Exchange Rate and its Volatility Effects of Covid-19 Pandemic: The Nigeria Case

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Abstract

The debate on the impacts of Covid -19 pandemic on exchange rate and its volatility is up and running. This study examines the case of Nigeria. Daily data from March 20, 2020 to September 3, 2021 for relevant variables were utilized. The bounds test for cointegration and autoregressive distributed lag (ARDL) and GARCH (1,1) methods were employed to examine the effect. The bounds co-integration test results disclosed that there is both short-run and long-run relationship among the variables. The result from the ARDL estimation shows that new Covid-19 cases has a positive but insignificant effect on parallel market exchange rate while numbers of recovered patients from covid-19, oil and stock prices negatively and significantly affects parallel market exchange rate. Results from the GARCH also indicates that new Covid-19 cases have negative, albeit, insignificant effect on the parallel market exchange rate volatility while recovered cases of Covid-19 has negative and significant effect. Further, oil and stock prices have positive and significant effect on parallel market exchange rate volatility. Following these results, it was recommended that government should embark on policy that will diversify its revenue base and also intensify efforts on preventing any forms of pandemic so as not only to achieve the objective of increasing the value of Nigeria currency but also to reduce its volatility.

Keywords**:** Pandemics, Foreign exchange, Autoregressive Distributed lag (ARDL), Generalized Autoregressive Conditional Heteroscedasticity (GARCH) Model

JEL Classifications: I11, F310, C32

Introduction

The novel coronavirus pandemic (Covid-19) began to spread in late 2019 and on January 9, 2020, the first verified case of the disease was announced in Wuhan, China, a second-tier city with a population of 11 million people. On January 13, 2020, Thailand reported the first verified case and over 3 million additional confirmed cases were reported in the first month of 2020. More than 200,000 individuals died as a consequence of complications related to the illness. In addition, the epidemic restricted nearly a billion people globally to their homes.

The market uncertainty induced by the Covid-19 epidemic may have prompted financial agents to be risk averse in the face of uncertainty (Cardona-Arenas and Serna-Gomez, 2020). As the virus spreads in the first quarter of 2020, governments declare a cluster of cases and then shut down their economy to stop the pandemic from spreading further. Consequently, the worldwide supply chain was affected, resulting in closing down of businesses and factories. The pandemic has created an unstable economic environment and financial position throughout the world since manufacturing facilities have been shut down or are working at a reduced capacity in order to comply with WHO Covid-19 preventive guidelines. The forced shutdown of companies to stop the pandemic's spread has a detrimental impact on the world economy, which is heavily interwoven, linked, and reliant on commerce (Abu Bakar and Rosbi, 2020).

The effect of the virus was also felt in the global oil market. This effect was caused by the shrinking demand for oil and the subsequent crude oil price crash, reaching an all-time low of $36 per barrel in the Brent market. The oil price crash was a point of concern for the Nigerian government, whose crude oil price benchmark for its national budget of 2020 was reversed to $30 from an initial $57. The fall of oil prices below the benchmark of the Nigerian budget created a shortage of financial resources mainly because the Nigerian government depends heavily on oil. Specifically, oil revenue was not less than 70 percent of federal government total revenue (CBN, 2021).

Crude oil and natural gas accounts for about 90 percent of Nigeria's export, according to statistics from *commodity.com*. The top five nations purchasing crude oi from Nigeria are Japan, India, United States, South Africa and United Kingdom while top five countries importing natural gas from Nigeria are Japan, Spain, India, South Korea, and Brazil. Incidentally, data released by WHO on December 14, 2020 reveal that Covid-19 are threatening the economies of these countries. for instance, India, largest importer of crude oil from Nigeria, on

March 23, 2020, imposed a three-week lock-down to curtail the spread of the pandemic and cut its crude oil import from Nigeria by 70%.

Expectedly, the reduction in oil purchase from Nigeria coupled with movement restrictions affect the revenue generation of the Federal Government. Nigeria's foreign direct investment (FDI) also took a hit as investors look to move their funds to more perceived secure assets such as, Gold, Silver, and so on. The exchange rate of naira to dollars, according to the Central Bank of Nigeria (CBN) has proved to bed a poor store of value as it continues to depreciate year on year from ₦82.5/$1 on July 11, 1995, to ₦381.5/$1 as at April 9, 2021 (CBN, 2021). This perception of the exchange rate prompted investors to diversify their investments to a more secure portfolio, as evidenced in the massive reduction in the FDI**,** which dipped by a massive 21.21% from an initial of $3.3bn in 2019 to $2.6bn in 2020 (CBN, 2021).

The outbreak of Covid-19 brought with it various economic concerns not conceived. Various studies have been carried out to determine the economic effect of the pandemic. Abid et al. (2022) affirmed market sentiments sparked by the media play a huge role in the negative effect of Covid-19 pandemic on exchange rate. Gherghina et al. (2021) also confirmed that there was pressure on exchange rate to depreciate owing to the impact of Covid-19 on one hand, and the disruption of the functioning of the financial markets on the other hand. Whereas exchange rate depreciates with increasing number of reported cases of Covid-19 infection, falling numbers of new cases and the increasing numbers of patients recovered from the pandemic alongside social distancing measure tend to improve the value of the domestic currency (Zahro et al. (2020); Villarreal-Samaniego (2021); Kumeka, Uzoma-Nwosu, and David-Wayas, 2022; Kunjal, 2023).

Few studies have been undertaken to evaluate the pandemic's impacts on Nigeria's macroeconomic variables like the exchange rate, inflation rate, aggregate demand, unemployment rate, and so on. Because there hasn't been enough research done on the influence of Covid-19 pandemic on the exchange rate and its volatility, this study seeks to push the frontier of knowledge forward in this regard. Specifically, the study seeks to provide answers to the following research questions: do Covid-19 pandemic and crash in crude oil price significantly influence exchange rate movement? Does Covid-19 outbreak and crash in Crude oil price lead to exchange rate volatility? At what period does

Covid-19 and Crude oil price significantly influence exchange rate changes (short run or long run or both runs)? The reasons why this research work is carried out is that while the majority of the research show that Covid-19 pandemic and the drop in crude oil prices leads to exchange rate depreciation, very few indicates that appreciation can occur when numbers of recovered patients are increasing. Does this happen in Nigeria?

Several theoretical investigations have demonstrated that most investors, particularly the risk-averse always frown at high exchange rate volatility. On the one hand, risk-averse investors who expect wild swings in the exchange rate may prefer to halt trading temporarily until the rate stabilizes (Hooper and Kohlhagen, 1978). On the other hand, a risk-neutral investors maximizing projected proceeds, where cash flow is defined as a positive function of the real exchange rate will not bother about high exchange rate volatility. But because of the implication of exchange rate volatility on investment, it is important to assess the role played by Covid-19 pandemic and prices of stock and oil in exchange rate volatility in Nigeria. It is expected that providing evidence on the effect of Covid-19 pandemic on exchange rate and its volatility will prepare policy makers with appropriate policy to deal with similar pandemic that may likely occur in future because of its seeming effect on exchange.

