



Modeling Volatility and Daily Exchange Rate Movement in Nigeria

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Abstract

This study modeled volatility and daily exchange rate movement in Nigeria with daily exchange rate between Nigeria Naira and US Dollar from January 2, 2001 to May 20, 2019 collected from the Central Bank of Nigeria (CBN). The results of the estimated models revealed that conditional variance (volatility) has positive and significant relationship with exchange rate returns between Nigeria Naira and US Dollars, which corroborates the theory that predicts positive relationship between return and volatility for risk averse investors. Also found that exchange rate volatility between Naira / US Dollar is persistent. It was also discovered that goods news produces more volatility than bad news of equal magnitude. The researchers therefore suggested that the Central Bank of Nigeria should always proffer timely intervention to reduce the volatility persistence. This will go a long way to counteract or moderate the excess volatility between Naira and US Dollar transactions.

Keywords: Exchange rate; Conditional variance (volatility); Asymmetric effects; Volatility persistence; EGARCH.



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1. Introduction

The movement of goods, services and financial assets take place across the frontiers of countries each with its own domestic currency. Economic interaction is only possible if there is a specific link between currencies so that the value of a particular or a given transaction can be determined by both parties in their own respective currencies. This indispensable link is the foreign exchange rate; which is simply the price of a domestic currency to the currencies of other countries, or the price of a domestic currency in terms of foreign currency i.e. one unit of domestic currency can afford. For example, the exchange rate between the Nigeria Naira and the United States of America (US) Dollar is seen as the number of Naira required to purchase a US Dollar. The exchange rate that is delivered immediately is known as spot rate as against forward exchange rate that is consummated in the future measured with premium or discount.

This movement of goods and services involves foreign exchange risk because the value of transactions in different currencies is sensitive to exchange rate changes. It is possible to manage a firm's foreign currency denominated assets and liabilities so as to avoid exposure to exchange rate changes; the cost involved is not always worth the effort (Husted and Melvin, 1993).

Exchange rate movement has different effects across the sectors of a country like Nigeria. The impact of a reasonable change or shift in the Exchange rate will usually worsen the financial condition of some investors and increase the loss or vice versa. Though, this impact on the economy may be compounded if regulation and management practices have limited sectors direct and indirect foreign exchange risk exposure. Notwithstanding, exchange rate instability and high levels of uncertainty negatively affect the business activities in a country. There is a general belief that exchange rate and its conditional variance (Volatility) are the determinant of economic activities especially in Nigeria and the rest of the world. This goes a long way to elucidate why the fluctuations in exchange rates have attracted considerable attention in both field economic and finance.

The issue of exchange rate volatility is an indispensable issue for policy makers, importers and exporters in international financial markets. Firms use volatility models in their daily estimations of risks and as a gauge when evaluating prices. The policy makers on their own make use of information about how the factors influence the exchange rate volatility so that the most appropriate policy can be conducted (Bauwens and Sucarat, 2005).

In support of the volatile nature of exchange rate, Husted and Melvin (1993) revealed overshooting exchange rates by arguing that it is possible that the exchange rate may not always move in such orderly fashion to the new long run equilibrium after a disturbance. Knowing fully that, purchasing power parity does not hold well under flexible exchange rates and that exchange rates exhibit much more volatile behavior than prices. It is expected that in the short run following some disturbance to equilibrium level, prices will adjust slowly to new equilibrium level, whereas interest and exchange rate will adjust quickly. This different speed of adjustment to equilibrium allows for some interesting behavior regarding exchange rates and prices. At time it appears that spot exchange rates move too much given some economic disturbances. Also, we have observed cases when country say Nigeria has a higher inflation rate than country say Ghana, yet Nigeria currency appreciates relative to Ghana's. Such anomalies is explained under the context of an 'over shooting' exchange rate model. It is assumed that financial markets adjust instantaneously to an exogenous shock, whereas goods markets adjust slowly over time.

According to [Husted and Melvin \(1993\)](#), exchange rates are difficult to forecast because the market is continually reacting to unexpected events or news. [Sun et al. \(2002\)](#), maintained that uncertainty in exchange rate has generally been perceived as one of the main determinants of international trade. That the impact of exchange rate volatility on international trade has been controversial and the results are inconclusive. While, [Adeoye and Atanda \(2011\)](#) is of the opinion that there exists widespread belief that volatility of exchange rate in developing countries is one of the main sources of economic stability around the world. They maintained the global economy on emerging countries like Nigeria is driven significantly by swings in the currencies of major economic powers like United States. According to [Ikumarijgebe and Ejem \(2018\)](#) exchange rate shocks constitute currency risk and affect financial stability of a country, the nature and extent of its volatility is of utmost interest to both domestic and foreign investors, policy makers and market observers.

There are two features of exchange rate volatility that continue to appear in the literature; volatility persistence and asymmetric effects. Volatility persistence means that unpredictable shocks have long memory and their effects last for many periods ahead. Furthermore, Volatility persistence has to do with how long it takes unpredictable shocks to die out or revert to its long run average. Volatility persistence is of particular interest to investors because it is one of the important determinants of financial asset returns. Volatility Persistence has been found to characterize most foreign exchange markets, especially the emerging markets ([Adeoye and Atanda, 2011](#); [Ikumarijgebe and Ejem, 2018](#); [Lugutaerah et al., 2015](#); [Miambo et al., 2003](#)).

[Ejem \(2017\)](#), asymmetric effect, on the other hand, is the tendency for negative news and positive news of equal size or magnitude to produce different impacts on volatility. If negative news produces more volatility than positive news, then the asymmetric effect becomes leverage effect ([Black, 1976](#)). In contrast, if positive news has more impact on volatility, then the asymmetric response is positive. Although, many empirical African studies have reported evidence of asymmetric effects in the foreign exchange markets, there is no agreement however, on whether the observed asymmetric response of volatility is positive or related to leverage effect.

Meanwhile, heated arguments abound on whether exchange rate volatility in Nigeria is persistent or not. Researchers here are bordered that the Central Bank of Nigeria is not doing enough to preserve or design an orderly pattern of exchange rate changes aimed at eliminating excess volatility. This is because, it is expected that rather than resist the underlying market forces, the Central Bank of Nigeria or other countries should occasionally intervene by buying or selling domestic currency for smooth transition from one rate to another. At other times they should intervene to moderate or counteract self-correcting cyclical or seasonal market forces.

