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FOREIGN EXCHANGE RESERVE DYNAMICS IN THE FREQUENCY DOMAIN ANALYSIS

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ABSTRACT

The study attempted to analyze the dynamics of foreign reserves across frequencies with respect to the fluctuations in exchange rates and oil revenues in Uganda, Côte d'Ivoire, Madagascar, Ghana, and Nigeria over the sample period, 2020 to 2024, using a daily data set. The researchers conducted the spectral frequency domain analysis. The spectral frequency of domain method is an advanced econometric technique used to analyze the relationships between variables across different frequencies or cycles. This method transforms time-series data into the frequency domain using techniques such as the Fourier transform, allowing us to investigate how variables interact at various frequencies. The results indicated that variation in oil revenues and the fluctuations in the exchange rates of all the countries in our sample exhibit significant cyclical patterns with foreign reserves, particularly in the low-frequency bands, which correspond to long-term cycles. Precisely, cyclical relationships are less stable, with more significant volatility observed across different frequency bands. This volatility indicates that African economies are less capable of managing long-term economic cycles, leading to greater instability in their foreign reserves. The cyclical nature of these relationships highlights the importance of considering both short-term and long-term dynamics when formulating reserve management policies. The results highlighted the importance of having mechanisms in place to manage periods of economic instability. The findings show the need for African countries to develop more effective economic policies and strategies to manage external shocks and stabilize their reserves over the long term. African countries should consider the establishment or enhancement of stabilization funds, which can be used to cushion the impact of the variations in oil earnings and exchange rate instability. These funds should be designed to accumulate surplus revenue during periods of high oil prices, which can then be drawn upon during downturns to stabilize foreign reserves. The significant differences in the impact of oil revenue changes on reserves between countries in the study suggest that managing capital flows is crucial. Policymakers should implement measures to monitor and manage volatile capital flows that can exacerbate exchange rate fluctuations and impact reserves. Also, structural reforms should focus on reducing the dependency on oil exports, improving the business environment to attract investment in non-oil sectors, and enhancing the competitiveness of their economies.

Keywords: *Crude oil export revenues, exchange rate volatility, African countries, foreign reserves holding, oil price changes*
JEL classification*: C10, D20, E40*

1. INTRODUCTION

African countries, with more fragmented economic policies and less integrated financial systems, often face greater challenges in managing the impacts of exchange rate volatility on their foreign reserves. According to the International Monetary Fund (IMF), an adequate level of reserves typically covers three to six months of imports, although the exact requirement varies depending on a country's specific economic conditions and vulnerabilities (IMF, 2023). The volatility of exchange rates and unexpected fluctuations in oil prices has profound implications for the economic stability of countries, particularly influencing their foreign reserves. This issue is of critical importance for both African, albeit in different contexts due to their distinct economic structures and dependencies. African countries, many of which are heavily reliant on oil exports and other primary commodities, face severe vulnerabilities due to these volatilities. African countries, with their economies more heavily

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dependent on oil exports, are more vulnerable to these external shocks, which can lead to significant reserve depletion and economic instability. Sudden drops in oil prices, can lead to significant reductions in export revenues, causing depletion of foreign reserves and subsequent fiscal imbalances.

For example, Nigeria, one of Africa's largest oil producers, saw its foreign reserves plummet from $45 billion in 2013 to $30 billion in 2016 following a collapse in global oil prices (Alao & Payaslioglu, 2021**).** This reduction in reserves complicates the management of exchange rate stability, exacerbating inflationary pressures and economic uncertainty. This volatility in exchange rates can stem from multiple sources, including economic fundamentals, speculative activities, and geopolitical events. However, in African countries, where economies are often more susceptible to external shocks and have less diversified economic bases, exchange rate volatility has posed substantial challenges. These challenges include increased uncertainty in trade and investment, higher inflationary pressures, and difficulties in maintaining economic stability (Adegboye *et al.,* 2020). Oil price changes are influenced by a myriad of factors, including geopolitical tensions, supply and demand imbalances, and macroeconomic trends. For oil-exporting African countries, unexpected changes in oil prices can have profound effects on foreign reserves. A surge in oil prices generally leads to increased foreign reserves due to higher export revenues, while a decline can cause significant fiscal imbalances and depletion of reserves (Vochozka *et al.,* 2020). The divergent economic realities of African countries influence their respective policy responses to exchange rate volatility and oil price shocks. In Africa, policy measures often focus on enhancing economic diversification, strengthening institutional capacities, and improving fiscal and monetary policy frameworks to better manage foreign reserves. These measures aim to reduce dependency on commodity exports and increase resilience to external shocks**.**

Foreign currency reserves are foreign currency deposits kept by central banks in various reserve currencies such as the pound sterling, euro, Swiss franc, Indian rupee, US dollar, and Japanese yen. Regrettably, since January 2022, the region of West Africa has had an average depreciation of 8%. Also, since 2022, there has been a fall in interbank foreign exchange turnover in many West African countries, which has led to a decrease in their foreign currency reserves. Among the low points were Ghana's dwindling reserves, Uganda's declining foreign exchange reserves and liquidity, and Côte d'Ivoire and Madagascar's deteriorating reserves and price stability. Ghana's foreign exchange (FX) reserves decreased to 0.6 months' worth of imports in 2022 from 2.4 months in 2021, while the total reserves of the African financial markets initiative countries decreased by 10%. Nigeria's foreign exchange reserves (FX) have experienced a sharp decline, falling by US$2.16 billion in just 29 days, despite the CBN's vigorous attempts to keep the country's currency (the naira) stable. The country's foreign exchange reserves as of April 15, 2024, were valued at US$32.29 billion, a sharp decrease from US$34.45 billion on March 18, 2024, according to the CBN (2024).

Owing to the naira's sharp devaluation, the growth rate of the Nigerian economy declined from 3.3% in 2022 to 2.9% in 2023. Because to the Naira's floating in June 2023, the exchange rate fell by 95.6% in 2023. As a result, there was a significant increase in inflation, which increased from 18.8% in 2022 to 24.5% in 2023. In light of this, growing inflation and the weakening naira contributed to increased fuel prices. From Naira 350 per liter in April 2022 to Naira 850 in August 2024, the price of gasoline climbed by 142.8%. In order to curb inflation, monetary policy was tightened, with the policy rate rising from 17.5% in January 2023 to 26.75% in January 2024. In 2023, the budget deficit increased to 7.6% of GDP from 5.1% in 2022. In 2023, the federal government's debt service to revenue ratio was high at 111%, owing to inadequate revenues, while public debt stood at 40% of GDP. As a result of difficult global finance conditions, the overseas reserves eventually decreased from 6.6 months of import cover in 2022 to 5 months in 2023. Nigeria's foreign exchange reserves have been steadily declining; on March 18, 2024, they were valued at US$34.45 billion, having lost over US$2.16 billion. Beginning the month at US$33.57 billion, the number gradually dropped until reaching US$33.43 billion by April 4. The reserves kept running out; as of April 8, they were worth US$33.04 billion, and as of April 15, they were worth US$32.29 billion.

The research is guided by the following questions; what is the impact of daily exchange rate fluctuations and oil price fluctuations on the volume of exchange reserves in five West African countries; Uganda, Côte d'Ivoire,

Madagascar, Ghana, and Nigeria? The objectives of the study are to; investigate the impact of daily exchange rate fluctuations and variation in oil revenues on the volume of exchange reserves in the above mentioned countries. Policymakers in both African countries will find the study invaluable as it provides a comprehensive analysis of the dynamics affecting foreign reserves. This information can guide the development of more robust economic policies and strategies to mitigate the adverse effects of external shocks, ensuring greater economic stability and resilience. Economists and financial analysts will benefit from the detailed empirical data and advanced econometric models used in the study. These tools can enhance their understanding of the causal relationships between exchange rates, oil prices, and foreign reserves, enabling them to make more accurate forecasts and informed recommendations. The next section is literature review; section three is research methodology. Section four is analysis of results and section five concludes.