Literature Review

Although there is a body of literature on the relationship between oil price and exchange rate, that of the effect of pandemics such as Covid-19 on exchange rate is still evolving. Nevertheless, this section reviews some empirical works on oil price/stock price-exchange rate nexus and covid-19 and exchange rate relationship. Starting from the relationship between exchange rate and oil price, Devpura (2021) investigates the case of Euro-US Dollar exchange rate and oil futures utilizing daily data from January 1, 2020, to November 30, 2020. The findings suggested that price of oil had an impact on the Euro/USD exchange rate, although the evidence is quite limited. The author also noticed that when the influence of Covid-19 on the Euro/USD is taken into consideration, the connection between Euro/USD and the oil price disappears. Specifically, the author argues that after adjusting for Covid-19, there is no forecasting ability of oil price on Euro/USD exchange rate.

Abid et al. (2020) investigated the core of the link between crude oil price, EUR/USD exchange rate, and gold price using monthly data from January 1999 through October 2020. The Autoregressive Distributed Lag (ARDL) model was employed as estimation method. The result indicates that the prices of oil, and gold, and the EUR/USD exchange rate cointegrated. The Granger causality test results reveal a one-way causation running from oi; price to the EUR/USD. Aslam (2020), in a study on the foreign exchange markets during the pandemic using 5-minutes interval of six (6) major currencies traded on the Forex market from October 1, 2020, to March 31, 2020. The author employed multi-Fractal Detrended Fluctuation Analysis (MF-DFA) and Seasonal-Trend Decomposition using Loess (STL). Results from the analysis confirms the presence of multifractality in forex markets which indicates a decline in the efficiency of the forex market during the pandemic. Results also indicated that the Australian Dollar (AUD) shows the lowest efficiency while the Canadian Dollar (CAD) and Swiss Franc (CHF) exhibit the highest efficiency.

From March 2010 to March 2020, Jawadi and Sellami (2021) utilized generalized autoregressive conditional heteroscedasticity (GARCH) to study the influence of oil price fluctuations on the US Dollar, the New York Stock Exchange (NYSE), and the real estate sector of the US in the form of COvid-19 (GARCH). According to the findings, there is a positive link between the NYSE and oil prices. Further. while the movement of oil prices has a substantial influence on the US stock market and the US dollar exchange rate, there is no meaningful relationship between oil price movement and the US real estate market.

Cutcu and Dineri (2021) used vector autoregressive (VAR) and Bayesian VAR models to capture the simultaneous effect of covid-19 on the exchange rates of Australian Dollar (AUD), Swiss Franc (CHF), British Pound (GBP), and Hong Kong Dollar (HKD). It was revealed that covid-19 has had a major influence on the operations of companies and financial institutions, resulting in a global currency devaluation. Further, the Bayesian VAR model revealed the influence of the pandemic on the exchange rate better than the ordinary VAR, which failed to shed light on the link. Eda (2020) employes structural breakdowns and the cointegration test to evaluate the influence of new Covid-19 infections and fatalities caused by Covid-19 complications on the movement of the Turkish Lira (TRY) against the US dollar from March 16, 2020 to May 6, 2020. The result suggests that new infections and fatalities connected to Covid-19 have a significant and depreciating influence on the TRY exchange rate.

During the pandemic, Narayan et al (2020) investigated the nature of the link between the volatility of the Japanese Yen (JPY) vs the US Dollar (USD) and the increases in Japanese stock returns. Two data sets were employed for this study: December 31, 2019, to August 17, 2020, and January 1, 2010, to December 30, 2020, corresponding to the covid-19 and pre-covid-19 eras, respectively. Using the GARCH approach and VAR, the findings showed that covid-19 had a significant influence on the exchange rate and stock market returns (VAR).

Hoshikawa and Yoshimi (2021) investigated the influence of covid-19 on South Korean Won (KRW) and stock market returns using data from January 2, 2019, to August 31, 2020 and subjected it to GARCH and VAR methods. The result indicates that an increase in the number of new infections prompted an increase in South Korean stock market volatility, resulting in fast dollar capital flight. Overall, the covid-19 epidemic has been an inhibiting factor to international investment. Consequently, the KRW experienced a severe depreciation against the US dollar.

Cardona-Arenas and Serna-Gómez (2020) uses daily data from February 16 to March 14, 2020, to investigate the impact of Covid-19 and oil price fluctuations on the Colombian Peso. VAR Model was used to verify the results. The findings showed that the weakening of the Colombian Peso against the US dollar during the study period is explained by a mixed impact of covid-19 and oil prices, with covid-19's variation being easier to understand than oil prices. Villarreal-Samaniego (2021) discovered that the buck were identified using daily data from January 13 to April 6, 2020, in his analysis of the impact of covid-19 and shifts in oil prices on the exchange rate of five emerging market economies, namely, Brazil, Colombia, Mexico, Russia, and South Africa currencies with respect to the US dollar. The study discovered that the exchange rates of the Brazilian Real and the South African Rand were regularly connected to covid-19 developments. The study also revealed that the movement of oil prices and currency rates had a diametrically opposed and significant link.

Fang and Cao (2021) used the vector error correction model to examine the impact of the pandemic on the volatility of the Chinese Yuan (RMB) to the US Dollar (USD) exchange rate from January 2005 to June 2020. (VECM). The VECM model was chosen for this study because it allows for the application of the VAR to multivariate time series. The projected results show that the pandemic's effect on the RMB/USD exchange rate is temporary. Kumeka et al (2022) investigated the dynamic correlation and volatility spillovers between stock price and exchange rate in BRICS (Brazil, Russia, India, China, and South Africa) economies from January 2 to September 15, 2020, using the Generalized

Autoregressive Conditional Heteroscedasticity (GARCH) model. The GARCH model was employed for this investigation because it successfully estimates data sets with large variation and delivers trustworthy findings. The data demonstrate that during the pandemic, there was a significant risk shift between the two economies, which resulted in a decline in domestic stock returns and subsequent capital outflows, increasing the exchange rate.

Abu Bakar and Rosbi (2020) employed descriptive statistics and correlation analysis to investigate the impact of covid-19 on the exchange rate of the Malaysian Ringgit (MYR) to the US Dollar and the stock output of the FTSE Bursa Malaysia KLCI (KLSE) index from January to March 2020. The study concluded that the covid-19 pandemic had a negative impact on the KLSE index, causing it to drop to its lowest point on March 15, 2020. The MYR/USD has also depreciated by 0.087 percent, reaching its lowest point for the time under consideration. Garg,and Prabheesh (2021) examines if the investors in the international assets and exchange rate markets take advantage of the relevant information obtained during the covid-19 pandemic. The authors utilized daily data from January 31, 2020 to June 30, 2020 for the BRIICS economies. The ARDL results indicate that interest rate differentials improve the predictability of changes in exchange rate in all six BRIICS economies during the pandemic.

