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# The Impact of Exchange Rate Volatility on Rice Output in Nigeria

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## Abstract

The effect of the volatility of the Nigeria's exchange rate on the rice output in Nigeria was assessed under the fully modified ordinary least squares estimation method and employing annual time series data from 1980 to 2024. The exchange rate volatility variable was obtained using the general autoregressive conditional heteroskedasticity method (GARCH). The study found rice production to be positively and substantially influenced by the volatility of the Nigeria's exchange at a five per cent level of significance. The following policy recommendations were made emanating from the findings of the study: adoption of a managed float exchange rate system by the Central Bank of Nigeria; the provision of agricultural extension support to local rice farmers by the federal and state ministry of Agriculture such as encouraging the sustainable use of fertilizer, and investment in arable land expansion for more cultivation of rice, and the promotion the use of technology in rice cultivation and processing.

**Keywords:** Rice output, Exchange rate, volatility

## 1. Introduction

In recent times, one of the most challenging issues that is besetting and unsettling the Nigerian economy is not just the fast depreciation of the Nigeria's Naira exchange rate against the convertible currencies of the world but the frequency of the fluctuations of the exchange rate which has develop a problem for households in terms of leading to the lost in value of their purchasing power; while for businesses, it has created a problem of uncertainty that has affected critical business decisions by complicating cost of production and investment. For the Nigerian government, the instability of the exchange rate has affected its budget implementation and leads to economic policy uncertainty.

Agricultural production which is a substantial contributor to the economic growth in Nigeria (Kenneth & Onyedikachi, 2021; Olamide et al., 2022) has not be spaced, this is because of the imported components used in the agricultural sector and the attendant consequence for cost of production and the resultant outputs. This has made the farming business very challenging and discouraging to farmers (Okoh & Nwakwanogo, 2024). One of the widely cultivated and commercial agricultural produces is rice, and it is also the number one staple food in Nigeria, consume by every household and has not cultural barrier. Rice is such a top staple that the price of product is a parameter for the general price of food in the Nigerian market. This means that whatever affect rice, affect the food security of Nigeria (Mba et al.,2021; Wudil et al., 2023). The country demand for rice as constantly augmented over the years corresponding to the rise in the population of Nigeria, as among Africa's largest economies and Africa's most populated country (United States Department of Agriculture, USDA, 2025; Yeboua et al., 2022).

Nigeria has not been able to meet this ever-growing domestic demand for rice and has often have to import rice from other countries to satisfy domestic demand which keep rising on a yearly. The effort to grow rice domestically to meet rice sufficiency has not yielded a positive outcome, it has complicated the domestic rice shortage issue and leads to astronomical rise in the price of rice. The domestically cultivated rice has been following the imported foreign rice in terms of price setting thereby compounding the problem and leading to loss of welfare by the Nigeran households. At the heart of this problem is the exchange rate instability (Abdulsalam et al., 2021; Aye et al., 2024).

Exchange rate unpredictability by affecting the raw materials in rice farming can impact the total output of rice farming activities. For example, raw materials such as fertilizers and agricultural machinery are mostly imported components of farming activities and therefore the variation can affect the general rice output and profitability of rice farming to rice farmers, affecting also the welfare of consumers (Iorember et al., 2024). When exchange rate volatility impact rice production it can also affect food security and sufficiency of Nigeria has even imported rice that will supplement domestic rice production will become very expensive due to the weaking of the exchange rate by its unpredictability (Akinbode & Ojo., 2017; Wudil et al., 2023).

A assessment of the prevailing related data on the trend of Nigerian exchange rate (EXCHR) and milled rice output (MRO) as showed in Figure 1 revealed that from 1981 to 1985, the exchange rate increased by 10.26%, while MRO increased by 5.83%; from 1986 to 1990, the exchange rate increased by 61.90%, representing a 503.31% from the previous period, and MRO also increased by 37.06%, representing a 535.68% increase from the previous period, this shows a strong positive association between EXCHR and MRO. From 1991 to 1995, the exchange rate decreased by 24.92%, representing a 59.94% decrease from the previous period, and MRO decreased by 5.66%, representing an 84.73% decrease from the previous period, this shows a negative relationship between EXCHR and MRO.