2. LITERATURE REVIEW

A. Erstwhile Studies on Reserves Effect of Exchange Rate Changes

Fapetu *et al.* (2023) investigated Nigeria's foreign reserves status and foreign exchange rates. The study used the error correction model's OLS version to determine how quickly the variables adjusted from a short- to long-term equilibrium state. According to the analysis's findings, the first period lag of external reserves has a positive and large impact on them, meaning that a rise in reserves during the prior year will result in an increase in reserves during the current year of around 34%. The results suggested that there is a positive and substantial correlation between the changes in foreign currency reserve inflow. Additionally, it shows that exchange rates have a major and detrimental impact on external reserves. Any increase in the exchange rate is expected to cause a decrease in external reserves, as shown by the coefficient's negative sign. The outcome shows that the first periods lag of the GDP and external reserves have a positive and substantial association. This suggests that an increase in GDP from the prior year will result in an increase in external reserves of 103%. This suggests that economic expansion will draw in more capital and boost government revenue, both of which will raise the nation's external reserve.

Demir & Razmi (2022) explored the effects of real exchange rate movements on economic development and foreign reserves. The study provides empirical evidence showing that real exchange rate volatility can lead to significant adjustments in foreign reserves as countries attempt to stabilize their currencies. The study argue that exchange rate management, through the accumulation and use of foreign reserves, is crucial for mitigating the adverse effects of volatility on economic growth. This work shows the dynamic interplay between exchange rate policies and reserve management in developing countries. Benigno *et al.* (2022) investigate the role of foreign reserve accumulation in economic growth and financial stability. The study utilizes a panel data approach to analyze the effects of reserve accumulation on exchange rate stability and economic resilience. The findings indicate that higher levels of foreign reserves help mitigate the impact of exchange rate volatility and reduce the likelihood of financial crises. The authors suggest that strategic reserve accumulation is essential for countries to manage exchange rate risks and promote sustainable economic growth.

David-Wayas *et al.* (2021) explore the implications of exchange rate volatility on economic growth in African countries, emphasizing the need for effective exchange rate management policies. According to Akinboade & Makina (2022), and Granger *et al*. (2019), foreign reserves are critical for maintaining a country's economic stability by providing a buffer against external shocks, facilitating international trade, and ensuring the smooth functioning of the financial system. This definition shows the protective function of reserves in cushioning the economy against unforeseen economic disruptions. Volatile exchange rates can also create economic uncertainty, influencing the behavior of investors and traders. Moreover, exchange rate volatility affects trade balances and, consequently, the accumulation or depletion of foreign reserves. For instance, when a country's currency is unstable, it can disrupt international trade by making exports less predictable and imports more expensive. This can lead to trade deficits, requiring the use of foreign reserves to pay for imports and service external debt (Yakub *et al.* 2019).

High volatility may lead to speculative attacks on a currency, prompting central banks to use foreign reserves defensively to maintain currency stability. This can be particularly challenging for emerging market economies, where financial markets are less developed, and

the impact of speculative movements can be more pronounced (Obstfeld *et al*., 2020). Such defensive actions deplete foreign reserves, which might otherwise be used for productive economic purposes. Foreign reserves contribute in managing exchange rate policies. They enable central banks to intervene in the foreign exchange market to stabilize the national currency by buying or selling foreign currencies. For instance, during periods of excessive volatility or speculative attacks, a country can use its reserves to defend its currency, thereby maintaining economic stability and preventing inflationary pressures **(**Naef, 2024**).** This intervention capability is particularly crucial for developing countries with less stable financial systems and higher susceptibility to external shocks.

Over time, persistent trade imbalances exacerbated by exchange rate volatility can lead to significant erosion of foreign reserves. Likewise, foreign reserves are essential for fulfilling international payment obligations. They ensure that a country can meet its foreign debt commitments, import bills, and other international transactions, which is vital for maintaining international creditworthiness and investor confidence (Zimanga & Khumalo, 2019). For oil-exporting countries, the accumulation of foreign reserves is often linked to revenue from oil exports. High oil prices can lead to an increase in reserves, providing a buffer for economic downturns, while low oil prices can deplete reserves and strain the economy. In the context of oil-exporting countries, which include several nations in both Africa and Europe, exchange rate volatility interacts with oil price fluctuations to impact foreign reserves. For oil-exporting countries, revenues from oil exports are typically denominated in foreign currencies. Thus, exchange rate volatility can affect the domestic value of these revenues. A depreciating local currency can increase the domestic currency value of oil revenues, potentially boosting foreign reserves if managed properly. Conversely, if the local currency appreciates, the domestic value of oil revenues decreases, which could negatively impact the reserves if oil prices are not sufficiently high to offset the exchange rate, effects (Chen & Yu, 2022).

Chukurna, Nitsenko, and Kralia (2019) the explored the impact of exchange rate fluctuations on the pricing of machine-building enterprises in Ukraine. This study shows the direct and indirect effects of exchange rate changes on the economic activities within an industry crucial to Ukraine's international trade. The researchers utilized econometric models to demonstrate how exchange rate volatility can alter production costs and, consequently, the pricing strategies of enterprises. They found that significant fluctuations in exchange rates necessitate adaptive pricing strategies to mitigate adverse economic impacts. This research is particularly relevant as it shows the necessity for countries to manage their exchange rate policies to maintain stable economic conditions, which, in turn, affects their foreign reserves. The findings indicate that maintaining a substantial volume of foreign reserves can provide a buffer against the volatility in exchange rates, thereby stabilizing domestic markets.

B. Erstwhile Studies on Reserves Effect of Oil Price Changes

Chen *et al.* (2024) investigated the dynamic relationships and asymmetric spillover between the WTI crude oil prices and the exchange rates of six different currencies: the Canadian dollar, the Australian dollar, the Swiss franc, the Japanese yen, and the euro. The authors discovered that big economies and resource-based economies are the ones that transmit instability. Furthermore, this phenomenon varies over time, particularly in the wake of major world economic shocks like Covid-19. The reaction of Nigeria's foreign reserves to changes in the price of oil internationally was evaluated by Jack & Akidi (2024). Secondary sources for annual data on the oil price of Brent crude, trade openness, official exchange rate, and external reserves as a percentage of GDP. The data were estimated using the ARDL technique. The bound test indicated co-integrating affiliation between Nigeria's foreign reserves and the variables of causality, according to level and first difference orders of stationarity. The long-term findings of the analysis make it clear that while trade openness and the price of Brent crude oil had a negligible and negative influence on external reserves, the Naira's rise versus the dollar greatly increased them. Additionally, it was shown that trade openness had a negligible and negative impact, the devaluation of the Naira against the dollar improved the nation's external reserves, and in the near term, higher Brent crude oil prices benefited the country's foreign reserves, albeit marginally. The short-term results clearly show that the price of Brent crude oil had a direct impact on the foreign reserve position. According to the predicted coefficient, changes

in "Brent crude prices" have a significant impact on the short-term external reserve position, and rising Brent oil prices have increased the external reserve. The study also noted a reversal in the impact of exchange rates.

