Shocks and volatility transmission between oil price and Nigeria's exchange rate

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Abstract

The study examined shock and volatility transmission between oil price and exchange rate markets using daily data covering the period from 23rd October 2009 to 30th November 2020. The contributions of the paper include (i) implementation of VAR-AGARCH model to capture spillover effect of shock and volatility; (ii) examining the nature of shock impact in oil price and exchange rate market; (iii) adopting of two measured of oil price (WTI and Brent); (iv) employing two measures of the exchange rate (USD/Naira and effective/Naira). The study revealed that past own shocks and volatilities significantly contribute to current volatilities in exchange rate and oil price markets. Also, there is bidirectional shock and volatility spillover between the exchange rate (USD/Naira and effective/Naira) and WTI oil price markets. There were bidirectional shock and volatility spillover between USD/Naira and Brent oil price and unidirectional shock and volatility from Brent oil price to effective exchange rate market. We found asymmetric shocks impacting exchange rates and WTI oil price while symmetric shock was observed in Brent oil price. Including innovation in oil price is essential in exchange rate policy formulation and modelling exchange rate shock and volatility.

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Introduction

The Nigerian economy is monolithic in structure and highly dependent on oil. Oil export revenue constitutes 95% of government revenue receipt, and income from oil export accounts for a substantial part of government expenditure (Ogbonna 2018). Given the above scenario, changes in the international oil market in the form of a reduction in oil demand given supply unchanged would have grave consequences on the economy's wellbeing. Oil price shock in the form of a fall in price would affect net oil exporters differently from net oil importers. For instance, a fall in oil price will lead to depletion of the foreign reserve, which results in depreciation of the local currency exchange rate and loss of appetite by foreign investors for local currency-denominated stocks of the net oil exporter. Specifically, devaluation of the Naira against USD will lead to an increase in the general price level resulting from the import of consumer goods as a country with a high appetite from imported products and increase in production cost resulting from imported input price will rise due to falling purchasing power of the local currency (Naira), as seen in recent time in Nigeria, resulting from a slump in oil demand due to the COVID-19 pandemic worldwide (Ogbonna and Appah 2012; Charles and Darné 2009). While the opposite happened for net oil importers, domestic price level and cost of production will fall, accumulation of foreign reserve which lead to the appreciation of the domestic currency and increase in demand for local currency dominated stocks of the net importer.

An economy with such a high dependence on one product and its price determined outside of its shore would suffer turbulent times, especially with adverse price shocks. Nigeria tends to experience economic crises whenever there is a fall in the international oil price and an economic boom during the oil price hike. Because oil export revenue constitutes major, if not the only source of foreign exchange earnings into the economy, a fall in price will reduce foreign reserve and subsequent rapid depletion of foreign reserve position (Bankole and Shuaibu 2013; Olanipekun 2016). Usually, the problem becomes complex because the country depends heavily on consumers and capital goods import to feed almost two hundred million population and local production needs. This situation tends to exacerbate foreign currency shortages when the oil price falls in the international oil market. Monetary authorities usually implement administrative measures such as foreign exchange restriction; by imposing the limit on how much one can access foreign exchange. As such, one must obtain administrative approval to procure foreign exchange and prohibit the import of some items into the country. These measures aim to conserve foreign exchange and maintain a suitable foreign reserve position that guarantees certain months of import bills to avoid unwarranted economic crises. A period characterized by a fall in oil price usually portends great danger for fiscal policy in Nigeria, as the revenue accrued to government coffers nosedive. It usually leads to public debt accumulation and austerity measures that retard economic growth, ultimately leading to massive unemployment in Nigeria. Also, following the downturn in oil price some time in 2015 and the recent COVID-19 induce fall in oil price, Nigeria economy fell into two recessions in quick succession due to these falls in global oil price.

Many studies on the nexus between oil price and exchange rate in Nigeria employed traditional methods of analysis, such as OLS, Co-integration, Vector autoregressive and autoregressive distributed lag method (Ademola and David 2011; Umoru et al. 2018; Bankole and Shuaibu 2013; Olanipekun 2016; Olayungbo 2019). However, the relationship might not necessarily be linear. High-frequency data usually exhibit stylized factors such as volatility clustering, the fat tail, asymmetry/leverage effect, and non-normal distribution characteristics; these methods cannot effectively model these characteristics. The study intends to fill the estimation method gap by employing vector autoregressive-asymmetric generalized autoregressive conditional heteroscedasticity (VAR-AGARCH) developed by Ling and McAleer (2003). The advantages of this method include removing computational complexity in estimating unknown parameters compared to other multivariate models. It enables estimates of spillover effects of conditional returns and volatility between/among financial variables and would enrich the existing literature. Also, Nigeria is the sixth-largest producer and exporter of global crude Oil and the largest producer and exporter of Oil in African. Shock in oil price is expected to affect its foreign exchange reserve position and, by extension, the purchasing power of its currency. Lastly, the government budget is based on oil revenue receipts. Therefore, the shock in oil price substantially impacts the government ability to provide an environment for economic growth and development. It is equally imperative to empirically examine the volatilities transmission between oil price and exchange rate in Nigeria and determine whether positive and negative oil price shocks have a symmetric or asymmetric impact on the foreign exchange rate in Nigeria to inform macroeconomics policy formulation.