Jamal and Bhat (2022) examine how illness outbreaks, such as the current covid-19, may be used to anticipate exchange rate changes for six countries' currencies where the pandemic is most pronounced, that is, Brazil (USD-real), China (USD-Yuan), India (USD-Rupee), Italy (USD-euro), Turkey (USD-Lira) and United Kingdom (USD-pounds. From December 31, 2020, to May 8, 2020, the employs daily data on the exchange rate and total worldwide daily reported cases. Using Descriptive Statistics and Conditional Heteroscedasticity in conjunction with Autoregressive Conditional Heteroscedasticity (ARCH). The results reveal that Covid-19 has better predictive ability over volatility than returns for a one-day ahead prediction window, but the converse is true for a five-day ahead forecast horizon. He argued that the Covid-19 epidemic indicated a new channel of exchange rate prediction, namely the illness outbreak channel.

Yilmazkuday (2022) studied the influence of US monetary policy on the exchange rates of ten (10) advanced nations and twenty-one (21) emerging market (developing) economies during the worldwide pandemic from February 15 to May 20, 2020, using the VAR approach. Based on the estimates for the US economy, the federal reserve system reduces interest rates in reaction to negative economic shocks. When the influence of US monetary policy on currency rates is investigated, the results show that the currencies of developing economies decline by 14 percent on average, with a range of -15 percent for Israel to 62 percent for Indonesia. The same shock causes a 12 percent depreciation in advanced countries' currencies.

Feng et al. (2021) analyzes the influence of covid-19 and related government response measures on exchange rate volatility in 20 countries from January 13, 2020 to July 21, 2020, using the General Method of Moments (GMM) estimate. The GMM generalizes the system of moments (MM) by allowing for more moment conditions than parameters, making the GMM more effective as an estimate technique than the MM. According to the empirical data, an increase in the number of reported instances of covid-19 substantially increases exchange rate volatility. She says that by adopting rigorous control measures, the government would successfully limit the effects of covid-19 on exchange rate volatility.

Sharma et al. (2021) investigated the link between newly verified covid-19 occurrences, temperature, exchange rate, and stock market returns in the 15 nations most impacted by the pandemic from February 1, 2020, to May 13, 2020, using Partial Wavelet Coherence (PWC). Because of its similarity to partial correlation, the PWC is used to calculate the resultant Wavelet Coherence (WTC) between two time series after the influence of their mutual dependency is removed. The results show that average daily temperature has a significant impact on covid-19 distribution in the nations investigated. The influence of newly reported covid-19 cases, fatalities from covid-19 complications, and sensationalized covid-19 news on stock and FX market volatility was also noticed.

Nwosa (2020) used VAR mrethod in a study of oil price, exchange rate, and stock market performance during the pandemic and its impact on Trans-National Companies (TNCs) operating in Nigeria and Foreign Direct Investment (FDI) in Nigeria from December 1, 2019, to May 31, 2020. (VAR). The VAR results show that the pandemic had a greater negative impact on oil prices, currency rates, and stock market performance than the 2008/2009 global recession and the 2016 global recession. The author also noted that the negative impact of the covid-19 epidemic on oil prices, currency rates, and stock market performance had a significant impact on the activities of TNCs and FDI inflows in Nigeria. Bhattachryya et al (20210) noted that covid-19 has impacted the economy of almost every country in the world. Of particular interest are the responses of the economic indicators of developing nations (such as BRICS) to the pandemic shock. The author studies the dynamic associations of pandemic, exchange rate and stock market indices in BRICS nations. The structural variable autoregression (SVAR) was employed to identify the dynamic underlying associations across the normalized growth measurements of the covid-19 cumulative case, recovery, and death counts, and those of the exchange rate, and stock market indices, using data between March 12 and September 30, 2020. The impulse response indicates that covid-19 shock to the growth of exchange rate persisted for more than 10 days, and that for stock exchange was seen to be around 15 days.

Hussain et al (2023) investigated the connectedness and spillovers of exchange rate and stock price volatility in the BRICS countries during the covid-19 pandemic-induced crises. Volatility was extracted through the GARCH method. Thereafter, volatility connectedness and spillover were investigated. The authors discovered that exchange rate volatility and stock return volatilities are connected during pandemic-induced crises. Further, Russia has strong volatility connectedness with India in these financial markets. The direction of volatility spillover is from Russia to India. Similarly, Brazil has strong volatility connectedness with South Africa and the direction volatility spillover is from Brazil to South Africa. Finally, China has a weak volatility connection with the remaining BRICS countries.

The brief empirical review indicates that while the majority of results show that the pandemic and the drop in crude oil prices have a negative influence on the exchange rate, none have addressed how these variables affect the volatility of exchange rate Nigerian viewpoint. The purpose of this study is to determine how the exchange rate and its volatility have been influenced by covid-19 pandemic, shocks in the stock and oil markets during the covid-19 pandemic.

Methodology and data

Conceptual Framework

Covid-19 and crude oil prices can influence an economy's exchange rate through a variety of ways. Intuitively, the portfolio balance approach (PBA) is used to describe the link between the exchange rate and the price of a company. It is based on the concept that the market capitalization of businesses may have a substantial impact on the health of the national currency (Figure 1). Pandemics such as covid-19 can also affect exchange rate. In this case, increase in the reported cases of covid-19 will result to reduction in economic activity, demand for medications from abroad which will lead to demand for foreign currency. The continuous demand for foreign currency (dollars) will lead to depreciation. However, as people recover from the pandemic, economic activity will rise and this enables people to engage in economic activity which may invariably influence exchange rate. Increase in oil price, holding demand constant will lead to increase in oil revenue and hence, supply of foreign currency and this is expected to lead to appreciation. However, during the pandemic, both demand for oil and price of oil fell considerably. Consiquently, it is expected that exchange rate depreciates owing to low supply of foreign exchange. Therefore, the chat in Figure 1 shows how these variables (covid-189, oil and stock prices affect exchange rate and its volatility.

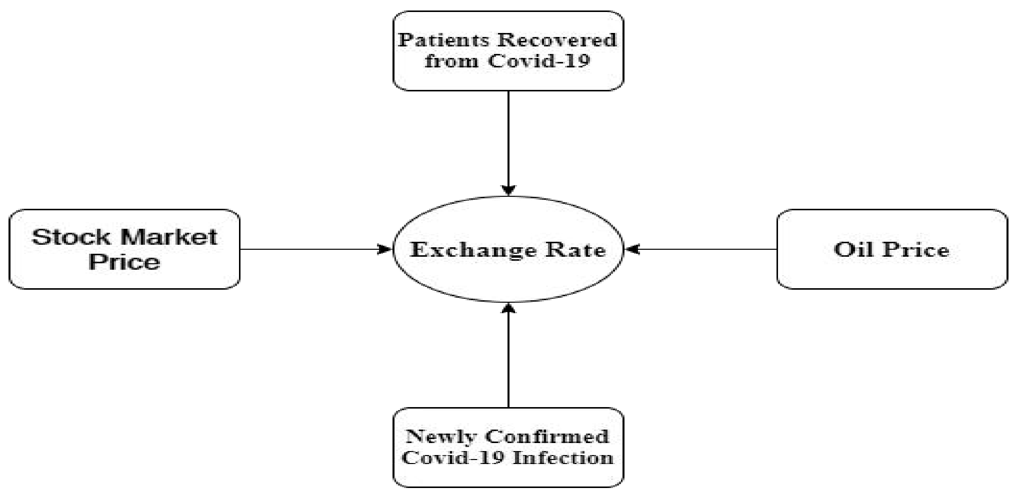

Figure 1: Diagram showing the link amongst Covid-19, exchange rate, oil price, and stock market price
Source: Authors' initiative