The weakening of the Naira versus the US dollar improves the foreign reserve position in the short term. Odhiambo (2020), and Qiang *et al* (2019) all analyzed the effects of oil price shocks on foreign reserves in oil-exporting African countries, providing an understanding into the fiscal and monetary policy adjustments required to mitigate adverse impacts. Fluctuations in oil prices can influence capital flows and investment decisions, impacting the overall financial stability of a country. For instance, periods of high oil prices can attract foreign investment into oil-exporting countries, leading to an increase in foreign reserves. Conversely, low oil prices can lead to capital outflows and reduced investment, straining foreign reserves and economic stability (Abdulaziz, 2024; Rousseau & Wachtel, 2020). Oil price changes can directly impact the foreign reserves of oil-exporting countries by altering their export revenues. For oil-exporting countries, such as those in Africa and the Middle East, rising oil prices typically lead to increased revenue and foreign reserves, which can bolster economic stability and growth. However, unexpected declines in oil prices can cause significant fiscal deficits, depleting foreign reserves and leading to economic instability (Zulfigarov & Neuenkirch, 2020).

Alao & Payaslioglu (2021) investigate the effects of oil price uncertainty on the industrial production of emerging oil-exporting countries and the implications for foreign reserves. The study employs a nonlinear autoregressive distributed lag (NARDL) model to capture the asymmetric effects of oil price shocks. The findings reveal that oil price volatility leads to significant fluctuations in foreign reserves as countries adjust their economic activities in response to changing oil revenues. This research shows the importance of maintaining adequate foreign reserves to buffer against the uncertainties in the global oil market. Van *et al.* (2019) examined the long-term impact of oil price volatility on economic growth and foreign reserves in OECD countries. By utilizing historical data spanning over a century, the study provides comprehensive investigation into how oil price fluctuations influence economic stability and reserve levels. The study finds that high oil price volatility adversely affects economic growth and leads to fluctuations in foreign reserves, as countries deploy reserves to stabilize their economies. This empirical analysis shows the critical role of foreign reserves in managing long-term economic stability amidst oil price fluctuations.

Gong *et al.* (2021) analyze the impact of international oil price shocks on economic fluctuations and their subsequent effect on foreign reserves. Using a VAR model, the study finds that oil price increases lead to significant economic volatility, affecting industrial production and foreign reserves. The results indicate that countries with substantial oil imports experience a depletion of foreign reserves as they struggle to manage the higher costs associated with oil price hikes. This shows the necessity for robust reserve management strategies to mitigate the adverse impacts of oil price volatility. The 2020 oil price collapse, exacerbated by the COVID-19 pandemic, is a case in point where many oil-exporting countries faced severe fiscal challenges and depletion of their foreign reserves due to the sharp decline in oil revenues (Abodakpi *et al*, 2024**).** This depletion limits their ability to manage exchange rate volatility and maintain economic stability. In oil-importing countries, the relationship between oil price changes and foreign reserves operates differently. When oil prices rise, these countries face higher import bills, which can lead to a depletion of foreign reserves as more foreign currency is spent on purchasing oil. This can strain the reserves and make it more challenging to manage other economic needs.

When oil prices rise, these countries experience an increase in their export revenues, leading to a boost in foreign reserves. For instance, during periods of high oil prices, oil-exporting African countries such as Nigeria and Angola see significant inflows of foreign currency, which enhances their foreign reserves and provides a cushion against economic shocks (Mlambo & Donga, 2020; Degiannakis *et al.*, 2020). These reserves can be used to stabilize the national currency, finance imports, and service external debts, contributing to overall economic stability. In contrast, when oil prices drop, export earnings fall as well, which reduces foreign reserves. This scenario can be particularly detrimental if the country relies heavily on oil revenues for its fiscal budget and economic activities. Olayungbo (2019) uses a frequency domain causality approach to analyze the impact of global oil price movements on

Nigeria's exchange rate, trade balance, and foreign reserves. The study reveals a significant causal relationship from oil price to foreign reserves, indicating that fluctuations in oil prices directly affect the volume of Nigeria's reserves. This empirical evidence supports the need for strategic management of foreign reserves to mitigate the impact of volatile oil prices on the national economy.

The wide-ranging review of empirical studies shows that a significant portion of the reviewed literature focuses on specific countries or regions, such as Nigeria (Olayungbo, 2019) or the BRICS nations **(**Gopinath *et al.*, 2021). This regional focus limits the generalizability of the findings to other contexts. There is a need for broader comparative studies that include a diverse range of countries with different economic structures, levels of development, and institutional frameworks. Such studies would provide a more comprehensive understanding of how exchange rate and oil price fluctuations impact foreign reserves globally. Additionally, there is an underrepresentation of small and emerging economies in the empirical literature. Most studies, such as those by Kalu *et al.* (2019) and Plakandaras *et al.* (2019), tend to focus on larger economies or those with significant oil production capacities. This bias overlooks the unique challenges faced by smaller and emerging economies, which may have less diversified economies and fewer resources to manage exchange rate and oil price volatility. Including these economies in future research would help to identify tailored strategies and policies that can be more broadly applied.

Despite significant advancements in the literature, several areas remain underexplored, showing the need for further research to fill these gaps. One prominent knowledge gap is the insufficient understanding of the long-term impacts of exchange rate and oil price volatility on foreign reserves. Most existing studies, such as those by Chukurna *et al.* (2019) predominantly focus on short-term effects and immediate responses. However, the long-term implications of sustained volatility on reserve accumulation and economic stability remain unclear. Longitudinal studies that examine these impacts over extended periods are necessary to provide a more thorough understanding of how countries can strategically manage their reserves in the face of prolonged economic instability.

A major theoretical gap is the limited focus on the impact of external shocks on exchange rate and foreign reserve relationships. While some studies, such as those by Plakandaras *et al.* (2019), acknowledge the influence of geopolitical risks, there is a lack of comprehensive theoretical frameworks that systematically incorporate these factors. The unpredictability of geopolitical events and their profound impact on oil prices and exchange rates necessitate the development of theories that can better account for these external shocks. Furthermore, the theoretical literature often does not fully address the implications of technological advancements and digital currencies on foreign reserves and exchange rate dynamics. With the rise of cryptocurrencies and digital payment systems, traditional theories need to be expanded to consider these emerging trends. The potential for digital currencies to influence exchange rates and foreign reserves represents a significant gap in the current theoretical landscape. Lastly, there is a need for theoretical models that better reflect the global interconnectedness and the spillover effects between economies. The reviewed studies frequently focus on individual countries or regions, but global financial markets are highly interconnected. Theories that account for cross-border capital flows, international trade linkages, and the global nature of financial crises are essential for a more comprehensive understanding of the subject.

3. RESEARCH METHODOLOGY AND DATA SOURCES

The frequency domain method was used for this study. The method involves transforming data from the time domain to the frequency domain using techniques such as Fourier transform. This method is particularly useful for identifying cyclical patterns and the impact of different frequencies (short-term vs. long-term fluctuations) on the dependent variable. The transformed model can be analyzed using spectral regression techniques, where we focus on the spectral density functions and cross-spectral densities between the dependent and independent variables. The frequency domain method allows us to analyze how these relationships vary over different frequency bands, capturing both short-term and long-term effects. The econometric model can be specified as follows:

$$FXRVS_t = \delta_0 + \delta_1 EXVAR_t + \delta_2 OLREV_t + \delta_3 INFLA_t + \upsilon_t \quad (1)$$

where: $FXRVS_t$ is the Total Reserve at time t, $EXVAR_t$ is the exchange rate volatility at time t, $OLREV_t$ is the oil revenue at time *t*, $INFLA_t$ is the

inflation rate at time *t*, δ_0 is the intercept term, $\delta_1, \delta_2, \delta_3$ are the coefficients for the independent variables, ϵ_t is the error term. The frequency domain method allows us to analyze how these relationships vary over different frequency bands, capturing both short-term and long-term effects. The cross spectrum of the series is;

$$h_{z,x}(D) = \sum_{T=-(N-1)}^{N-1} Cov(T)\upsilon^{-jt(2\pi d/N)} \quad (2)$$

$$Cov_{z,x}(T) = E[(\Delta Z_t - \varepsilon_z)(\Delta X_{t-y} - \varepsilon_y)],$$
$$\varepsilon_z = E(\Delta Z), \varepsilon_x = E(\Delta X) \quad (3)$$

