13.	2002	Re-introduction of the Dutch Auction System (DAS)	Retail DAS was implemented at first instance with CBN selling to end-users through the authorized users (banks)
14.	2006 - Date	Introduction of Wholesale DAS (WDAS)	Further liberalized market

Source: Mordi (2006).

The DAS, suspended in 2015, was specifically aimed at narrowing the significant gap between the parallel and official market exchange rates, a disparity driven by the consistently high demand for foreign exchange. The system was bifurcated into the Retail Dutch Auction System (RDAS) and the Wholesale Dutch Auction System (WDAS), with the RDAS being comparatively less stringent than the WDAS and the E-NOODLES (Electronic Naira/Dollar Exchange Rate System), which is driven by Information and Communication Technology (ICT). According to Auwal (2008), the Retail Dutch Auction System's flow chart vividly illustrates its relative laxity, as depicted in Figure 3.

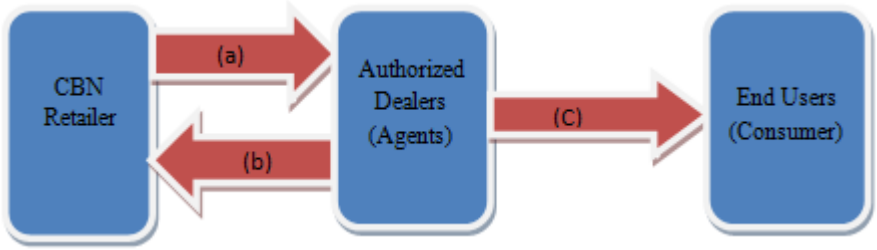

Figure 3: Retail Dutch auction flow chart
Source: Adopted from Auwal (2008)

Figure 3 elucidates how the Central Bank of Nigeria (CBN) could mitigate the discrepancy between the official and parallel market exchange rates in Nigeria, where (a) represents the supply of foreign exchange for onward delivery to consumers, (b) denotes the presentation of consumer effective demand, and (c) identifies the foreign exchange suppliers. This illustration underscores the CBN's efforts to effectively manage the exchange rate's spread.

The CBN has consistently prioritized economic growth as part of its objectives in light of the varied monetary policies implemented concerning exchange rate regimes. It is, therefore, crucial to assess the impact of different exchange rate regimes on Nigeria's economic growth. Kenny (2019) employs the Fully Modified Ordinary Least Squares (FMOLS) estimation technique in his study to ascertain the impact of exchange rate regimes on economic growth in Nigeria from 1981 to 2015. His findings suggest that a fixed exchange rate regime would not bolster economic growth in Nigeria in the long term, as indicated by a negative insignificant coefficient associated with the dummy variable. Conversely, maintaining a managed floating exchange rate regime could significantly enhance domestic production, thereby increasing Nigeria's external reserves (Kenny, 2019).

In conclusion, while the existing literature predominantly focuses on the superiority of exchange rate regimes without specifying whether data from the official market or parallel market exchange rates were utilized, there is a consensus that the chosen exchange rate regime ultimately affects domestic production and, by extension, the industrial sector. Dornbusch (1987) introduced an industrial organization approach to illustrate how relative prices adjust to exchange rate movements, noting that the extent of price adjustment, considering labour costs in respective currencies, depends on price substitutability, the relative number of domestic and foreign firms, and market structure. Thus, effective management of the exchange rate regime should prioritize industrialization in Nigeria to significantly increase foreign exchange inflow and positively influence the exchange rate. Various authors, including Kempaka (1999), Subair & Salihu (2010), and Demir & Caglayan (2012), have emphasized the impact of the exchange rate on the industry. However, this study shifts the focus by examining how the industrial sector influences exchange rate volatility, proposing a reversal in the conventional analysis approach.

METHODS

This study draws upon the portfolio balance theory, recognizing its significance in understanding industrial growth dynamics. The theory notably underscores the importance of expected returns from assets, thereby aligning with the principle that profit maximization constitutes the primary objective of every firm or industry. The portfolio balance model's approach to exchange rate determination illustrates the dynamic nature of examining exchange rate volatility and its implications for exchange

rate regimes. Concurrently, the managerial theory of the firm, which highlights the critical role of human resources as the essence of the firm, supports the perspective that industries can adapt and boost production in response to exchange rate fluctuations to maximize profits.

Given the study's aim to explore effective exchange rate management in Nigeria through industrial development, it becomes essential to refine the models proposed by Kempaka (1999), Subair & Salihu (2010), and Demir & Caglayan (2012) to more accurately reflect the impact of the industrial sector on exchange rate volatility and, consequently, on industrial growth within Nigeria. Kempaka (1999) observed that Uganda's manufacturing sector relies heavily on imported intermediate inputs, thus encountering increased production costs due to uncertain or adverse exchange rate movements. Similarly, Subair & Salihu (2010) identified that activities in the stock market are influenced by exchange rate movements, particularly through the interest rate premium impacting Nigeria's industrial sector. Demir & Caglayan (2012) further found that exchange rate volatility significantly negatively affects firm productivity in Turkey, which is attributed to real exchange rate appreciations and volatility.

The portfolio balance theory, with its focus on both short-term and long-term exchange rate volatility, reinforces the findings of Kempaka (1999), Subair & Salihu (2010), and Demir & Caglayan (2012). The long-term impact of exchange rate volatility on the cost of capital affects production costs, especially by importing inputs crucial for industrial development. Additionally, in less industrialized countries lacking sufficient resources, any change in the exchange rate prompts foreign investors to diversify their portfolios, affecting the country's industrial development process. Thus, adapting these models is imperative, considering Nigeria faces challenges similar to those of the countries examined in these studies, highlighting the profound influence of exchange rate movements on industrial development and the need for tailored exchange rate management strategies.