Model Specification

In line with the objectives, two separate models are built and estimated. The first is meant to assess the short and long run effect of pandemics, oil and stock prices on exchange rate. The second model is targeted at examining the effect of these variables on the volatility of exchange rate. For model 1, the autoregressive distributed lag (ARDL) is employed. The ARDL proposed by Pesaran, Shin & Smith (2001) is a standard least squared regression that incorporatse lags of both the regressands and the regressors in a single model (Greene, 2005). The ARDL has many advantages over other estimation methods. First, it can be used when there is a mix of I(0) and I(1). It is a single equation model from where both short run dynamic and long run can be obtained and this makes it a simple method to work with. Further, it has been established that if the series are free of residual correlation, ARDL is capable of dealing with endogeneity problem (Jalil et al, 2008). Pesaran and Pesaran (1997) submit that in the presence of endogeneity of the regressors, ARDL produces efficient and consistent coefficients. Pesaran and Shin (1999) and Pesaran and Shin (2001) later demonstrated that ARDL with appropriate lag(s) corrects for serial correlation and endogeneity problem. Consequence upon this, Schwarz-Bayesian Criterion (SBC) and Akaike Information Criterion (AIC) are employed to determine the optimal lag length included in the unit root test. The bounds testing to cointegration was also carried out to inspect the long run convergence of the system following shocks from any of the independent variables.

The functional relationship between exchange rate and covid-19 pandemic alongside prices of oil and stock is shown in equation 1

$$EXR = f(COVN, COVR, OP, SMP) \quad (1)$$

where EXR is exchange rate of naira with respect to the US dollar, COVN is the confirmed numbers of new cases of covid-19 infection, COVR is the confirmed numbers of cases treated and completely recovered from the pandemic, OP is oil price and SMP is stock price. The equation says that exchange rate is influenced by the pandemics (both confirmed and recovered cases), and prices of stocks and oil. The ARDL specification of equation 1 is provided in equation 2

$$\Delta lnEXR_t = \pi_0 + \sum_{j=1}^{n1} \beta_{1j} \Delta lnEXR_{t-j} + \sum_{j=0}^{n2} \pi_1 \Delta lnCOVN_{t-j} + \sum_{j=0}^{n3} \pi_2 \Delta lnCOVR_{t-j} + \sum_{j=0}^{n4} \pi_3 \Delta lnOP_{t-j} + \sum_{j=0}^{n5} \pi_4 \Delta lnSMP_{t-j} + \theta_0 lnEXR_{t-1} + \theta_1 lnCOVN_{t-1} + \theta_2 lnCOVR_{t-1} + \theta_3 lnOP_{t-1} + \theta_4 lnSMP_{t-1} + \varepsilon_t \quad (2)$$

Equation 2 says that exchange rate is partially explained by its lagged values, the current and past lags of confirmed and recovered cases of covid-19, oil price and stock price the explanatory variables The equation is into two parts. The first part, which is the first 5 terms are the short run dynamics while the rest terms (excluding the error term) is the convergence to long run, that is, the cointegrating equation (Pesaran and Shin, 1995). From equation 2, the long run model can be estimated by dividing the coefficients of the lag values of COVN, COVR, OIL and SPM by the lag value of EXR.

The second model is the one that captures the volatility of exchange rate. The reason for modelling volatility of exchange rate and how covid-19 pandemic alongside prices of stock and oil is that the risk-averse investors may demand a premium in order to hold a risky asset. The risk premium is a positive function of the premium, that is, the higher the risk, the higher the premium. If the volatility or conditional variance represent the risk, the variance may enter the conditional mean function of exchange rate. To specify the volatility of exchange rate model, it is assumed that the series of exchange rate can be lagged q times, so that the mean and variance can be estimated as indicated in equations 3 and 4 respectively

$$EXR_t = \gamma + \sum_{i=1}^{q} \tau EXR_{t-i} + \pi \mathrm{COVN}_t + \varphi COVR_t + \tau OIL_t + \vartheta PMS_t + \mu_t \quad (3)$$

$$\sigma_t^2 = \pi + \sum_{i=1}^{q} \beta_i \mu_{t-i}^2 \quad (4)$$

Equation (4) says that the variance of the residual in equation 3 at time t is explained by the squared of the lagged error term. The μ_t^2 is the ARCH term and it is expected that β_i takes on a positive value less than 1. The closer the value of the estimator to 1, the slower the mean reverting and vice versa. But the conditional variance in equation (4) could be influenced by its lagged values, particularly when dealing with high frequency series. Hence, it is imperative to capture this situation so that the variance equation is modified as follows:

$$\sigma_t^2 = \pi + \sum_{i=1}^{q} \beta_i \mu_{t-i}^2 + \sum_{j=1}^{z} \gamma_j \sigma_{t-j}^2 \quad (5)$$

Equation 5 is the generalized ARCH (GARCH) model. The second and the third terms on the righthand side of equation 5 is the corresponding ARCH and GARCH effects. It is assumed that the sum of β_i and γ_j should be positive and less than 1 to ensure that the shock is temporary. If it is greater than 1 then the shock is permanent. Meanwhile, the conditional mean could be influenced by its own conditional variance but not that the conditional variance is affected by its lagged values. This is the famous GARCH-M model. When analyzing volatility in the financial markets, the most appropriate ARCH-type is the GARCH-M because it removes the news inherent in the variance of the residuals, thus, it measures a time-varying risk premium to explain asset returns (Olubiyi and Olopade, 2018). Specifically, GARCH-M model allows the conditional mean to depend on its conditional variance while the conditional variance is assumed not to depend on its lag(s). The GARCH-M specification as it applies to this study is given in equation 6.

$$EXR_t = \gamma + \sum_{i=1}^{q} \tau EXR_{t-i} + \pi \text{COVN}_t + \varphi COVR_t + \delta\sigma_t^2 + \mu_t \qquad (6)$$

The focus is on the value of δ, and it is expected that the value will be significant so that the mean reverting can be captured. To capture risk using the standard deviation of the series instead of its variance, equation is modified as follows:

$$EXR_t = \gamma + \sum_{i=1}^{q} SQRT(\tau EXR_{t-i}) + \pi SQRT(\text{COVN}_t) + \varphi SQRT(COVR_t) + \delta\sigma_t^2 + \mu_t \qquad (7a)$$