It suffices to know that *Cov(T)* is not an even function, so $h_{z,x}(D)$ is a complex number as given by equation (4):

$$h_{z,x}(D) = \delta(d)Cos\left(\frac{2\pi d}{N}\right) + jq(k)Sin\left(\frac{2\pi d}{N}\right) \quad (4)$$

The cross spectrum has both magnitude and phase as follows:

$$g(d) = \sqrt{\delta^2(d) + q^2(d)} \quad (5)$$

$$w(d) = Tan^{-1}\left(\frac{q(d)}{\delta(d)}\right) \quad (6)$$

These equations are called magnitude spectrum and phase spectrum respectively. From the above, if Cov $_{x,y}$(T) is an even function, then the phase spectrum is zero which means there is no series X_t over series Y_t and vice versa. This can also be expressed as:

$$h_{z,x}(D) = g(d)\upsilon^{jp(d)} \quad (7)$$

The proximity of time series is coherence, analysed in a correlation coefficient way as:

$$Cov_{z,x}(D) = \frac{h_{z,x}(D)}{h_{z,x^{0.5}}(D)h_{z,x^{0.5}}(D)} \quad (8)$$

Equation (8) corresponds to the correlation in the time domain, which is standardized by square roots of the two series spectra and the two series standard deviations respectively. The study uses daily data collected from December 30, 2019 to September 30 2024, providing a recent and relevant dataset that captures the economic fluctuations and trends in these regions. The African countries covered by this study (Uganda, Côte d'Ivoire, Madagascar, Ghana, and Nigeria) are key oil producers in both continents, ensuring that the analysis is grounded in economies significantly affected by oil price changes. The data for this study was sourced from the IMF and the World Bank. These institutions regularly publish data and reports that are widely used in economic research and policy analysis.

4. RESULTS

The data collected was analyzed in this chapter using inferential statistical techniques. As part of this analysis, daily data pooled for the variables total reserves, exchange rate fluctuation, oil revenue, and inflation rate for Uganda, Côte d'Ivoire, Madagascar, Ghana, and Nigeria respectively. Table 1 show the descriptive statistics, the mean value of foreign exchange reserves is approximately 1.79102, indicating that on average and the selected African countries hold significant foreign reserves. However, the median value of 1.36710 suggests that the distribution of reserves is skewed, with a few countries holding substantially higher reserves than the rest. The maximum value of 4.08105 and the minimum value of 1.10082 show the wide range of reserve levels, with the negative minimum value indicating possible periods of reserve depletion or data anomalies. The standard deviation of 1.57190 reflects high variability in reserve levels across countries, pointing to significant disparities in their capacity to manage economic shocks. The skewness of 0.53947 indicates a moderately positive skew, meaning that while most countries have lower reserve levels, there are some with exceptionally high reserves. The kurtosis value of 1.70695, which is less than 3, indicates a flatter distribution compared to the normal distribution. The Jarque-Bera statistic of 646.8916 with a probability of 0.000000 suggests that the distribution of reserves is not normal.

The mean exchange rate value of 180.2135 suggests that the local currencies of the selected African countries, on average, have relatively high values when converted to a common reference currency. The median value of 15.19583 indicates a significant skewness, where most countries have lower exchange rates, but a few have extremely high rates. This is further supported by the maximum value of 691.9687 and the minimum value of -9.803991, indicating extreme volatility in exchange rates. The high standard deviation of 249.9401 confirms the considerable variability in exchange rates across these countries. The positive skewness of

0.932147 indicates that the distribution is heavily right-skewed, with more countries experiencing lower exchange rates but a long tail of higher rates. The kurtosis value of 2.172010 suggests a slightly platykurtic distribution. The Jarque-Bera statistic of 949.2651 with a probability of 0.000000 again indicates non-normality in the distribution of exchange rates.

Oil revenue shows a mean value of 42.84116, reflecting the importance of oil revenues for these African countries. The median value of 31.01343 suggests that half of the country's export fuel at a rate lower than the mean, indicating a right-skewed distribution. The maximum value of 96.15410 and the minimum value of -11.105491 show significant differences in oil export levels, with some countries potentially having negative values due to net imports. The standard deviation of 36.44011 indicates substantial variability in fuel export levels among these countries. The skewness of 0.447209 is relatively low but positive, showing a mild right skew. The kurtosis value of 1.528330 suggests a flatter distribution compared to the normal distribution. The Jarque-Bera statistic of 676.5728 with a probability of 0.000000 indicates that the distribution of fuel exports significantly deviates from normality. The mean inflation rate of 18.46032% indicates relatively high inflation levels in the selected African countries. The median inflation rate of 16.95613% suggests that inflation rates are moderately skewed to the right, with a few countries experiencing significantly higher inflation. The maximum value of 38.40302% and the minimum value of 4.935564% reflect considerable variation in inflation rates. The standard deviation of 10.10364 shows that there is notable dispersion in inflation rates across the countries. The positive skewness of 0.451172 indicates that the distribution is moderately right-skewed, with more countries experiencing lower inflation rates but a long tail of higher rates. The kurtosis value of 2.034565 is close to 3, suggesting a distribution that is relatively close to normal but slightly platykurtic. The Jarque-Bera statistic of 398.3721 with a probability of 0.000000 confirms the non-normality of the inflation rate distribution.

Table 1: Descriptive statistics for selected countries

Measures	FXRVS	EXVAR	OLREV	INFLA
Mean	1.79102	180.2135	42.84116	18.46032
Median	1.36710	15.19583	31.01343	16.95613
Maximum	4.08105	691.9687	96.15410	38.40302
Minimum	1.10082	-9.803991	-11.105491	4.935564
Std. Dev.	1.57190	249.9401	36.44011	10.10364
Skewness	0.53947	0.932147	0.447209	0.451172
Kurtosis	1.70695	2.172010	1.528330	2.034565
Jarque-Bera	646.8916	949.2651	676.5728	398.3721
Probability	0.000000	0.000000	0.000000	0.000000
Sum	9.782913	986669.0	234555.4	101070.3
Sum Sq. Dev.	1.022424	3.425708	7268823.	558804.9

Source: Authors' results

Table 2 shows the results of stationarity test. The entire stationary tests show that the with the exemption of foreign exchange reserves which was stationary at level, the data on all other variables in the study only became stationary after being differenced at order 1.

The panel co-integration test results of Table 3 reveal a long-term equilibrium relationship exists between the variables total reserves, exchange rate fluctuations, oil revenue, and inflation rate for the selected African countries. Accordingly, the null hypothesis of no co-integration is rejected on the basis of the significant Fisher Trace and Max-eigen test statistics.