Therefore, the researchers seek to investigate the nature of the relationship between volatility and daily exchange rate movement in Nigeria, also to investigate the exchange rate volatility clustering, persistence of volatility and asymmetric effects in Nigeria with emphasis on Naira & US Dollar.

The other sections of this study are structured as follows. Section 2 reviews some conceptual, theoretical and empirical literature related to this study, section 3 describes the data and methodology, section 4 analyzes and discusses the findings of this study, and finally section 5 concludes and recommends for policy making.

2. Review of Related Literature

2.1. Theoretical Review

Exchange rate theories have both the traditional and the modern approaches. According to [Gartner \(1993\)](#), the modern exchange rate theory is conducted on the assumption that exchange rate theory is conducted on the decision on how to spread wealth over different assets, instead of the assumption that exchange rate is determined by the demand and supply of foreign currency as opined by the traditionalists.

In this study efforts will be made to examine both the traditional and modern theories of exchange rate.

2.1.1. Purchasing Power Parity Theory (PPPT)

According to [Abbasi and Safdar \(2014\)](#), the purchasing power parity theory is the most controversial, but fundamental hypothesis in international finance. Parity theory explains long run exchange rate equilibrium, thus making the theory attractive tool. The purchasing power parity theory is a fundamental or traditional theory that elucidates the relationship between expected domestic prices and domestic exchange rate. PPPT explains movement between two currencies as being a direct result of the changes or price levels between the countries ([Abbasi and Safdar, 2004](#); [Works, 2016](#)). This theory (PPP) suggests that the equilibrium exchange rate between two inconvertible paper currencies is determined by the equality of their purchasing power ([Nzotta, 2004](#)). That means the rate of exchange is determined by their relative price levels. Succinctly, rate of exchange between two currency pairs is the same as the price levels of the countries. A single unit of domestic currency expects to purchase equal baskets of goods in the domestic economy and in foreign economy at the given rate of exchange. A rise in domestic price levels causes a decline in the domestic purchasing power and a decline of the rate of exchange ([Works, 2016](#)). At various transactions, a decrease in domestic price will lead to increase in the purchasing power and in turn lead to appreciation in the exchange rate, vice visa,

2.1.2. Monetary Theory

This theory informs that changes brought about by money supply influence the exchange rate in many ways. That change in exchange rates is brought about by demand for and supply of money between two countries two countries. The monetary theory according to [Becmann \(2013\)](#) is an outgrowth of the purchasing power parity that

emerged after the Brettonwoods and revitalized long run equilibrium interpretations. Beckman added that monetary models of exchange rates assume that the demand and supply for money is the result of financial markets.

Monetary exchange rate theory advocates that the demand and supply of money determines exchange rates. That monetary policy underlies exchange rate movements, hence joining the theory of purchasing power parity with the quantity theory of money. The monetarists approach hypothesizes that a reduction in the relative purchasing power will yield to increasing the domestic supply of money. This models used in determining exchange rates were seen to be the bedrock of international finance after the collapse of the fixed exchange rate regime (Works, 2016).

2.1.3. Balance of Payments (BOP) Theory

This theory suggests that the balance of payments affects and determines the exchange rate of a currency under a freely floating exchange rate regime. For instance if the BOP has a favourable balance, the exchange rates tend to appreciate. On the contrary, when the BOP has unfavorable balance, the exchange rates tend to depreciate. An unfavorable BOP implies an increased demand of foreign currencies, whereas favorable BOP shows an increase in the demand of domestic currency which tend to appreciate. The implication is that the demand and supply of foreign exchange determine the exchange rate of currency. BOP theory is also an outgrowth of the purchasing power parity theory (Nzotta, 2004).

2.1.4. The Asset Approach Model

This modern theory places emphasis on the role of exchange rate as one many prices in the global market for financial assets. The modern exchange rate theory laid emphasis on finance-asset markets. Rather than the traditional view of exchange rates adjusting to equilibrate international trade in goods, the exchange rate is viewed as adjusting to equilibrate international trade in financial assets. Because goods price adjust slowly relative to financial asset prices and financial assets are traded continuously each business day and the shift in emphasis from goods market to asset market has important implication. Exchange rates will change every day or even every minute as supplies and demands for financial assets of different nations change. An implication of the asset approach is that exchange rate should be much more variable than goods' prices. This seems to be empirical facts. For example, if mean of absolute changes in price and exchange rate of countries are taken, we then look at the average absolute change because exchange rate could be very volatile (Husted and Melvin, 1993). However, exchange rate models emphasizing financial-asset markets typically assume capital mobility, Husted & Melvin added. That means capital flows freely between nations as there are no significant transaction cost or capital controls to serve as barriers to investment. In such a world, covered interest arbitrage will ensure covered interest rate parity.

$$i - i_f/1 + i_f = F \cdot E / E$$

Where, i is the domestic interest rate, i_f is the foreign interest rate. Since this relationship will hold continuously spot and forward exchange rates as well as interest rates adjust instantaneously to changing financial-market condition (market efficiency).

As recorded by Husted and Melvin (1993), within the family of asset-approach models, there are two basic groups: the monetary approach and the portfolio-balance approach. The monetary approach argues that exchange rate for any two currencies are determined by relative money demand and supply between the two countries. Those relative supplies of domestic and foreign bonds are unimportant.

The portfolio balance approach allows relative bonds supplies and demands as well as relative money market conditions to determine the exchange rate.

The essential difference is that monetary approach (MA) models assume domestic and foreign bonds to be perfect substitutes, whereas portfolio balance (PB) models assume imperfect substitutability.

2.2. Conceptual Literature

The movement of goods and services across national frontiers in one direction involves the movement of foreign exchange in the opposite direction. This creates the need for a rate of exchange between the currencies of two trading parties to settle indebtedness' arising from trade and thus introduces us to the concept of exchange rate. Exchange rate is therefore, the price of one currency in terms of another. This price can be viewed as the result of the interaction of the forces of supply and demand for foreign currency in a particular period of time (Appleyard *et al.*, 2008; Nzotta, 2004).