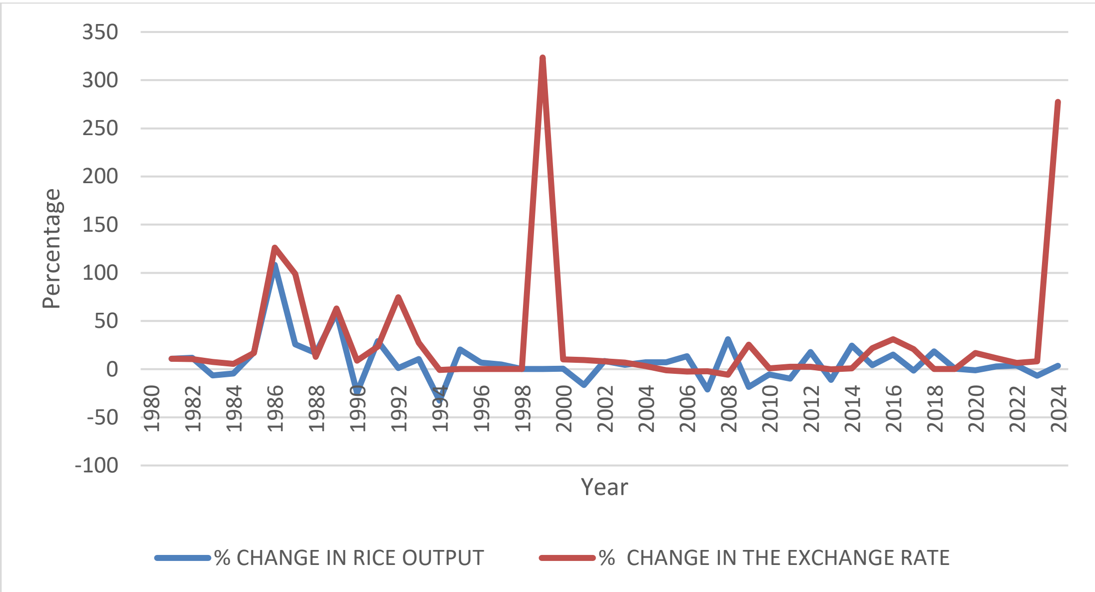


Fig. 1. Trend of percentage changes in milled rice output and exchange rate of Nigeria (1981 – 2024)

The trend analysis of the movement of exchange rates (EXCHR) and milled rice output (MRO) in Nigeria from 1996 to 2000, revealed that the exchange rate increased by 66.74%, while MRO decreased by 2.50%, indicating a negative association between the two variables in that period. This period showed an increase in exchange volatility and may negatively impact milled rice output. From 2011 to 2015, the exchange rate increased by 5.46%, while MRO increased by 5.10%, displaying a tendency of positive association between exchange rate and MRO; from 2016 to 2020 and 2021 to 2024, the trend of exchange rate instability and milled rice impact was mixed, which revealed a tendency of a mixed impacts on milled rice output. Seeing that the influence of exchange rate on rice output may not be cleared looking at trend analysis from figure 1, the study investigated the influence of exchange rate unpredictability on rice output in Nigeria.

## 2. Literature Review

### 2.1. Conceptual literature

#### Exchange Rate Volatility

Exchange rate volatility is the oscillation in the value of one country's currency against the currency of another, particularly the convertible currencies over time (Broda & Romalis, 2011). It captures the uncertainty or risk of the exchange rate, and it can have a negative influence on some monetary activities (Klein & Shambaugh, 2010). The GARCH model helps in the derivation of the exchange rate volatility (Hansen & Lunde, 2005).

#### Rice Output

Rice output is the amount or tonnes of milled rice produced in an economy within a specific period typically a year. Rice output is measured in tonnes or metric tonnes per year (Burki, 2022). Several factors influence the production of rice in an economic such as climate, weather, fertilizer usage, soil quality, inflation rate, government agricultural policy and even the unpredictability of the exchange rate (Bashir & Yuliana., 2019; Tun & Kang, 2015).

## 2.2. Theoretical Framework

### The agricultural household theory

The agricultural household theory was offered by Inderjit Singh, Lynn Squire and John Straus, and the theory proclaimed that households are both manufacturers and consumers of agronomic goods and the choice of what to produce, how to produce and to whom to produce is on the households, especially in developing countries that are predominantly agrarian (Singh et al., 1986). The theory asserted that the households in developing countries face uncertainty and risk in taking the decision on production and consumption, and they also face a problem resource constraint due to inadequate access to credit services and insurance services. The theory recommended that both the manufacture and feeding choices of the households should be harmonized by taking cognizance of the uncertainty and risk plus the limited resources available to the households (Coles & Xiong, 2017).

The theory has been criticized for assuming that the household decision making process on what to produce and what to consume is an easy one (Janvry et al., 1991); the theory does not contemplate the role of government policies and price mechanism (Bardhan, 2004) and did not that households ae heterogenous (Xie & Huang, 2021). Notwithstanding these criticisms of the theory, it offers an understanding of the exchange rate unpredictability on the production of rice. It explains how the household decision process on rice production could be affected by risk and ambiguity caused by exchange rate instability (Oluwaseun et al., 2024). This explains changes in household decision which can cause changes in rice production due to household limited resources. (Bashir & Yuliana., 2019).

### The theory of purchasing power parity (PPP)

This theory is credited to Gustav Cassel who propounded it in 1916 and it asserts that the exchange rate between two legal tenders is determined by the ratio of the general price levels or inflation rate between the two countries. The assumptions of the theory are the existence of free trade between the two countries, the presence of a perfect competitive market, the absence of transportation cost and similarity of goods in questions for exchange.

The criticisms of the theory are that it ignores transaction cost of international trade which is not realistic because every international trade activity involves a transaction cost the it captures in the final unit price of the goods; the theory also ignores the fact the between the two countries there may be alterations in taste and preference for goods, therefore, the assumption of homogeneity of goods is not a realistic assumption. Nevertheless, the theory helps to explain exchange rate determination and by extension how external factors may be accountable for the volatility of the exchange rate.

### The supply response function

The supply response function is employed to describe the association concerning the quantity output and input such as the association between the quantity of a good supplied and the factors that influence this supply such as the price of own good, the price of other goods, the cost of production, and technology capability. This supply response function assumes that the objective function of the supplier is to maximize profit, and minimize cost of production (Ball, 1988). The supply response function has been criticised by making a complex relationship between supply and demand look simply and ignores the intricacies of the marking forces (Nerlove, 1958). Despite the criticism, the supply response function is important in understanding that the production of rice in any economy depends the signal from the market that tell the suppliers when it will be profitable for them or not and the exchange rate unpredictability is some sort of a price signal and its impact on rice production cannot be ignored due to the objective function of the rice production which may be profit maximization or cost minimization which could be exaggerated by exchange rate instability (Askari & Cummings, 1977).

