OIL PRICE AND EXCHANGE RATE NEXUS IN NIGERIA: EVIDENCE FROM WAVELET ANALYSIS

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ABSTRACT
Crude oil is the source of essential petroleum products for productive economic activities. Primarily, Nigeria exports crude oil and imports petroleum products, and this has a link with the unfavourable exchange rate of the Nigerian currency vis-à-vis the US dollar over the years. Based on the proposition that there is no significant relationship between oil price and exchange, the paper examines the oil price-exchange rate nexus in Nigeria, with monthly data from 1980M1 to 2020M12 analysed within the framework of wavelet analysis. The results show evidence of a mixed relationship between oil prices and exchange rates during the period under study. The results also show evidence of the lead-lag effect of oil prices on exchange rates in the long run but not in the short and medium terms. Thus, oil price has a time varying effect on the exchange rate only in the long run. Furthermore, there is evidence of unidirectional causality from oil price to exchange rate in the short and medium run but bidirectional causality in the long run. Hence, oil price is a key determinant of exchange rate in the short and medium terms but not in the long term. Consequently, this study emphasizes the need for purposeful economic diversification in order to attain and sustain a stable exchange rate in Nigeria.

Keyboards: Oil price, Exchange rate, Wavelet analysis, Granger causality, Decomposition.
JEL classification code: O24, P22, P33

1. INTRODUCTION

The relevance of oil as a crucial source of energy seems to make it essential in all socioeconomic operations of many countries. For instance, oil products constitute an energy source for electric power generation, heating, fuel, industry operations and transportation,
among others (Jiang & Yoon, 2020). The literature documents that main economic activities
involve the use of refined oil products as inputs in the production process and, in turn, directly affect traded assets as well as returns on investment (Ji, Bouri, Roubaud & Kristoufek, 2019; Aviral, Ibrahim, Seref & Shawkat, 2020). According to Kibunyi, Charles and Kevin (2018), crude oil is one of the basic drivers of economic growth and sustainable development. In this regard, Zhuhua and Seong (2020) noted that crude oil is scarce relative to other primary sources of energy, such as natural gas and coal. Consequently, every economy accords great importance to oil products, although modern energy policies are shifting towards the adoption of renewable energy sources. Moreover, the policies face a major drawback because of high procurement costs associated with renewable energy sources (Raheem, 2017). As a result, the demand for crude oil has increased over the years (Chazan, 2012), with significant implications for the energy market. Corroborating this, Akalpler and Nuhu (2018) observed that the total global utilization of oil has quadrupled and represented approximately 70% of world energy utilization. Given the increased demand for oil, the price per barrel depends on the grade, which is determined by attributes such as specific gravity, amount of sulfur content and originating location (Thomas, 1995)

Lin and Xu (2019) indicated that oil price is a major factor to consider in factors influencing macroeconomy fluctuations because it prompts investors' strong interest (Ma, Ji, & Pan, 2019).

Oil price studies are important because they directly impact economic performance and influence changes in financial variables such as exchange rates (Tantatape, Jui-Chi & Yaya, 2014). According to Antonakakis and Kizys (2015), the exchange rate is a major determinant of investment; its volatility may affect the value attached to finished products, influence domestic countries' competitiveness in the international market and lead to economic stability. When oil prices and exchange rates are compared, the exchange rate is said to be more sensitive to oil prices because oil has more features of global marketization than coal, gas, or other fuels (Ma, Zhang, Ji, & Pan, 2019b). With the wealth derived from oil futures, oil prices have been observed to significantly influence exchange rates in the financial system and have led to many studies probing into the empirical link between oil prices and exchange rates (Lin & Su, 2020).

Reviewing the relationship between oil price and exchange rate markets is important because the US dollar (USD) is the main billing and payment currency in international oil markets. Therefore, fluctuations in the USD exchange rate will affect oil traders, oil-exporting and oil-importing countries. This indicates that a fragile USD will raise the purchasing power of all oil-importing countries and reduce that of all oil-exporting countries, implying that it will negatively affect them. Likewise, an overvalued USD will negatively affect oil-importing countries, which will bring about dclining demand leading to demand shock that will eventually affect oil-exporting countries (Reboredo & Rivera-Castro, 2013). According to Shupei, Haizhong and Brian (2020), changes in crude oil prices can cause instabilities in exchange rates worldwide, redistributing wealth and interrupting equilibrium among trading countries. Ma et al. (2019b) observed that with the globalization and financialization of the crude oil market, portfolio managers and investors are progressively including crude oil in their currency portfolio to strengthen the movement between crude oil and currency markets. This means that countries involved in the global market could be sensitive to changes in the crude oil market. However, the response of the exchange rate to the dynamics of crude prices is heterogeneous owing to different exchange rate policies in the countries (Lv, Lien, Chen & Yu, 2018) and financial market efficiency (Volkov & Yuhn, 2015).

This view is clearly supported by available statistics on crude oil price and exchange rate for Nigeria in the period considered in this study. For instance, crude oil price in the international market was relatively stable at 32.5 naira dollar barrel in 1980M1 and throughout the early 1980s. The price witnessed a sharp decline to 29.840 dollar per barrel in 1983M11, sinking further to 12.618 dollar per barrel in 1986M3. The price showed sustained gradual increases during 2004M1 to 2013M10, and peaked at 106.57 dollar per barrel in 2013M8. Subsequently, oil price fluctuated considerably, and as of 2020M12 the price per reached 47.020 dollar per barrel in the international market. On the other hand, Nigeria's currency, exchanged at the rate of between 0.554 naira and 0.96 naira per US dollar during 1980M1 to 1985M12. Thereafter, the exchange rate of the country's currency to US dollar increased in favour of the latter. However, the Government of Nigeria officially pegged the exchange rate of the naira at 21.996 naira to the US 1 dollar for the period 1993M5 to 1998M12. From then, the exchange rate of Nigeria's currency vis-à-vis the US dollar has unfavourably been on continual increased, and stood at 379.5 to US 1 dollar as of 2020M12. These show that, as suggested in the literature (Volkov & Yuhn, 2015; Reboredo & Rivera-Castro, 2013; Lv et al., 2018; Shupei et al., 2020), the movements in oil price and exchange rate seem to depict causal relationship.

In addition, prior to the advent of crude oil, the Nigerian economy was mainly mono-cultural, with the dominant agricultural sector. However, that changed with the discovery of crude oil in commercial quantity in the early 1970s, which stimulated the growth of the petroleum industry (Onodugo, Amujiri & Ndibe, 2015). Subsequently, Nigeria became and remains over dependent on crude oil as the major determinant of economic growth, to the neglect of other hitherto viable sectors such as agriculture, renewable and non-renewable resources, manufacturing, service sector among others (Shaari, Hussain & Rahim, 2013). This exposes the Nigerian economy to the vagaries of external shocks and price volatilities in the international oil market, especially through the exchange rate channel, with attendant negative consequences on the revenue of the government. The negative consequences spill over to other key macroeconomic variables more so as the Central Bank of Nigeria and the Federal Ministry of Finance inevitably factor in oil prices in the national budget and economic policy decisions (Ani, Ugwunta, Inyiama & and Ike-Ekweremadu, 2014).

From the foregoing, we consider it imperative to examine the oil price-exchange rate nexus in Nigeria, with a view to articulating appropriate policy recommendations aimed at mitigating the adverse external shock resulting from price-induced exchange rate movements. For the purpose, this paper is structured into five sections. Following the introduction is section two, which is the review of literature. The methodological procedure deployed in the paper is discussed in section three, while analysis and results are discussed in section four. Section presents the conclusion and recommendations.