Model specification

The model specification outlined for this study is informed by the findings of Kempaka (1999), Subair and Salihu (2010), and Demir and Caglayan (2012), who all identified a negative impact of exchange rate volatility on industrial growth and development. This insight informs the model's premise: Nigeria must escalate its industrial development to align with the ranks of highly industrialized economies. Achieving such a status is a strategic approach to effectively managing its exchange rate and fostering a sustainable exchange rate regime. Consequently, the model recalibrates the frameworks provided by the studies above to examine the influence of industrialization on exchange rate volatility in Nigeria. The model is specified as follows:

$$h_t = f\,(ind_t, oil_t, cap_t,) \quad \ldots\ldots (1)$$

This equation (1) posits a linear relationship between exchange rate volatility and the determinants, industrial output, crude oil spot prices, and market capitalization, at a lag of one period to capture the effect of past values on current volatility. This relationship is further refined in equation (2) as:

$$h_t = \alpha + \beta_1 ind_{t-1} + \beta_2 oil_{t-1} + \beta_3 cap_{t-1} + \epsilon_{i.} \quad \ldots\ldots (2)$$

In this refined model:
h_t represents the exchange rate volatility at time t
ind_{t-1} is the industrial output at time $t-1$

oil_{t-1} denotes the crude oil spot prices at time $t-1$,
cap_{t-1} is the market capitalization at time $t-1$,
$\epsilon_{i.}$ is the error term, encapsulating the unobserved factors affecting exchange rate volatility.

Based on the identified gap in the recalibrated models, the model in equation (2) specifically identifies market capitalization as another major source of exchange rate volatility that tends to complement the influence of oil in the Nigerian economy. The model, thus, implicitly buttresses the need to determine the appropriate exchange rate regime considering the margin between the official and parallel markets exchange rates.

Going by the characteristics of the time series data – time-varying mean, variance and covariance exhibited by the models of this study, the autoregressive conditional heteroscedasticity (ARCH) and its extension are adopted and modified. The ARCH (Engle, 1982) specifies the residuals as a combination of unconditional and conditional variance and, therefore, depends linearly on the squared innovation generated by the autoregression framework. This study thus proposes the ARCH(1) specification as:

$$h_t = \alpha + \beta v_{t-1}^2 \quad \text{.......} \quad (3)$$

Where: h_t is the volatility term, the squared residual v_{t-1}^2 is defined as the ARCH term, meaning that squared residuals are autocorrelated over time. The restriction imposed on this model is that $\alpha > 0, \beta \geq 0$. If $\alpha = 0$ and β is not significantly different from zero, the volatility follows a martingale process. However, if the parameter (β) is significant and $\alpha > 0$ the volatility trend follows the ARCH process, it implies that innovations or shocks are significantly autocorrelated. Therefore, This study utilizes the vector error correction (VEC) method and BEKK-GARCH model, which are rooted in the conditional variance of a vector autoregression (VAR) specification. Hence, the baseline model is VAR (p) identification defined as:

$$\begin{aligned} r_{ext} &= a_{01} + a_{11} r_{ext-1} + ... + a_{1p} r_{ext-p} + b_{11} r_{indt-1} + ... + b_{1p} r_{indt-p} + u_{t1} \\ r_{indt} &= a_{02} + a_{21} r_{indt-1} + ... + a_{2p} r_{indt-p} + b_{21} r_{ext-1} + ... + b_{2p} r_{ext-p} + u_{t2} \end{aligned} \quad \text{.......} \quad (4)$$

Furthermore, assuming that y_t is a column vector of r_{ext} and r_{indt} respectively, in which case the two variables are treated symmetrically as given in equation 4

$$y_t = d_0 + d_1 y_{t-1} + ... + d_p y_{t-p} + \Sigma_t, \Sigma_t \approx MND(0, I_N) \quad \text{.......} (5)$$

Where: the contemporaneous error (Σ_t) is assumed as a product of time-variant and time-invariant variances, given as:

$$\Sigma_t = \Omega_t H_t^{0.5} \quad \text{.......} (6)$$

$$H_t = CC' + A_1 v_{t-1} v_{t-1} A_1' + B_1 h_{t-1} B_1' \quad \text{.......} (7)$$

From 7, an extension of the so-called univariate GARCH ($h_t = \eta + \sum_{i=1}^{p} \theta_i v_{t-p}^2 + \sum_{j=1}^{q} \vartheta_j h_{t-j}$) can be achieved by introducing the VECH representation of the MGARCH developed by Engle and Kroner (1995). The reason is due to the weakness of the VEC-GARCH specification in equation 10 below, as it is impossible to measure the impact of the volatility of one variable on the volatility of the other. The exchange rate and industrial

growth series are analyzed using the BEKK-MGARCH specification to overcome this weakness. That is:

$$H_t = CC' + \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} v_{1t-1}^2 & v_{1t-1}v_{2t-1} \\ v_{2t-i}v_{1t-1} & v_{2t-1} \end{pmatrix} \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}' + \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} \begin{pmatrix} h_{11t-1} & h_{12t-1} \\ h_{21t-1} & h_{22t-1} \end{pmatrix} \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}' \quad \text{.....(8)}$$

Hence, the MGARCH-VECH is given as:

$$vecH_t = C + \sum_{i=1}^{q} A_i vecv_{t-i}(v_{t-i})' + \sum_{j=1}^{p} B_j vecH_{t-j} \quad \text{..... (9)}$$

$$vecH_t = C + A(L)vecv_t(v_t)' + B(L)vecH_t \quad \text{.....(10)}$$

The estimation of equation 7 makes it possible to investigate the exchange rate volatility on the volatility of industrial output and vice versa. To explain whether industrial growth has an impact on the volatility of the exchange rate,

The matrix polynomial $A(L) = \sum_{i=1}^{q} A_i L^i; i = 1, 2, ..., q$ and $B(L) = \sum_{i=1}^{p} B_i L^i; i = 1, 2, ..., p$, VEC are the VEC half operators expressed as $N(N+1)/2$. Therefore, C is $N(N+1)/2X1$ a column vector while A and B are $N(N+1)/2XN(N+1)/2$ matrices. Since N is 2 in this study, the VECH-GARCH (1, 1) representation is given as:

$$\begin{vmatrix} h_{11,t} \\ h_{21,t} \\ h_{22,t} \end{vmatrix} = \begin{vmatrix} c_1 \\ c_2 \\ c_3 \end{vmatrix} + \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{vmatrix} v_{1t-1}^2 \\ v_{1t-1}v_{2t-1} \\ v_{2t-1}^2 \end{vmatrix} + \begin{pmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{pmatrix} \begin{Vmatrix} h_{11,t-1} \\ h_{21,t-i} \\ h_{22,t-i} \end{Vmatrix} \quad \text{.....(11)}$$