Additionally, while our study uses similar variables and analytical methods with Salisu and Mobolaji (2013), we differ in the period covered. Secondly, this study employed two oil price measures; Brent and West Texas Intermediate (WTI), against the single unspecified, measured used in their work; thirdly, our study examines the natures of shock in oil price and exchange rate markets which they did not treat in their research.

The remainder of the paper is structured thus: following the introduction is the literature review, the subsequent section gives the detailed research method employed in the study and then the presentation and data analyses are explained. The last section concludes the study.

Literature review

Theoretical links between oil price and exchange rate

There is controversy concerning the direction of causation between oil price and exchange rate. We discussed briefly the theoretical proposition linking these variables.

Terms of trade channel

This theory is traced to Amano and van Norden (1998); they propounded a two-sector model: tradable and non-tradable. The model assumed both sectors use a tradable input called Oil, and a non-tradable input called labour. Also, in the model, both inputs are mobile between the sectors.

This model further assumed that the output price of the tradable sector is fixed in the international market. For instance, Bénassy-Quéré et al. (2007) posited that suppose there is a rise in the price of oil; this would affect the output prices of both tradable and non-tradable sectors, an increase in the price of oil could lead to either an appreciation or a depreciation of the domestic exchange rate. However, its effect depends on oil intensity in the input mix of both sectors. Consequently, the real exchange rate is equal to the non-tradable sector output price.

In fact, in the event where the non-tradable sector is more (less) energy-intensive than the tradable one, its output price rises (falls) and the real exchange rate appreciates (depreciates) (Nouira et al. 2018).

The balance of payments and international portfolio choices

The theory is commonly referred to as the wealth transmission channel. This theory is traced to research by Golub (1983) and Krugman (1983), which were premised on the impact of oil price changes on international portfolio decisions and trade balances. According to this theory, higher oil prices will transfer wealth from oil importers to oil exporters. For instance, Krugman (1980) empirically examined the effect of an increase in oil price on the U.S. dollar. He argued that in the short run U.S. dollar would appreciate and depreciate in the long run.

Furthermore, he posited that the differences witnessed in foreign exchange markets due to oil shocks in the 1970s were specifically due to oil-exporting and oil-importing countries' portfolio choices. In the beginning, there will be a positive relationship as oil profits are invested in U.S. dollar-dominated assets. However, the relationship becomes negative in the long run due to the rise in OPEC spending over time, resulting from wealth accrued from higher oil prices, given the manufactured commodity's preference from industrial countries. If OPEC imports come from countries other than the U.S., the U.S. dollar will appreciate in the short run but not in the long run.

The elasticity approach

This theory is premised on the principle of import elasticity of demand. The exchange rate changes in response to the change in oil price depend on the elasticity of import of an importing country. For instance, Jehle and Reny (2011) define demand elasticity as a measure of the quantity demand's responsiveness to a change in the imported product's price. He further stated that if the quantity demanded is highly responsive (non-responsive) to a price change, demand is relatively elastic (inelastic). Nkomo (2006) put forward that if there is a rise in the price of a country's export product (oil), the products become relatively more expensive in the international market. Hence, importing countries will reduce their imports of oil. However, the rate at which the quantity of imports changes depends on the elasticity of imports. Indeed, if oil import demand is highly inelastic, a rise in oil price causes domestic currency depreciation in the importing country. An increase (decrease) in the oil price means that the importing country requires more (less) of its currency to buy the same amount of Oil it used to buy before. Hence, there would be deprecation (appreciation) in the importing country's currency (Nouira et al. 2018).

We now turn our attention to the exchange rate change's theoretical effect on the oil price. The transmission mechanism from the U.S. dollar exchange rate to oil price is rooted in its impact on demand and supply and hinge on the dominate role of the U.S. dollar as an international settlement currency.

Bloomberg and Harris (1995) relied on the law of one price for tradable goods and offered concise exposition on the probable impact of exchange rates on oil price changes. They show that, since Oil is a homogeneous and internationally traded commodity priced in U.S. Dollars, a depreciation of this currency reduces the oil price to foreigners relative to the price of their commodities denominated in U.S. Dollars. Thus, as their purchasing power and oil demand increases, the crude oil price in U.S. Dollars rises. This proposition is further bolstered by the following analogy cited in Beckmann and Czudaj (2013a, b). The horizontal transmission from the U.S. dollar exchange rate to oil price is premised on the changes in demand and supply of U.S. dollar as an international settlement currency.