1. LITERATURE REVIEW

2.1 Conceptual Literature

Crude Oil and Crude Oil Price: Great importance has been attached to crude oil so much so that Hathaway (2009) said a world without crude oil will collapse. Crude oil price are determined by its grade and attributes such as specific gravity, amount of sulfur content, originating location (closeness to tidewater and refineries). Hamilton (2009) described four factors that determines crude oil price are demand, supply, Organization of the Petroleum Exporting Countries (OPEC) countries and speculation

Exchange Rate: This **is** the price of a nation's currency in terms of another foreign currency, implying comparing the domestic currency with a foreign currency. It can be of two types, nominal or real exchange rate; this study made use of nominal exchange rate.

2.2 Theoretical Literature

The Law of One Price expresses the relationship between oil price and exchange rate. This economic concept dates back to classical intellectual economists from France in 1760 to 1770, who applied the law to markets in international trade (Persson, 2008). The law shows the influence of market arbitrage and trade on the prices of similar goods traded in two or more markets. The law states that similar assets or commodities will have the same price globally, regardless of location, when currencies are changed to a common currency and certain factors are considered (Miljkovic, 1999). The law holds that for any good represented as $i,\ P_i = EP_i^*$, where P_i is the home-currency value of good i, P_i^* is the foreign currency value, and E is the exchange rate, defined as the home-currency price of foreign currency. Only one commodity price is expected to exist in any efficient market, irrespective of where they are traded (Persson, 2021). By implication, the strength of the law of one-price lies in a frictionless market, where there are no transaction costs, transportation costs, legal restrictions, price manipulation by buyers or sellers, and the currency exchange rates are the same. Hence, the law exists because differences in asset prices in different locations would eventually be removed where there is arbitrage opportunity. Market equilibrium forces will also lead to price convergence of the assets (Charles, 2020). In a recent work, Giulietti, Iregui and Otero (2015) tested the validity of the theory and confirmed its existence. Other theoretical review in line with this study are wealth and portfolio channels by Krugman (1983) and Golub (1983) and the monetary model of exchange rate determination (Frenkel,1978, 1999; Frenkel and Froot,1989; Vries,1994; Backetti, Craig & Jones,1995).

2.3 Empirical Literature

Jammazi, Lahiani and Nguyen (2015) deployed the wavelet-based nonlinear autoregressive (W-NARDL) model to study the exchange rate-crude oil nexus in a group of 18 developed and developing countries. The findings showed a significant and asymmetric pass-through of exchange rates to oil prices in both the short and long run. Zou, Yu and He (2015) constructed a new wavelet model termed the wavelet entropy algorithm to analyse the complex and nonlinear crude oil price dynamics and movement in oil prices. The results obtained from the study indicated that in the algorithm modelled, crude oil markets outperformed the benchmark model in terms of predictable performance evaluation criteria for the model forecasting accuracy.

Živkov, Đurašković and Manićl (2019) investigated how oil price changes affect consumer price inflation in eleven Central and Eastern European countries between January 1996 and June 2018. The study adopted a wavelet-based Markov switching approach to capture the effects at four different time horizons for nonlinear shock transmission from Brent oil to national inflations. The result found that the transmission of oil price changes compared to inflation is relatively low in the Central and Eastern European countries. Jung, Das and McFarlance (2019) examined the asymmetric relationship between the oil price and the US-Canada exchange rate employing nonlinear autoregressive distributed lag models (NARDL) and Granger causality testing. The results from the study found a bidirectional long-run cointegration relationship between the real price of oil and the US-Canada exchange rate, which runs from the US-Canada exchange rate to the real price of oil. The Granger causality test shows that there is a short-run asymmetry from the US-Canada exchange rate to the real price of oil, which reinforces the long-run results. Liu, Fang, Gao, An, Jiang and Li (2019) indicated that the time-varying memory series for the dynamic series could forewarn the reversal trend of price spread series. The study implored the policy makers that when they estimate the movement of crude oil price spread under the influence of exchange rates in non-US countries, they should pay attention to the position of direct crude oil suppliers and all markets involved, including WTI and Brent.

Attahir (2019) examined the oil price and exchange rate nexus in Nigeria for asymmetries. The study employed threshold autoregressive (TAR), momentum autoregressive (MTAR) and structural vector autoregressive (SVAR) models to examine the linear relationship between oil prices and exchange rates in Nigeria from January 1986 to June 2018. The results from the TAR and MTAR models showed that for Nigeria, there was an absence of an asymmetric relationship between oil prices and exchange rates. The SVAR model shows steady appreciation of naira following progressive shocks to oil prices. In conclusion, the study advised Nigeria's economy to diversify the country's foreign exchange earnings to reduce the effect of unfavourable oil price shocks. Olayungbo (2019) studied the Granger causal effects of oil prices on exchange rates, trade balances, and foreign reserves in Nigeria using seasonally adjusted quarterly data from 1986Q4 to 2018Q1. The results indicated that the variables are nonstationary, but cointegration exists between oil prices and foreign reserves, which indicates the presence of a long-run relationship between the variables. In the short period, the results showed that oil prices strongly Granger caused foreign reserves but not trade balance and exchange rates. Jiang and Yoon (2020) studied the dynamic co-movement between oil and six stock markets from China, India, Japan, Saudi Arabia, Russia, and Canada. They employed two types of wavelet analysis: wavelet multiscale decomposition and wavelet coherence. Several results were obtained from the study. It was finally concluded that oil prices are more influenced by oil exporting countries than oil importing countries.

Several results were obtained from Huang, An and Lucey (2020) study of how do dynamic responses of exchange rates to oil price shocks co-move from a time-varying perspective. They suggest that unexpected oil price shocks could have a greater influence on the exchange rate in various markets over time, with an asymmetric effect occurring only when extreme market situations and unexpected oil price shocks appear simultaneously. In a study of interdependence and contagion relationships among exchange rates of five important emerging Asian markets, namely: Indonesia, Malaysia, the Philippines, Singapore and Thailand, Qureshi and Aftab (2020) found co-movement among many exchange rate pairs, with a substantial increase during the global financial crisis. In addition, there is observable long-run convergence among regional markets in the countries. For oil price-macroeconomic fundamentals connection, Tiwari, Raheem, Bozoklu and Hammoudeh (2020) found the existence of signal explored the oil price-macroeconomic fundamentals connection for emerging market economies, finding a relevant signal from wavelet analysis. The study employed cross wavelet analysis and the phase difference to decompose the time frequency effects of oil prices on major aggregate macroeconomic variables such as the real effective exchange rate, interest rate yield spread and stock market for emerging market economies. The result was not able to identify among the variables those leading or lagging. Likewise, since there was a significant presence of time-varying co-movement between oil price and combined macroeconomic variables across different time frequencies, the study advised the investors and policy makers to take account of varying frequency bands in their decision-making and economic stabilization programs.

Lin and Su (2020) studied how oil prices affect the exchange rates of Brazil, Russia, India, China and South Africa (BRICS). The results obtained showed that two oil price shocks produced different effects on net oil-importing countries and net oil-exporting countries. It was also observed that the exchange rate will have a significant response to oil shock, primarily at high frequencies. China in this study is a typical case in which its oil price shock was insignificant to other countries. Similarly, there is a significant relationship between oil shocks and exchange rate prices for all BRICS countries in the short run but not always exist in the long run. Deploying Nonlinear autoregressive distributed lag (NLARDL) framework, Okwu, Akpa, Oseni and Obiakor (2020) examined the asymmetric effects of oil export revenue and exchange rates on household consumption expenditures in Nigeria. The short-run analysis showed negative shocks to the exchange rate, while the long-run exhibited positive and negative shocks to the exchange rate and oil export earnings, respectively.