Data requirement and sources

The dataset utilized in this research is secondary. Consequently, data about the exchange rate (rext), exchange rate volatility (ht), industrial output (indt), crude oil spot prices (oilt), and market capitalization (capt) were gathered monthly from the Annual Abstract of Statistics by the National Bureau of Statistics (NBS) and the Statistical Bulletin by the Central Bank of Nigeria (CBN), spanning from the first quarter of 2000 to the fourth quarter of 2019.

Estimation technique

This study employs the Conditional Maximum Likelihood Technique (CMLT) estimation technique. This choice is predicated on the ability of CMLT to estimate the parameters within the models without the necessity for prior distributions. Moreover, applying the Conditional Maximum Likelihood Technique in this context facilitates establishing a robust relationship between exchange rate volatility and industrial growth in Nigeria. This approach is found to be superior when compared to other estimation techniques previously utilized by researchers such as Kempaka (1999), Subair and Salihu (2010), and Demir and Caglayan (2012), thereby offering a more accurate and reliable analysis of the underlying dynamics affecting the Nigerian economy.

RESULTS AND DISCUSSION

Descriptive statistics

The data on industrial output (IND), official exchange rate (OFR), and parallel market exchange rate (PMR) have been analyzed using descriptive statistics over a monthly period from 2000 to 2019. Observations regarding the normality conditions of

the dataset indicate that both the means and medians of these variables fall between their respective maximum and minimum values, suggesting a degree of central tendency. The dataset exhibits positive skewness, as detailed in the summary of descriptive statistics presented in Table 2.

Table 2. Summary of descriptive statistics

Variable List	PMR	OFR	IND
Mean	169.8413	150.2811	45411995
Maximum	497.0000	309.7300	3.52E+08
Minimum	103.5000	98.15000	130000.0
Std. Dev.	74.69669	45.00342	58702908
Skewness	2.715029	2.277818	3.173240
Kurtosis	9.974537	8.353367	15.01411
Jarque-Bera	683.6349	432.3582	1615.396
Probability	0.000000	0.000000	0.000000

The computed statistics show that the mean industrial output is approximately US$45,411,995, with the lowest recorded value being US$130,000 and the highest reaching US$35,200,000,000. This range demonstrates the increasing trend of industrial output over the study period, as indicated by its positive mean value. The lowest recorded values for the PMR and OFR were ₦103.50 and ₦98.15 per dollar, respectively, both observed in January 2000. Conversely, the maximum observed rates for the PMR and OFR were ₦497 and ₦309.73 per dollar, achieved in January 2018 and August 2017, respectively. The standard deviation indicates greater volatility in the PMR compared to the OFR, highlighting the PMR's contribution to production costs and inflation tendencies in Nigeria.

The skewness values for PMR, IND, and OFR are 2.72, 3.17, and 2.28, respectively, indicating that all variables are positively skewed, suggesting a distribution with higher values. This skewness, coupled with their positive mean values, underlines the variables' high volatility and its impact on the instability of Nigeria's currency. The kurtosis values exceeding 3 signify that the distributions are leptokurtic, featuring pronounced peaks and outliers indicative of volatility.

Given that the Jarque-Bera test results in probability values below 0.01, the null hypothesis of normality is rejected at the 1 per cent significance level, indicating that PMR, IND, and OFR do not follow a normal distribution. This non-normality and observed volatility provide a strong basis for developing volatility models, as proposed in this study. The trends of these variables, both at raw and differenced levels, are further illustrated through line graphs in subsequent figures (Figure 5 – 7), showcasing the dynamics of IND, OFR, and PMR over the study period.

The analysis of the industrial sector's performance during the study period reveals significant insights through the distribution trends of industrial output (IND), official exchange rate (OFR), and parallel market exchange rate (PMR). Figure 4 demonstrates that the lowest production levels marked the period between 2000 and 2001, while the highest output occurred between 2017 and 2018. This variation underscores the fluctuating nature of industrial production in Nigeria, with the pie chart vividly illustrating the disparity in output across different years.

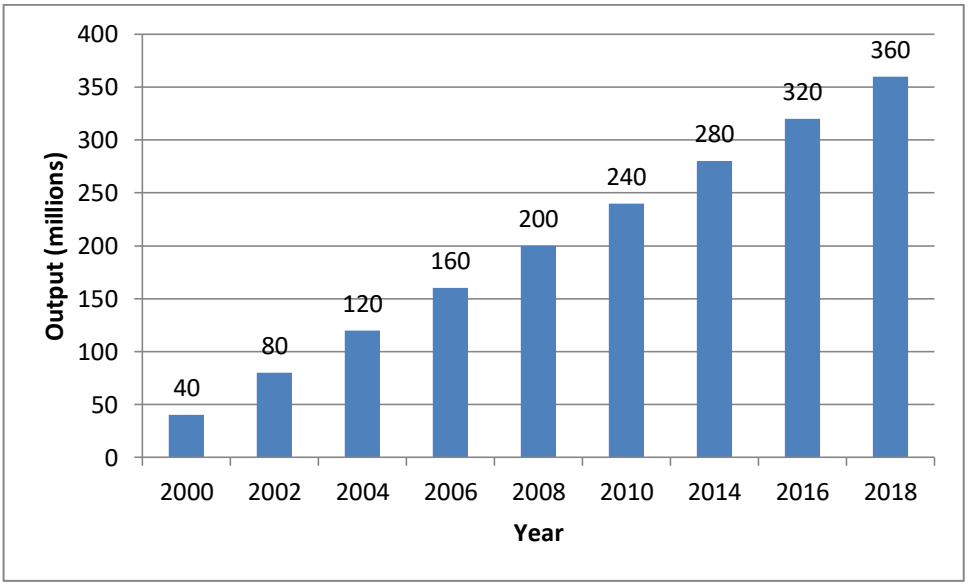

Figure 4. Industrial output (2000-2018).