Table 2: Panel unit root results for selected countries

S/N	Variable	ADF-Fisher Chi-Square	ADF – Choi Z-Stat	ADF-Fisher Chi-Square Probability	ADF – Choi Z-Stat Probability	Order of Integration/ Level
1	FXRVS	13.627	-5.91433	0.0001	0.0002	I(0)
2	EXVAR	1.9640	-0.7838	0.4587	0.3879	-
3	OLREV	1.2785	-1.9085	0.1386	0.2694	-
4	INFLA	0.5436	-0.1913	0.5870	0.2789	-
S/N	**Variable**	**ADF-Fisher Chi-Square**	**ADF – Choi Z-Stat**	**ADF-Fisher Chi-Square Probability**	**ADF – Choi Z-Stat Probability**	**Order of Integration/ Level**
2	EXVAR	193.663	-7.91433	0.0000	0.0000	I(0)
3	OLREV	873.278	-32.9085	0.0000	0.0000	I(1)
4	INFLA	774.435	-27.1913	0.0000	0.0000	I(1)

Source: Authors' results

Table 3: Panel unit co-integration test results for selected countries

	Test	Values
Uganda	Fisher Trace test statistic (5% Critical)	123.489*** (101.142)
	″	119.390*** (92.107)
	″	63.304** (58.211)
	Fisher Max-eigen statistic (5% Critical)	89.267*** (75.124)
	″	72.530*** (64.015)
	″	49.016 (50.118)
	Test	**Values**
Côte d'Ivoire	Fisher Trace test statistic (5% Critical)	159.031*** (132.165)
	″	130.127***(114.389)
	″	89.354 (95.091)
	Fisher Max-eigen statistic (5% Critical)	72.281** (68.212)
	″	51.237(53.892)
	″	40.593(42.117)
	Test	**Values**
Madagascar	Fisher Trace test statistic (5% Critical)	187.894*** (123.458)
	″	120.528*** (110.387)
	″	78.152*** (89.236)
	Fisher Max-eigen statistic (5% Critical)	90.267*** (74.289)
	″	57.256** (56.146)
	″	34.567(45.895)
	Test	**Values**
Ghana	Fisher Trace test statistic (5% Critical)	179.267*** (120.487)
	″	130.148*** (109.387)
	″	111.286*** (97.256)
	Fisher Max-eigen statistic (5% Critical)	100.107*** (80.272)
	″	98.146** (63.487)
	″	56.470 (57.209)
	Test	**Value**
Nigeria	Fisher Trace test statistic (5% Critical)	145.189*** (112.389)
	″	122.393*** (101.287)
	″	102.147*** (90.3287)
	Fisher Max-eigen statistic (5% Critical)	74.502** (60.145)
	″	58.256** (50.281)
	″	23.139** (20.387)

Source: Authors' results

The spectral frequency domain analysis for Uganda, as presented in Table 4, provides a comprehensive view of the cyclical behavior of the key economic variables total reserves, exchange rate fluctuations, oil revenue, and inflation rates over time. The total foreign reserves exhibit an angular frequency of 0.091461, corresponding to a frequency of 0.011265 cycles per time unit. This implies a cycle frequency of 154.19 time units per cycle, indicating that changes in reserves follow a relatively shorter cycle compared to the other variables. The high periodogram value of 15,259,524 for reserves suggests that the fluctuations in total reserves are significantly pronounced and have a substantial impact on the overall economic stability of Angola. This strong periodic behavior reflects the sensitivity of Uganda's reserves to external factors such as exchange rate fluctuations and oil price volatility. The exchange rate fluctuation has a lower angular frequency of 0.091809, with a frequency of 0.014612 cycles per time unit and a cycle frequency of 68.44 time units per cycle. This longer cycle compared to aggregate foreign reserves suggests that exchange rates fluctuate rapidly over time. However, the periodogram value of 12.025450 indicates that these fluctuations are also significant, albeit less impactful than those observed in total reserves. The longer cycle frequency implies that exchange rate movements exert a continuous and considerable influence on Uganda's reserves.

Oil revenue has an angular frequency of 0.114761 and a frequency of 0.018265 cycles per time unit, resulting in a cycle frequency of 193.12000 time units per cycle. The periodogram value for oil income or earnings, however, is much lower at 2.607296, suggesting that the impact of oil export revenue on the reserves is less pronounced compared to that of exchange rate variation. This indicates that while crude oil exports are important, their cyclical impact on the reserves is overshadowed by the more dominant periodicity of the variations in exchange rate. Inflation rates exhibit the lowest angular frequency of 0.045905, corresponding to a frequency of 0.007306 cycles per time unit and the longest cycle frequency of 176.8750 time units per cycle. This suggests that inflation changes occur much slowly over time. The periodogram value of 11.731686 indicates gradual effect on foreign reserves.

Table 4: Spectral frequency of domain results for Uganda

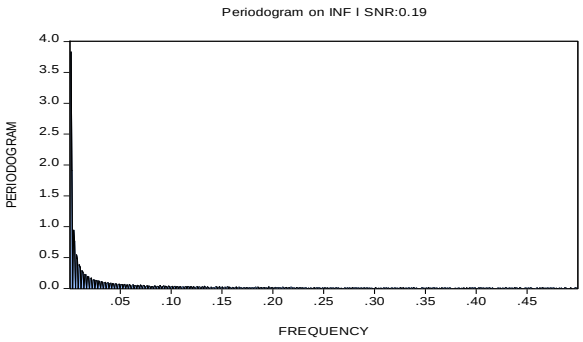
Variables	Angular Frequency (Omega)	Frequency (Cycle/ Time Unit)	Cycle Frequency (Time Unit/ Cycle)	Periodogram
FXRVS	0.091461	0.011265	154.19000	15259524
EXVAR	0.091809	0.014612	198.43750	12.025450
OLREV	0.114761	0.018265	193.12000	2.607296
INFLA	0.045905	0.007306	176.8750	11.731686

Source: Authors' results

The spectral frequency domain graph for Uganda of Figure 1 below shows that the periodogram for total reserves shows significantly higher amplitude compared to the other variables, indicating that fluctuations in foreign reserves occur with considerable magnitude. This suggests that changes in total reserves are highly impactful on the country's economic stability, with pronounced cyclical behavior at specific frequencies.

The strong signal-to-noise ratio associated with foreign reserves emphasizes its critical importance in Angola's economic dynamics. For exchange rate fluctuations, the periodogram indicates much lower amplitude compared to foreign reserves. This suggests that while exchange rates do fluctuate, their impact on total reserves is less pronounced. The lower SNR for EXVAR reflects that exchange rate volatility, although present, does not dominate the economic landscape as significantly as total reserves do.

The periodogram for inflation rates also shows relatively low amplitude, indicating that the cyclical fluctuations in inflation have a minor impact on the total reserves. The SNR associated with inflation suggests that, while inflationary pressures are present, they are not the primary drivers of reserve fluctuations within the analyzed frequency range. Oil revenues present moderate amplitude in the periodogram, higher than that of exchange rate fluctuation and inflation but still significantly lower than foreign reserves. This suggests that fluctuations in fuel exports have a noticeable, though not dominant, impact on the total reserves. The SNR for FUE further implies that while changes in oil prices and export volumes are important, their effect on the reserves is moderate compared to the overall volatility seen in total reserves.



Source: Authors' results

Figure 1: Periodogram for foreign exchange reserves of Uganda

The total reserves in Côte d'Ivoire show an angular frequency of 0.017382, equivalent to a frequency of 0.0092566cycles per time unit, with a cycle frequency of 219 time units per cycle, according to the spectral frequency domain study for the country, as shown in Table 5. This suggests that major adjustments in reserves happen gradually over lengthy periods of time and that changes in total reserves follow a long and slow cycle. The extraordinarily high periodogram value for foreign reserves, which is almost 794 million, indicates that even with the slow-moving cycle, aggregate reserve variations are very noticeable and have a significant effect on the economic stability of Côte d'Ivoire.