## 2.3. Empirical literature

The empirical literature on the influence of exchange rate on the agricultural sector output is extensive and the results divergent. The divergent findings could be due to the study's areas, methodology deployed or the time scope of the study. The influence of the exchange rate on the agricultural sector found mixed results with some studies found the optimistic influence of the exchange rate on agricultural output while others found an adverse influence. There are also studies that found a helpful effect in the short run but a harmful influence in the long run, signifying an unequal impact of the exchange rate on agricultural output.

Çatuk (2025) assessed the influence of exchange rate instability on agricultural exports in Turkey using time series data from 2016 to 2023. The study utilised a multiple regression analysis as an estimation method and found that exchange rate instability has a helpful influence on agricultural export in Turkey. Raja et al. (2025) assessed the effect of oil prices and exchange rates on food prices in OECD countries using panel data from of 38 OECD countries. The study employed ARDL bounds test and Granger causality methods and found that an improvement in food prices in sample countries is associated with the exchange rate and energy prices.

Okoh and Nwakwanogo (2024) investigated the influence of exchange fluctuation on agricultural export in Nigeria. The study employed the vector autoregressive estimation method using annual time series data from 1986 to 2021. The study found that exchange rate variation has a helpful and statistically significant influence on agricultural export in Nigeria. Turaki et al., (2023) using the Multivariate Generalize Autoregressive Heteroscedasticity (MGARCH), a Vector Autoregressive (VAR) and a monthly time series data from November 2015 to January 2019 to investigate the influence of urban food price instability spillover to exchange rate in Nigeria. The study found that exchange rate instability has a helpful shock in both urban food prices and money supply volatilities.

Iorember et al., (2024) assessed the influence of exchange rate, energy prices and sectoral expenditure on agricultural value added, household consumption and domestic investment in Nigeria using time series data from 1981 to 2020. The study employed Kernel regularized least squares (KRLS) estimation method and found that exchange rates have a helpful influence on agricultural expenditure and the effect of the exchange rate is helpful and statistically insignificant. Shabanzadeh-Khoshrody et al. (2023) investigated the effects of exchange rate on the food consumption in rural areas of Iran using panel data from 2005 to 2021. The panel ARDL estimation method was employed. The study found that exchange rates have a helpful influence on household food consumption in both the short term and long-term period.

Ogunjobi et al. (2022) investigated the effect of exchange rate on agricultural exports in Nigeria using time series data from 1981 to 2019. The study employed the ARDL model estimation method and found that exchange rate has a significant influence on not just agricultural product but agricultural exports in the long term in Nigeria. Olaoye (2022) employed the ARDL method to investigate the influence of exchange rate fluctuations on the Nigerian agricultural sector production. The study found that in the short term, the exchange rate harmfully influenced agricultural production, but the effect was statistically insignificant. But in the long term, the exchange rate helpfully influenced agricultural production, and the effect was statistically significant.

Fiaz et al. (2021) assessed the asymmetric effect of the exchange rate on the agricultural sector stands in Pakistan using annual time series data from 1970 to 2019. The study employed a nonlinear ARDL estimation method. The study found that helpful movements have lesser influences than those of harmful movements in the exchange rate on the agriculture sector both in short term and in the long term in Pakistan. Lestari et al. (2021) assessed the asymmetric effect on the rupiah exchange rate on every subsector agriculture export in Indonesia using time series data from 2006 to 2020. The study employed a non-linear ARDL estimation method. The study found an asymmetric effect of the rupiah exchange rate on exports of the agricultural sub-sector in the long term but no non-linear effect in the short term.

Siami-Namini (2019) assessed the influence of the instability of exchange rate on agricultural commodities prices using monthly time series from January 2006 to November 2015. The exponential generalized autoregressive conditional heteroscedasticity (EGARCH) model and VECM estimation methods were used. The study found that the instability of exchange rate has an important influence on the agricultural commodities returns in the pre-crisis than the post-crisis periods while the exchange rate instability in the post-crisis period, which in turn affects the instability of the agricultural commodities returns through changes in prices.

### 2.4. Research gap

The study on the influence of exchange rate instability on rice output in Nigeria is scarce. Many studies on the influence of exchange rate instability on agricultural output in Nigeria focus on the agricultural sector output at a whole. This study specifically focused on rice, a staple in every Nigeria household.

## 3. Research Methodology

### 3.1. Research design

The study adopted the ex-post facto research design in investigating the influence of exchange rate instability on rice output in Nigeria. The logic of the ex-post facto research design is that the data used for the study were already collated and are available in reputable databases by reputable statistical authorities, the current study can only look for any causal relationship between the key variables of the study and draw inference from it.