The line graph of industrial output at the raw level, presented in Figure 5, further evidences the inconsistent trajectory of industrial output, showcasing significant fluctuations with peaks in 2003 and 2015. These observations highlight the instability within the Nigerian industrial sector, characterized by periods of both high and low production outputs.

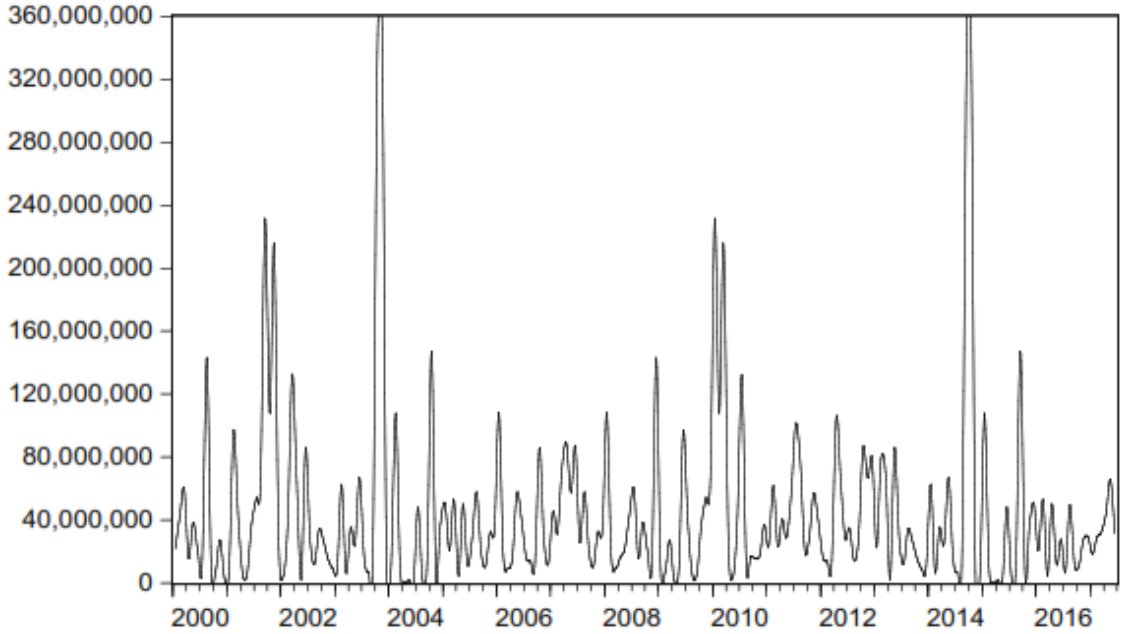

Figure 5. Line graph of industrial output (IND) at raw level

Figure 6 shows the official exchange rate's evolution, indicating a gradual increase from 2000 to 2003, followed by a decline leading up to 2008. A sharp rise was noted in 2009, with a steady increase until 2011, a decline in 2012, and a notable increase in 2014, reaching its peak in August 2016. Subsequently, a slight decline was observed through to 2018, illustrating the OFR's variable trend over the years.

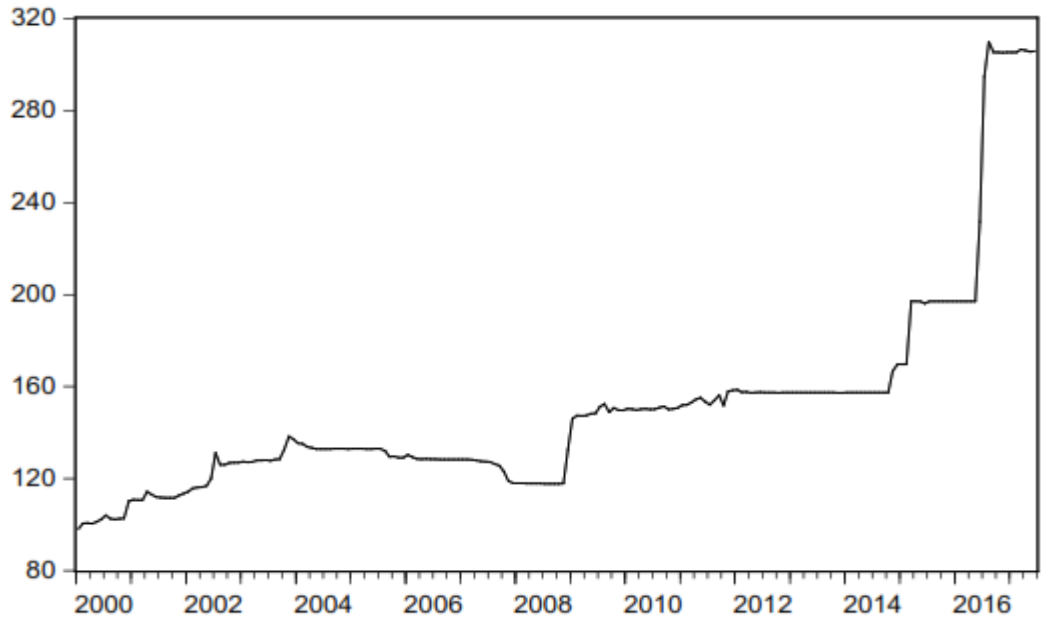

Figure 6. Line graph of official exchange rate (OFR) at raw level

Conversely, Figure 7, depicting the parallel market exchange rate, illustrates a rise from 2000 to 2001, a decline in 2003, an increase in 2004, and a decline in 2005. Between 2006 and 2007, the PMR experienced a gradual fall, followed by a steady rise until 2014, culminating in a sharp increase and reaching its peak in January 2017. Post-January 2017, the rate gradually declined, with a notable increase towards the end of 2019, indicating the PMR's erratic behavior over time.