Adebayo (2020) studied how oil prices influence exchange rates in Nigeria. The study focused on the period between January 2007 and March 2020. To buttress the result, Granger and Toda

Yamamoto causality tests were conducted to confirm the wavelet coherence techniques. He reported that oil prices and exchange rates were vulnerable in some identified periods. There was negative co-movement between the exchange rate and oil in the wavelet coherence technique for some identified periods. A bidirectional interaction between oil price and exchange rate was observed from the Granger and Toda Yamamoto causality tests. The inconsistency of 40.2% and 40.5% in the exchange rate can be explained by the fluctuations in the oil price from the variance decomposition, indicating that oil can predict the exchange rate in the long run.

Several wealth of methodology exists in the study of exchange rates in relation to oil prices as well as other macroeconomic variables in the literature (See Iloka & Nnamani (2017); Emediegwu & Okeke (2017); Nwosu, Ihugba & Osmond (2019); Obukohwo, Patricia & Enoh (2019); Akighir & Kpoghul (2020)) However, few researchers have deployed the wavelet analytical framework in the study of the exchange rate-oil price nexus. The literature indicates that only Adebayo (2020) used the wavelet methodology in examining the relationship between exchange rates and oil prices in Nigeria. This study contributes to bridging the knowledge gap observed in the literature.

3. METHODOLOGY

3.1. Data and Sources

The data we use for this study are spot crude oil prices (in US dollars) and exchange rates of Nigeria currency vis a vis US dollar. The oil price data are obtained from West Texas Intermediate (WTI) published on the Federal Reserve bank of St. Louis (Federal Reserve Economic Data): website: https://fred.stlouisfed.org. The exchange rates are extracted from the Census and Economic Information Center (CEIC). The data are monthly observations from 1980M1 to 2020M12. We consider these data sources to be authoritative, authentic and reliable.

3.2 Analytical Model: Wavelet Approach

We adapt the wavelet model as the analytical framework in this study. The pioneer work on the wavelet framework in the 1980s is credited to Grossman, Kronland, Martinet and Morlet (1989), Coifman, Meyer, Quake and Wickerhauser (1989). However, Daubechies (1988) expanded the scope of the theory from other applied mathematics to signal processing, statistics, and numerical analysis. Modern wavelet research endeavours to create a set of basic functions (or general expansion functions) and transformations that would efficiently produce informative and useful descriptions of a function or signal (Sidney, Ramesh & Haitao, 1998). Engineers, scientists and mathematicians commonly use the wavelet framework for periodic, time-invariant, or stationary phenomena analysis. This is because of its effectiveness in providing efficient localization in both time and frequency or scale when signals are represented as a function of time.

One advantage of wavelet analysis is the multiresolution decomposition, which seems to separate components of a signal in a way that is superior to most other methods for analysis, processing or compression. The discrete wavelet transform has the ability to decompose a signal at different independent scales and in a very flexible way. In this regard, Burke (1994) describes wavelets as a mathematical microscope. Moreover, the flexible decomposition, linear and nonlinear processing of signals in the wavelet transform domain offers new methods for signal detection, filtering, and compression. In addition, it provides the basis for robust numerical algorithms (David, 1992; David, 1993; Naoki, 1994; Haitao 1997; DongWei, Raymond & Sidney 1998). Furthermore, the framework can expose aspects of data that other signal techniques miss, such as trends, breakdown points, and discontinuities in higher derivatives and self-similarity. It can also compress or de-noise a signal without appreciable degradation. In addition, the framework does not require pretest estimation and captures series that are not stationary either at levels, first difference or second difference. This and the fact that both oil price and exchange rate are high-frequency data justify our decision to adapt the wavelet analytical framework in this study.

The basic characteristic of wavelet is the capability to appropriately analyse a signal or function over time [*f (t)*] as a linear decomposition (Wim, 1996). According to Wim, the function is expressed as:

$$f(t) = \sum_{\ell} a_{\ell}\psi_{\ell}(t) \qquad (1)$$

where ℓ is an integer index for the finite or infinite sum. a_ℓ is the real-valued expansion coefficient, and $\psi_\ell(t)$ is a set of real-valued functions of t (expansion set).

If the expansion (1) is unique, the set becomes a basis for the class of functions that can be so expressed. If the basis is orthogonal, then:

$$< \psi_k(t), \psi_\ell(t) >= \int \psi_k(t)\, \psi_\ell(t)dt = 0 \qquad k \neq \ell \qquad (2)$$

Subsequently, the coefficients can be calculated by the inner product:

$$a_K =< f(t), \psi_k(t) > = \int f(t)\, \psi_k\, (t)dt \qquad (3)$$

This uses a two-variable set of basic functions that is similar to the short-time Fourier transform, the Gabor transform, or the Wigner distribution for time-frequency analysis (Cohen, 1989; 1995). The goal is to generate a set of expansion functions such that any signal in $L^2(R)$ (the space of square integrable functions) can be represented by the series:

$$f(t) = \sum_{j,k} a_{j,k}\, 2^{j/2}\psi(2^j t - k) \qquad (4)$$

where the two-dimensional set of coefficients $a_{j,k}$ is called the discrete wavelet transform (DWT) of *f (t)*. A more specific form showing and analysing how $a_{j,k}$ are calculated can be written using inner products as:

$$f(t) = \sum_{j,k} a_{j,k}\, \psi_{j,k}(t) \qquad (5)$$

According to Antonini, Barlaud, Mathieu and Daubechies (1990), if $\psi_{j,k}$ (t) form an orthonormal basis for the space of signals of interest, the inner product is then defined as:

$$< x(t), y(t) = \int x^*(t) y\, (t)dt. \qquad (6)$$

However, the signal expansion becomes a discrete-time wavelet transform (DTWT) with sequences of numbers, functions of continuous variables and inner products. In addition, when the signal is a function of a continuous variable and a transform, the continuous wavelet transform (CWT) is expressed as

$$F\,(a, b) = \int f(t) w\left(\frac{t-a}{b}\right) dt \qquad (7)$$

and its inverse transform is written as:

$$F\,(t) = \int\int F(a, b)\, w\left(\frac{t-a}{b}\right) da\, db \qquad (8)$$

where w (t) is the basic wavelet and a, b ∈ R are real continuous variables.

We modify the wavelet framework and thus specify the following simple bivariate model on the basis of which we test simple hypotheses of association between oil price and exchange rate:

$$EXR_t = \emptyset_0 + \emptyset_1 OPD_t + \varepsilon_t \qquad (9)$$

where EXR_t is the exchange rate of the Nigerian naira to the US dollar at time t. OPD_t is the oil price in US dollars at time t. $\emptyset_0$ is the intercept of the model, and it depicts the exchange rate at zero oil price. $\emptyset_1$ is the coefficient of oil price. It denotes the measure of the nature and magnitude of the impact of a given change in oil price on exchange rate. ε_t depicts the white noise error term at time t to accommodate the influence of other factors not explicitly included in the model.

Furthermore, we specified the following equation in the context of which we test for the direction of causality between oil price and exchange rate:

$$\Delta OPD_t = \propto_1 + \sum_{k=1}^{m} \propto_{11} \Delta OPD_{t-k} + \sum_{k=1}^{m} \propto_{12} \Delta EXR_{t-k} + \varepsilon_t \qquad (10)$$

$$\Delta EXR_t = \propto_2 + \sum_{k=1}^{m} \propto_{21} \Delta EXR_{t-k} + \sum_{k=1}^{m} \propto_{22} \Delta OPD_{t-k} + \varepsilon_t \qquad (11)$$

Based on the following specified wavelet transformation:

$$\psi(rEXC, OIL)(t,\sigma) = \int_{-\infty}^{+\infty} WT(rEXC)(\tau + t, \sigma) WT(OIL)((\tau,\sigma)^* dt \qquad (12)$$

We express and analyse the following specification for cointegration between oil price and exchange rate:

$$EXR_t = \mu_{11} + \mu_{12}\gamma_{t,\tau} + \delta_{13}^T OIL_t + \varepsilon_{1,t} \qquad (13)$$

Ordinarily, wavelet transform does not use absolute values in estimating the wavelet analysis; rather, it makes use of return series generated via the formula:

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \qquad (14)$$

Thus, we express the equation of the return series of the exchange rate as follows:

$$EXR_t = \text{In}\left(\frac{EXR_t}{EXR_{t-1}}\right) \qquad (15)$$

Similarly, for the return series of oil prices, we specify the following equation:

$$OIL_t = \ln\left(\frac{OIL_t}{OIL_{t-1}}\right) \qquad (16)$$

where EXR_{r_t} and OIL_{r_t}represent the respective return series of exchange rate and oil price generated from the present series of exchange rate (EXR_t) and oil price (OIL_t) as well as the previous value of the exchange rate (EXR_{t-1}) and oil price (OIL_{t-1}).