Following from transaction costs theory, assume the relationship between the logarithms of the oil price measured in U.S. dollar (o_t) and another currency (0_t^*) are based on purchasing power parity (law of one price) given as:

$$0_t^* = s_t - 0_t,$$

s_t is the logarithm of a domestic currency's nominal exchange rate against the U.S. dollar (domestic currency per one unit of U.S. dollar). Given a commodity such as oil measured in the U.S. dollar, an appreciation of domestic currency against the U.S. dollar lowers the price of oil measured in terms of the domestic currency, which increases demand and may result in a general rise in oil prices (Akram 2004). This transmission channel is called the 'denomination channel'. However, its impact on the supply side is not straightforward. Positive effects could come from an exchange rate induced rise in oil price on drilling activities and production capacities. Although, these causal links has changed over time. On the other hand, depreciation

of the domestic currency could decrease purchasing power and move resources away from oil production, which would lead to a decrease in supply (Coudert et al. 2008).

Empirical review

The literature on oil price and exchange rate nexus is broadly divided into two streams: oil price change will cause exchange rate change, and exchange rate movement will cause oil price change. However, these are further subdivided into the linear and non-linear relationships between the two variables. This paper will briefly review earlier works on the nexus between oil price and exchange rate in the literature.

The literature on oil price change causes exchange rate movement was pioneered by Krugman (1983) and Golub (1983), where their studies linked oil price changes to change in U.S. dollar exchange rate. These researches open the gate for the subsequent inquiry into the relationship between oil price and exchange rate; for instance, these studies showed that oil price changes cause exchange rates movement (Amano and van Norden 1998; Chaudhuri and Daniel 1998; Bénassy-Quéré et al. 2007; Coudert et al. 2007; Lizardo and Mollick 2010).

Castro and Jime'nez-Rodrı'guez (2020) examined the interactive relationship between effective exchange rate and oil price for U.S. as an oil-importing country. They employed a time-varying VAR model, using monthly data from January 1974 to July 2019. They found the exchange rate appreciates after oil price shock in the long run and short-run, and the exchange rate response differently to oil price shock in the long run. Ahmad and Hernandez (2013) examined the long-run relationship and asymmetric adjustment between the real bilateral exchange rates and real oil prices for twelve major oil producers and consuming nations. They employed threshold autoregressive and momentum threshold, autoregressive models, using monthly data from January 1970 to January 2012. They found that six of the twelve countries' oil prices and exchange rates are cointegrated and asymmetric adjusted in four countries. And Brazil, Nigeria and the U.K. show higher adjustment after a positive shock than a negative shock, while revise is the case for Eurozone. A related study by Basher et al. (2015) examined the impact of oil shocks on the real exchange rate by employing Markov-switching models for a sample of Oil exporting and oil-importing countries. They found oil supply shocks impact the exchange rate, and global demand shocks impact the real exchange rate of both importing and exporting nations. They could not find uniform appreciating and depreciating patterns in real exchange rates. Bebonchu et al. (2015) examined the asymmetric response of U.S. real and nominal trade-weighted U.S. dollar exchange rate indexes to the oil price shock by disaggregating oil shock into demand and supply shock. They found oil supply shock has an insignificant impact on exchange rates while global aggregate and oil-specific demand shocks lead to depreciation. Also, exchange rates respond asymmetrically to shocks in the crude oil market, and it depends on the scales and magnitude of the shock.

On the contrary, some studies found causality run from exchange rate to oil price. For instance, Cheng (2008) found an increase in the real (nominal) oil price as a

direct response to the appreciation of the real (nominal) effective U.S. dollar. Also, Buetzer et al. (2012) examined the impact of U.S. dollar depreciation on five OPEC countries and found crude oil export prices positively respond to the depreciation of the domestic currency against the dollar stabilize export revenues. In the same vein, Krichene (2005, 2006) examined the impact of nominal effective U.S. dollar exchange rates on oil price. He found an appreciation of the nominal effective U.S. dollar exchange rate could increase and decrease oil prices. Zhang et al. (2008) used VAR and ARCH models on daily data for 4th January, 2000, to 31st May, 2005. They concluded that the U.S. dollar drives the international crude price. Beckmann and Czudaj (2013b) applied co-integration techniques by employing two measures of effective U.S. dollar exchange rates from January 1974 to November 2001. They found causality run from nominal exchange rates to nominal oil price. Also, Sadosky (2000) found that exchange rate and energy prices are cointegrated, and causal analysis shows the exchange rates movement causes changes in heating oil and crude oil prices in the short run. In like manner, Akram (2009) posited that depreciation of U.S. dollar leads to higher oil prices. Also, Jung, et al. (2019) examined the relationship between the US–Canada exchange rate and real oil price by employing a nonlinear autoregressive distributed lag method and a granger causality test from January 1982 to March 2019. They found US–Canada exchange rate and the real price of Oil are cointegrated. Also, long-run asymmetry causality runs from the US–Canada exchange rate to the real oil price. However, Ding and Vo (2012) found bidirectional causality between oil price and exchange rate.