### 3.2. Model specification

#### Estimating exchange rate volatility

To examine the effect of exchange rate volatility on rice output, the study estimated the exchange rate return volatility series and included it as a variable in the fully modified ordinary least square model. Volatility measurement methods vary, with some studies using standard deviation to capture fluctuations around the mean (Schnabl, 2009; Gadanecz & Mehrotra, 2013). To capture exchange rate volatility the GARCH model (Bollerslev, 1986) that accounts for fluctuation in the current exchange rate as a function of the deviation of past exchange rate values was used, the underlying GARH process is thus:

Given that the current exchange rate is given as:

$$EXCHR_t = a_t + EXCHR_{t-1} + \varepsilon_t \qquad 1$$

### The exchange rate -rice output volatility model

The exchange rate -rice output volatility model is anchored on the agricultural household theory, purchasing power parity theory, and supply response function. agricultural employment and rural infrastructure are included based on the agricultural household theory, recognizing labor and infrastructure as critical factors in agricultural production. Agricultural machinery, arable land, fertilizer consumption, and water productivity are incorporated based on the supply response function, which considers technology, inputs, and factors affecting production decisions. Inflation is included based on the PPP theory, acknowledging its impact on price changes and economic decisions. Exchange rate volatility is also considered, drawing from both the purchasing power parity theory and supply response function, as it affects trade, prices, and production decisions.

The functional specification of the study's model is as follows:

$RO = f($ AGREMP, AM, ARL, FERCON, INFL, RIF, WATP, ERV) 2

Where:

RO = Rice output, proxied milled rice product. Measured in metric tonnes.

AGREMP = Agricultural employment. Measured percentage share of agricultural employment to total employment.

AM = Agricultural machinery. Measured in tractor by square kilometers of arable land.

ARL = Arable land. Measured in percentage of arable land share of land areas.

FERCON = Fertilizer consumption. It is measured in kilogram per hectare of arable land.

INFL = inflation rate. Measured in percentage change in consumer price index

RIF = rural infrastructure. Measured in access to electricity of per cent of rural population.

WATP = Water productivity. Measured in units such as kilograms per cubic meter ($kg/m^3$) of water.

ERV = exchange rate volatility.

The functional relationship between the dependent variables and their determinants is as:

Equation 1 is specified in a mathematical form thus:

$$RO_t = \alpha_0 + \alpha_1 AGREMP_t + \alpha_2 AM_t + \alpha_3 ARL_t + \alpha_4 FERCON_t + \alpha_5 INFL_t + \alpha_6 RIF_t + \alpha_7 WATP_t + \alpha_8 ERV_t \quad \dots \quad 3$$

Equation 3 is specified in an econometric form thus:

$$RO_t = \alpha_0 + \alpha_1 AGREMP_t + \alpha_2 AM_t + \alpha_3 ARL_t + \alpha_4 FERCON_t + \alpha_5 INFL_t + \alpha_6 RIF_t + \alpha_7 WATP_t + \alpha_8 ERV_t + \mathcal{E}_t \quad \dots \quad 4$$

Where:

$\mathcal{E}_t$ is the error term which represents other variables that affect rice output that are not captured explicitly in the model.

Equation 4 is presented in loglinear form thus:

$$log(RO)_t = \alpha_0 + \alpha_1 AGREMP_t + \alpha_2 AM_t + \alpha_3 ARL_t + \alpha_4 FERCON_t + \alpha_5 INFL_t + \alpha_6 RIF_t + \alpha_7 WATP_t + \alpha_8 ERV_t + \mathcal{E}_t \quad \dots \quad 4$$

Where:

where $\alpha_0$ *is the intercept of the model and* $\alpha_1$ $\alpha_2$ $\alpha_3$ $\alpha_{4,}$, $\alpha_5$ $\alpha_6$, $\alpha_7$ *and* $\alpha_8$, are the respective coefficients of the model.

### 3.3. Definition of the variables and theoretical expectations

RO = Rice output, proxied milled rice product. This variable refers to the quantity of rice produced, specifically measured in terms of milled rice products. Milled rice is rice that has been processed to remove its outer layers, resulting in the white rice being commonly consumed. The output is measured in metric tonnes, which is a unit of mass corresponding to 1,000 kilograms or 2,204.62 pounds. It is a dependent variable of the study's model.

AGREMP = Agricultural employment. Measured percentage share of agricultural employment to total employment. This variable refers to the number of workers engaged in agricultural activities, measured as a percentage of total employment. The theoretical expectation is that agricultural employment can have a helpful influence on rice output (Fasakin et al., 2022)

AM = Agricultural machinery. Measured in tractor by square kilometers of arable land. Agricultural machinery is mechanized farming tools or implements. it is predictable to have a positive influence on the production of rice (Min & Paudel, 2021).

ARL = Arable land. It is as a share of arable land share of land areas and nominated in percentage. Arale land is actually the land area that is suitable for the cultivation of crops. It is measured as the share of cultivable land or agrarian land to the total land mass; it is nominated in percentage. It is predictable to have a helpful effect on the production of rice (Cornia, 1985).

FERCON = Fertilizer consumption. It is measured in kilogram per hectare of arable land. This is quantity of fertilizer utilized in farming activities. Fertilizer consumption is predictable to have helpful effect on rice production (Adnan et al., 2017).

INFL = Inflation rate. Measured as percentage change in consumer price index. Inflation rate is predictable to have a helpful effect on the production of rice (Setiawan et al., 2024).

RIF = Rural infrastructure. Proxied by access to electricity percent of rural population. It is measured as the percentage of the rural population with access to electricity. it is predictable to have a helpful effect on rice production.
WATP = Water productivity. Measured in units such as kilograms per cubic meter ($kg/m^3$) of water. It is the efficient utilization of water in agricultural production. Measured as the quantity of crop yield or output per unit of water used. It is predictable to have helpful effect on the production of rice (Monaco & Sali, 2018).
ERV = Exchange rate volatility. The influence of exchange rate volatility on rice output is predictable to be harmful (Kandilov, 2008).