4. RESULTS AND DISCUSSION OF FINDINGS

4.1 Descriptive Analysis

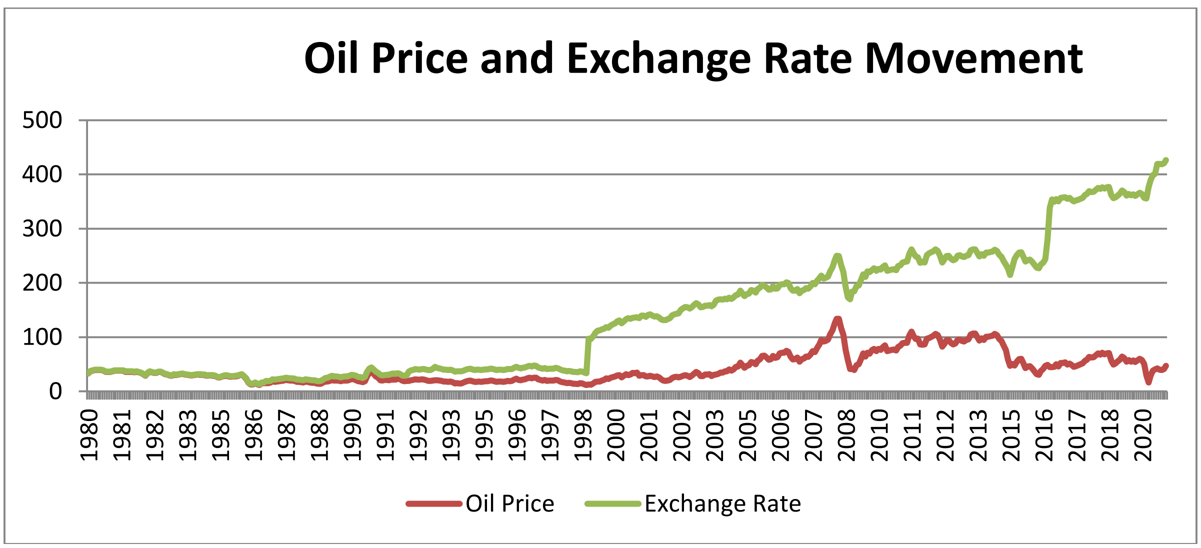


Figure 1: Oil price and exchange rate movement (1980 – 2020)
Source: Authors' illustration (2021)

The spot crude oil price and exchange rate movement above are high-frequency data that show the variability of the series in monthly data. From oil, it is obvious that the series started with an initial low price, which was relatively stable over a long period of time from approximately 1992 to 1996. It witnessed a sharp decline in 1998 but picked up thereafter. The increase witnessed continued to increase over time to reach a peak between 2007 and 2008 and a sharp decline in 2008. However, it picked up again and witnessed continuous fluctuation until 2015. The spike that occurred around July 2008 was due to the occurrence of the global financial crisis, and the effect was prolonged to several periods before it dies out. Additionally, there was a significant fall in the price of crude oil around April 2020 due to the outbreak of the COVID-19 pandemic that led to the shortage in demand for crude oil. Another factor that led to the oil price plunge is the Saudi Arabia and Russia oil production cut war in 2020.

Figure 1 also reveals that the exchange rate in the early years between 1980 and 1985 was less than a naira. Its price began to increase in 1986 throughout the year under study. It was stable in some periods, such as from 1992 to 1998. For example, the rate stood at ₦21.866 for the periods between May 1993 and December 1993 and ₦21.996 for the period from January 1994 to January 1995. It dropped and stood at ₦ 21.886 from February 1995 to December 1998. Thereafter, it rose to a value of ₦84.57 and continued to maintain a steady rise in value over time. The US dollar vis-à-vis Naira began to maintain a triple digit value in the month of March 2000 and dropped in the following month before it continued to maintain the race of triple digit until December 2020. The exchange rate value moved from the single digit of ₦9.37 in May 1991 to the double digit of ₦10.172 in June 1991, which continued until it changed to three digits in May 2000 and has been continuously increasing ever since.

Table 1: Descriptive Statistics

Variable	EXR	OIL	EXR_r	OIL_r
Mean	97.774	42.364	1.321	0.075
Median	101.596	31.670	0.000	0.786
Maximum	379.500	133.930	135.173	54.562
Minimum	0.530	11.280	-15.427	-56.813
Std. Dev.	99.531	26.970	8.576	9.325
Skewness	0.956	1.092	11.912	-0.686
Kurtosis	3.160	3.240	167.928	11.300
Jarque-Bera	75.424	99.029	569258.100	1450.822
Probability	0.000	0.000	0.000	0.000
Observations	492	492	492	492

Source: Authors' Compilation

Notes: Table 1 presents the descriptive statistics of ordinary and return series of exchange rates and oil prices for the monthly dataset from January 1980 to December 2020. EXR_r and OILr represent the return series descriptive statistics.

These descriptive statistics used a total of 492 raw data for each of the two variables in the sample analysed. The mean values representing the average exchange rate and oil price are 97.774 and 42.364, respectively. The maximum values are 379.5 and 133.930, and the minimum values are 0.530 and 11.280 for the exchange rate and oil price, respectively. The standard deviations (99.531 and 26.970) for exchange rate and oil price, respectively, explain the extent to which observations in this study are far from the sample average. Kurtosis and skewness serve as measures of normality. The kurtosis values of 3.160 and 3.240 measure the peakness or flatness of the data and show that both data have normal distributions and are therefore mesokurtic in nature. The skewness (measure of the degree of

asymmetry of the series) shows that series of the variables are positively skewed, with a long right tail and higher values. The Jarque-Bera statistics of 75.424 and 99.028, with 0.0000 p values, show that the time series values of the variables are not normally distributed over time. This is expected since the variables change at high frequency. The probability values of 0.000 and 0.000 for exchange rate and oil price clearly indicate that the probability values are highly statistically significant; therefore, we clearly reject the null hypothesis of the normal distribution.
From the descriptive analysis of the return series, there was an average rate representing the mean value of 1.321 and 0.075 for exchange rate and oil price returns, respectively, followed by the median of 0.000 for exchange rate returns and 0.786 for oil price returns. The maximum and minimum values of exchange rate returns are 135.173 and -15.427, respectively. These results indicate that the return series of the exchange rate differs across the time period. Similar to the return series of oil prices, the maximum value is 54.562, and the minimum value is -56.813, which also signify variety across time in the data. The standard deviation shows that the return series of the exchange rate (8.576) and oil price (9.325) are likely to change frequently over time. Finally, the Jarque-Bera statistics, which combine the results of the skewness and kurtosis tests, show that exchange rate and oil price returns are not normally distributed based on evidence of rejection of the null hypothesis of normality.

4.2 Inferential Analysis

The results of the inferential analysis, which form the basis of the conclusion and articulation of policy implications, are presented and discussed in this subsection.