With equal frequencies of 0.013786 cycles per time unit and cycle frequencies of 219 time units each cycle, exchange rate volatility and oil revenue have the same angular frequency. This convergence of cyclical behavior suggests that the long-term cycle of aggregate reserves is shared by oil revenue and exchange rate variation. Nonetheless, the EXVAR (1547257) and oil revenue (1831304) periodogram values are significantly greater than the foreign reserve periodogram, indicating that although these variables cycle at the same rate, the magnitude of their fluctuations is highly significant than the changes in foreign reserves. Inflation rates display a cyclical pattern with an angular frequency of 0.057381, resulting in a frequency of 0.009132 cycles per time unit and a cycle frequency of 109.5 time units each cycle. In comparison to the other variables, this shorter cycle suggests that inflationary changes happen more frequently. The inference is that inflation affects the reserves, albeit significantly over shorter time periods.

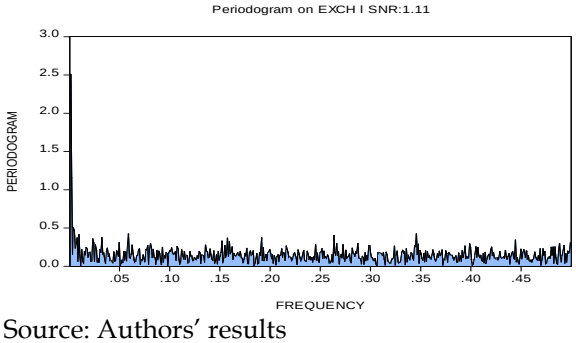
Table 5: Spectral frequency of domain result for Côte d'Ivoire

Variables	Angular Frequency (Omega)	Frequency (Cycle/ Time Unit)	Cycle Frequency (Time Unit/Cycle)	Periodogram
FXRVS	0.017382	0.0092566	219.0000	794208
EXVAR	0.013786	0.004566	219.0000	1547257
OLREV	0.013786	0.004566	219.0000	1831304
INFLA	0.057381	0.009132	109.5000	1402847

Source: Authors' results

The periodogram for total reserves in the Côte d'Ivoire spectral frequency domain graph exhibits noticeably large amplitude, indicating that variations in foreign reserves happen on a sizable scale. This implies that Egypt's economic stability is significantly impacted by fluctuations in total reserves. The signal-to-noise ratio for foreign reserves is modest (0.20), which means that while there is a clear pattern in the fluctuations, there is also some degree of noise or variability that may not be easily foreseeable.

Compared to FXRVS, the EXVAR periodogram has a higher SNR of 0.49 but lower amplitude. This suggests that exchange rates show more pronounced and regular cycles, which is why they are an important consideration when analyzing foreign reserves. The high SNR indicates that, albeit to a lesser extent than reserves holding, exchange rate variations are more predictable and have a significant impact on reserves. The periodogram's low amplitude for oil revenue suggests that its influence on total reserves is negligible. Similar to TOR, the SNR for OLREV is 0.20, indicating that fuel exports have some cyclicality but a less direct and more varied impact on reserves. Low frequency inflation rates are also evident, with an SNR of 0.18. This suggests that the reserves are only little and inconsistently affected by fluctuations in inflation. Although inflation is significant, it does not appear to be the primary driver of reserve changes, based on the low frequency and SNR.



Source: Authors' results

Figure 2: Periodogram for total foreign reserves of Côte d'Ivoire

Madagascar's total reserves show an angular frequency of 0.017214 in the spectrum frequency domain study shown in Table 6. This equates to a frequency of 0.00324 cycles per time unit and a cycle frequency of 165 time units per cycle. This suggests that variations in total reserves happen in a very short cycle. The foreign reserve periodogram value of 4,532,055 indicates that while the cycle is short, the size of variations in total reserves is noteworthy; this shows that changes in reserves, when they happen, have a major effect on the nation's economic stability. An angular frequency of 0.011476, corresponding to a frequency of 0.00126 cycles per time unit and a larger cycle frequency of 178.5000, 189.5000, and 119.5000time units per cycle, is shared by variations in exchange rates, oil revenue, and inflation rates. This suggests that major changes occur over a considerably longer period of time and that these factors fluctuate even more rapidly in their influence of aggregate reserves of Madagascar. Their periodogram results, however, show that these variables have different effects on the reserves.

Although exchange rate variations do occur over a long cycle, their impact on the overall reserve amount is generally small, as indicated by the periodogram value of 1.166323. Conversely, the periodogram value of 5.594928 for oil income indicates that fluctuations in crude oil exports have a stronger impact on reserves than do fluctuations in exchange rates. Inflation has a far larger periodogram value of 7.003231. This suggests that inflation affects accumulated reserves more significantly even when it changes gradually over time. The stronger impact of inflation on reserves implies that price level changes within the economy, particularly when occurring over extended periods, can considerably influence the level of foreign reserves in Madagascar.

Table 6: Spectral frequency of domain result for Madagascar

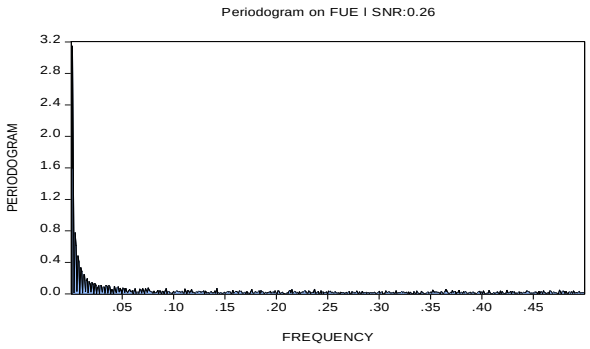
Variables	Angular Frequency (Omega)	Frequency (Cycle/Time Unit)	Cycle Frequency (Time Unit/Cycle)	Periodogram
FXRVS	0.017214	0.00324	165.0000	4532055
EXVAR	0.011476	0.00126	178.5000	1.166323
OLREV	0.013652	0.00143	189.5000	5.594928
INFLA	0.001469	0.00196	119.5000	7.003231

Source: Authors' results

The spectral frequency domain graph for Madagascar provides a good depiction of the periodogram for total reserves exhibits notably

high amplitude, showing that swings in foreign reserves occur with large size. This indicates that variations in total reserves, which exhibit strong cyclical behavior and need for regular monitoring, are essential to Madagascar's economic stability. The reserves have a moderate signal-to-noise ratio (0.20), which suggests some variability that may make predictions difficult to make but also a discernible pattern in the variations. The periodogram exhibits a higher SNR of 1.11 but smaller amplitude for exchange rate swings when compared to foreign reserves. This implies that although exchange rate variations have a less noticeable effect on overall reserves, they are more regular and predictable.

Despite not to the same extent as foreign reserves, exchange rate variability have a major impact on Madagascar's reserves. Proceeds from crude oil exhibit moderate amplitude in the periodogram, higher than EXVAR but lower than foreign reserves, with an SNR of 0.26. This suggests that although not as much as foreign reserves, variations in fuel exports have a noticeable effect on overall reserves. Fuel export patterns are significant, but they also show some unpredictability that may compromise their predictability, according to the moderate SNR. With an SNR of 0.18, inflation rates likewise exhibit comparatively small amplitude in the periodogram. This suggests that, in comparison to the other factors, fluctuations in inflation have a less noticeable effect on total reserves. The low amplitude and SNR for inflation suggest that its effects on reserves are more subdued and less consistent, though still relevant to the overall economic stability.



Source: Authors' results

Figure 3: Periodogram for foreign exchange reserves of Madagascar

Based on the spectrum frequency domain analysis presented in Table 7, it can be observed that Ghana's foreign reserves have an angular frequency of 0.015214. This translates to a frequency of 365 time units per cycle and a time unit frequency of 0.002740 cycles. This suggests that changes in overall reserves happen over a period of time that is fairly long—roughly a year. The foreign reserve periodogram value is 6,296,428. This indicates that although the cycle is lengthy, the size of swings in total reserves is noteworthy, implying that changes in reserves constitute an essential component of Tunisia's economic stability.