### 3.4. Data sources and collection

The data used for this study were basically secondary data which are yearly time series data taking the time scope from 1980 to 2024. The data were collated from different statistical and reputable databases. The World development indicators database (2025) provided the annual time series data for agricultural employment, agricultural machinery, arable land, fertilizer consumption, rural infrastructure, exchange rate, and water productivity. The time series data for rice output was sourced from the United States of America Department of Agriculture, USDA, (2025). The exchange rate volatility variable was estimated or derived by the use of the Autoregressive conditional heteroskedasticity estimation technique.

### 3.5. Estimation techniques

The estimation method and procedure involved running a preliminary test on the time series data to test for the stationarity of the data or variables. The results of the unit root test were used as the criterion of choosing the appropriate estimation method for the study's model which is the fully modified ordinary least squares (FMOLS) estimation technique.

## 4. Results presentation and analysis

### 4.1. Descriptive analysis

The descriptive statistics for the variables are presented in TABLE 1. Rice output averaged approximately 3.32 million metric tonnes, with a range of 579,000 to 5.61 million metric tonnes. Water productivity had a mean value of 27.40%, fluctuating between 17.21% and 40.84%.

TABLE 1: Descriptive statistics of the study's variables

| | RO | WATP | RIF | INFL | FERCON | ERV | ARL | AM | AGREMP |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 3,317,413.00 | 27.3979 | 19.6850 | 19.1014 | 10.4042 | 0.5013 | 36.7215 | 5.8977 | 45.9068 |
| Median | 3,275,000.00 | 22.7439 | 22.8000 | 13.0070 | 8.9576 | 0.5475 | 39.2185 | 6.2857 | 46.9048 |
| Maximum | 5,607,000.00 | 40.8412 | 34.0000 | 72.8355 | 20.2959 | 0.5605 | 40.4844 | 6.7027 | 52.3566 |
| Minimum | 579,000.00 | 17.2118 | 4.0439 | 5.3880 | 4.1476 | 0.0003 | 29.3938 | 4.1996 | 37.9867 |
| Std. Dev. | 1,317,768.00 | 8.5688 | 9.2168 | 16.2842 | 5.2863 | 0.1067 | 4.0404 | 0.8138 | 5.9189 |
| Skewness | -0.2849 | 0.5322 | -0.6501 | 1.8624 | 0.6471 | -3.1187 | -0.8102 | -0.4880 | -0.1694 |
| Kurtosis | 2.9137 | 1.6611 | 2.2479 | 5.4588 | 2.0886 | 13.4699 | 1.9515 | 1.7065 | 1.2949 |
| Observations | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 |

Source: Author's computation (2025) using Eview-10.

Rural infrastructure, measured by access to electricity, averaged 19.69% of the rural population, with values ranging from 4.04% to 34%. The inflation rate had a mean of 19.10%, with significant variation between 5.39% and 72.84%. Fertilizer consumption averaged 10.40 kg/ha, with a range of 4.15 to 20.30 kg/ha. Additionally, the exchange rate volatility averaged 0.50%, ranging from 0.003% to 0.56%. Arable land accounted for an average of 36.72% of the land area, with a range of 29.39% to 40.48%. Agricultural machinery usage averaged 5.90 tractors per square kilometer of arable land, varying from 4.20 to 6.70. Employment in agriculture averaged 45.91% of total employment, with a range of 37.99% to 52.36%.
The analysis of skewness in TABLE 1 revealed that rice output, rural infrastructure, exchange rate volatility, arable land, agricultural machinery, and agricultural employment were negatively skewed, indicating that their mean values were less than their median values. In contrast, water productivity, inflation rate, and fertilizer consumption were positively skewed, meaning their mean values exceeded their median values. The kurtosis investigation presented that inflation rate and exchange rate volatility were leptokurtic (peaked with thick tails), suggesting potential outliers. Conversely, rice output, water productivity, rural infrastructure, fertilizer consumption, arable land, agricultural machinery, and agricultural employment were platykurtic (flat distribution), indicating normal distribution.

### 4.2. Correlation analysis

The correlation matrix of the study's variables is presented in TABLE 2. The result of the correlation coefficient between log (RO) and exchange rate volatility is 0.3358. This revealed that there is a weak positive correlation or association between log (RO) and exchange rate volatility.

TABLE 2: Correlation matrix of the study's variables

| | LOG(RO) | WATP | RIF | INFL | FERCON | ERV | ARL | AM | AGREMP |
|---|---|---|---|---|---|---|---|---|---|
| LOG(RO) | 1 | | | | | | | | |
| WATP | 0.4973 | 1 | | | | | | | |
| RIF | 0.7472 | 0.5503 | 1 | | | | | | |
| INFL | 0.0171 | -0.2576 | -0.2690 | 1 | | | | | |
| FERCON | 0.3516 | 0.6466 | 0.0425 | 0.1465 | 1 | | | | |
| ERV | 0.3358 | 0.4198 | 0.2059 | 0.1253 | 0.3265 | 1 | | | |
| ARL | 0.7838 | 0.5595 | 0.9459 | -0.2956 | 0.0642 | 0.1568 | 1 | | |
| AM | 0.5594 | 0.7140 | 0.8460 | -0.3804 | 0.1682 | 0.1662 | 0.8787 | 1 | |
| AGREMP | -0.6372 | -0.9154 | -0.7993 | 0.3564 | -0.3898 | -0.3367 | -0.8216 | -0.9072 | 1 |

Source: Author's computation (2025) using Eview-10

### 4.3. Unit root test results

TABLE 3 presents the unit root test results using both Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The results indicate that the variables exhibit mixed stationarity, with some being stationary at level, others at first difference, and some at second difference. This mixed order of integration justifies the use of the Fully Modified Ordinary Least Squares (FMOLS) estimation technique in this study.