4.2.1 Wavelet Decomposition: Oil Price

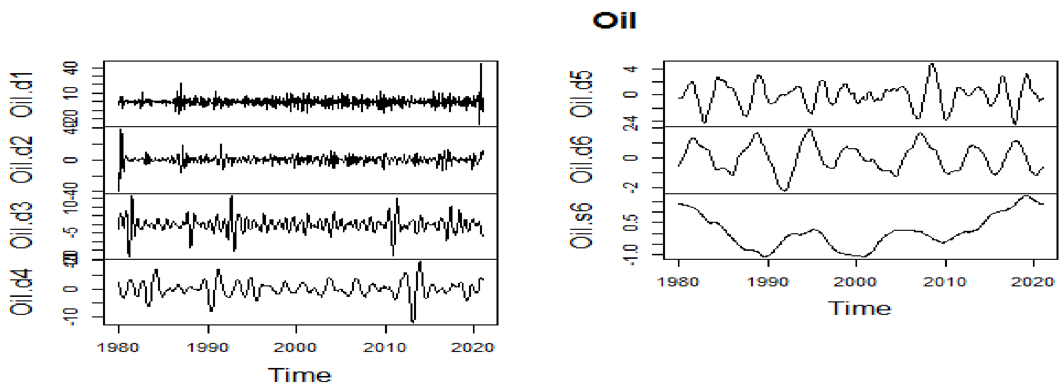


Figure 2: The wavelet decomposition of oil price returns into 6 wavelet levels
Source: Authors' estimation using RStudio
Notes: Figure 4.1 represents the wavelet decomposition of the return series of oil prices from January 1980 to December 2020 into the following periods: Oil.d1 & Oil.d2➔Short run period, Oil.d3 & Oil.d4➔Medium run period, Oil.d5 & Oil.d6➔ Long run period and Oil.s6➔Very long run period.
From this study, wavelet-based analyses are generated using codes written by Afshan, Sharif, Loganathan and Jammazi (2017). It divides the series into seven different (7) time periods, such as the short run ($D_1 - D_2$), medium run ($D_3 – D_4$), long run ($D_5 – D_6$) and very long run (S_6) periods, in different frequencies to determine the degree of variability of the series of oil prices over the different periods. Observations from this analysis show that in the short run ($D_1 – D_2$), the series are extremely volatile and seriously changing, especially over all periods of time. In the medium run ($D_3 – D_4$), the volatility was relatively stable. A sharp increase was noticeable in the early 1980s, 1990s and approximately 2014 to 2015. In the long run ($D_5 – D_6$), the series are more stable, and the price does not change anyhow. However, in the very

long run (S_6), price declines steadily between 1980 and 1990 to fall sharply in 1990 but pick up again to fall approximately 22000, after which an increase was observed again to slightly decrease in 2010. After this, it continued to increase until a noticeable decline was observed again in 2020.

4.2.2 Wavelet Decomposition: Exchange rate

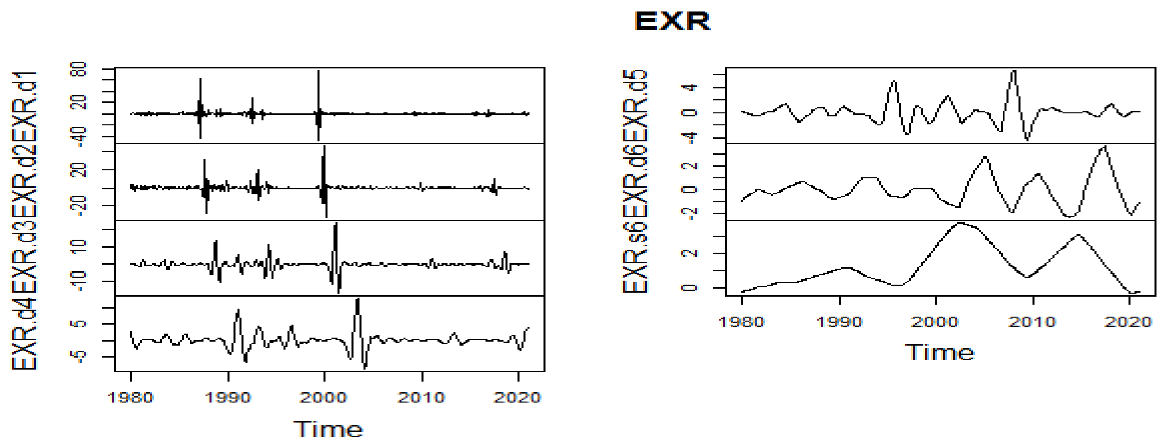


Figure 3: The wavelet decomposition of exchange rate returns into 6 wavelet levels
Source: Author's estimation using RStudio
Notes: Figure 4.2 represents the wavelet decomposition of the return series of the exchange rate from January 1980 to December 2020 into the following periods: Oil.d1 & Oil.d2➔Short run period, Oil.d3 & Oil.d4➔Medium run period, Oil.d5 & Oil.d6➔ Long run period and Oil.s6➔Very long run period.

This also divides the series into different time periods, such as the short run ($D_1 - D_2$), medium run ($D_3 - D_4$), long run ($D_5 - D_6$) and very long run (S_6) periods, at different frequencies to determine the degree of variability of the exchange rate series over the different periods. From the observation in the short run ($D_1 - D_2$), the series are very volatile, most especially before 1990, from approximately 1995 to 1998 and sharply approximately 22000. The medium run ($D_3 – D_4$) is less volatile than the short run. In the long run ($D_5 – D_6$), it varies to different degrees, and less volatility and stability are observed. In the very long run (S_6), it was more stable as it increased from 1980 to 1990, before there was a noticeable decline approximately 1998 and a sharp increase (2000, 2005) and decrease (2010, 2020) over a long period of time.

4.2.3 Wavelet Covariance

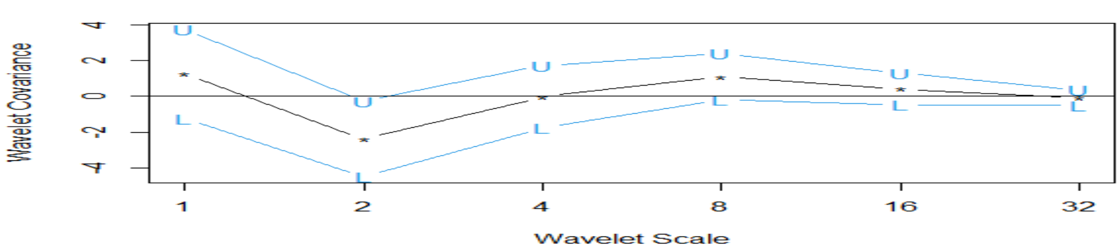


Figure 4: The wavelet covariance analysis for exchange rate and oil price returns
Source: Authors' estimation using R-Studio
Notes: Figure 4.3 represents the wavelet covariance of the return series of exchange rates and oil prices from January 1980 to December 2020. The upper (U) and lower (L) bounds are 95% confidence intervals, while the black dotted line denotes the covariance between the exchange rate and oil price in Nigeria.

It measures how the series co-varies over the different frequencies domain and observes the way variables move over a given time period. This checks the movement to see if they are positive or negative for exchange rate and oil price over the given period. When the covariance is positive (0 – 4 on the horizontal line), it shows that the series are moving in the same direction. When it is a negative covariance (0 – -4 on the horizontal line), it implies that variables are moving in the opposite direction. The wavelet covariance is measured on a vertical wavelet scale 1 - 32, where 1 – 4 measures the short-term period, 4 – 8 measures the medium-term period, 8 - 16 measures the long-term period and 16 – 32 measures the very long-term period. The black line was used to interpret the wavelet covariance, while the blue lines represent the upper and lower limits. Observations for the short-term period showed that there was a positive covariance between the series in the early 1980's; however, it changed to a negative correlation between the series, which implies that they are moving in the opposite direction in the later early years (end of the short-term period). When one increases, the other decreases and vice versa. However, during this period, as it was going down, it seen going up, such that by the time it entered the medium run period (4 – 8), it was exhibiting a positive covariance between the two series. This implies that during this period, the series are moving together. During the long-term period (8 – 16), there was a positive covariance between the variables, but it was declining in nature. In the very long run period (16 – 32), the relationship is still positive, but at the tail end of the very long run, it was already exhibiting a declining relationship, which implied they are already moving in an opposite direction.