Foreign exchange refers to bank notes, coins, bank deposits, money equivalents and monetary claims others than those of the reporting country available for settlement or payment for international obligations, including the balance of payments deficits. In Nigeria, the widely transacted foreign currencies are the United States Dollar, British Pound sterling, Euro and the CFA. The rate at which a currency is exchanged for another is termed exchange rate (Central Bank of Nigera, 2018).

Central Bank of Nigera (2018), further clarifies that a foreign exchange market is the medium where sellers and buyers of foreign exchange negotiate a mutually acceptable price for independently floating exchange/currencies. CBN went ahead to inform that the major participants in the foreign exchange market in Nigeria are the monetary authority (Central Bank of Nigeria), authorized dealers (banks) agents of the public sectors and the private sectors. That the supply of foreign exchange to the market is derived from proceeds of oil and non-oil exports; capital receipts including draw-down on loans, expenditure of foreign tourists, repatriation of capital by Nigerians resident abroad; as well as invisible receipts by the private sector. The demand for foreign exchange on the other hand consists of payments for imports, external debt service obligations, personal home remittances (PHR) by foreign

nationals resident in the country, financial commitments to international organisations and the country's embassies abroad, as well as other visible out-payments by the private sector.

Uma (2010), argued that transactions between countries involve acceptable currency. Naira is not acceptable in United State of America (USA) as a medium of exchange. If a Nigerian wants to obtain any commodity from USA, she has to change her naira to Dollars. This means buying United States dollars in the exchange market.

Exchange rate policy is categorized into fixed exchange and flexible exchange rate. A fixed exchange rate system is one which each country has its currency's exchange rate fixed at a given parity rate in terms of some international money or vehicle currency (example the dollars and pounds), while, flexible or floating exchange rate is one which is allowed to find its level as determined by the forces of supply and demand. The type of exchange with absence of intervention in the foreign exchange market by central banks and other government agencies (often called official intervention), the exchange rate will settle at the point at which the market clears (Ejem and Jombo, 2011; Nzotta, 2004).

Nzotta (2004), went further to examine exchange rate appreciation and depreciation. That when one country's currency becomes more expensive in terms of another, it is said that the country's currency has appreciated, whereas when more units of a domestic currency buys the other currency there is a case of depreciation. Appleyard *et al.* (2008) saw it as home-currency depreciation or foreign currency appreciation (when there is an increase in the home currency price of the foreign currency or alternatively, a decrease in the foreign currency price of the home currency) and home-currency appreciation or foreign currency depreciation (when there is a decrease in the home currency price of foreign currency or an increase in the foreign currency price of the home currency).

The discrepancy in the exchange rate movement in different areas in the same country can be corrected by arbitrage. According to Appleyard *et al.* (2008), arbitrage refers to the process by which an individual purchase a product (in this case foreign exchange) in a low priced market for immediate resale in a high priced market for the purpose of making profit. In the process, the price is driven up in the low price market and down in the high price market. This activity will continue until the price in the two markets are equalized, or until they differ only by the transaction costs involved.

Volatility is the change in the returns of a currency pair over a specific period, annualized and reported in percentage terms; the larger the number, the greater the price movement over a period of time. There are a number of ways to measure volatility, as well as different types of volatility. Ejem (2017), stated that volatility is a degree of variation of a trading price series over time as measured by the standard deviation. It can also be seen as the variations or fluctuations or dwindling of prices over a period of time.

There are two specific types of volatility. What has already happened is known as historical volatility. Historical volatility simply involves calculating the variance (standard deviation) of returns in the usual way over some historical period. What market participants think is going to happen is referred to as implied volatility. The market's estimate of how much a currency pair will fluctuate over a certain period in the future is known as implied volatility. All pricing models for financial options require a volatility estimate or forecast as an input. Given the price of a traded option obtained from transactions data, it is possible to determine the volatility forecast over the lifetime of option implied by the option's valuation. The former, can be used to predict the latter, but the latter is a market input, determined by the people that are participating in the foreign exchange options market (Brooks, 2008).

2.3. Exchange Rate Volatility

Exchange rate as earlier defined in the study is the price of one currency in terms of another currency. In this context, it is the price of Naira in terms of the US Dollars. Then volatility on the other hand is unobserved or latent variable deterministic or stochastic (Bauwens and Sucarat, 2005). That is to say that exchange rate volatility is an unobservable variable or a stochastic or random variable with varied results. It is pertinent to note that volatility is a risk for companies trading on international market since it is a variable that is unpredictable.

Exchange rate has recently become more volatile since the abandonment of fixed exchange rates in 1971; hence resulting in unquantifiable volume in exchange rate transaction. Foreign exchange transactions have grown geometrically faster than international trade and international investments flows of capital. The risk inherent in exchange transactions among nations at the foreign exchange market has gone up as noticed by the speculators in the market. These resulted in devising several protection measures to insulate or immunize against risk by the speculators in the foreign exchange market (Salvatore, 2004).

Exchange rates seem to be very volatile mostly in the short run, as such very responsive to monetary and fiscal policies, politics, changes in expectations and other exogenous factors. In the long run, these exchange rates are determined by the relative prices in various countries, though exchange rate is more volatile than the fundamental variables which determine the exchange rate in the long run (Gartner, 1993; Samulson and Nordhaus, 2001).

As recorded by Jones and Kenen (1990), exchange rate volatility is influenced by plethora of macro variables, example are demand and supply for goods services, investment, inflation rates in different countries, different growth, and changes in relative rates of return and other factors. Jones and Kanem further argued that volatility can arise from 'overshooting behavior as earlier recorded in this study; which happens when current spot rate does not equal a measure of the long run equilibrium calculated from a long run model. If such behavior arises as a result of the inefficiency of the financial market high exchange rate volatility does not have to imply high transaction costs. Jones and Kenen suggested that, it would only be efficient for the exchange rate to be highly volatile if the underlying economic variables are equally volatile. Otherwise abnormal profit will be presented for speculators in order to smooth exchange rate movement. That is there will be abnormal profit opportunities for the speculators in

the exchange market that will smooth exchange rate movement. The exchange rate normally cannot accommodate any pattern or signals about future rates, since it could be used to make a profit.

2.4. Empirical Review

In Africa, several research works have been done to investigate or model the relationship between volatility and exchange rate movement. For example in Ghana, [Lugutaerah et al. \(2015\)](#) examined Ghana cedi/ US dollar exchange rate volatility with the GARCH family using exchange rate data from January 1990 to November 2013. The result revealed evidence of volatility persistence and asymmetric effects.