Ademola and David (2011) examined the correlation between oil price and the Naira exchange rate against the U.S. Dollar, using monthly data for 1999–2009. The study employed spot oil price and Naira/U.S. Dollar exchange rate. They employed the ordinary least square method. They found weak significant links between oil price and exchange rate in Nigeria for the period under review. Umoru et al. (2018) examined the effects of oil price volatility on exchange rate variability, foreign exchange reserve, real gross domestic product and government expenditure. They used vector auto-regressive as well as impulse response analysis. They found oil price accentuate exchange rate volatility, foreign reserves, government expenditure and real gross domestic product. Bankole and Shuaibu (2013) examined the effect of the oil price change on international reserve accumulation from 1960 to 2011. The study employed a Vector Auto-regressive (VAR) method. They found that oil price change has substantially and negatively impacted the reserve in the long run and moderate in the short run. More so, Olanipekun (2016) examined the relationship between oil price shocks, exchange rate, external reserve and real GDP from the first quarter of 1971 to the first quarter of 2014. The study employed a structural Vector Autoregressive (SVAR) model and impulse response function. They found oil price shocks impacted negatively on foreign reserve, exchange rate and economic growth.

Osigwe (2015) Examined the impact of exchange rate on oil price, using ordinary least square and two-stage least squares regressions and Granger causality. The study found that the exchange rate negatively impacted Nigeria's oil price, and both the exchange rate and the oil price have positive effects on Nigeria's economic growth. Oriavwote and Eriemo (2012) examined the impact of oil price volatility on the exchange rate from 1980 to 2010. They employed Johansen co-integration and

Granger causality tests. They found a long-run relationship between oil price and exchange rate. Also, oil price change granger cause exchange rate.

Chen and Chen (2007) examined the long-run relationship between oil price and real exchange rate, using monthly data for G7 countries. They found that oil price has a dominant effect on the real exchange rate movement in these countries. Also, Aziz (2009) examined the impact of oil price fluctuation on net oil exporter and importer countries real exchange rates. They found evidence of a long-run relationship among the variables and oil price exact positive significant effect on the real exchange rate of net exporter and importer countries. Suleiman and Muhammad (2011) examined the long-run relationship among real oil price, real effective exchange rate and productivity differential, using annual data from 1980 to 2010. The study revealed that long-run relationship exists among the variables and real oil price exact positive significant impact on real effective exchange rate while productivity differential exact negative significant impact on real effective exchange rate. Similarly, Ozsoz and Akinkunmi (2011) affirmed the positive effects of oil prices on Nigeria's exchange rate. In the same vein, Coleman et al. (2011), in their penal study of 13 African countries, found a long-run relationship between real oil price and real effective exchange rate in Nigeria.

Osuji (2015) examined the effect of oil price on Nigeria's exchange rate, using monthly data from January 2008 to December 2014. The research employed the ordinary least squared and granger causality test. The study found that oil price has a significant negative impact on the exchange rate, and oil price granger cause exchange rate volatility in Nigeria. In a related work, Adeniyi et al. (2012) posit that Naira/U.S. Dollar exchange appreciates with an increase in the Oil price during the study period, and Basher et al. (2012) found a unidirectional causality from the oil price to the exchange rate.

Olomola and Adejumo (2006) examined the effect of oil price on the exchange rate and economic growth, using annual data from 1970 to 2003 and employed Vector autoregressive model (VAR). They found a significant impact of oil price on the exchange rate and an insignificant impact on Nigeria's economic growth. Olayungbo (2019) examined the impact of oil price change, external reserve, and the exchange rate on the exchange rate using annual data from 1970 to 2011. The study employed the GARCH model as well as the Johansen co-integration and error correction method. They found a proportional change in oil price led to more than a proportional change in Nigeria's exchange rate.

On the contrary, Olayungbo (2019) examined the causal link between oil price and exchange rate, international reserve and trade balance in Nigeria. They revealed that oil price does not cause exchange rate, trade balance, and the only international reserve has a long-run relationship with Nigeria's oil price. However, Salisu and Mobolaji (2013) examined returns and volatility transmission between oil price and US-Nigeria exchange rate and hedging strategy by calculating the optimal weights of holding oil and foreign exchanges assets. They employed the VAR-GARCH model to capture the spillover effects in the returns and volatility transmission between oil price and exchange rate. They identified bidirectional returns and spillover transmission between oil and foreign exchange markets. Also, Oil and foreign exchange markets can effectively hedge against each other.

Methodology

This study employed a recently developed VAR-AGARCH model by Ling and McAleer ([2003](#)) by adopting a bivariate form of Bollerslev ([1986](#)) model to estimate the interrelationship between Oil price and foreign exchange markets (hereinafter FX.) in Nigeria. The bivariate-AGARCH(1,1) takes the form:

The conditional mean equation expresses as follows:

$$R_t = \zeta + \Pi R_{t-1} + \varepsilon_t, \tag{1}$$

$$\varepsilon_t = H\eta_t, \tag{2}$$

$R_t = \left(\text{EXRR}_t, \text{OLPR}_t\right)'$ is the vector of returns of Oil price and exchange rate at a given time t, respectively; ζ is a (2×1) vector of constant of the form $\zeta = \begin{pmatrix} \zeta^{\text{EXRR}} \\ \zeta^{\text{OLPR}} \end{pmatrix}$;