4.2.4 Wavelet Correlation

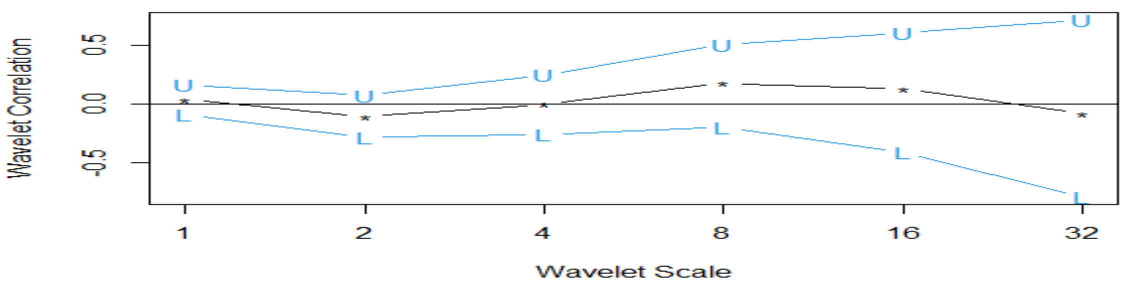


Figure 5: The wavelet correlation analysis for exchange rate and oil price returns
Source: Authors' estimation using RStudio.
Notes: Figure 4.4 represents the wavelet correlation of the return series of the exchange rate and oil price from January 1980 to December 2020. The upper (U) and lower (L) bounds are 95% confidence intervals, while the black dotted line denotes the correlation between the exchange rate and oil price in Nigeria.

The wavelet correlation shows the positive and negative association that exists between the variables series, which are exchange rate and oil price. When the correlation is positive (0.0 – 0.5 on the horizontal line), it shows that the series have a positive relationship. When it is a negative correlation (0.0 – -0.5 on the horizontal line), it implies that series have a negative relationship. The wavelet correlation is also measured on a vertical wavelet scale 1 - 32, where 1 – 4 measures the short run period, 4 – 8 measures the medium run period, 8 - 16 measures the long run period and 16 – 32 measures the very long run period. The black line was used to interpret the wavelet covariance, while the blue lines represent the upper and lower limits. The short-run analysis shows that there is a negative

relationship between the series, while the medium- and long-run analyses show that there is a positive relationship, but it declines
towards the end of the long-run period. Here, this means that an increase in oil prices leads to an increase in the exchange rate. In the beginning of the very long-term period, the association was positive but became negative just before the end of the very long-term period approximately 2016 to 2020. This implies that in the very long run, an initial increase in the oil price will lead to an increase in the exchange rate; however, observations showed that the final increase in oil does not lead to an increase in the exchange rate.

4.2.5 Continuous Wavelet Spectrum: Exchange rate

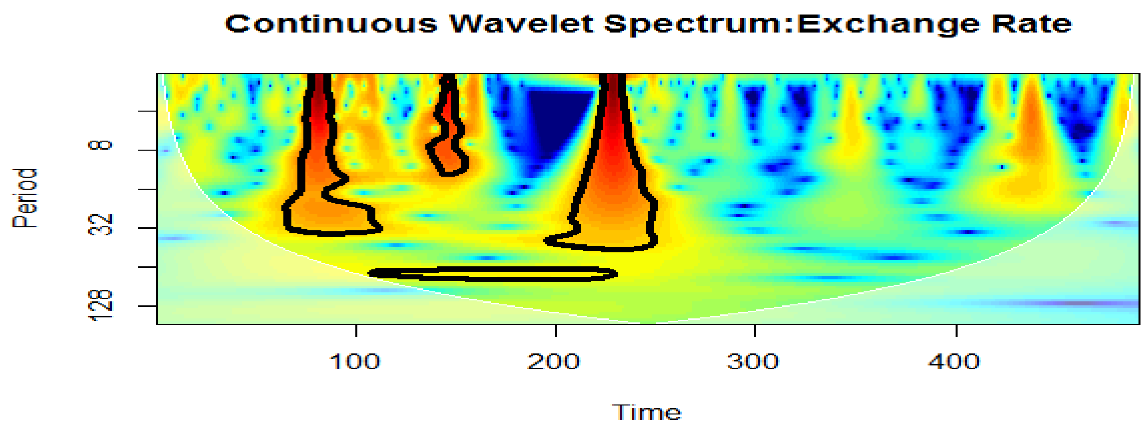


Figure 5: The continuous wavelet spectrum of exchange rate returns
Source: Authors' estimation using RStudio
Notes: Figure 5 represents the continuous wavelet spectrum of the return series of the exchange rate from January 1980 to December 2020. The thick black contour indicates that the significance level is 5% for the region in the cone of influence (COI).
The code of the colour for the power varies from blue (low power) to red (high power).
The continuous wavelet spectrum for the exchange rate showed the degree of variability in the series over different time and frequency domains. The series are divided into five different times, 0 - 100, 101 - 200, 201 – 300, 301 - 400 and 400 – 492, on the horizontal axis. Observations were also made for four different periods, such as the short run period (0 – 8), medium run period (8 – 32), long run period (32 – 64) and very long run period (64 – 128), on the vertical axis. From the results, it is obvious that only the cone of influence can be interpreted, which is represented by the U area. The region shows the statistical significance of the series variability. The red regions show where there is high variability in the series. The blue regions display the area of low variability in the series. The black lines display the series significance at the 5% level. The yellow regions are just the lower portion of the red region. Therefore, the following can be seen:

1 - 100 frequency/period
Short run period (0 – 8): With the presence of the blue areas, there are low levels of variability in the early to middle short run period of the series. However, with the presence of red areas towards the tail end of the first hundred (100) series, there is high variability. The series are also significant at the 5% level. Medium run period (8 – 32): With the presence of the blue areas, there are low levels of variability in the early to middle short run period of the series. However, with the presence of slight red areas, there is high variability but extremely low variability in the first hundred (100) series. More series are also significant at the 5% level than in the short run. Long run period (32 – 64): With the

presence of slight blue areas, there are low levels of variability in the early period of the series. The series are also significant at the 5% level only at the beginning of the long run period; at the end, it does not. The very long run
period (64 – 128): With the presence of slight blue areas, there are low levels of variability in the early period of the series. There is no variability in the series, and the levels are not significant.

101 - 200 frequency/period
Short run period (0 – 8): Only the blue areas show low levels of variability in the middle short run period of the series. There is presence of few high variability in the middle periods with the presence of red areas. The series are also significant at 5% level. Medium run period (8 – 32): slight presence of low levels of variability, slight presence of high variability in the middle period in the series. The series are also significant at the 5% level. Long run period (32 – 64): With the presence of slight blue areas, there are observable low levels of variability in the series, and the series are not significant at all. The very long run period (64 – 128): There are observable low levels of variability and a 5% level of significance across the period. There is no high variability in the series, and the levels are not significant.

201 - 300 frequency/period
Short run period (0 – 8) and Medium run period (8 – 32): With the presence of red areas, there is high variability in the series. Very strong low variabilities can also be observed in the series with the presence of strong blue areas. All series are also significant at the 5% level. Long run period (32 – 64): With the presence of slight blue areas, there are low levels of variability in the early period of the series. The series are also significant at the 5% level. The very long run period (64 – 128): No presence of variability in the series variability in the early period of the series. The series are however significant at the 5% level.