Also, [Therlie et al. \(2014\)](#) examine the Sierra Leone /US Dollar exchange rate volatility from January 2004 to December 2013 using both symmetric and asymmetric GARCH models. The results showed evidence of leverage effect in the Sierra Leone /US dollar Exchange rates.

While in Nigeria, [Adeoye and Atanda \(2011\)](#) found evidence of persistence of shocks in Nigeria Naira / USA dollar exchange after investigating exchange volatility of Naira/US with monthly data for the period of 1986 to 2008 inclusive. The study employed ARCH and GARCH models.

In support, [Olowe \(2009\)](#) examined the volatility persistence and asymmetric response to the shocks of Naira/ US Dollar with the GARCH, GARCH (1, 1) GJR- GARCH (1, 1) and IGARCH (1, 1). [Olowe \(2009\)](#), in the study used data with monthly observations of Naira/Dollar for January 1970 to December 2007. The study also found evidence of persistence in Naira/US Dollar exchange rates.

In the same vein, [Bala and Asemota \(2003\)](#), used exchange rate of Nigeria with USA (Naira/US Dollar), 1985-2011, Great Britain and Nigeria (Naira/Pounds) 2004-2011, to investigate the volatility in their exchange rates with Nigeria with monthly exchange returns. The results found evidence of volatility clustering in the three currencies (Dollar, Pound and Euro), also found evidence of leverage effect and presence of volatility persistence with GARCH variants.

Recently, [Ikumariogbe and Ejem \(2018\)](#), examined exchange rate volatility stock persistence comparing Nigeria, Ghana, South Africa and the study employed GARCH and TGARCH to evaluate daily exchange rate of USA Dollar for Nigeria, Ghana and South Africa. The results show evidence of volatility clustering in the three markets and also evidence that volatility is persistent in the three markets. The results also found evidence of asymmetric effect in the Nigeria, Ghana and South Africa.

3. Methodology

3.1. Data

For analysis in this study data are made up of 4527 observations of daily exchange between Nigeria Naira and US Dollar from January 2, 2001 to May 20, 2019. The data are sourced from the Central Bank of Nigeria (CBN) and are converted into continuously compounded returns as follows.

$$R_t = \ln(P_t/P_{t-1})$$

R_t is the exchange rate return, current exchange period, P_{t-1} is the exchange rate for the past period.

3.2. Techniques for Estimation

This study employed Autoregressive Conditional Heteroscedasticity (ARCH) and its variants; Generalized Autoregressive Conditional Heteroscedasticity (GARCH), Threshold Generalized Autoregressive Conditional Heteroscedasticity (TGARCH) model, and Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) in order to capture conditional variance, volatility clustering, volatility persistence and asymmetric effect for Nigeria exchange rate with the United States America Dollar(US dollar) and Great Britain Pounds. GARCH is employed because it captures volatility clustering and persistence ([Bollerslev, 1986](#)), while TGARCH and EGARCH are used because it captures asymmetric effects on volatility ([Zakoian, 1994](#)).

3.3. Model Specifications

The mean equation is specified as

$$R_t = \vartheta + \varepsilon_t$$

$$\varepsilon_t \sim Niid(0, \vartheta^2)$$

The GARCH model is specified as

$$\vartheta_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \vartheta_{t-1}^2$$

Where R_t is returns, ϑ is intercept, ε_t is white noise error term, α_0 is constant representing the long-term average, α_1 is the ARCH term which captures the last period information about volatility, β_1 is the GARCH term which captures the forecasted variance from the previous period and $(\alpha_1 + \beta_1)$ is coefficients which governs both the stationarity of the GARCH model and persistence of volatility.

If $(\alpha_1 + \beta_1) > 0$, then the model is stationary and volatility is mean reverting. On the contrary if $\alpha_1 + \beta_1 = 1$, then the model have long memory and volatility is persistent.

The TGARCH (1.1) is specified as;

$$\vartheta_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \gamma \cdot z_{t-1} \varepsilon_{t-1}^2 + \beta_1 \vartheta_{t-1}^2$$

Where,

$z_{t-1} = 1$, if $\varepsilon_{t-1} < 0$ and 0 otherwise; the TGARCH model assumes that the effect of good news and bad news volatility ϑ_t^2 are different, while $\varepsilon_{t-1} > 0$ indicates good news, $\varepsilon_{t-1} < 0$ indicates bad news. Further, while α , captures the effect of goods news.

$\alpha_1 + \gamma$ captures the effect of bad news. There is asymmetric effect if $\gamma \neq 0$, and leverage effect γ is positive.

3.4. EGARCH

The EGARCH-in-Mean Model: If the conditional variance is introduced into the mean equation, the ARCH-in-mean (ARCH-M) model is derived.

$$\gamma_t = \alpha_1 \gamma_t + \alpha_2 \vartheta_{t-1}^2 + \varepsilon_t$$

This is often used in financial applications where the expected return on an asset is related to the expected asset risk. It is however often the case that the conditional variance, ϑ_t^2 is not an even function of the past disturbances, $U_{t-1}, U_{t-2}, \dots, U_{t-n}$, an important feature which often observed when analyzing returns (Koulakiotis *et al.*, 2006).

In order to arrest this important feature, Nelson (1991) proposed the EGARCH model which incorporates leverage effect and observed asymmetric volatility changes with the change in return sign. In this model, the log of conditional variance implies that the leverage effect is exponential, rather than quadratic and that forecast of the conditional variance is guaranteed to be non-negative.