Π is a (2×2) matrix of the coefficient of the form $\begin{pmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{pmatrix}$; where π_{12} denotes volatility spillover effects from oil price to exchange rate and π_{21} denotes volatility spillover effects from the exchange rate to the oil price. $\varepsilon_t = \left(\varepsilon_t^{\text{EXRR}}, \varepsilon_t^{\text{OLPR}}\right)'$ is the vector of error term for the mean equation for oil price and FX., respectively; $\eta_t = \left(\eta_t^{\text{EXRR}}, \eta_t^{\text{OLPR}}\right)$ is the vector of independently and identical distributed (iid) random error; $H = \text{diag}\left(\sqrt{h_t^{\text{EXRR}}}, \sqrt{h_t^{\text{OLPR}}}\right) = \begin{pmatrix} h_t^{\text{EXRR}} & h_t^{\text{EXRROLPR}} \\ h_t^{\text{EXRROLPR}} & h_t^{\text{OLPR}} \end{pmatrix}$ is the matrix of conditional variance for oil price and exchange rate respectively, and h_t^{OLPR} h_t^{EXRR} are the conditional variance of oil price and exchange rate. Equation ([1](#)) is used to measure return independent in each market.

The shocks spillover and volatility transmission across markets, as well as asymmetric term is stated as follows:

$$\begin{aligned} h_t^{\text{EXRR}} = &\varpi_0^{\text{EXRR}} + \beta_1^{\text{EXRR}} h_{t-1}^{\text{EXRR}} + \alpha_1^{\text{EXRR}} \left(\varepsilon_{t-1}^{\text{EXRR}}\right)^2 \\ &+ \beta_2^{\text{EXRR}} \left(h_{t-1}^{\text{OLPR}}\right) + \alpha_2^{\text{EXRR}} \left(\varepsilon_{t-1}^{\text{OLPR}}\right)^2 \\ &+ \gamma B\left[\left(\varepsilon_{t-1}^{\text{EXRR}}\right) \times \left(\left(\varepsilon_{t-1}^{\text{EXRR}}\right) < 0\right)\right], \end{aligned} \tag{3}$$

$$\begin{aligned} h_t^{\text{OLPR}} = &\varpi_0^{\text{OLPR}} + \beta_1^{\text{OLPR}} h_{t-1}^{\text{OLPR}} + \alpha_1^{\text{OLPR}} \left(\varepsilon_{t-1}^{\text{OLPR}}\right)^2 \\ &+ \beta_2^{\text{OLPR}} \left(h_{t-1}^{\text{EXRR}}\right) + \alpha_2^{\text{OLPR}} \left(\varepsilon_{t-1}^{\text{EXRR}}\right)^2 \\ &+ \gamma B\left[\left(\varepsilon_{t-1}^{\text{OLPR}}\right) \times \left(\left(\varepsilon_{t-1}^{\text{OLPR}}\right) < 0\right)\right] \end{aligned} \tag{4}$$

Equations ([3](#)) and ([4](#)) explicitly show how volatility is transmitted over time and across markets under consideration. The volatility transmission across oil price and the exchange rates are measured by the error terms $\left(\varepsilon_{t-1}^{\text{OLPR}}\right)^2 \left(\varepsilon_{t-1}^{\text{EXRR}}\right)^2$ gross value, which captures the direct impact of shock transmission and lags conditional volatilities $h_{t-1}^{\text{EXRR}} h_{t-1}^{\text{OLPR}}$, which directly account for risk transfer across markets. The null hypothesis is that the alpha two and beta two coefficient in Eqs. ([3](#)) and ([4](#)) are equal

to zeros; hence, there is no spillover of shock and volatility in either direction, oil price to exchange rate and exchange rate to the oil price. Also, gamma (γ) were used to measure the asymmetry effect, using the TARCH model, also called GJR-GARCH in Eqs. (3) and (4) were examined using the sign and significance of γ coefficients. A zero γ coefficient implies that positive and negative shock of the same magnitude has the same effect on volatility in oil price and exchange rate markets. The impact of shocks is asymmetry $\gamma \neq 0$; if γ coefficients are negative, the negative shocks have more impact than positive shock, and the opposite is true if γ positive.

Equations (3) and (4) provide us with relevant information to judge shock and volatility spillover between oil price and exchange rate markets as well as existences of asymmetry shock effect.

Data description

The data covered the period from 23rd October 2009 to 30th November 2020; the exchange rate (is the daily exchange rate of one U.S. dollar to Naira and effective/Naira exchange rate, sourced from Central bank Statistic via http://www.cenbank.gov and Oil price is daily West Texas intermediate and Brent crude price in U.S. Dollar per barrel of crude, sourced from U.S. Energy Information Administration (EIA) via http://www.eia.gov.

This study employed continuously compounded returns due to its advantages over the simple net returns and attractive statistical properties. It allows for infinitely numerous periods; this means that the frequency of compounding does not matter, making returns of different assets easier to compare while simple net return does not allow for comparison across assets; also continuous compounding is symmetric while the net return is not: positive and negative values of equal magnitude do not cancel each other out and result in a net change. In addition, Continuous compounding is time additive; that is, returns are the sum of the logarithm and prevent the return from being negative.