Or capture risk using the log of the series instead of its variance. Such that:

$$lnEXR_t = \gamma + \sum_{i=1}^{q} SQRT(\tau lnEXR_{t-i}) + \pi SQRT(ln\text{COVN}_t) + \varphi SQRT(lnCOVR_t) + \delta\sigma_t^2 + \mu_t \qquad (7b)$$

and finally, the GARCH-M(q,z) is specified as follows

$$EXR_t = \gamma + \sum_{i=1}^{m} \tau EXR_{t-i} + \pi \text{COVN}_t + \varphi COVR_t + \sum_{i=1}^{q} \beta_i \mu_{t-i}^2 + \sum_{j=1}^{z} \gamma_j \sigma_{t-j}^2 \qquad (7c)$$

Various diagnostic tests are also carried out in order to substantiate the validity and reliability of the estimation method adopted. The Lagrange Multiplier (LM) test is a generic approach for evaluating parameter hypotheses in a probability framework. The hypothesis is defined by one or more restrictions on parameter values. To run an LM test, the parameters subject to the restrictions must be estimated. Wald tests, which are based on unconstrained estimates, and likelihood ratio tests, which need both limited and unrestricted estimates, on the other hand, require both restricted and free estimates. The name of the test is derived from the fact that it may be seen as a test to check if the Lagrange multipliers employed to impose the limits are considerably different from zero. Another test that was carried out is the correlogram squared residuals. This test displays the autocorrelations and partial autocorrelations of the squared residuals up to a specified number of lags and computes the lags' Ljung-Box Q-statistics. The correlogram of the squared residuals can be used to check for autoregressive conditional heteroscedasticity (ARCH) in the residuals.

Sources of data and definition of variables

Following equation 2 and 7, the relevant variables are official exchange rate of naira with respect of US dollar, newly confirmed covid-19 cases, covid-19 recovery patients, crude oil price (Brent), and stock market price. Confirmed covid-19 cases is the daily number of people officially confirmed by the Nigerian Centre for Disease Control (NCDC) to have contracted covid-19 pandemic. Recovered patients of covid-19 is the daily number of patients recovered from the covid-19 pandemic as reported by the NCDC. It represents the number of patients discharged at isolation wards and/or patients who once tested positive for Covid-19 infection but later tested negative upon treatment. Exchange rate is the officially quoted quantity of naira exchanged for a unit of dollar in nominal term. Crude oil price is the price for which a barrel of crude oil (approximately 160 litres) is sold at the international market using the BRENT crude oil price. Stock market price is the all-share index of companies listed and traded on the floor of the Nigerian Stock Exchange. In this study, the SMP is used as a control variable because previous studies such as Nwosa (2020) agreed that it plays a significant role in determining the movement and to which direction the exchange rate movement propagates. Cases of covid-19 and reported number of recovered patients are sourced from the NCDC website. Data on official nominal exchange rate, oil and stock prices are extracted from Central Bank of Nigeria database. Data for all the variables are extracted from February 28, 2020 to February 21, 2021 based on the availability of data and the scope of the study.

As can be observed from the Table, the average COVN is 394.44, which indicates that Nigeria confirmed on average approximately 394 covid-19 cases every 24 hours within the coverage period. Also, the observed averages of COVR, EXR, OP, and SMP, are computed to be 355.73, 468.64/$1, $52.14 and 33008.93 respectively. The maximum covid-19 case reported by the NCDC was 1,964, and this occurred on the 21st January 2020. Also reported on the 3rd March 2020 that 11,301 Covid-19 patients were recovered and discharged from various isolation centers across the country after testing negative.

Results and discussions

The presentation begins with the descriptive analysis of all the variables, followed by the interpretation of the regression results (including the volatility estimates). Table 1 presents the summary of the descriptive statistics of the variables.

Table 1: Descriptive statistics of the variables

Statistics	EXR	COVN	COVR	OP	SMP
Mean	468.64	394.44	355.73	52.14	33008.93
Maximum	525	1964	11301	79.18	42412.66
Minimum	374	4.00	1	5.26	20669.38
Std. Dev.	24.59	400.7	741.77	16.61	6930.02
Skewness	-0.454	1.592	10.228	-0.404	-0.309
Kurtosis	4.110	5.281	144.860	2.617	1.360
Jarque-Bera	28.553	212.944	285031.5	11.115	42.591
Probability	0.000	0.000	0.000	0.004	0.000
Observations	333	333	333	333	333

COVN, COVR, SMP, EXR and OP represent number of reported cases of people infected with covid-19, number of people that recovered from the pandemic after treatment, stock market price, parallel market exchange rate and oil price respectively. The values of stock market price and exchange rate are measured as index, oil price is measured as dollar per barrel, COVN and COVR are measured in units.
Source: Author's Computation, 2023

The maximum value for parallel market exchange rate was 525/$1. Also, during the period being observed, oil price had the maximum of $79.18/barrel while the lowest daily price in the history of the commodity was $5.25. Table 1 also shows that the price of Nigerian stocks hit its maximum of ₦42,412.66 during the period while the lowest was recorded to be ₦20,669.38, which was less than half of the maximum value. This is an indication that the stock market may likely be affected negatively during the pandemic. The minimum value of COVR and COVN reported by the NCDC are 4 and 1, respectively. Also, minimum values of the parallel market exchange rate was ₦374/$1.

The standard deviation, which measures deviation from the sample mean, is 400.7 and 741.77 for COVN and COVR respectively, while for EXR, OP and SMP is ₦ 24.59/$1, $ 16.61 and ₦6930.02 respectively. The skewness of COVR and COVN is 1.59 and 10.23, respectively; this observation is greater than zero (0), which indicates a positively skewed result of having a positive value. EXR, OP, and SMP have a skewness of -0.45, -0.4, and -0.3, respectively; both values are less than zero, signifying that EXR, OP, and SMP are negatively skewed. The kurtosis statistics shows that EXR, COVN, and COVR are leptokurtic (highly peaked) since their values are well above the threshold of 3. Conversely, OP and SMP are observed to be platykurtic as their values are less than 3.

Conclusion cannot be made based on single consideration of skewness and kurtosis. Hence the Jarque-Bera statistics is more useful as it pools the property of both skewness and kurtosis and gives a more robust result. The probability of the Jarque-Bera indicates that virtually all the series are not normally distributed since the null hypothesis of the Jarque-Bera of normality is rejected at 1% level of significance.

Unit root Test

Unit root tests are used to assess the time-series' level of stationarity. The unit root test evaluates if a time series' mean, variance, and covariance are time independent. Many economic and financial time series show trending (non-stationarity) in the mean. In this case, unit root testis usually employed to determine the stationarity of time series. Many approaches are available for this test, but the most commonly utilized are the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) unit root tests, and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationarity tests. All these tests are considered for the series in this study. The ADF tests whether there is a unit root in a time series data. The null hypothesis is that there is presence of unit root in the series.