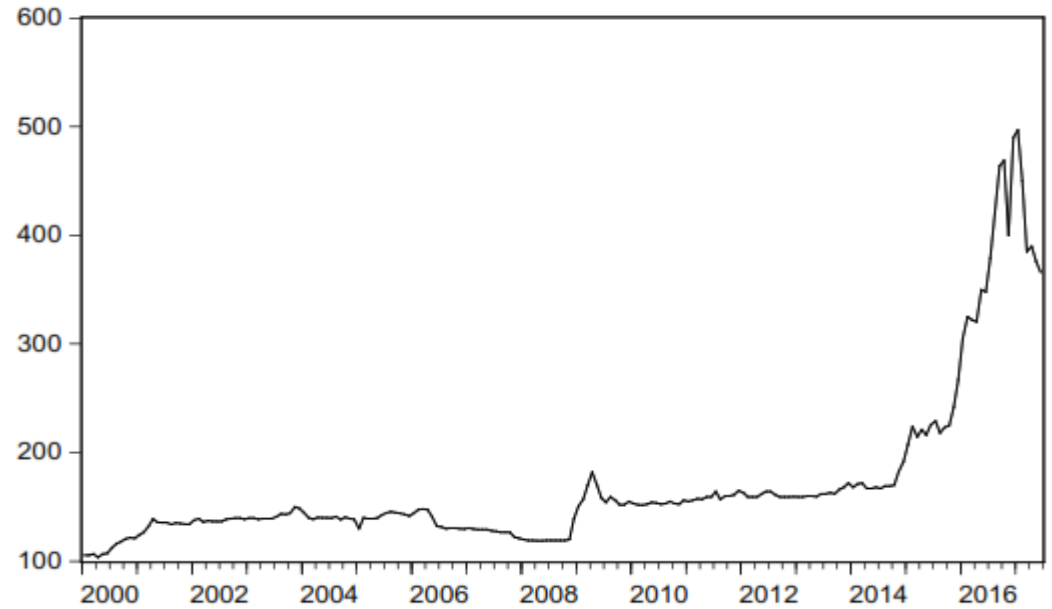

Figure 7. Line graph of the parallel market exchange rate (PMR) at the raw level

The comparative analysis of the OFR and PMR, showcased in Figure 8 through a bar chart, reveals the unpredictable nature of the PMR when compared to the OFR. Throughout the study period, the PMR demonstrated a tendency for erratic increases, emphasizing its unpredictability relative to the more stable OFR trends. This comparative analysis highlights the complexities and dynamics influencing Nigeria's

exchange rates and underscores the need for a nuanced understanding of the factors driving these fluctuations.

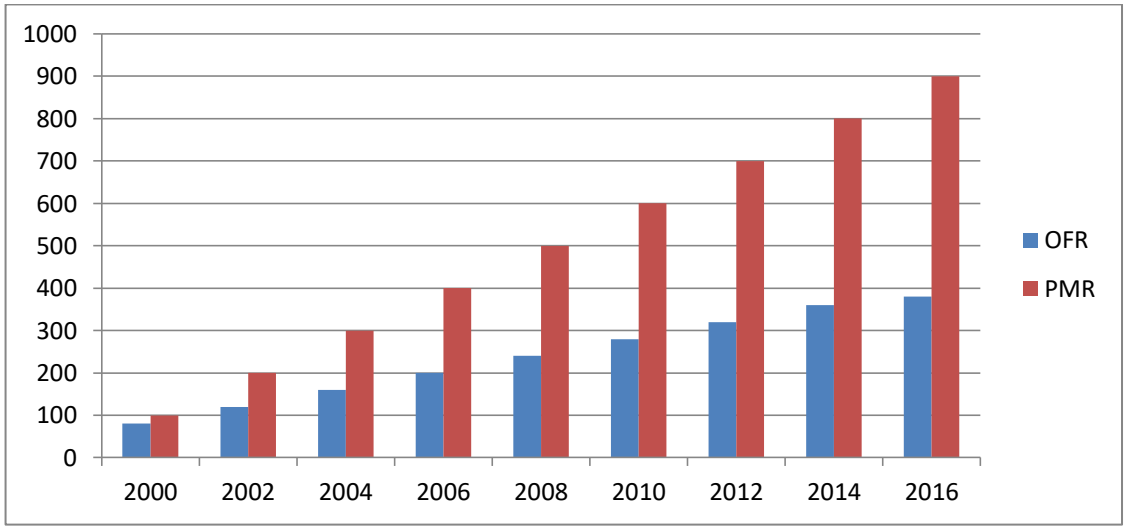

Figure 8. Official and parallel market exchange rates

Data diagnostic tests

The necessity of employing time series data in this study stems from the specific nature of the variables required to assess the impact of industrial growth on exchange rate fluctuations. Time series data are inherently characterized by observational dependence and variability over time, necessitating rigorous testing to ensure their reliability for analysis. Consequently, the data undergo a series of diagnostic tests, including the correlogram Q test, the Brook, Dechert, and Sheinkman (BDS) test, tests for Autoregressive Conditional Heteroskedasticity (ARCH) effects, and the Augmented Dickey-Fuller (ADF) unit root test for each variable under consideration. Through the application of these tests, the results affirm their utility in facilitating the selection of the most suitable models and estimation techniques to effectively address the issue of exchange rate volatility in Nigeria.

Detecting autocorrelation using Correlogram-Q test

The detection of autocorrelation using the Correlogram-Q test is a critical step in confirming the presence of autocorrelation within a series of variables, a precondition for estimating the effects of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models. This necessitates the testing for the null hypothesis, which posits the absence of autocorrelation. The Correlogram-Q test serves a dual purpose: it tests for any remaining serial correlation in the mean equation and verifies its specification.