The returns are defined as follows: $r_t = \ln(R_t/R_{t-1}) \times 100$.

Data analysis and discussion of result

Table 1 shows a descriptive statistic for the exchange rate returns series (EXRR and EEXRR), and the oil price returns series [OLP (WTI) and OLP (Brent)]. The mean returns of USD/Naira exchange rate (EXRR) and the effective/Naira exchange rate (EEXRR) have the same value of 0.033 Naira. This point to the dominant position of the U.S. dollar in the effective exchange rate in Nigeria, and Oil price (WTI) return mean is 0.007 U.S. Dollar while Brent has a mean value 0.011 U.S. Dollar. On average, investors gain in both markets, and returns behave in like manner in both markets. As it is with the mean, the exchange rates minimum and maximum were 35.15 Naira and 32.37 Naira, respectively, given the narrow difference between the maximum and the minimum value in the exchange rate, which shows the exchange rate is relatively stable. This fact

Table 1 Descriptive statistics

Statistics	Exchange rate ($/N)		Oil price ($/B)	
	EXRR	EEXRR	OLPR(WTI)	OLPR(BRT)
Mean	0.033	0.033	0.007	0.011
Maximum	35.15	35.16	42.58	41.20
Minimum	32.37	32.38	28.14	25.64
Std. Dev.	0.85	0.85	2.88	2.55
Skewness	30.94	30.86	1.37	1.31
Kurtosis	1166.52	1162.22	48.45	49.50
Jarque–Bera	1.57	1.56	239,724.7	250,823.5
Probability	0.000	0.000	0.000	0.000
Observation	2783	2783	2783	2783
ARCH (1)	0.002**	0.003**	0.004**	0.001**
ARCH (5)	0.000**	0.000**	0.000**	0.004**
ARCH (10)	0.000**	0.000**	0.000**	0.000**
ADF	− 52.193**	− 52.231**	− 26.946**	− 19.834**
PP	− 52.189**	− 52.229**	− 34.425**	− 5.429**

***, **, * denote rejection of associated null hypothesis at 1%, 5% and 10%, respectively, ADF and P.P. carried out with regression equation with constant but no trend. EXRR is the USD/Naira exchange rate return, and EXRR is an effective/Naira exchange rate return

is further confirmed by the standard deviation of 0.85 for exchange rate returns. The minimum values of WTI and Brent oil price were 42.58 US Dollar and 41.20 US Dollar, while the maximum values were 28.14 U.S. Dollar and 25.64 U.S. Dollar, respectively. Again, the difference between the maximum and the minimum is not significant. Again, this is further confirmed by the small values of the standard deviation of 2.88 and 2.55, respectively, implying low volatility. However, WTI crude price is more volatile compared to Brent and exchange rate returns. The exchange rate has the highest return, while the oil price has the least return. Hence, there were gains in exchange rate returns and the oil price returns market. As represented by the skewness and kurtosis, the stochastic returns show exchange rate returns (USD/Naira & effective/Naira) and oil price (West Texas Intermediate & Brent) were positively skewed. These represent a case of an extreme right tail or thick tail. Each kurtosis were greater than 3 cut off points for normal distribution and further affirmed by Jacque–Bera statistic with probability (0.000) for the null hypothesis of normal distributions were rejected.

The ARCH tests were significant with probability values of less than 0.05 for 1, 5 and 10 lags, respectively, implying rejection of the null hypotheses of no ARCH effect in the returns series. Both ADF and PP unit root tests are significant; they suggest rejection of unit root in the returns series. Having found these results, we proceed to estimate shocks and volatilities transmission between oil prices (WTI and Brent)-exchange rate market (USD/Naira and effective/Naira) using asymmetric GARCH model as positive and negative shocks may have a different effect on return in both markets.

Table 2 AGARCH(1,1) model estimate (West Texas Intermediate and exchange)

Variables	Exchange rate US/N	Oil price WTI	Exchange rate Effective/N	Oil price WTI
Mean equation				
Constant	0.033**	− 1.077	0.0328**	− 1.076
R_{t-1}	0.010**	0.294**	0.009**	0.285**
Variance				
Constant	0.713**	2.270**	0.727*	2.272
$\left(\varepsilon_{t-1}^{\text{EXRR}}\right)^2$	0.150**	0.226**	0.150*	0.123
$\left(h_{t-1}^{\text{EXRR}}\right)$	− 0.600**	0.646**	0.603**	0.023
$B\left[\left(\varepsilon_{t-1}^{\text{EXRR}}\right)\times\left(\left(\varepsilon_{t-1}^{\text{EXRR}}\right)<0\right)\right]$	− 0.052**	0.054		
$\left(\varepsilon_{t-1}^{\text{OLPR}}\right)^2$	− 2.521**	0. 115	− 2.914*	0.108**
$\left(h_{t-1}^{\text{OLPR}}\right)$	0.520**	0. 104**	0.020	− 0.012
$B\left[\left(\varepsilon_{t-1}^{\text{OLPR}}\right)\times\left(\left(\varepsilon_{t-1}^{\text{OLPR}}\right)<0\right)\right]$	− 0.205**	− 0.183*		
Log likelihood	− 3435.63	− 90,274.54	− 3961.76	− 90,071.03
LB(5)	0.997	0.681	0.915	0.721
LB^2(5)	1.000	1.000	1.000	1.000
LM(5)	1.000	1.000	1.000	1.000
Norm.	0.000**	0.000**	0.000**	0.000**
No. Obs.	2783	2783	2783	2783