TABLE 3: Unit root test results: ADF and PP: summarized result of the unit root test results

| Variable | At level | | After first difference | | After second difference | | Remark |
|---|---|---|---|---|---|---|---|
| Test type | ADF | PP | ADF | PP | ADF | PP | |
| AGREMP | -2.1409 (0.5092) | -1.8666 (0.6547) | -1.8703 (0.6524) | -1.7669 (0.7032) | -8.0987 (0.0001) | -8.0971 (0.0001) | I(2) |
| AM | -2.1620 (0.4981) | -2.3138 (0.4180) | -7.8787 (0.0001) | -7.8674 (0.0001) | NE | NE | I(1) |
| ARL | -0.2754 (0.9890) | -0.5937 (0.9745) | -6.0415 (0.0001) | -6.1415 (0.0001) | NE | NE | I(1) |
| FERCON | -1.7296 (0.7211) | -1.7296 (0.7211) | -7.7963 (0.0001) | -7.8084 (0.0001) | NE | NE | I(1) |
| INFL | -3.8748 (0.0218) | -3.1310 (0.1120) | NE | -12.7201 (0.0001) | NE | NE | I(0)/ I(1) |
| RIF | -1.2847 (0.8785) | -3.1024 (0.1184) | -4.3322 (0.0072) | -14.5099 (0.0001) | NE | (NE) | I(1) |
| LOG(RO) | -2.1793 (0.4886) | -2.2256 (0.4642) | -7.6485 (0.0001) | -7.5845 (0.0001) | NE | NE | I(1) |
| WATP | -2.1845 (0.4855) | -1.5272 (0.8049) | -3.2392 (0.0905) | -3.2112 (0.0958) | -5.6064 (0.0002) | -21.9007 (0.0001) | I(2) |
| ERV | -3.6949 (0.0337) | -3.6949 (0.0337) | NE | NE | NE | NE | I(0) |
| Note: figures in parenthesis are the respective probability values of the unit root test results; NE = not estimated because of reaching stationarity; the statistical significance of the unit root results is at 5 % level of significance. | | | | | | | |

Source: Author's computation (2025) using Eview-10

### 4.4. The co-integration result of the study's variables

The unrestricted cointegration rank test results in TABLE 4 revealed the presence of long-run relationships between the variables. The Trace test indicates 9 cointegrating equations at the 0.05 level, while the Maximum Eigenvalue test suggests 4 cointegrating equations. Although the two tests differ in the number of cointegrating relationships identified, both tests confirm the existence of cointegration.

TABLE 4: The long run cointegration results

| Unrestricted Cointegration Rank Test (Trace) | | | | |
|---|---|---|---|---|
| Hypothesized | | Trace | 0.05 | |
| No. of CE(s) | Eigenvalue | Statistic | Critical Value | Prob.** |
| None * | 0.9060 | 338.3262 | 197.3709 | 0.0000 |
| At most 1 * | 0.8064 | 241.3732 | 159.5297 | 0.0000 |
| At most 2 * | 0.7465 | 174.0625 | 125.6154 | 0.0000 |
| At most 3 * | 0.6435 | 117.7982 | 95.7537 | 0.0007 |
| At most 4 * | 0.4282 | 75.5060 | 69.8189 | 0.0164 |
| At most 5 * | 0.3745 | 52.5884 | 47.8561 | 0.0168 |
| At most 6 * | 0.2949 | 33.3495 | 29.7971 | 0.0187 |
| At most 7 * | 0.2417 | 19.0238 | 15.4947 | 0.0141 |
| At most 8 * | 0.1708 | 7.6780 | 3.8415 | 0.0056 |
| Unrestricted Cointegration Rank Test (Maximum Eigenvalue) | | | | |
| Hypothesized | | Max-Eigen | 0.05 | |
| No. of CE(s) | Eigenvalue | Statistic | Critical Value | Prob.** |
| None * | 0.9060 | 96.9530 | 58.4335 | 0.0000 |
| At most 1 * | 0.8064 | 67.3107 | 52.3626 | 0.0008 |
| At most 2 * | 0.7465 | 56.2643 | 46.2314 | 0.0032 |
| At most 3 * | 0.6435 | 42.2922 | 40.0776 | 0.0277 |
| At most 4 | 0.4282 | 22.9176 | 33.8769 | 0.5368 |
| At most 5 | 0.3745 | 19.2390 | 27.5843 | 0.3963 |
| At most 6 | 0.2949 | 14.3256 | 21.1316 | 0.3389 |
| At most 7 | 0.2417 | 11.3458 | 14.2646 | 0.1377 |
| At most 8 * | 0.1708 | 7.6780 | 3.8415 | 0.0056 |

Source: Author's computation (2025) using Eview-10

The existence of cointegrating relationships suggests that the variables share common fundamental trends and are tied together in the long run. This suggests that a FMOLS estimation technique is the right framework for analyzing the relationships between the variables, considering their long-run dynamics.