301 - 400 frequency/period
Short-run period (0 – 8), Medium-run period (8 – 32), Long-run period (32 – 64) and the very long-run period (64 – 128): With the presence of the blue areas, there are many low levels of variability in the series, and the series are not statistically significant at the 5% level.

401 - 492 frequency/period
Short run period (0 – 8), medium run period (8 – 32), Long run period (32 – 64) and very long run period (64 – 128): With the presence of the blue areas, there are many low levels of variability in the series, and the series are not statistically significant at the 5% level.
4.2.6 Continuous Wavelet Spectrum: Oil Price

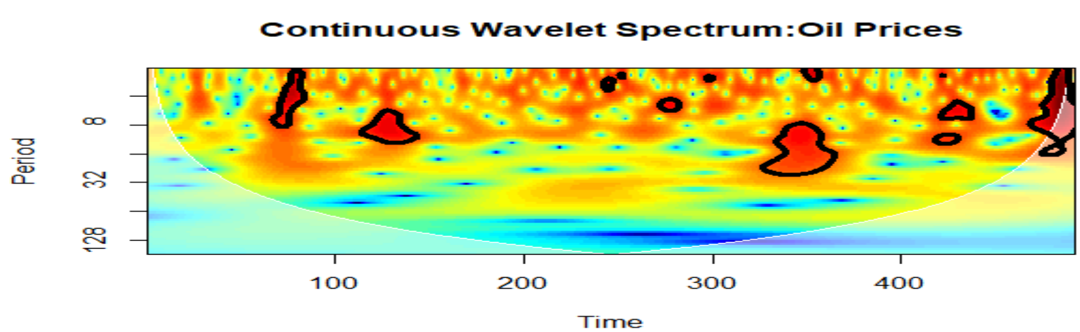


Figure 7: The continuous wavelet spectrum of oil price returns
Source: Authors' estimation using RStudio

Notes: Figure 6 represents the continuous wavelet spectrum of return series of oil prices from January 1980 to December
2020. The thick black contour indicates that the significance level is 5% for the region in the cone of influence (COI). The code of the colour for the power varies from blue (low power) to red (high power).

The continuous wavelet spectrum for oil prices shows the degree of variability in the return series over different time and frequency arenas. The series are divided into five different times, 0 - 100, 101 - 200, 201 – 300, 301 - 400 and 400 – 492, on the horizontal axis. Observations were also made for four different periods, such as the short run period (0 – 8), medium run period (8 – 32), long run period (32 – 64) and very long run period (64 – 128), on the vertical axis. From the observation, it is only the cone of influence that can be interpreted, which is represented by the U area. This is the region that shows the statistical significance of the series variability. The red regions show where there is high variability in the series. The blue regions show areas of low variability in the series. The black lines show the series significance at the 5% level. The yellow regions are just the lower portion of the red region.

From this result, the following can be seen:

1 - 100 frequency/period: Short run period (0 – 8):
There is evidence of high variability towards the tail end of the first hundred (100) series, which is also supported by the statistical significance of the region at the 5% level. Medium run period (8 – 32): There is an absence of variability in the series in the period for the series region. Long run period (32 – 64): There is evidence of stable variation in the series for this period, and there is evidence of low power variation towards the end of the period. The very long run period (64 – 128): There is no variability in the series, and the levels are not significant.

101-200 frequency/period: Short-run period (0–8)
There is presence of high variability towards the end of the period with the presence of red areas. The series are also significant at the 5% level. Medium-run period (8–32): There are high levels of variability from the beginning until the middle point of the period, and the degree of the variation is highly significant at the 5% level. Long run period (32–64): With the presence of slight blue areas, there are observable low levels of variability in the series, and the series are not significant at all. The very long run period (64 – 128): There are observable low levels of variability. There is no high variability in the series, and the levels are not significant.

201 - 300 frequency/period: Short run period (0 – 8)
There is a significant high variation of oil price returns at the middle and towards the tail of the 201-300 observation. Medium run period (8 – 32), long run period (32 – 64) and very long run period (64 – 128): No presence of variability in the series variability in the early period of the series.

301 - 400 frequency/period: Short run period (0 – 8) and Medium run period (8 – 32)
There is presence of high variation at the beginning of the short run period and the whole of the medium run period reveal huge significant variability across frequency domain. Long-run period (32 – 64) and the very long-run period (64 – 128): With the presence of the blue areas, there are many low levels of variability in the series, and the series are not statistically significant at the 5% level.

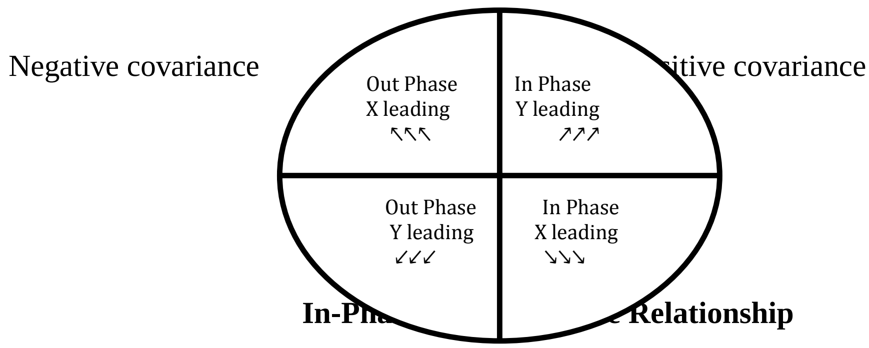
401 - 492 frequency/period: Short run period (0 – 8) and Medium run period (8 – 32)
There is presence of high variation at the beginning of the short run period and the whole of the medium run period reveal huge significant variability across frequency domain. Long-run period (32 – 64) and

the very long-run period (64 – 128): With the presence of the blue areas, there are many low levels of variability in the series, and the series are not statistically significant at the 5% level.

In summary, the null hypothesis of no short-run, medium-run, long-run and very long-run relationship between oil price and exchange rate in Nigeria is rejected on the significance level of 5% based on the evidence reported from the result of wavelet covariance, correlation and continuous wavelet transforms of exchange rate and oil price returns.

4.2.7 Wavelet Coherence: Exchange Rate-Oil Price

To interpret the wavelet coherence, we used the in-phase out phase relationship presented below.



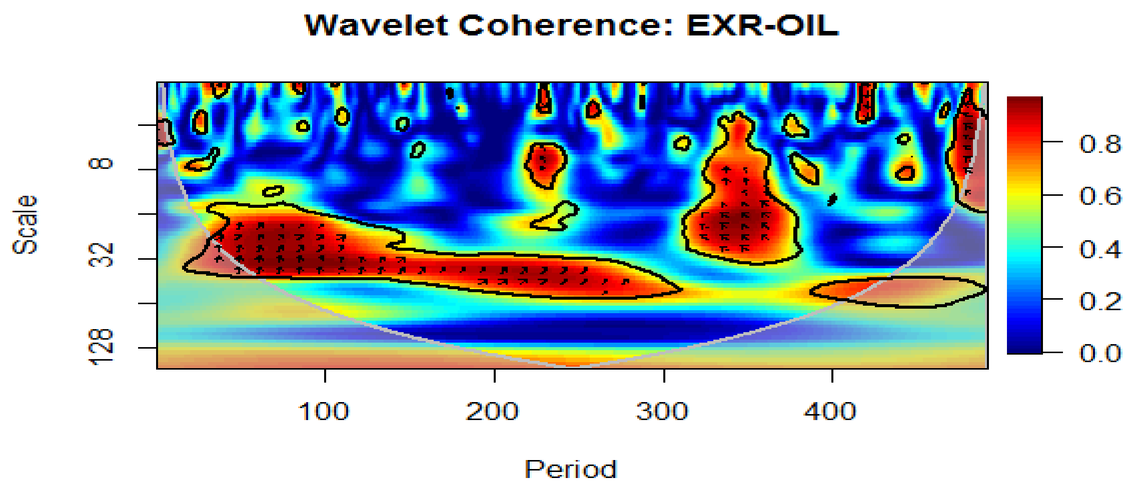


Figure 8: Wavelet coherence transforms of exchange rate and oil price returns

Source: Authors' estimation using R-Studio

Notes: Wavelet coherence transform (WCT) of exchange rate return (EXR) and oil price return (OIL) for the period between January 1980 and December 2020 in Nigeria. The deep black contour represents the significance level at 5% over the red noise for areas covered by the cone of influence (COI). The dark red portion represents regions with significant interrelation, while areas covered by the deep blue colour signify low dependence between the series. However, the cold regions beyond the significant areas represent time and frequency bands with no dependence. Arrows pointing to the right (either up or down) signal in-phase effects, while arrows pointing to the left (either up or down) feature out-phase effects for both series.