Table 2: Augmented Dickey-Fuller (ADF) unit root test

Variables	Level			first difference			Remark
	constant	constant and trend	no constant and trend	constant	constant and trend	no const. & trend	
EXR	-	-5.42***	-	-	-	-	I(0)
COVN	-	-	-	-16.87***	-	-	I(1)
COVR	-7.56***	-	-	-	-	-	I(0)
OP	-	-	-	-24.11***	-	-	I(1)
SMP	-	-	-	-15.25***	-	-	I(1)

Table 3: Phillip Perron (PP) unit root test

Variables	Level			First difference			Remark
	Constant	constant and trend	no constant and trend	constant	constant and trend	No const. & trend	
EXR	-3.85***	-	-	-	-	-	I(0)
COVN	-4.19**	-	-	-	--	-	I(0)
COVR	-17.36***	-	-	-	-	-	I(0)
OP	-	-	-	-25.76***	-	-	I(1)
SMP	-	-	-	-15.61	-	-	I(1)

Table 4: Kwiatkowski-Philips-Schmidt-Shin (KPSS) unit root test

Variables	Level			first difference			Remark
	constant	constant and trend	no constant and trend	constant	constant and trend	no constant and trend	
EXR	1.85	-	-	-	-	-	I(0)
COVN	-	0.14	-	-	-	-	I(0)
COVR	-	0.24	-	-	-	-	I(0)
OP	1.95	-	-	-	-	-	I(0)
SMP	1.89	-	-	-	-	-	I(0)

*Note: EXR = Exchange rate; COVN = newly confirmed cases of Covid-19; COVR = Discharged patients of Covid-19; OP = Daily price of crude oil; SMP = Stock \price. *, ** and *** represents significance level at 10%, 5% and 1% respectively*
Source: Author's compilation, 2023

Table 2 presents the result for the case that EXR is stationary at level but with constant and trend, COVR is stationary at level with constant only. while COVN, OP and SMP are stationary at first difference with constant. The PP test, like the ADF, tackles the issue that the process generating data for may have a higher order of autocorrelation than the test equation admits. The null hypothesis for the PP is that unit root is present in the series. From Table 3, it can be observed that EXR, COVN, and COVR are stationary at levels with constant while OP and SMP are stationary at first difference with constant.

The KPSS is a test for the presence of stationarity of time series. The aim of the KPSS is to determine and remove deterministic trend of the series in order to make it stationary. The null hypothesis of the KPSS is that there is the presence of stationarity in the series. It can be observed that all variables are stationary at levels with only COVN and COVR being stationary at constant and trend while EXR, OP, and COVN are stationary at constant only (Table 4). With the outcome of the unit root and stationarity tests, it is clear that all the variables are of a combination of I(0) and I(1). By implication, the appropriate technique of estimation is the autoregressive distributed lag (ARDL).

Results of the Estimated Models

Model 1: the ARDL and Bounds Test to Cointegration

The result of ARDL bounds test to long run convergence is shown in table 5. The bounds test F-statistics result (5.25) is greater than the upper critical bounds (I1) at the 5% significant level, implying that the model converges to long run following any shock to the system.

Table 5: ARDL Bound Test Result

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	5.25	10%	2.63	3.35
K	4	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5
			Finite Sample: n=333	
Actual Sample Size	228	10%	2.915	3.695
		5%	3.538	4.428
		1%	5.155	6.265

Note: the ARDL bounds tests provide information about the possible long run convergence of the model. The F-distribution is the critical value that is associated with the test. The k is the degree of freedom, I0) is integrated of order 1 (the lower bound and I(1) is integrated of order 1, that is , the upper bound. For long run convergence to take place, the F-statistic must be greater than, at least 5% level of significance.
Source: Authors' computation, 2023.

The result of the short-run dynamics is presented in Table 6. The result indicates that recovered covid-19 patients, oil price, and stock price have significant effect on exchange rate. Specifically, increase in the previous numbers of people confirmed to have the virus will lead to depreciation of naira against the dollar. However, the effect is mild because if the numbers of confirmed cases doubled, exchange rate will only depreciate by approximately 1 percentage point. But the positive effect suggests that incidence of pandemic contributes to exchange rate depreciation in Nigeria. In fact, this is further confirmed by the numbers of recovered cases where the doubling of recovered cases will prompt naira to appreciate against the dollar to the tune of approximately 0.2 percentage point. A cursory look at these magnitudes suggests that although as people recovered, exchange rate will appreciate, the value of naira against the dollar will eventually reduce. This may not be impossible because of the momentum built in the market. In the case of oil price effect, a 1% increase in oil price leads to approximately 0.2% depreciation of parallel market exchange rate. Some papers including Abubakar (2019) found naira appreciating against the dollar following oil price increase. Perhaps the reason for such finding is that these authors employ official exchange rate. But is noteworthy that foreign exchange is much more traded and mostly affect the economy more than official exchange rate. Increase in oil price can lead to depreciation if the nontradable goods in the exporting sectors is energy (petroleum products) dependent (Beckmann, Cuzdad and Arora, 2020). Besides, depreciation may follow oil price rise if the benefitting country has flair for imported products. These two factors are in existence in Nigeria, and so, this could be an explanation for the reason why increase in oil price leads to depreciation in Nigeria. Similarly, previous stock market price has a positive effect on parallel market exchange rate. In this case, a 1% increase in stock price will engender parallel market exchange rate depreciation to the tune of 2.7%.

Table 6: ARDL short-run dynamic estimated result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.091***	1.022	4.002	0.002
D(LNEXR(-1))	0.332*	0.167	1.994	0.062
D(LNCOVN(-1))	0.000907	0.001	0.673	0.501
D(LNCOVR(-1))	-0.001757*	0.001	-1.672	0.096
D(LNOP(-1))	0.01886***	0.006	3.402	0.001
D(LNSMP(-1))	0.016947**	0.008	2.033	0.043
CointEq(-1)	-0.273303***	0.038	-7.182	0.000

*Where *, ** and *** represents significance level at 10%, 5% and 1% respectively*
Source: Author's Compilation, 2023

Clearly, the stock market has a notable, albeit, worrisome effect on the parallel market exchange rate. Increase in stock price will lead to more supply of stocks, leading to increase in economic activity. However, there will be too much money in circulation, particularly if supply cannot meet the needs of economic agents, inflation will rise. The inflation expectation may be perceived by foreign investors as negatively affecting them so that their demands for currency reduce and hence leading to depreciation. It is also of note that the previous parallel market exchange rate has a positive and significant effect on the current exchange rate. The speed of convergence, captured by CointEq(-1) suggests that 27.3 % of the total short-run disequilibrium converges back to its long-run equilibrium daily including the day that the shock occurs.