Table 3. Correlogram-Q test results on industrial output, official market foreign exchange rate and parallel market exchange rate

	IND		OFR		PMR	
	Lag Q-Stat	Prob	Q-Stat	Prob	Q-Stat	Prob
1	32.637	0.00	25.993	0	9.0225	0.00
2	39.361	0.00	26.045	0	9.6066	0.01
3	40.878	0.00	26.225	0	10.379	0.02
4	40.881	0.00	26.565	0	14.833	0.01
5	45.849	0.00	26.695	0	14.966	0.01

The results presented in Table 3 from the Correlogram-Q Test on Industrial Output (IND), Official Market Foreign Exchange Rate (OFR), and Parallel Market

Exchange Rate (PMR) reveal significant autocorrelation across these variables. The Q-Statistics reported are notably high, with associated probabilities close to or at zero across various lags, indicating a significance level below the 1 per cent threshold. Such findings lead to a rejection of the null hypothesis for each variable under study, thus providing compelling evidence of autocorrelation within the series of IND, OFR, and PMR. This outcome aligns with the foundational assumptions of GARCH model estimation, underscoring the importance of autocorrelation detection in the econometric analysis of financial data.

Detecting linear dependency using the BDS test

The BDS test assesses whether a random sequence exhibits independence and identical distribution (IID), challenging the classical assumption inherent in traditional linear equations that presume IID. This test is particularly useful for identifying the presence of linear or non-linear dependencies among variables. In the context of this study, the BDS test was applied to investigate the relationship among variables such as industrial output, official market foreign exchange rate, and parallel market exchange rate. The results in Table 4 illustrate the BDS statistics and associated probabilities for each variable across five dimensions.

Table 4. BDS test results on industrial output, official market foreign exchange rate and parallel market exchange rate

Dim	IND		OFR		PMR	
	BDS-Stat	Prob	BDS-Stat	Prob	BDS-Stat	Prob
1	0.033837	0.00	0.071896	0.00	0.074456	0.00
2	0.070220	0.00	0.117478	0.00	0.134996	0.00
3	0.090078	0.00	0.138319	0.00	0.179280	0.00
4	0.098630	0.00	0.153007	0.00	0.195216	0.00
5	0.100298	0.00	0.155130	0.00	0.196253	0.00

The findings from Table 4 reveal that, particularly in the third, fourth, and fifth dimensions, the probabilities are significantly low, leading to the rejection of the null hypothesis of IID—or absence of linear dependency—in three out of the five dimensions evaluated. Moreover, the BDS statistics for industrial output (IND), official market foreign exchange rate (OFR), and parallel market exchange rate (PMR) each correspond to probabilities below the 5 percent significance level, indicating a rejection of the null hypothesis for all three variables. Consequently, this provides substantial evidence to suggest that IND, OFR, and PMR, along with their margins, exhibit non-linear, chaotic characteristics, and can be considered deterministic variables. This analysis underscores the importance of employing the BDS test to uncover underlying dependencies in economic variables, challenging traditional assumptions and contributing to a more nuanced understanding of economic dynamics.

Unit root test on industrial output, official market exchange rate and parallel market exchange rate

This study employs the Augmented Dickey-Fuller (ADF) test to ascertain the integration level or order of the variables under consideration, ensuring that none of the proposed variables for this study exhibit I(2) stationarity. The significance of this verification stems from the incompatibility of I(2) variables with conditional variance equations. The outcomes of the ADF test are detailed in Table 5, which presents the ADF statistics for industrial output, official market foreign exchange rate, and parallel market exchange rate..

Table 5. ADF test results on industrial output, official market foreign exchange rate and parallel market exchange rate

Series	ADF-stat	5%-c-value	Prob.
DIND	-12.17	-2.88	0.00
DOFR	-.954	-2.88	0.00
DPMR	-11.51	-2.88	0.00

The ADF statistics for industrial output (DIND), official market foreign exchange rate (DOFR), and parallel market exchange rate (DPMR) are -12.17, -9.54, and -11.51, respectively. These statistics significantly exceed the critical values between -2.87 and -2.88, indicating a strong rejection of the null hypothesis at the 5 per cent significance level. The null hypothesis posits that the series becomes stationary only after differencing. Given that the observed ADF statistics are substantially greater than the critical values in absolute terms, it is concluded that all variables are integrated of order one, or I(1).

This result confirms that the variables under study do not exhibit I(2) stationarity, satisfying a crucial prerequisite for their inclusion in conditional variance equations. Identifying all variables as I(1) is pivotal for the subsequent analysis, as it ensures the appropriateness of the econometric models employed in this research.

Test of ARCH effects on industrial output, official market foreign exchange rate and parallel market exchange rate

The investigation into the presence of Autoregressive Conditional Heteroskedasticity (ARCH) effects is a pivotal step before the estimation of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) and Bollerslev, Engle, and Kroner Multivariate GARCH (BEKK-MGARCH) models. Identifying ARCH effects is necessary to ensure that the innovations of the variables in question exhibit time-varying volatility, a prerequisite for the meaningful estimation of GARCH and BEKK-MGARCH models. Without time-variant innovations, the estimations of these models would yield biased and inconsistent results. The findings from the ARCH effects test are summarized in Table 6, which provides a detailed analysis of industrial output, official market foreign exchange rate, and parallel market exchange rate.

Table 6. ARCH effects test on industrial output, official market foreign exchange rate and parallel market exchange rate

Variable	ARCH-Coefficient	Std-error	Z-Stat	Prob.
DIND	0.280	0.12	2.37	0.00
DOFR	0.340	0.10	3.34	0.00
DPMR	0.500	0.17	3.02	0.00

Table 6 highlights the ARCH coefficients for industrial output (DIND), official market foreign exchange rate (DOFR), and parallel market exchange rate (DPMR) as 0.28, 0.34, and 0.5, respectively. The positive values of these coefficients align with the theoretical expectation that ARCH coefficients should be positive. The statistical significance of these coefficients is affirmed by their p-values and Z-statistics, indicating significant ARCH effects across all variables. This finding underlines the presence of autocorrelation, non-linear dependency, and leptokurtosis within the variables, thereby justifying the subsequent estimation of GARCH and BEKK-MGARCH models as initially proposed.