***, *** and * indicate significance at 1%, 5% and 10%, respectively. LB(5) and LB^2(5) represent the Ljung–Box Q-statistics of order 5 for the standardized residuals and squared standardized residuals, respectively, LM(5) represent order 5 Autoregressive conditional heteroscedasticity (ARCH) test and Norm., is the normality test

Table 2 presents the estimated result of the oil price model (WTI) and the exchange rate return series (USD/Naira & Effective/Naira). The mean equation revealed lagged return of oil price (WTI) positive significantly impact exchange rate returns (USD/Naira & effective/Naira). Similarly, the lagged exchange rate return (USD/Naira & effective/Naira) positively significantly impacted oil price return (WTI). This result implies that a higher oil price enhances the exchange rate's appreciation and ultimately leads to Naira's depreciation against USD. This result is consistent with (Salisu & Mobolaji 2013; Ghosh 2011; Coudert et al. 2008). In the same vein, the increase in oil price due to appreciation in USD lend credence to Zhang et al. (2008) that the appreciation USD was the critical driver of global oil price.

The Variance equation showed that past own shocks and volatilities contribute positively and significantly to current volatilities in USD/Naira and effective/Naira exchange rates return markets. Though effective/Naira exchange rates own shock is significant at just 10%. That is, there exists short term predictability in both exchange rates through time. Past own shocks accentuate current volatilities in USD/Naira and effective/Naira exchange rate, while own past volatility tends to reduce current volatility in USD/Naira exchange rate market. However, both past own shock and volatility heighten current volatility in the WTI oil price market. When we compared

volatility persistent between USD/Naira and effective/Naira exchange rate, volatility was more persistent in the effective/Naira exchange rate market. However, a comparison between markets shows volatility was more persistent in WTI Oil price market.

The direction of volatility and shocks spillover between WTI Oil price and USD/Naira exchange rate markets. The result revealed bi-directional shock and volatility transmission in both markets, as shown by significance (h_{t-1}^{EXRR}) (h_{t-1}^{OLPR}) $(\varepsilon_{t-1}^{OLPR})^2$ $(\varepsilon_{t-1}^{EXRR})^2$ values in both markets. This result is consistent with (Salisu and Mobolaji 2013; Ding and Vo 2012).

Also, shocks and volatility in the USD/Naira exchange rate significantly impacted the oil price market. Similarly, volatility in WTI oil price significantly impacted the USD/Naira exchange rate market and was insignificant in the effective/Naira exchange rate market. This finding is inconsonant to (Basher et al. 2015). Shocks and volatilities from either market have more impact on current volatility than own shock and volatility in USD/Naira and WTI oil price markets. This finding aligns with our prior expectations and previous research for an oil-exporting country (Castro and Jime'nez-Rodrı'guez 2020).

We also determined whether positive and negative shocks have the same impact; our result shows a significant negative value for USD/Naira and WTI oil price; this implied existence of leverage effect; bad news has more impact on current volatility than positive news of the same magnitude in USD/Naira exchange rate and WTI oil price markets. Our result is consistent with (Ahmad and Hernandez 2013; Lizardo and Mollick 2010; Coudert et al. 2007). However, effective exchange was positive and insignificant, signifying a lack of leverage effect. The diagnostic test, such as the L.B. test for autocorrelations for standardized residual and squared standardized residual at lags 5, shows no autocorrelation in either case. The ARCH LM test shows the GARCH model has effectively taken out ARCH in the data. The non-normality of the residual as depicted by the probability value less than 0.05 justified the usage of t-student distribution in our estimation.

Table 3 presents the Brent oil price and exchange rate series (USD/Naira & Effective/Naira). The mean equation revealed lagged return of oil price (Brent) negatively impacted exchange rate returns (USD/Naira & effective/Naira) and, on the contrary, lagged return of exchange rate (USD/Naira & effective/Naira) positively significantly impacted oil price return (Brent).

The variance equation showed that own past shocks and volatilities significantly influenced current volatilities in USD/Naira and effective/Naira exchange rates markets. However, the USD/Naira exchange rate was significant at just 10%. It points to short-term predictability in both exchange rates markets through time. Past own shocks exacerbate current volatility in USD/Naira and pass own volatility dampens current volatility, and past own shock and volatility exacerbate current volatility in the effective/Naira exchange rate.

Similarly, past own shock and volatility exacerbate current volatility in the Brent crude oil price market. When we compared volatility persistent between USD/Naira and effective/Naira exchange rate, volatility was more persistent in the effective/Naira exchange rate market. However, a comparison between markets shows volatility was more persistent in the Brent oil price market.