Table 7: ARDL Long-run result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNCOVN)	0.00332	0.004894	0.67839	0.4980
D(LNCOVR)	-0.006429*	0.003777	-1.701933	0.0897
D(LNOP)	0.069008***	0.01633	4.225765	0.0000
D(LNSMP)	0.062008***	0.030048	2.0636	0.0398
C	5.253675***	0.266088	19.744123	0.0000

*Where *, ** and *** represents significance level at 10%, 5% and 1% respectively*
Source: Author's Compilation, 2023

It turns out that after the disturbance, the system should adjust to a new equilibrium within three to four days. In the long-run, confirmed new cases of covid-19 patients has no significant effect on parallel market exchange rate (Table 7). Perhaps the reason for this could be due to some measures that have been put in place to reduce reported cases. Other variables exhibit the same significant pattern as in the short run dynamic results. In particular, a 1% increase in the number of recovered patients of covid-19 would lead to appreciation of the naira against dollars in the parallel market by 0.64%. Further, a 1% increase in crude oil price will lead to depreciation of naira against dollar in the parallel market by around 6.9%. Similarly, a 1% increase in the stock price will depreciate exchange rate in the parallel market by around 6.2%. This result therefore indicates that exchange rate in the parallel appreciates as numbers of recovered patients increases from pandemic both in the short and long runs. In addition, the magnitude of effect is larger in the long run than in the short run.

Model Two: Results of the Volatility Model

The second objective of this study is to carry out volatility estimates of exchange rate as it is affected by covid-19 variables, oil and stock prices. Out of all the ARCH-type available, ARCH-M (ARCH-mean) is chosen as the appropriate technique. However, in order to explicit, various versions of ARCH-M is estimated and the results are presented in Table 8. It can be observed from the Table that the coefficient of confirmed new cases of covid-19 and confirmed numbers of patients reportedly recovered from the pandemic are negative, indicating that both variables have a negative effect on the volatility of exchange rate, albeit, only recovered cases was significant. What this suggests is that the volatility of exchange rate will reduce as more recovered cases are confirmed. This result corroborates the estimates obtained from the ARDL. Therefore, not only that recovered cases will lead to appreciation of naira against the dollar in the parallel market, it also reduces the volatility rate. Also observed from the ARCH-M section are the ARCH and GARCH coefficient and probability values; the ARCH coefficient is positive and significant at 1%, while the GARCH coefficient is not significant event at 10%. Similarly, the ARCH-M(Std. Dev.) suggests both reported cases and recovered cases have negative effect on the volatility of parallel market exchange rate. However, in this case, both are significant (Table 8). Stock and oil prices have positive and significant effect on exchange rate volatility, and this suggests that increase in stock or oil price will trigger upwards, parallel market exchange rate volatility.

Also observed from Table 8 is the variance equation of the ARCH-M(Std. Dev.), which contains the ARCH and GARCH coefficient and the probability value. The square of ARCH residuals (ARCH (RESID(-1)^2)) and the GARCH (GARCH(-1)) are both positive and significant at 1%. Next is the log of variance of ARCH-M (ARCH-M (Log(Var))). It is revealed that both reported cases and recovered cases indicate significantly negative effects on the parallel market exchange rate volatility, and so, the log of variance of ARCH-M is consistent with the earlier results. Similarly, it is also confirmed from the ARCH-M(Log(Var)) that both stock and oil prices positively and significantly effects parallel market exchange rate volatility in Nigeria. The variance equation associated with ARCH-M(Log(Var)) indicates that the ARCH and GARCH are positive and significant at 1%.

Table 8: GARCH Estimation results

ARCH-M	LNCOVN	LNCOVR	LNOP	LNSMP	C	
Coeff.	-0.002353	-0.007103	0.08383	0.053294	5.308 403	
Prob.	0.1072	0.000	0.000	0.000	0.000	
			Variance Equation			
	C		RESID(-1)^2		GARCH(1)	
Coeff.	0.0002		0.793		0.006	
Prob.	0		0.000		0.523	
	R^2	Adj. R^2	LL	SIC	AIC	
R2	0.593	0.588	752.724	-4.381	-4.47	
ARCH-Variance H-M (Std. Dev.)						
	LNCOVN	LNCOVR	LNOP	LNSMP	C	SQRT(GARCH)
Coeff.	-0.0006	-0.002	0.049	0.071	5.226	0.130
Prob.	0.0185	0.000	0.000	0.000	0.000	0.000
Variance equation						
	C		RESID(-1)^2		GARCH(-1)	
Coeff.	2.47E-06		2.714		0.061	
Prob.	0.1415		0.000		0.004	
	R^2	Adj. R^2	LL	SIC	AIC	
	0.601	0.595	815.2	-4.739	-4.84	
ARCH-M (Log(Var))						
	LNCOVN	LNCOVR	LNOP	LNSMP	C	LOG(GARCH)
Coeff.	-0.005	-0.0009	0.083	0.052	5.396	0.010
Prob.	0.000	0.000	0.000	0.000	0.000	0.000
Variance Equation						
	C		RESID(-1)^2		GARCH(-1)	
Coeff.	4.86E-05		1.51276		0.1829	
Prob.	0.000		0.000		0.000	
	R^2	Adj. R^2	LL	SIC	AIC	
	0.633	0.627	801.9	-4.659	-4.76	
ARCH-M (Variance)						
	LNCOVN	LNCOVR	LNOP	LNSMP	C	GARCH
Coeff.	7.89E-05	-0.004	0.081	0.018	5.649	0.176
Prob.	0.8896	0.000	0.000	0.000	0.000	0.764
Variance Equation						
	C		RESID(-1)^2		GARCH(-1)	
Coeff.	3.47E-05		2.104		-0.004	
Prob.	0.000		0.000		0.789	
	R^2	Adj. R^2	LL	SIC	AIC	
	0.593	0.587	796.68	-4.628	-4.73	

Note: LNSMP = Log of stock market price; LNCOVN = Log of New Covid-19 cases; LNCOVR = Log of Patients recovered from Covid-19; LNOP = Log o Oil price; RESID(-1)^2 = return squared ARCH coefficient; GARCH(-1) = GARCH coefficient; GARCH = Conditional Variance; @SQRT(GARCH) = square root of Conditional Variance; LOG(GARCH) = Log Conditional Variance. Source: Author's Compilation, 2023

The final check of how parallel market exchange rate volatility is affected by covid-19 variables, oil and stock prices is the ARCH-M (Variance). Consistent with the earlier results, reported and recovered cases negatively affect parallel market exchange rate negatively (Table 8). In addition, the probability value associated with the coefficient of recovered cases is significant but that which is associated with confirmed cases is not significant. In the same vein, stock and oil prices have positive and significant effect on parallel market exchange rate volatility. The variance equation indicates that the ARCH value is positive and significant at 1%, while the GARCH value in significant.

Which of the models best explain the volatility effect on parallel market exchange rate of covid-19 pandemics? The most appropriate will be the model with most efficient coefficients. The test for efficiency of model is the information criteria. Although there are many of such, two are considered in this paper. The model that gives the lowest value is considered the most efficient and hence, the appropriate one. To see the appropriate model clearly, a summary of the GARCH-M results extracted from Table 8 is presented succinctly in Table 9.