Further analysis reveals that the variables exhibit positive skewness, indicating a distribution with a tendency towards larger values rather than smaller ones. This trend suggests a persistent increase over time in the variables under study, particularly

reflecting the dynamics of exchange rates and currency prices in Nigeria. Additionally, the leptokurtic nature of these variables suggests a propensity for the occurrence of large values in the future, corroborated by the significant Jarque-Bera (J.B.) statistics, which suggest deviations from a normal distribution pattern.

The presence of significant ARCH effects underscores the chaotic nature of the variables, alongside the detection of non-linear dependencies as evidenced by the BDS test. This chaotic characteristic, manifesting in non-linear distributions with mean reversibility, is vividly illustrated in line graphs of differenced series, where large and small shocks follow one another in close succession. These empirical findings provide a robust foundation for applying advanced econometric models, such as GARCH and BEKK-MGARCH, to capture the complex dynamics of volatility and dependency in the variables under study.

Estimation of pass-through of volatility between exchange rate and industrial output

The coefficients of the BEKK representation within the Bivariate GARCH (1,1) model were estimated to determine the existence of pass-through effects between Industrial Output (IND) and the Official Foreign Exchange Rate (OFR), as well as between IND and the Parallel Market Exchange Rate (PMR). The findings, presented in Tables 7 and 8, elucidate the dynamics of these relationships.

Table 7. Results on the examination of a pass-through between industrial output and official exchange rate

Descriptor	Coefficient	Std-error	Z-value	P-value
A1(1,1)	0.774409	0.089018	8.699427	0.0000
A1(2,2)	0.677607	0.081714	8.292458	0.0000
B1(1,1)	0.666744	0.052660	12.66122	0.0000
B1(2,2)	0.017764	0.487184	0.036463	0.9709

Table 7 showcases the results concerning the pass-through between Industrial Output and the Official Exchange Rate. The coefficients for internal shocks (A1(1,1) and A1(2,2)) and own-family volatility (B1(1,1) and B1(2,2)) for IND and OFR respectively reveal significant values. Notably, the coefficient for A1(1,1) at approximately 0.77 and A1(2,2) at about 0.67, both with p-values significantly below the 1 per cent threshold, suggest that historical shocks from IND have a more pronounced effect on its current shocks than those originating from OFR. This indicates the transmission of significant changes from the industrial sector to the official foreign exchange market, with the volatility transmission being notably one-sided from IND to OFR, as evidenced by the larger coefficient and significant p-value for B1(1,1) compared to B1(2,2).

Contrarily, historical shocks from the industrial sector (IND) impact the current shocks of the official foreign exchange market (OFR) more than the historical shocks of OFR itself. Given that the p-values are less than 0.01, it indicates significant transmissions of large changes, shocks, surprises, or innovations from the industrial sector to the official foreign exchange market. Moreover, the coefficient of B1(1,1) at 0.67 is significantly higher than that of B1(2,2) at 0.02, with their corresponding probabilities being 0.00 and 0.97, respectively. These findings suggest a clear volatility transmission from the industrial sector to the official foreign exchange market but not vice versa. Furthermore, the results highlight that the previous volatility of IND has a greater impact on its current volatility than the previous volatility of OFR does on its

current state. Simultaneously, the current volatility of OFR is more influenced by the historical volatility of IND than by the historical volatility of OFR itself.

Table 8. Results on the examination of a pass-through between industrial output and parallel market exchange rate

Descriptor	Coefficient	Std-error	Z-value	P-value
A1(1,1)	0.681660	0.074372	9.165524	0.0000
A1(2,2)	0.876277	0.143366	6.112173	0.0000
B1(1,1)	0.741385	0.041039	18.06526	0.0000
B1(2,2)	0.533740	0.071618	7.452542	0.0000

Table 8 outlines the coefficients for internal shocks within the industrial sector (IND) as A1(1,1) and for the parallel market rate (PMR) as A1(2,2), alongside the coefficients for family volatility within IND as B1(1,1) and within PMR as B1(2,2), recorded as 0.68, 0.88, 0.74, and 0.53, respectively. Notably, all coefficients are associated with probabilities that fall below the 1 per cent significance level, indicating high statistical significance. The coefficient for A1(2,2) surpassing that of A1(1,1) suggests that historical shocks in PMR exert a greater influence on the current shocks within IND than the historical shocks of IND itself.

Similarly, the current shocks of PMR are predominantly influenced by its historical shocks rather than those originating from IND. This illustrates a significant transmission of shocks between parallel and foreign exchange markets and the industrial sector, indicating a bidirectional volatility pass-through. Despite this interaction, it is observed that the current volatility of IND is more significantly affected by its historical volatility than by the historical volatility of PMR. Conversely, the historical volatility of IND has a greater impact on the current volatility of PMR than PMR's previous volatility, highlighting a complex web of influences across these sectors.

Anticipating that fluctuations in exchange rates would directly affect industrial performance, notably through the output generated by industries, adhering to the traditional belief is expected. Contrary to these expectations, the study, employing the BGARCH (11) model, discovered that the official foreign exchange rate (OFR) exerts minimal historical shocks on the industrial sector (IND). In contrast, the anticipated shocks of IND significantly influence its present shocks. According to the findings presented in Table 7, it appears that volatility within the industrial performance substantially impacts the current volatility of the OFR more than the OFR's volatility. This unexpected outcome suggests that while there is a positive volatility transmission from the industrial sector to the official foreign exchange market, the reverse—namely, from the official foreign exchange market to the industrial sector—is negative. Such findings stand in contrast to the positions held by Adebiyi and Omotayo (2009) as well as Aghion et al. (2009), due to the reverse causality observed between IND, OFR, and the parallel market rate (PMR) in this study.

However, Table 8 illustrates that the Purchasing Managers' Index (PMR) has a more pronounced impact on the current shocks of the Industrial Sector (IND) than on the current shocks of the industrial sector itself. This finding substantiates the widely held belief that the PMR significantly affects industrial production, aligning with the assertions made by Kempaka (1999) and Kenny (2019). Consequently, there is a reciprocal relationship between the industrial sector and the foreign exchange market.