This shows the lead-lag effect of the two variables. It shows where one variable cross and granger cause the other over different time frequency domains. From this analysis, all regions circled with black lines are significant at the 5% level. Red regions are regions with strong variabilities. Blue regions show low variabilities. The in-phase regions show a positive covariance. The out phase region exhibits a negative covariance. The analysis is interested in seeing which one affect or granger causes

the other by observing the in-phase and out-phase relationship. X represents the exchange rate, which is the exogenous variable, and Y represents the oil price, which is the endogenous variable. Where X is leading, it means that the exchange rate is leading, and where Y is leading, it means that the oil price is leading. The time differences are 0 - 100, 101 - 200, 201 – 300, 301 - 400 and 400 – 492 on the horizontal axis, while the periods are the run period (0 – 8), medium run period (8 – 32), long run period (32 – 64) and very long run period (64 – 128) on the vertical axis.
In the short and medium run, there is no evidence of a lead lag effect; nothing is granger causing the other. There is no evidence of in-phase and out-phase relationships. In the long run, for the first 100 series, there is evidence of lead lag effects. Some series point to Y, meaning Y leads to X; therefore, the exchange rate is granger causing oil prices for those regions, and there is an out-phase effect. Those arrows pointing upwards show that there are no relationships between the exchange rate and oil price. In conclusion, there is significant evidence to reject the null of no time-varying effect of oil price on exchange rate in Nigeria at the 5% level of significance and accept the alternative hypothesis of significant evidence of the time-varying effect of oil price on exchange rate in Nigeria.

4.2.8 Granger Causality
Table 2: VAR Granger Causality and F Statistics Result Summary

Time Domain	OIL ⇏ EXC	EXC ⇏ OIL	Remarks
Ordinary series	(1.58534) {0.0924}	(0.79947) {0.6512}	No causality
D_I	(2.09458) {0.0161}*	(1.38242) {0.1706}	Unidirectional Causality
D_2	(2.19991) {0.0109}*	(1.28138) {0.2261}	Unidirectional Causality
D_3	(2.63689) {0.0020}*	(1.41128) {0.1569}	Unidirectional Causality
D_4	(1.80570) {0.0448}**	(2.12869) {0.0142}**	Bidirectional Causality
D_5	(2.38808) {0.0054}*	(2.82509) {0.0009}*	Bidirectional Causality
D_6	(6.04140) {0.0000}*	(2.99840) {0.0005}*	Bidirectional Causality
S_6	(6.05137) {0.0000}*	(6.21713) {0.0000}*	Bidirectional Causality

Note: F statistics results are presented in ( ), while results for probabilities are presented in { }. * and ** denote significance levels at 1% and 5%, respectively. D1 & D2➔Short run period, D3 & D4➔Medium run period, D5 & D6➔ Long run period and S6➔Very long run period.

For robustness purposes and to answer research question three, this study used the ordinary and decomposed series of oil price and exchange rate returns to estimate the vector autoregressive (VAR) Granger causality. However, before proceeding to the estimation of the decomposed series, the study discovered that there is absence of causal effect between the ordinary return series of exchange rate and oil price. Conversely, the outcome of the decomposed series VAR estimates shows evidence of unidirectional causality from oil price to exchange rate for the short-run period (D1 & D2) and medium-run period (D3), whereas the other medium-run period (D4) revealed evidence of bidirectional causation between oil price and exchange rate. Furthermore, the long-run (D5 & D6) and very long-run (S6) periods show evidence of feedback causality between oil prices and exchange rates. This therefore clarifies that the relationship between oil price and exchange rate is dependent on time-period, and as such, considering the nexus between the periods over a single period could result in inconclusive verification.

Finally, the hypothesis of the study is tested based on the result of the causality test for the time period. Thus, with the evidence of uni-or-bidirectional causality, this study rejects the null hypothesis of no direction of causality between oil prices and exchange rates in Nigeria. Hence, the alternative hypothesis of the presence of directional causation between oil prices and exchange rates in Nigeria was accepted at the 5 percent level of significance.

5. Summary, Conclusion and Recommendations

Three hypotheses and results are reported for this study. The first hypothesis analysed the short-run, medium-run, long-run and very long-run relationships between oil prices and exchange rates in Nigeria. The study shows evidence of positive and negative associations between exchange rates and oil prices over the periods. This evidence corroborates the findings of Yang et al. (2017), Adebayo (2020) and Huang, An and Lucey (2020), which revealed that there is a 50% co-movement between the exchange rate and oil price and that they both move negatively and positively. The second hypothesis examined the time-varying effect of oil prices on exchange rates in Nigeria revealed that in the short and medium run, there is no evidence of a lead-lag effect, which implies the absence of a time varying effect. However, in the long run, there is evidence of lead-lag effects between oil prices and exchange rates in those regions. This result is in line with the conclusion given by Reboredo and Rivera-Castro (2013), Aloui, Hkiri, Hammoudeh & Shahbaz (2018) and Yang, Cai and Hamori (2017) that there is evidence of profound lead-lag effects between exchange rates and oil prices during the global financial crisis compared to the pre-global financial crisis. The third hypothesis analyses the direction of causality between oil prices and exchange rates in Nigeria. The results revealed that oil price has a one-way Granger effect on the exchange rate in the short run and medium run; however, in the long run and very long run, there is bidirectional Granger causality between oil price and exchange rate in Nigeria. Following this evidence, this finding was in line with the evidence reported by Kisswani, Harraf and Kisswani (2018), Adebayo (2020) and Musa and Maijama (2021).

Conclusively, empirical evidence of this study supports the presence of a lead-lag relationship between oil prices and exchange rates in Nigeria. In addition, there is evidence of a unidirectional effect of oil prices on exchange rates in Nigeria in the short run and medium run periods. The bidirectional causality surfaced in the long run and very long run period between the observed series. This study therefore concludes that oil price is a significant factor that causes changes in the exchange rate in Nigeria in the short run and medium run periods. However, in the long run and very long run periods, oil price and exchange rate reflect a feedback effect such that fluctuation in oil price influenced exchange rate changes and changes in exchange rate thereafter caused shocks to oil price.

Based on the finding that oil price shocks induce fluctuations in exchange rates, economic activities and government revenue, there is the need for policy makers to promote effective economic diversification, such as looking for alternative ways of financing the budget by fully diversifying into agriculture, which was the source of income and employment for the economy before oil discovery. This would enhance export production in other sectors of the economy, reduce overdependence on oil and, ultimately, stabilize the exchange rate of the naira via-a-via the US dollar. The results show bidirectional causality between oil prices and exchange rates in the long run. Thus, monetary authorities should adopt the Mundell–Fleming model of fixed exchange rates to reduce exchange rate fluctuations induced by oil price shocks. For instance, a fixed exchange rate policy that is export-friendly would be appropriate to stimulate export production and reduce exchange fluctuation. This will make it possible to maintain a fair swing in external financial activities as well as trade fluctuations and oil-related products, especially in periods of oil price crises.

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