The model for conditional variance is specified as follows:

$$\ln \vartheta_t^2 = \omega + \beta_{in} \vartheta_{t-1}^2 + \alpha \left[\frac{\varepsilon_{t-1}}{\vartheta_{t-1}} - \frac{2}{x} \right] + \gamma \left| \frac{\varepsilon_{t-1}}{\vartheta_{t-1}} \right|$$

Where,

$\omega, \beta, \alpha, \gamma$ are constant parameters,

$\ln \vartheta_t^2$ = the one period ahead volatility forecast

ω = the mean level, β = persistence parameter

α = volatility clustering coefficient

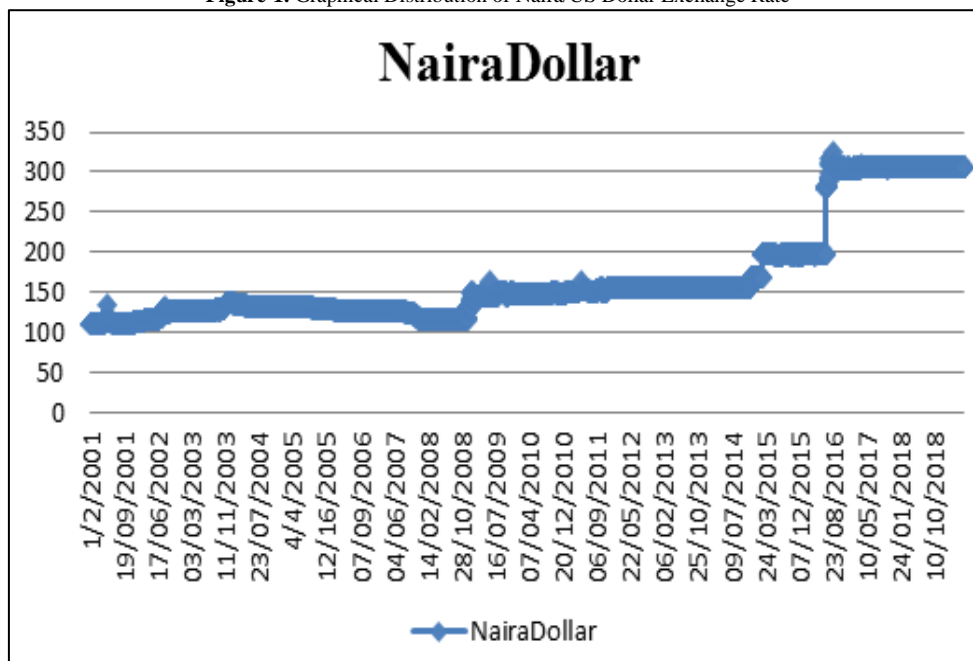
$\ln \vartheta_{t-1}^2$ = the past variance, γ = the leverage effect. Unlike the GARCH model, the EGARCH model allows for leverage effect. If the expected variance can be used to predict expected returns, then the value of β_2 should be positive and significant for a risk averse investor, that is to say that the higher the risk of an investment, the higher the reward accruable for having undertaken such a risky investment.

The EGARCH-M model, a refinement of the GARCH imposes a non-negativity constant on market variable, and allows for conditional variance to respond asymmetrically to returns innovations of different signs. If γ is negative, leverage effect exists. That is unexpected drop in price (bad news) increases predictable volatility more than an unexpected increase in price (good news) of similar magnitude (Black, 1976; Christie, 1982). In other words, negative value of γ is called the 'sign effect'. If α is positive, then the conditional volatility tends to rise (fall) when the absolute value of the standardized residuals is larger (smaller). α is called the 'magnitude effect'.

4. Estimation Results and Interpretations

First and foremost, let's graphically describe the data to show the behaviour of exchange rate and also to employ descriptive statistics to know the distribution of exchange rate in Nigeria.

Figure-1. Graphical Distribution of Naira/US Dollar Exchange Rate



Source: Authors' computation

The Figure 1 above shows the Naira/US Dollar spot rate exchange from February 2, 2001 to September 28, 2018. This exchange rate is the total amount of Naira received for one US Dollar. The graph shows that the exchange rate moved up a little above ₦100/US\$1 from February 2, 2001 to ₦150/US\$1 on December, 23, 2003. On June 6, 2006 Naira gained a little value when exchange rate moved down to ₦100/US\$1 after August 30, 2008 to February 19, 2009. Again the Naira depreciated more to above ₦150/US\$1 after February 19, 2009, continued to January 30,

2015. Exchange rate then jump up to ₦200/US\$1 immediately after January 30, 2015 to July 04, 2016. Worse still, it moved up astronomically to above ₦300/US\$1 after July 14, 2016 and deteriorated up to September 28, 2018 to the scope of the study.

In summary, Figure 1 above simply illustrates the appreciation in the value of US Dollars and depreciation in the value of Naira from February 2, 2001 to September 28, 2018. This suggests that US Dollar gained in values as it increased the quantity of Naira required to purchase one US Dollar. However, a drastic depreciation happened after July 14, 2016 and continued up to 2019.

Table-1. Descriptive Statistics between Naira/US Dollar Exchange Rates

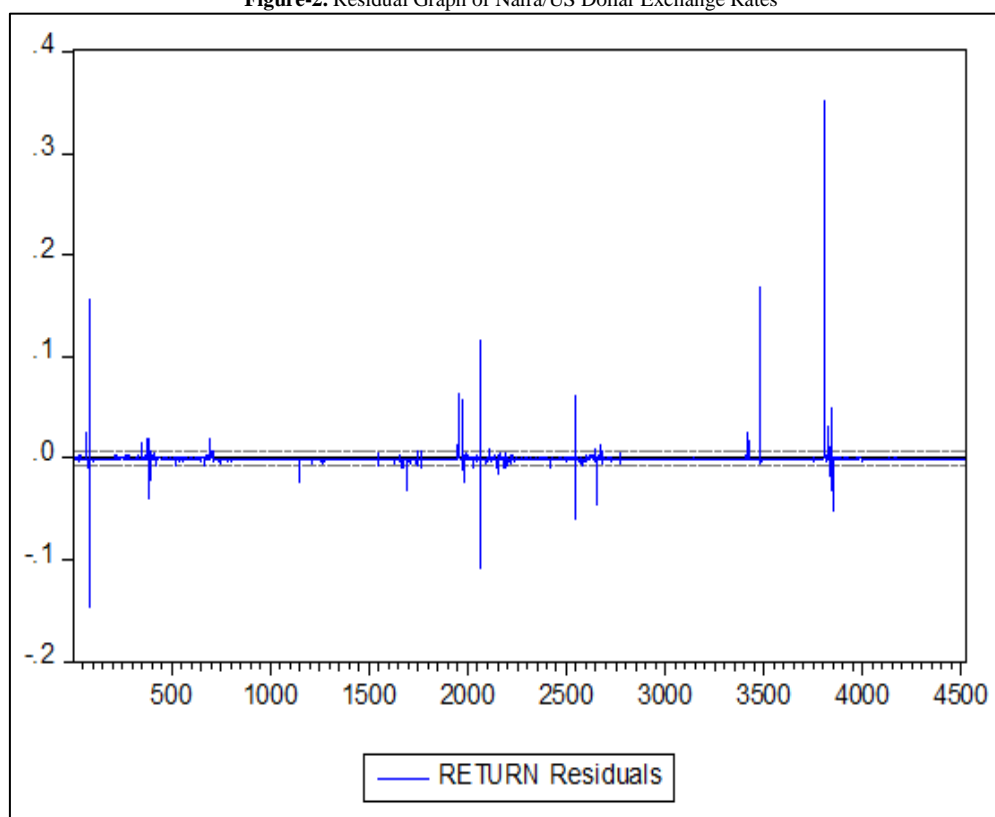
	NAIRADOLLAR
Mean	168.2452
Median	148.7100
Maximum	325.0000
Minimum	110.0000
Std. Dev.	63.17676
Skewness	1.481927
Kurtosis	3.683790
Jarque-Bera	1745.157
Probability	0.000000
Sum	761646.1
Sum Sq. Dev.	18064639
Observations	4527