Table 3 AGARCH(1,1) model estimate (Brent and exchange)

Variables	Exchange rate US/N	Oil price Brent	Exchange rate Effective/N	Oil price Brent
Mean equation				
Constant	0.0136**	1.223**	0.013**	0.879**
$R_{t\text{-}1}$	− 0.005**	0.175**	− 0.009**	0.098**
Variance				
Constant	0.621**	4.044	0.621**	0.111**
$(\varepsilon_{t-1}^{\text{EXRR}})^2$	0.121*	0.002**	0.119**	− 0.009
(h_{t-1}^{EXRR})	− 0.542*	− 0.049	0.542**	− 0.354
$B\big[(\varepsilon_{t-1}^{\text{EXRR}}) \times ((\varepsilon_{t-1}^{\text{EXRR}}) < 0)\big]$	− 0.022**	− 0.025**		
$(\varepsilon_{t-1}^{\text{OLPR}})^2$	− 0.004*	0.144**	0.001**	0.028**
(h_{t-1}^{OLPR})	2.023	0.553**	0.005**	− 0.735**
$B\big[(\varepsilon_{t-1}^{\text{OLPR}}) \times ((\varepsilon_{t-1}^{\text{OLPR}}) < 0)\big]$	0.135**	0.247**		
Log likelihood	− 3048.99	− 5967.64	− 3052.76	− 4545.39
LB(5)	0.438	0.091	1.000	0.238
LB²(5)	0.643	0.762	1.000	0.257
LM(5)	1.000	0.468	1.000	0.276
Norm.	0.000**	0.000**	0.000**	0.000**
No. Obs.	2783	2783	2783	2783

***, *** and * indicate significance at 1%, 5% & 10%, respectively. LB(5) and LB²(5) represent the Ljung–Box Q-statistics of order 5 for the standardized residuals and squared standardized residuals, respectively, LM(5) represent order 5 Autoregressive conditional heteroscedasticity (ARCH) test and Norm., is the normality test

The direction of volatility and shocks spillover between Brent oil price and USD/Naira exchange rate markets. The result revealed bi-directional shocks transmission between USD/Naira and Brent oil price markets. On the contrary, there was unidirectional shock and volatility transmission from Brent oil price to effective exchange rate market.

Using Brent oil price and exchange rate (USD/Naira & effective/Naira), we determined whether there is asymmetric shocks impact; the result revealed significant negative values in exchange rate market (USD/Naira & effective/Naira), that is, there is leverage effect; bad news has more impact on current volatility than positive news of the same magnitude in exchange rate markets, our result is consistent with the findings by (Bebonchu et al. 2015; Ahmad and Hernandez 2013). However, Brent oil price markets show both positive and negative shock has the same effect, signifying the lack of leverage effect in Brent oil price return market. Our findings are consistent with Nigeria's foreign exchange market over the years, which usually experienced chaotic volatilities in the Naira exchange rate, especially against the USD, whenever a negative shock hits global oil prices.

The policy implication is that formulating an appropriate exchange policy will require incorporating innovation from oil price and anticipated oil price change in

exchange rate policy in Nigeria, which will lead to stable domestic currency going forward. The inclusion of oil price information is vital when modelling exchange rate volatility. Participants in the foreign exchange market should factor in development in oil price when making investment decisions in the foreign exchange market.

The diagnostic test, such as LB test for autocorrelations for standardized residual and squared standardized residual up to lags 5, shows no autocorrelation in either case; the ARCH LM test shows the GARCH model has effectively taken out ARCH in the data. The non-normality of the residual, as depicted by the probability value less than 0.05, justified the *t*-student distribution used in our estimation.

Conclusion

The study examines shock and volatility transmission between Oil price and exchange rate markets using daily data covering the period from 23rd October 2009 to 30th November 2020. The paper contributes to the literature in the following ways: (i) we implement VAR-AGARCH model to capture Asymmetric impact of shock and volatility; (ii) We adopt two measured of oil price (WTI and Brent); (iii) We also employed two measured of the exchange rate (USD/Naira and effective/Naira).

Our result revealed that past shocks and volatilities significantly contribute to the current exchange rate and WTI oil price markets. However, shock and volatility from either market impact current volatility than past own shock and volatility in exchange rate and WTI oil price markets. There were bidirectional shock and volatility spillover between exchange rate and WTI oil price markets. Also, own shock and volatility significantly impact current volatility in the exchange rate and Brent oil price markets and own shock and volatility had more impact on current volatility in both markets. In contrast, there was bidirectional shock and volatility transmission between USD/Naira and Brent oil price and unidirectional shock and volatility transmission from Brent oil price to effective/Naira exchange rate.

We found asymmetric shocks impacting exchange rates and WTI oil price while symmetric shock was observed in Brent oil price. The policy implication is that incorporating innovation from oil price shocks is very important in formulating Nigeria's exchange rate policy and the inclusion of information from the oil price market is vital when modelling exchange rate volatility and participants in the foreign exchange market should factor in development in oil price when making investment decision in the foreign exchange market.

Declarations

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