The exchange rate variations have an angular frequency of 0.048952, which is equivalent to a cycle frequency of 416.91 and a frequency of 0.003653 cycles per time unit. This implies that, in comparison to reserves, exchange rate swings happen over a slightly shorter cycle. The periodogram value for EXCH, on the other hand, is extremely low at 23.054014, suggesting that while exchange rate cycles occur more frequently, they have considerable effect on the overall reserves holding of Ghana. This implies that, although it exists, exchange rate volatility does significantly affect Ghana's reserves in this particular situation.

The angular frequency and cycle frequency of oil revenue were found to be identical to those of exchange rates, suggesting that they also adhere to the 416.75-time unit cycle. OLREV's periodogram value is 11.034193, higher than inflation, indicating that the influence of oil exports on reserves is marginally greater than that of inflation. A reduced cycle frequency of 219 time units per cycle and a frequency of 0.004566 cycles per time unit are the outcomes of inflation, which has the maximum angular frequency of 0.061790. This indicates that compared to the other factors, inflationary fluctuations happen more frequently. The inflation periodogram value of 10.360152 shows a strong effect on total reserves. By and large, inflation cycles occur more frequently; notwithstanding a smaller one compared to variability in the exchange rates and oil revenue.

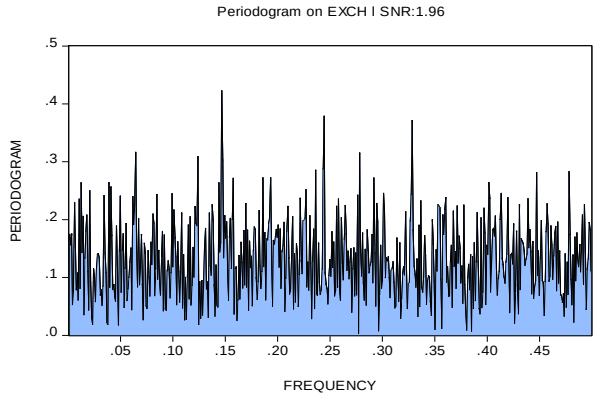
Table 7: Spectral frequency of domain result for Ghana

Variables	Angular Frequency (Omega)	Frequency (Cycle/ Time Unit)	Cycle Frequency (Time Unit/ Cycle)	Periodogram
FXRVS	0.015214	0.002740	365.0000	6296428
EXVAR	0.048952	0.003653	416.9100	23.054014
OLREV	0.048952	0.003653	416.7500	11.034193
INFLA	0.061790	0.004566	219.0000	10.360152

Source: Authors' results

According to Ghana's spectral frequency domain graph, the periodogram for total reserves shows strikingly high amplitude, suggesting that changes in foreign reserves happen on a large scale. The 365 time unit cycle frequency indicates that these changes happen over an extended period of time, roughly a year. The large amplitude suggests that fluctuations in total reserves are vital to the stability of Tunisia's economy. With a signal-to-noise ratio of 0.38 for foreign reserves, the cyclical pattern appears to be quite predictable, albeit with some degree of fluctuation that requires cautious management. With an SNR of 1.96, the exchange rate volatility periodogram exhibits significantly smaller amplitude than foreign reserves, suggesting a higher level of consistency and predictability in exchange rate changes. But as the low periodogram value shows, these oscillations have very little effect on the reserves. This implies that although exchange rates are subject to regular fluctuations, the effect they have on Tunisia's reserves is not as significant as that of other factors.

Oil revenue has modest periodogram amplitude, which is larger than EXVAR but still much lower than foreign reserves. While there is some stability in the cyclical behavior of fuel exports, the impact on reserves is mild and less substantial than that of foreign reserves, according to the SNR for OLREV, which is 0.23. With an SNR of 0.21, inflation rates likewise show modest amplitude, indicating that while inflationary fluctuations are there; their effect on total reserves is negligible.



Source: Authors' results

Figure 4: Periodogram for foreign exchange reserves of Ghana

The entire reserves of Nigeria show an angular frequency of 0.026257, which translates to a frequency of 0.0018293 cycles per time unit and a cycle frequency of roughly 278.22 time units per cycle, according to the spectral frequency domain study shown in Table 8. This suggests that variations in overall reserves take place over a comparatively extended period of time. The foreign reserve periodogram value is very high, at roughly 9.123 billion, indicating that although the cycle is lengthy, the changes in reserves are of notable magnitude, making this variable crucial for the stability of Nigeria's economy.

Exchange rate variations follow an extremely long-term cycle as total reserves with an cycle frequency of 396.7500. The periodogram value for EXVAR is 57.13988, which shows significant fluctuation in exchange rates during the same cycle; it is significantly more severe than the oscillations observed in total reserves. This implies that while fluctuations in exchange rates themselves are the primary factor influencing foreign reserves. With an angular frequency of 0.001233 and a cycle frequency of 260.1300 time units, oil revenue likewise exhibits a high cyclical feature as EXVAR. Though crude oil exports do follow the same cycle, and their effect on overall reserves is significant, as seen by the periodogram value for OLREV, which is 20.314288. This implies that, in spite of Nigeria's reliance on revenues from crude oil exports, the variations in oil export proceeds have a substantial direct effect on foreign reserves holding in relation to other variables. With an angular frequency of 0.040166 and a higher frequency of 0.0016393 cycles per time unit, inflation exhibits a different cyclical behavior, resulting in a shorter cycle frequency of roughly 156.43 time units each cycle. This suggests that compared to the other factors, inflationary fluctuations happen more frequently. The INF periodogram value of 39.548551 indicates that although inflation cycles more frequently, and its effect on the reserves is likewise very great.

Table 8: Results of spectral frequency of domain for Nigeria

Variables	Angular Frequency (Omega)	Frequency (Cycle/Time Unit)	Cycle Frequency (Time Unit/Cycle)	Periodogram
FXRVS	0.026257	0.018293	278.22	9.12300
EXVAR	0.036257	0.054293	396.7500	57.13988
OLREV	0.001233	0.058293	260.1300	20.314288
INFLA	0.040166	0.0016393	156.4286	39.548551

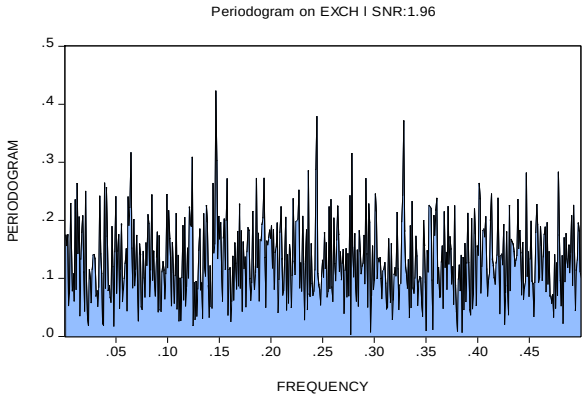
Source: Authors' results

The Nigerian spectral frequency domain graph indicates substantial variations in foreign

reserves over time, with the periodogram for total reserves displaying exceptionally high amplitude. Given the essential scale of these swings, it is likely that variations in total reserves have the greatest influence on the stability of Nigeria's economy. While there is significant variance in foreign reserves, the pattern is somewhat noisy and less predictable, as indicated by the comparatively low signal-to-noise ratio of 0.18. With a periodogram value of 57.13988, the EXVAR periodogram has significantly smaller amplitude when compared to foreign reserves. This suggests that while reserves are impacted by exchange rate swings, the effect is not as great.