Source: Authors' computation

Table 1 revealed the mean and median of exchange rate between Naira and US Dollar to be 168.2452 and 148.7100 respectively. The maximum exchange rate within scope of this study is ₦325/US\$1 with minimum of ₦110/ US\$1. The coefficient of Jarque-Bera is 1745.157 with probability value of 0.0000 indicating abnormal distribution.

Having described the exchange rate, the researchers then proceeded to examine the volatility of exchange rate between the Naira and US Dollar can be estimated using variants of ARCH.

Figure-2. Residual Graph of Naira/US Dollar Exchange Rates



Source: Authors' computation

A close look at figure 2 indicates that volatility of exchange rate between Naira and US Dollar series appears in bunches. The Researchers then have sufficient evidence that there is ARCH effects in the model, hence are bold to use the ARCH/GARCH models to capture the times varying properties of all data.

The researchers then proceeded to estimating the relationship between conditional variance (volatility), exchange rate volatility clustering, volatility persistence and asymmetric effects using ARCH and its variants;

Table-2. Summary of parameter estimates ARCH (1, 1), GARCH/TGARCH AND EGARCH

Coefficients	ARCH(1,1)	GARCH/TGARCH	EGARCH
b_0	0.012322(0.0000)	0.000495(0.8219)	0.012322(0.0000)
b_1	0.0997655(0.0000)	1.000183(0.0000)	0.0997655(0.0000)
b_2	1.026644(0.0231)	0.153813(0.0000)	1.026644(0.0231)
ω	-3.245782(0.0000)	-	-3.245782(0.0000)
β	0.666835(0.0000)	-	0.666835(0.0000)
α	-0.234604(0.0000)	-	-0.234604(0.0000)
Υ	0.467173(0.0000)	-	0.467173(0.0000)
Dw	2.252063	2.045275	2.252063
ARCH LM	0.000180(0.9893)	1.33E-08(0.9999)	0.005664(0.9400)

*Probabilities are in bracket

Source: Authors' computation extracted from Appendices 1, 2, 3 and 4

Table 2 above revealed that the coefficient of the conditional variance (volatility) (b_2) for ARCH(1,1), GARCH/TGARCH and EGARCH are 1.026644, 0.158813 and 1.026644 with probability values of 0.0231, 0.0000 and 0.0231 respectively indicating that the relationship between volatility and exchange rate returns in Nigeria is positive and significant. This supports the theory that predicts a positive relation between expected returns and volatility if investors are risk averse. That means premium in forward exchange provides more compensation for risk when volatility is relatively high (Ejem, 2017; Ejem *et al.*, 2018). That means investors in Nigeria will always look out for more returns for each additional risk taken.

The persistent parameters (β) for ARCH (1,1) and EGARCH have coefficient 0.66835 for both with probability values of 0.0000 for both indicating that it is positive and significant. The persistent coefficient ($\alpha_1 + \beta_1$) is very close to 1. With both conditions, the researchers have enough evidence to state that exchange rate volatility between the US Dollar and Naira is persistent.

The asymmetric coefficient (Υ) for both ARCH (1, 1) and EGARCH are 0.467173 with probability value of 0.0000 for both, which is positive and significant. This shows that good news increases volatility in exchange rate between Nigeria and USA more than bad news of the same magnitude. This contradicts the leverage effect theory which states that bad news increases volatility more than goods news with equal magnitude.

Magnitude effect (α) (volatility clustering) has coefficient of -0.234604 with probability value of 0.0000 for both ARCH (1, 1) and EGARCH, which is negative and significant. That means the conditional volatility will not rise or fall when the absolute value of the standardized residual is larger (smaller).

The ARCH LM statistic have coefficient of 0.000180, 1.33E-08, and 0.005664 with probability values of 0.9893, 0.9999 and 0.9400 respectively for ARCH (1.1), GARCH/TGARCH and EGARCH. This shows ARCH LM statistic is insignificant at conventional level between exchange rate of Nigeria and USA, indicating that there is no further ARCH effect of all the estimated models. It also shows that the models are homoscedasticity and correctly specified.

The Durbin-Watson (Dw) statistics for ARCH (1, 1) GARCH/ TGARCH and EGARCH are 2.252063, 2.045275 and 2.252063. That shows the absence of autocorrelation in all the models.

5. Conclusion and Recommendation for Policy Making

In this study, modeling of volatility and daily exchange movement in Nigeria, the researchers made frantic efforts to unravel issues concerning exchange rate volatility persistence, volatility clustering, asymmetric effects and relationship between volatility (conditional variance) in the exchange rate movements of Naira/US Dollar.

From the various estimates, the researchers found that conditional variance (volatility) has positive and significant relationship with exchange rate returns between Nigeria Naira and US Dollars, which corroborates the theory that predicts positive relationship between return and volatility for risk averse investors. Consequently this shows that premium provides more reward for risk when volatility is relatively high.

Similarly, the researchers also found that exchange rate volatility between Naira/US Dollar is persistent. This corroborates all the empirical literatures reviewed in this study. It is equally instructive to note that the researchers discovered that goods news produces more volatility than bad news of equal magnitude. This is consistent with finding of Olowe (2009); Bala and Asemota (2013); Ikumariogbe and Ejem (2018).