## 4.5. The estimated FMOLS results of the study's model

The results of the FMOLS model are shown in TABLE 5. The long-term parameter of water productivity is -0.1004 with its corresponding probability value of 0.0026. This shows a harmful and statistically substantial influence of water productivity on rice output at a five per cent level of significance in the long term, given that the corresponding probability value is less than the 5% level of significance. This suggests that a 1% rise in water productivity leads to a 10.04% decline in rice output in the long term, ceteris paribus. This finding is not in line with theoretical expectations.

TABLE 5: The results of FMOLS estimated model

| **Dependent Variable: LOG(RO)** | | | | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **Standard Error** | **t-Statistic** | **Probability value** |
| WATP | -0.1004 | 0.0308 | -3.2625 | 0.0026 |
| RIF | 0.0058 | 0.0108 | 0.5331 | 0.5976 |
| INFL | 0.0043 | 0.0023 | 1.8812 | 0.0688 |
| FERCON | 0.0665 | 0.0125 | 5.3117 | 0.0001 |
| ERV | 0.8200 | 0.3576 | 2.2927 | 0.0284 |
| ARL | 0.1103 | 0.0351 | 3.1433 | 0.0035 |
| AM | -0.6916 | 0.1399 | -4.9428 | 0.0001 |
| AGREMP | -0.1869 | 0.0610 | -3.0633 | 0.0043 |
| Constant | 24.9466 | 4.8658 | 5.1269 | 0.0000 |
| Diagnostic test results | | | | |
| R-squared | | | 0.8334 | |
| Breusch-Godfrey Serial Correlation LM test result | | | | |
| Obs*R-squared | 3.3393 | Prob. Chi-Square(2) | | 0.1057 |
| Heteroskedasticity Test: Breusch-Pagan-Godfrey test result | | | | |
| Obs*R-squared | 13.3238 | Prob. Chi-Square(2) | | 0.1012 |

Source: Author's computation (2025) using Eview-10

The long-term parameter of RIF is 0.0058 with a probability value of 0.5976. This result is helpful but not statistically substantial at a 5% level of significance in the long term. This implies that a 1% rise in rural infrastructure will lead to a 0.58% rise in rice output in the long term, holding all other things constant.

The long-term parameter of INFL is 0.0043 with a probability value of 0.0688. This result is helpful but not statistically substantial at a 5% level of significance in the long term. This implies that a one percent rise in inflation rate will lead to about 0.43 percent decline in rice output in the long-term, holding all other things constant.
The long-term parameter of FERCON is 0.0665 with a probability value of 0.0001. This result is helpful and statistically substantial at a 5% level of significance in the long term. The means that fertilizer consumption has a helpful and statistically substantial impact on rice production in the long term. And a 1% rise in fertilizer consumption will lead to about 6.65% rise in rice production in the long term, holding other factors equal.
The long-term parameter of EXV is 0.8200 with a probability value of 0.0284. This result a helpful and statistically substantial a 5% level of significance in the long term. The means that a 1% rise in exchange rate volatility will lead to a 0.82% rise in rice production in the long term, holding other things equal.
The long-term parameter of ARL is 0.1103 with a probability value of 0.0035. This result is helpful and statistically substantial at a 5% level of significance in the long term. This means that a one percent rise in arable land will lead to about 11.03 percent rise in rice output, all other things being equal in the long term.
The long-term parameter of AM is -0.1869 with a probability value of 0.0043. This result is harmful and statistically substantial at a 5% level of significance in the long term. This means that a one percent rise in agricultural machinery will lead to about 18.69 percent decline in rice output in the long term, all other things being constant.
The empirical findings signify that the model has a good fit, with an adjusted R-squared of 0.8334, which suggests that approximately 83.34% of the variation in rice output is explained by the independent variables, showcasing a relatively high explanatory power. The model's reliability is further supported by diagnostic tests, which reveal no significant serial correlation, as evidenced by the Breusch-Godfrey test (p-value = 0.1057), and homoscedasticity, as indicated by the Breusch-Pagan-Godfrey test (p-value = 0.1012). These results imply that the model's residuals are not autocorrelated and have constant variance, meeting key assumptions. Overall, the model appears well-specified and reliable, providing a robust foundation for interpreting the coefficients and drawing meaningful conclusions about the relationships between the variables.

### Hansen stability test result

TABLE 6: The results of Hansen stability test of the study's model

| Cointegration Test - Hansen Parameter Instability | | | | |
|---|---|---|---|---|
| Lc statistic | Trends (m) | Trends (k) | Trends (p2) | Prob.* |
| 1.99375 | 8 | 1 | 0 | < 0.01 |

Source: Author's computation (2025) using Eview-10

The cointegration test result in TABLE 7 shows that the null hypothesis of no cointegration is rejected, signifying that there is a long-run relationship between the variables in the model. This implies that while the variables may exhibit short-term fluctuations, they tend to move together in the long run.
The result of the graph of exchange rate volatility from GARCH 1 model