The SNR for EXCH is likewise low, at 0.18, indicating that managing the impact of exchange rate swings on reserves is made more difficult by their relative unpredictability.

Oil revenue has a small effect on overall reserves, as seen by their periodogram's minimum amplitude. Although the influence of fuel export fluctuations on reserves is minimal, the SNR for OLREV is 0.44, which is larger than that of EXVAR and foreign reserves. This suggests a more consistent pattern in fuel export fluctuations. Low amplitude inflation is also evident, with the periodogram displaying little variations in relation to foreign reserves. With an SNR of 0.19 for INF, it is clear that although inflationary pressures are present, they are not the primary factor affecting foreign reserves, and the pattern is still somewhat erratic.



Source: Authors' results

Figure 5: Periodogram for foreign exchange reserves of Nigeria

DISCUSSION

The results of the study indicated that exchange rates exhibit significant cyclical patterns with foreign reserves, particularly in the low-frequency bands, which correspond to long-term cycles. Long-term fluctuations in foreign reserves have resulted from notable fluctuations in the exchange rate, which can affect competitiveness for exports contingent upon how much the currency devalues or appreciates and make it challenging for firms to make strategic investments. Such considerable fluctuations in the U.S. dollar and Australian dollar exchange rates have a negative effect on trade flows, affect inflation, and may even cause financial instability. This is particularly evident if the reserves affected by exchange rate fluctuations fall sharply, which makes it harder to pay off foreign borrowing or pay off import costs during recessions. The reason is that a decrease in the volume of foreign reserves leads to rising inflation as the value of the native currency declines, increasing the cost of imported commodities. When imports require more foreign exchange than exports generate, a significant trade deficit results, and foreign reserves are steadily eroded. As a result, fluctuations in foreign reserve volume further communicate instability to investors, which may weaken the national currencies and restrict capital inflows. This renders the nations susceptible to outside disturbances such as worldwide economic downturns or fluctuations in commodities prices. In general, import and export prices are impacted by the unstable currency exchange rate, which may have an effect on trade outcomes and inclusive economic growth.

The preceding analysis flowing from the considerable influence of exchange rate fluctuation on foreign reserve accumulation support earlier findings reported by Gajurel (2022), Gereziher & Nuru (2021), Bošnjak et al. (2020), Oyeniran & Alamu (2020), Sanusi et al. (2019), Khomo et al. (2018), and Ajayi & Olomola (2018). Our results are consistent with those of Gajurel (2022), who found that the official exchange rate has a negative effect on the size of foreign reserves over the medium term. Gereziher & Nuru (2021) empirically assessed the factors influencing Ethiopia's foreign exchange reserves using the ARDL approach and discovered that exchange rate significance had a long-term detrimental effect on the building of foreign reserves. According to Bošnjak et al. (2020), North Macedonia's foreign currency reserves were significantly impacted by the real effective exchange rate at quantile levels. The findings of Oyeniran & Alamu (2020) also demonstrate how Nigeria's ideal reserve level reacts to currency rate volatility and the adjustment cost of retaining reserves. The current study's results corroborated those of

Sanusi et al. (2019), who used the panel ARDL model to show that the exchange rate was a key positive factor that influenced Southern African countries' foreign reserve holdings over the long term. Khomo et al. (2018) discovered that Eswatini's exchange rate swings significantly reduced the country's foreign exchange reserves. The results of our study also support those of Ajayi and Olomola (2018), who found that fluctuations in exchange rates had a lasting impact on the amount of foreign reserves. In particular, the authors that employed the panel ARDL approach said that, over an extended period of time, the pooled reserves in the West African governments were positively impacted by the nominal effective exchange rate's appreciation.

The study's findings additionally showed that there are notable cyclical patterns in oil income and currency rates with regard to foreign reserves, especially in the long-term cycles. This is consistent with the findings of Elshan (2023), and Alao & Payaslioglu (2021) who found that oil prices have a persistent long-term impact on macroeconomic variables in oil-exporting countries. Also, in line with Chen & Chen (2023), the findings show the need for African countries to develop more effective economic policies and strategies to manage external shocks and stabilize their reserves over the long term. The cyclical nature of these relationships highlights the importance of considering both short-term and long-term dynamics when formulating reserve management policies. The results highlighted the importance of having mechanisms in place to manage periods of economic instability. African countries should consider the establishment or enhancement of stabilization funds, which can be used to cushion the impact of oil price declines and exchange rate volatility. These funds should be designed to accumulate surplus revenue during periods of high oil prices, which can then be drawn upon during downturns to stabilize foreign reserves. The significant differences in the impact of oil price changes on reserves between African countries suggest that managing capital flows is crucial. One major contribution of the study to knowledge is that the research highlighted the dynamics of foreign exchange reserves across different frequencies. Adopting counter-cyclical fiscal policies that increase public savings during economic booms and provide stimulus during recessions could help mitigate the impact of external shocks.

Policymakers should implement measures to monitor and manage volatile capital flows that can exacerbate exchange rate fluctuations and impact reserves. This may include the use of capital controls during periods of extreme volatility, as well as measures to attract stable, long-term investment. Strengthening institutions, particularly those involved in economic governance, fiscal management, and monetary policy is crucial. This could involve reforms to enhance the independence and capacity of central banks, improve the efficiency and transparency of public financial management systems, and strengthen legal frameworks that support economic diversification and stability. Structural reforms aimed at improving economic flexibility and resilience is necessary for African countries, albeit with different emphases. Specifically, structural reforms should focus on reducing the dependency on oil exports, improving the business environment to attract investment in non-oil sectors, and enhancing the competitiveness of their economies. Such reforms could include measures to improve infrastructure, joint investment in regional infrastructure projects including, and the establishment of regional stabilization funds.

5. CONCLUSION

The study attempted to role of fluctuations in exchange rates, and oil revenues in foreign reserve holdings in Africa countries namely Uganda, Côte d'Ivoire, Madagascar, Ghana, and Nigeria. The frequency domain method was utilized by the researchers to analyze the cyclical behavior of the variables. The frequency domain analysis allowed for the investigation of cyclical relationships between the variables over different time horizons. This method transforms time-series data into the frequency domain using techniques such as the Fourier Transform, allowing us to investigate how variables interact at various frequencies. The findings showed that there are notable cyclical patterns in oil income and exchange rates with respect to foreign reserves, especially in the low-frequency bands that correlate to long-term cycles. These interactions' cyclical nature underscores how crucial it is to take into account both short-term and long-term dynamics when developing reserve management strategies.

African nations may lower the long-term dangers connected with oil dependency, diversify their economy, and generate new sectors and jobs by investing in renewable energy. A move like this would improve the sustainability and resilience of local economies

while also being in line with global environmental aspirations. Based on the results, it is evident that in order to manage the effects of oil price changes and exchange rate volatility on foreign reserves, African countries must implement comprehensive and forward-looking policies. This entails a combination of institutional strengthening, fiscal discipline, economic diversification, and regional collaboration for African nations. African countries with high dependence on oil exports can mitigate risks by diversifying their reserves into more stable assets or currencies. These countries can construct a portfolio of foreign reserves that minimizes risk through diversification, thereby enhancing economic stability. Our study is limited by the insufficient consideration of the impact on different economic sectors within countries. Existing studies like ours treated the national economy as a monolithic entity. Future research should aim to disaggregate the data to understand how different sectors are affected and how these sectoral impacts contribute to overall economic stability and foreign reserve holdings.

Competing Interests

The author(s) declare that there are no competing interests relevant to the content of this article.

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