Therefore, the researchers are of the opinion that the Central Bank of Nigeria should always proffer timely intervention to reduce the volatility persistence. This will go a long way to counteract or moderate the excess volatility between Naira and US Dollar transactions.

References

- Abbasi, J. and Safdar, S. (2004). What determines the behaviour of exchange rate Pakistan: Monetary model analysis? *Josr Journal of Humanities and Social Science*, 19(2): 27-35.
- Abbasi, J. and Safdar, S. (2014). What determines the behaviour of exchange rate Pakistan: Monetary model analysis? . *JOSR Journal of Humanities and Social Science*, 19(2): 27-35.
- Adeoye, B. W. and Atanda, A. A. (2011). Exchange rate volatility in Nigeria: Consistency, persistency and severity analysis. *CBN Journal of Applied Statistics*, 2(2): 29-49.
- Appleyard, D. R., Field, A. J. and Cobb, S. L. (2008). *International Economics*. Mc Graw-Hill Irwin: New York, NY. 6th.

- Bala, D. A. and Asemota, J. O. (2003). Exchange rate volatility in Nigeria: Application of GARCH model with exogenous break. *CBN Journal of Applied Statistics*, 4(1): 89-116.
- Bala, D. A. and Asemota, J. O. (2013). Exchange rate volatility in Nigeria: Application of GARCH model with exogenous break. *CBN Journal of Applied Statistics*, 4(1): 89-116.
- Bauwens, L. and Sucarat, G. (2005). General to specific modeling of exchange rate volatility; A forecast evaluation. Available: <https://www.cemfies/ftp/pdf/papers/wshop/gets.pdf>
- Becmann, J. (2013). Non linear exchange rate adjustment and the monetary model. *Review of International Economics*, 12(4): 654-70.
- Black, B., 1976. "Studies of stock price volatility changes." In *Proceeding of the 1976 meetings of the American Statistical Association, Business and Economic Statistics*. pp. 177-81.
- Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics*, 31(3): 307-27.
- Brooks, C. (2008). *Introduction to econometrics for finance*. 2nd edn: Cambridge University Press: UK.
- Central Bank of Nigeria (2018). *Central bank of Nigeria annual briefs*. Research Department: Abuja.
- Christie, A. A. (1982). The stochastic behavior of common stock variance-value, leverage and interest rate effects. *Journal of Financial Economics*, 10(4): 407-23.
- Ejem, C. A. (2017). *Volatility modeling and daily stock returns in Nigeria*. (Ph.D. thesis). Department of Banking and Finance, Abia State University Uturu, Nigeria.
- Ejem, C. A. and Jombo, C. O. (2011). *International finance*. Ker Export Publisher: Aba.
- Ejem, C. A., Ogbonna, U. G. and Ezirim, B. C. (2018). The relationship between stock market return and conditional variance (volatility) in the Nigeria stock market. *International Journal of Business and Economic perspective*, 13(1): 89-105.
- Gartner, M. (1993). *Macro economics under flexible exchange rate*. Harvester Wheatsheaf: UK.
- Husted, S. and Melvin, M. (1993). *International economics*. 2nd edn: Harper Collins College Publications: New York.
- Ikumariogbe, V. O. and Ejem, C. A. (2018). Exchange rate volatility shock persistence: A comparative analysis of Nigeria, South Africa and Ghana. *Uniport Journal of Business, Accounting and Finance Management*, 8(3): 205-2012.
- Jones, R. W. and Kenen, P. B. (1990). *Handbook of international economics*. 2 vols.: Elsevier Science: Netherlands.
- Koulakiotis, A., Papasyriopoulos, N. and Molyneux, P. (2006). More evidence on the relationship between stock price returns and volatility: A Note. *International Research Journal of Finance and Economics*, 1(1): 21-28.
- Lugutaerah, A., Akumbode, R. A. and Yaan, E. A. (2015). Modeling exchange rate volatility of the Ghana cedi to the us dollar using garch. *Mathematical Theory and Modeling*, 5(8): 92-103.
- Miambo, C., Maredza, A. and Sibanda, K. (2003). Effects of exchange rate volatility on the stock market: A case of South Africa. *Mediterranean Journal of Social Sciences*, 4(14): 561.
- Nelson, D. (1991). Conditional heteroscedasticity in asset returns: A new approach. *Journal of Econometrics*, 59(2): 347-70.
- Nzotta, S. M. (2004). *Money, banking and finance: Theory and practice*. Hudson –Jude Nig. Publishers: Owerri.
- Olowe, R. A. (2009). Modelling naria/dollar exchange rate volatility: Application of garch and asymmetric models. *International Review of Business Research Papers*, 5(3): 377-98.
- Salvatore, D. (2004). *International economics*. 8th edn: John Wiley and Sons: USA.
- Samulson, P. A. and Nordhaus, W. D. (2001). *Economics*. MC Graw-Hill: USA.
- Sun, C., Kim, M., Koo, W., Cho, G. and Jin, H. (2002). Effect of exchange rate volatility on wheat trade worldwide. *Agribusiness and Applied Economic Report*. 488.
- Therlie, M. A., Song, L., Wang, X. and Amin, M. (2014). Modeling exchange rate volatility using asymmetric GARCH Models: Evidence from Sierra Leone. *International Journal of Science and Research*, 3(11): 1206-14.
- Uma, K. E. (2010). *International economic: An introduction*. De-Adroit Innovation: Enugu.
- Works, R. F. (2016). *Economic modeling of exchange rate determinants by market classification: An empirical analysis of Japan and South Korea using the sticky price monetary theory*. ProQuest LLC: USA.
- Zakoian, J. M. (1994). Threshold heteroskedastic models. *Journal of Economic Dynamics and Control*, 18(5): 931-55.