Table 9: GARCH estimation results summary

Description	**GARCH-M**	**GARCH-M (Std.Dev)**	**GARCH-M (Log(Var))**	**GARCH-M(Variance)**
Non-Significant Coefficient(s)	LNCOVN	NO	NO	LNCOVN
ARCH Significant?	YES	YES	YES	YES
GARCH Significant?	NO	YES	YES	NO
Log Likelihood	752.724	815.1882	801.875	796.6786
R^2	0.592629	0.600725	0.63304	0.593451
Adj. R^2	0.587661	0.59462	0.62742	0.587234
Schwarz IC	-4.38133	-4.739049	-4.6591	-4.62788
Akaike IC	-4.472817	-4.841971	-4.7620	-4.730802

Note: numbers of people confirmed to have contacted covid-19 (LNCOVN) is not significant in both ARCH-M and ARCH-M(variance). The ARCH is significant in all the models but GARCH is not significant in ARCH-M and ARCH-M(variance). Looking at all the models, ARCH-M (std. dev) has the lowest values for both SIC and AIC) and so considered the most efficient and appropriate.

Source: Authors' Compilation, 2023

The most efficient GARCH-M estimation method is the GARCH-M (Std. Dev.) because it has the lowest values as indicated by the Schwarz Information Criterion (-4.74) and complemented by Akaike Information Criterion (-4.84). In addition, the GARCH-M (Std. Dev.) also have the highest log likelihood value of approximately 815.19. Thus, the best approach to estimating parallel market exchange rate volatility with respect to pandemic in Nigeria is the GARCH-M(Std. Dev). In this case, number of confirmed cases does not significantly affect exchange rate volatility while numbers of recovered patients have a negative and significant effect of exchange rate volatility in Nigeria, that is, increasing numbers of people recovered from pandemic will lead to reduction in parallel market exchange rate volatility.

Post-Estimation Test

The accuracy of any estimated model is reliant on fact that some specific conditions are satisfied. When the estimated model fails to follow these guiding principles, the resulting estimates are unreliable, inconsistent, inefficient, and unsuited for making solid forecasts and predictions. Table 10 shows correlogram test. extracted from correlogram graph. A correlogram is a graphical depiction of serial correlation in time-varying data. A serial correlation occurs when a mistake at one point in time travels to a later point in time. For example, the price of stock market may have been exaggerated in the first day, resulting in an overestimation of price in subsequent days. As observed from the results, there is the absence of Autocorrelation (AC), Partial Autocorrelation (PAC) and Serial Autocorrelation (SAC) in the estimates got from the ARDL model (Table 9).

Table 10: Correlogram Squared Residuals of GARCH(1,1) models

Indicator	**GARCH-M**		**GARCH-M (Std. Dev)**		**GARCH-M (Log(Var))**		**GARCH-M(Variance)**	
	Lag(s)	Value	Lag(s)	Value	Lag(s)	Value	Lag(s)	Value
Autocorrelation	1	-0.007	1	-0.002	1	0.016	1	-0.009
Partial Correlation	1	-0.007	1	-0.002	1	0.016	1	-0.009
Serial Correlation	1	0.895	1	0.967	1	0.763	1	0.864

Source: Author's Compilation, 2023

Next is the test for the presence of ARCH in the model. In a GARCH models, the Lagrange Multiplier (LM) is used to test whether there is any remaining ARCH effect in the residuals. Table 11 presents the diagnostic tests for each of the GARCH(1,1) estimation methods. The results show that for all the models, the presence of heteroscedasticity in the residual term is to be rejected at 10%. This indicates that the residuals are not heteroscedastic in nature. Since all the tests satisfy conditions for reliability, normality and efficiency, the coefficients from the ARDL estimates and the GARCH-M can be utilized for prediction in the parallel foreign exchange market.

Table 11: ARCH-LM test of GARCH model

Description	F-Stat/Value	Prob	Obs*R-squared	Prob
GARCH(1,1) ARCH-M	0.017202	0.08957	0.017305	0.08953
GARCH(1,1) ARCH-M (Log(Var))	0.089313	0.07652	0.089830	0.07644
GARCH(1,1) ARCH-M (Std. Dev.)	0.001677	0.09674	0.001687	0.09672
GARCH(1,1) ARCH-M (Variance)	0.028737	0.08655	0.028908	0.08650

Source: Author's Compilation, 2023

Conclusion and Policy Implications

This study empirically examines the effects of covid-19 pandemic on the parallel market exchange rate and its volatility in Nigeria, by employing data from 20th March 2020 to 18th May 2021 in the context of ARDL and GARCH. The ARDL method was employed to determine whether there is a long-run and/or short-run effect of confirmed and recovered cases of covid-19 alongside stock and oil prices on parallel market exchange rate. The GARCH(1,1) estimation method helps capture the effect of heteroscedasticity in the estimation and helps predict if there would be future risk of a variable being volatile in the foreseeable future.

The ARDL result estimate indicates that recovered covid-19 patients, oil price, and stock market price significantly determine parallel market exchange rate in Nigeria, both in the long-run and short-run. It can be concluded from the results that parallel market exchange rate volatility will persist, and, it is expected that barring any change in the Central Bank of Nigeria regarding exchange rate policy, naira/dollar exchange rate will remain unstable in the parallel market for the time being. What will trigger this effect is changes in stock and oil prices. Positive shock to either oil or stock market will further fluctuate parallel market exchange rate in Nigeria. From the ARDL, recovered patients of covid-19, oil and stock prices have positive and significant effects on parallel market exchange rate, both in the short- and long-run. It can therefore be concluded that the recent pandemic (Covid-19) and the crash in the global oil price, increased volatility of parallel market exchange rate.

The economic implication of the result is that investors can learn a lesson from this result that in times of any pandemic, exchange rate will be highly unpredictable particularly when oil price surges or when the stock market experienced a shock. Policy implications arising from this result is that since the exchange rate stability in the parallel market is significantly influenced by pandemic, crude oil price, and the stock market price, it is recommended that the Federal Government should diversify its revenue base into other commodities (e.g., Cocoa, Iron Ore, Groundnut) to help cushion the crash in revenue generated from crude oil sales. The reason for this is that the Nigerian government earn its major revenue from oil proceeds, this is an indication that if there is a disturbance in the petroleum industry, either through domestic action or international incidences like the disruption caused by covid-19, the stability of the exchange rate will be greatly affected. Furthermore, the current covid-19 pandemic has led to the total shut-down of most economic activities in the country. Because of the dilapidated state of the Nigerian health sectors and the inability of the Nigerian state to manufacture her own Personal Protective Equipment (PPE), coupled with lack of human and material resources to manufacture her vaccines locally, the Nigerian government has to go into the international bidding process for vaccines and PPE which are in short supply. Thus, the Federal Government must invest heavily in the health sector of the Nigerian economy and invest heavily in the Nigerian Centre for Disease Control (NCDC) to help prevent another pandemic and to be readily available to engage in vaccine manufacturing and draft out planned response should in case there is another pandemic. It will also be highly appreciative if the Central Bank can harmonize various exchange rates such that there will not be room for large profits by the exchange rate arbitrageurs. Foreign investors also need to diversify. But since recovery from pandemic slows down exchange rate volatility, government may encourage foreign investors to invest in Nigeria by ensuring that any pandemic deem to affect the exchange rate market is immediately dealt with. In this regard, the health sector must be equipped and be on the red alert to combat any possible influx of pandemic.

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