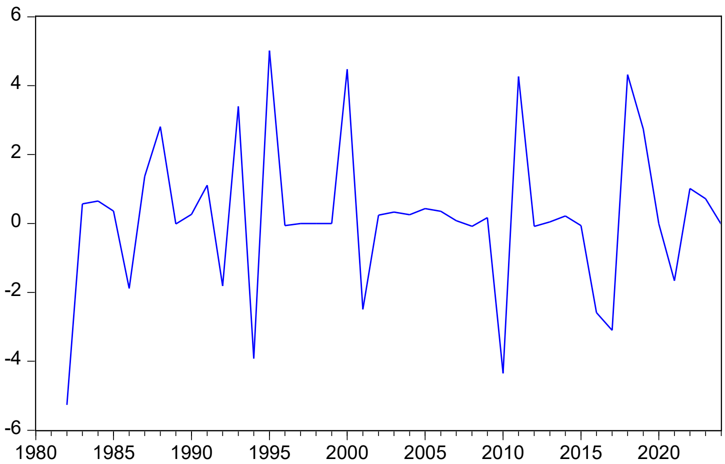

Figure2: The graph of exchange rate volatility variable

The graph of the exchange rate volatility is shown in figure 2. Looking at this graph, the exchange rate has been quite volatile over the past year, with several sharp fluctuations. There is a clear trend of depreciation in the early period, followed by a period of relative stability. However, around the middle of the period, the exchange rate starts to rise substantially before undergoing another sharp depreciation. The volatility is evident in the large swings, indicating a high level of uncertainty and potential economic instability. The outliers, particularly the extreme depreciation in the latter part of the period, may be attributed to specific economic events or shocks.

### 4.6. Discussion of findings

The study found a help and statistically substantial effect of exchange rate instability on rice output at a five per cent level of significance in the long term, given that the corresponding probability value is less than the 5% level of significance. The empirical finding of a help and statistically substantial effect of exchange rate instability on rice output did not align with theoretical expectations that exchange rate instability was expected to have a harmful influence on rice production due to the fact the exchange rate instability could lead to higher input costs due to more expensive imports and inflation, which could affect production costs and consumer purchasing power. The unexpected influence of exchange rate instability on rice output in Nigeria may be attributed to the depreciation of the Naira which makes Nigerian rice more competitive internationally, boosting exports and production. Additionally, this depreciation encourages import substitution, reducing reliance on imported rice and promoting domestic production. Higher prices for imported rice due to instability might also increase demand for local rice, benefiting local producers. This finding agreed with the finding of Çatuk (2025) and Ogunjobi et al. (2022) which found that exchange rate fluctuation and instability have helpful influence on agricultural production.

The study found that fertilizer consumption and arable land have a help and statistically substantial effect on rice production in Nigeria in the long term, this means that inflation rate, fertilizer consumption and arable land were major drivers of increase in the production of rice in Nigeria in the long term. this is in line with theoretical expectations.

The study also found that rural infrastructure and inflation rate have a help but not statistically substantial effect on rice production at a five per cent level of significance. This means though rural infrastructure helps increase rice production, it is not one of the major drivers of increased rice production in Nigeria in the long term.

The study found a harmful and statistically substantial influence of water productivity, agricultural machinery, and agricultural employment on rice production at a five per cent level of significance in the long term. these findings are not in line with theoretical expectations, but these adverse results can be attributed to the inefficient use of machinery and water in rice cultivation, unattractiveness of rice farming to young graduates in Nigeria and lack of opportunities in agriculture for young school leavers due to limited commercial farms in their localities in Nigeria.

## 5. Conclusion and Recommendations

### 5.1. Conclusion

The study investigated the influence of exchange rate volatility on rice output in Nigeria employing yearly time series data from 1980 to 2024. The FMOLS and the GARCH estimation methods were utilized to estimate the study model, and the study found a helpful and statistically substantial impact of exchange rate volatility on the production of rice in Nigeria in the long-term period. This means that rice farmers and producers are more likely to benefit from the volatility of the exchange rate through high price of rice which will translate into high profit for them.

### 5.2. Policy recommendations

The results of the estimated model put forward the following policy recommendations:

The helpful and statistically substantial influence of exchange rate volatility on rice output at a 5% level of significance in the long-term calls for the Central Bank of Nigeria to maintain a managed float exchange rate regime in order to balance the benefit of exchange rate volatility for rice farmers and the welfare cost through high price of rice for rice consumers and the general Nigerian public.

The harmful and statistically substantial influence of water productivity on rice output at a 5% level of significance in the long-term calls for the training of rice farmers on the proper water management and utilization in rice cultivation to reduce wastage and improve their overall productivity. This could be done by the ministry of water resources in collaboration by the Ministry of Agriculture in Nigeria. this will help reverse the harmful impact of water productivity on rice output.

The helpful and statistically substantial of fertilizer consumption on rice output at a 5% level of significance in the long term calls for the provision of fertilizers at a subsidized rate to rice farmers and training of rice farmers on the proper application of fertilizer on rice farms to maximize rice yield. This should be done by the Nigeria's Ministry of Agriculture.

The helpful and statistically substantial influence of arable land on rice output simply calls for more cultivation of rice. The general public who and local authorities how are in charge of arable land should expand the use of this arable land by cultivation of rice and other agricultural produces in order to ensure Nigeria's food security and food sufficiency.

The harmful and statistically substantial of agricultural machinery on rice output at a 5% level of significance in the long term simply indicates inefficient use of these farm implements, this calls for proper training of rice farmers on how to make use of agricultural tools and equipment to improve rice production. This should be done by the local authorities in collaboration with their local departments of agriculture.

### Declaration of Competing Interests

The authors declare that they are not aware of any competing financial interests or personal relationships that may have influenced the work described in this document.

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### Ethical considerations

The article followed all ethical standards appropriate for this kind of research.

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