Appendices

Appendix-1. ARCH (1,1)

Dependent Variable: RETURN				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
Date: 10/01/19 Time: 11:18				
Sample (adjusted): 2 4527				
Included observations: 4526 after adjustments				
Failure to improve likelihood (non-zero gradients) after 135 iterations				
Coefficient covariance computed using outer product of gradients				
Presample variance: backcast (parameter = 0.7)				
LOG(GARCH) = C(4) + C(5)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(6)				
*RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1))				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	1.026644	0.451957	2.271553	0.0231
RETURN(-1)	0.997655	5.47E-05	18236.36	0.0000
C	0.012322	0.000130	94.46685	0.0000
Variance Equation				
C(4)	-3.245782	0.077913	-41.65897	0.0000
C(5)	-0.234604	0.006632	-35.37217	0.0000
C(6)	0.467173	0.009852	47.41784	0.0000
C(7)	0.666835	0.008198	81.34432	0.0000
R-squared	0.984695	Mean dependent var		5.069608
Adjusted R-squared	0.984688	S.D. dependent var		0.315652
S.E. of regression	0.039059	Akaike info criterion		-7.107681
Sum squared resid	6.900365	Schwarz criterion		-7.097756
Log likelihood	16091.68	Hannan-Quinn criter.		-7.104185
Durbin-Watson stat	2.252063			

Appendix-2. GARCH/TGARCH

Dependent Variable: RETURN				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
Date: 10/01/19 Time: 11:15				
Sample (adjusted): 2 4527				
Included observations: 4526 after adjustments				
Convergence achieved after 36 iterations				
Coefficient covariance computed using outer product of gradients				
Presample variance: backcast (parameter = 0.7)				
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	-2.766073	3.761466	-0.735371	0.4621
RETURN(-1)	1.000183	0.000443	2258.607	0.0000
C	-0.000495	0.002198	-0.225092	0.8219
Variance Equation				
C	4.15E-05	1.22E-06	33.98864	0.0000
RESID(-1)^2	0.234126	0.038854	6.025713	0.0000
GARCH(-1)	0.153818	0.024925	6.171122	0.0000
R-squared	0.999384	Mean dependent var		5.069608
Adjusted R-squared	0.999384	S.D. dependent var		0.315652
S.E. of regression	0.007835	Akaike info criterion		-7.047886
Sum squared resid	0.277685	Schwarz criterion		-7.039378
Log likelihood	15955.37	Hannan-Quinn criter.		-7.044889
Durbin-Watson stat	2.045275			

Appendix-3. EGARCH

Dependent Variable: RETURN				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
Date: 10/01/19 Time: 11:18				
Sample (adjusted): 2 4527				
Included observations: 4526 after adjustments				
Failure to improve likelihood (non-zero gradients) after 135 iterations				
Coefficient covariance computed using outer product of gradients				
Presample variance: backcast (parameter = 0.7)				
LOG(GARCH) = C(4) + C(5)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(6)*RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1))				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	1.026644	0.451957	2.271553	0.0231
RETURN(-1)	0.997655	5.47E-05	18236.36	0.0000
C	0.012322	0.000130	94.46685	0.0000
Variance Equation				
C(4)	-3.245782	0.077913	-41.65897	0.0000
C(5)	-0.234604	0.006632	-35.37217	0.0000
C(6)	0.467173	0.009852	47.41784	0.0000
C(7)	0.666835	0.008198	81.34432	0.0000
R-squared	0.984695	Mean dependent var		5.069608
Adjusted R-squared	0.984688	S.D. dependent var		0.315652
S.E. of regression	0.039059	Akaike info criterion		-7.107681
Sum squared resid	6.900365	Schwarz criterion		-7.097756
Log likelihood	16091.68	Hannan-Quinn criter.		-7.104185
Durbin-Watson stat	2.252063			

Appendix-4. Arch Effects ARCH (1,1)

Heteroskedasticity Test: ARCH				
F-statistic	0.000180	Prob. F(1,4523)		0.9893
Obs*R-squared	0.000181	Prob. Chi-Square(1)		0.9893
Test Equation:				
Dependent Variable: WGT_RESID^2				
Method: Least Squares				
Date: 10/01/19 Time: 11:24				
Sample (adjusted): 3 4527				
Included observations: 4525 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.002938	0.580375	1.728086	0.0840
WGT_RESID^2(-1)	0.000200	0.014869	0.013434	0.9893
R-squared	0.000000	Mean dependent var		1.003138
Adjusted R-squared	-0.000221	S.D. dependent var		39.02351
S.E. of regression	39.02782	Akaike info criterion		10.16687
Sum squared resid	6889302.	Schwarz criterion		10.16970
Log likelihood	-23000.54	Hannan-Quinn criter.		10.16787
F-statistic	0.000180	Durbin-Watson stat		2.000000
Prob(F-statistic)	0.989282			

GARCH/TGARCH

Test Equation:				
Dependent Variable: WGT_RESID^2				
Method: Least Squares				
Date: 10/01/19 Time: 11:16				
Sample (adjusted): 3 4527				
Included observations: 4525 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.000221	0.585049	1.709637	0.0874
WGT_RESID^2(-1)	-1.72E-06	0.014869	-0.000115	0.9999
R-squared	0.000000	Mean dependent var		1.000219
Adjusted R-squared	-0.000221	S.D. dependent var		39.33805
S.E. of regression	39.34240	Akaike info criterion		10.18292
Sum squared resid	7000809.	Schwarz criterion		10.18576
Log likelihood	-23036.87	Hannan-Quinn criter.		10.18392
F-statistic	1.33E-08	Durbin-Watson stat		2.000000
Prob(F-statistic)	0.999908			

EGARCH

Heteroskedasticity Test: ARCH				
F-statistic	0.005664	Prob. F(1,4523)		0.9400
Obs*R-squared	0.005666	Prob. Chi-Square(1)		0.9400
Test Equation:				
Dependent Variable: WGT_RESID^2				
Method: Least Squares				
Date: 10/01/19 Time: 11:19				
Sample (adjusted): 3 4527				
Included observations: 4525 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.992223	0.515474	1.924875	0.0543
WGT_RESID^2(-1)	0.001119	0.014869	0.075258	0.9400
R-squared	0.000001	Mean dependent var		0.993335
Adjusted R-squared	-0.000220	S.D. dependent var		34.65692
S.E. of regression	34.66073	Akaike info criterion		9.929534
Sum squared resid	5433781.	Schwarz criterion		9.932370
Log likelihood	-22463.57	Hannan-Quinn criter.		9.930533
F-statistic	0.005664	Durbin-Watson stat		1.999998
Prob(F-statistic)	0.940013			