Moreover, the study provides additional confirmation that the current volatility of the IND is more influenced by its historical volatility than by the preceding volatilities of the Official Foreign Reserves (OFR) and PMR, as indicated in Figure 9.

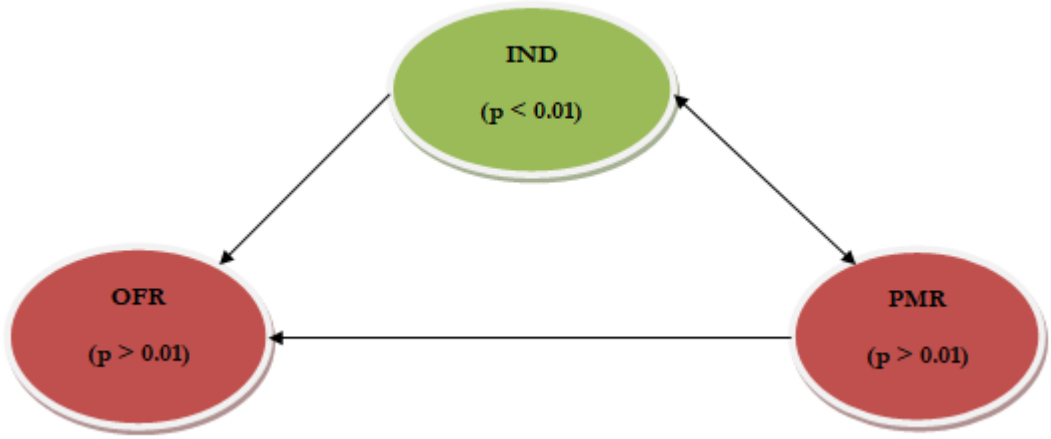

Figure 9. Estimated pass-through (EPTR) of volatility

Figure 9 provides a concise overview of the calculated volatility transmission patterns among the Industrial Sector (IND), Official Foreign Reserves (OFR), and Purchasing Managers' Index (PMR). It is observed that the IND primarily responds to its own historical shocks, indicated by the bidirectional arrow (↔), but it also imparts a greater degree of volatility to both OFR and PMR.

The analysis reveals that IND (1.83^{-9}, $p < 0.01$) has a substantial and statistically significant positive impact on the volatility margin between OFR and PMR. However, it is noteworthy that this influence is accompanied by a negative and statistically significant margin (-6.72^{-05}, $p > 0.01$).

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study highlights several significant findings. Firstly, it reveals a bidirectional transmission of shocks between the industrial sector and the official foreign exchange market, with the direction of flow favouring the official market. Conversely, there is a unidirectional volatility transmission from the foreign exchange market to the industrial sector, favouring the official market. However, it is noteworthy that a bidirectional transmission of shocks and volatility exists between the parallel market and the industrial sector.

Furthermore, the study emphasizes the importance of anticipated shocks in the industrial output, as they have a more pronounced impact on its current shocks than the historical shocks of the official market. Conversely, the previous shocks of the parallel market exchange rate do not significantly influence its current value compared to the historical shocks of industrial output. Additionally, the current volatility of the parallel market exchange rate is primarily influenced by its historical volatility rather than the historical volatility of the industrial output.

Moreover, the research findings suggest an inverse relationship between market capitalization, crude oil spot prices, and industrial output indexes with official exchange rate volatility, although these relationships are deemed statistically insignificant. An increase in these factors appears to lead to a reduction in official market exchange rate volatility. Furthermore, evidence indicates that market capitalization increases with rising parallel market exchange rate volatility. Conversely, parallel market exchange rate volatility tends to decrease with higher crude oil spot prices and industrial output

indexes. This outcome suggests that as industrial development in Nigeria advances, the prospect of currency stability becomes increasingly attainable.

Recommendations

Based on the analysis above, it is imperative to pursue a policy to promote the consumption of domestically produced goods while reducing the demand for foreign currencies. This policy can be effectively implemented by providing subsidies and ensuring stringent quality control through the active involvement of regulatory bodies such as the Standard Organization of Nigeria (SON) and the National Agency for Food and Drug Administration and Control (NAFDAC).

Furthermore, a concerted effort should be made to establish a policy focusing on foreign exchange earnings and its responsible utilization by corporations and individuals. This approach will render the transition more attainable and realistic, effectively curbing the volatility and shocks in the foreign exchange markets. Additionally, it is essential to explore alternative measures to mitigate exchange rate instability and stabilize the Nigerian currency.

One such measure involves securing funding for industrial development through innovative financial strategies, such as issuing Diaspora bonds. This approach allows the economy to access additional foreign exchange from expatriates residing in affluent nations, expediting industrial development. Increasing remittances from overseas and repatriating illicit financial flows are other innovative sources of financing that can augment the foreign exchange supply. This has the potential to diminish exchange rate fluctuations while fostering economic growth and enhancing industrial performance.

Incorporating modern technological innovations like robotics, artificial intelligence, machine learning, advanced manufacturing, and the Internet of Things (IoT) into the industrial sector should be pursued through comprehensive research, training, and collaboration with foreign investors. This initiative will incentivize the industrial sector to operate at higher capacities, substituting imported products with domestically manufactured goods. Ultimately, this approach will contribute to overall economic stability, alleviating pressure on the Nigerian Naira (₦).

At this juncture, Nigeria can strive for self-sufficiency without relying on foreign aid; however, it cannot thrive without a stable foreign exchange market. If the nation channels its abundant resources towards industrial development, it will reduce its dependency on foreign assistance. Nevertheless, without efficient supervision of the exchange rate, the benefits of industrial development may be squandered, a predicament Nigeria has grappled with since the 1980s.

In alignment with the preceding, this study recommends the continuation of a managed floating exchange rate system, wherein the value of the national currency is maintained within a specific range against other currencies, albeit not entirely free or fixed. This approach should be coupled with transparency and unwavering integrity, centring on accurate record-keeping of foreign exchange inflows and outflows. Additionally, stringent measures should be enacted to prevent round-tripping, illicit practices, and the use of foreign exchange for local transactions within Nigeria.

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